Università IUAV di Venezia
Universidad de Sevilla
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Erasmus Mundus Master Course on
Maritime Spatial Planning

# Sustainable aquaculture allocation and governance in relation to Marine Protected Areas

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2016/18

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*Acronyms and Abbreviations*

ARDITI – Regional Agency for the Development of Research, Technology and Innovation

CBD – Convention on Biological Diversity

CDDA – Common Database on Designated Areas

EAA – Ecosystem Approach to Aquaculture

ECOAQUA – Instituto Universitario de Acuicultura Sostenible y Ecosistemas Marinos

EEZ – Economic Exclusive Zone

EIA – Environmental Impact Assessment

EMP – Environment Monitoring Programme

EU – European Union

EUNIS – European Nature Information System

FAO – Food and Agriculture Organization of the United Nations

GBRMP – Great Barrier Reef Marine Park

GBRMPA – Great Barrier Reef Marine Park Authority

GES – Good Environmental Status

GIS – Geographic Information System

ICZM – Integrated Coastal Zone Management

IEHEM – Spanish Inventory of Marine Habitats and Species

IMTA – Integrated Multitrophic Aquaculture

IUCN – International Union for Conservation of Nature

IUU – Illegal, Unreported and Unregulated

MAB – Man and the Biosphere Programme

MPA – Marine Protected Area

MS – Member State

MSP – Marine/Maritime Spatial Planning

MSFD – Maritime Strategy Framework Directive 2008/56/EC

OSPAR – Oslo/Paris convention for the Protection of the Marine Environment of the North-East Atlantic

PROAC – Regional Aquaculture Management Plan for Canary Islands

ULPGC – Universidad de Las Palmas de Gran Canaria

WDPA – World Database on Protected Areas

*Summary*

In order to supply food for the growing human population, sustainable management of natural resources and biodiversity have to focus on how and where the protein source should be exploited from. Aquaculture production, which is promised to achieve this mission, has increased dramatically in the last decade, representing one of the fastest-growing sources of food globally. At the same time that food production must be increased, the Convention on Biological Diversity, on its Target number 11, proposes to protect 10% of the entire ocean by 2020. With that, aquaculture brings an alternative option to be performed within Marine Protected Areas (MPAs), where the activity can enhance coastal communities as a key role for food security, poverty alleviation and economic resilience, likewise promoting synergies, diversifying local markets and livelihoods. This study aims to find the best spatial scenario for allocation of sustainable aquaculture activities within MPAs in the Macaronesia using the IUCN (International Union for Conservation of Nature) classification. The study analysis consists of identifying protected areas and analyzing open data basis as EUNIS (European Nature Information System), CDDA (Common Database on Designated Areas) and Natura2000. These repositories include details, among others, IUCN classification, level of protection, biodiversity, preservation status, surface area, the percentage of coverage to identify compatibilities with sustainable aquaculture. This study includes processed GIS results, percentage of the area appropriate for sustainable aquaculture within the areas designated for protection, as much as opportunities for the Macaronesia Region. In total, 19 278.97 $km^2$, represented by 64 different marine protected areas, are able to have this activity in a sustainable way in Macaronesia. Identifying co-existence areas, is a valuable information to Maritime Spatial Planning, management and decision-making for aquaculture and conservation.



*Keywords*

Sustainable Aquaculture, Marine Protected Area, Zoning, Multiuse Area, Aquaculture Allocation, IUCN, Natura 2000

## 1) Introduction

In order to supply the demanding needs of the growing world's human population, sustainable management of natural resources and biodiversity have to focus on how and where the source of food is exploited from. According to UN, population is likely to reach the 9.8 billion by 2050, coupled with the longer life expectancy in an increasingly prosperous world, total food demand is expected to increase around 70% in the same period (United Nations, Department of Economic and Social Affairs, Population Division, 2017). Thus, the necessity to increase the production of enough food, energy and other required products from sustainable sources emerges to tackle the future demand gap (WRI, 2013). Additionally, pressures and conflicts, as pollution and competition for space, might increase significantly from the intensification of human activities if not properly planned. In this scenario, the oceans can suffer severe consequences, since certain areas are already being disputed nowadays (Meaden et al., 2016).

Seafood will have to be produced on more substantial and coordinated scale from oceans, in order to ensure food security (Troell et al., 2014). Questions such where the food is coming from, whether it is from a sustainable and traceable source and if it is healthy and nutritious are issues that must be accounted for the future of the whole seafood chain (United Nations, 2014). Currently, 85 percent of all wild seafood stocks in all oceanic basins are overexploited according to FAO (2016a). In addition, fishery production, according to The State of World Fisheries and Aquaculture from FAO (2018) statistics, has already reached a production plateau where, although fishing effort is increased, the result does not vary significantly (Figure 1). Consequently, arises the need to produce more proteins from reliable, traceable and sustainable sources avoiding deplete wild seafood stocks, as much as coordinate management between fishery and aquaculture sectors (Tacon and Metian, 2016).

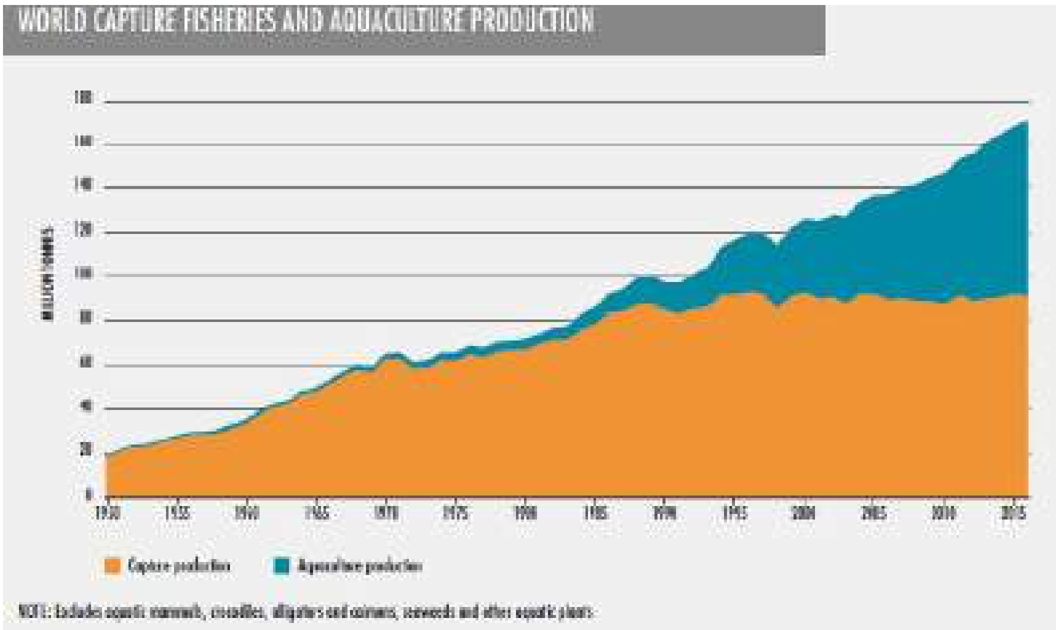



Figure 1. World capture fisheries and aquaculture production (FAO, 2018)

Aquaculture production, which is promised as an alternative to fisheries to help feed the world, has dramatically increased in the last decade (Figure 1), representing one of the fastest-growing sources of food globally (FAO, 2016a). Currently, this sector contributes to about half of the global food fish production and, according to FAO, this figure will reach around 62 percent by 2030 (FAO, 2016a). Also, this sector provides in its majority nutritious and healthy food, rich in essential micronutrients that are often missing in peoples' diets (HLPE, 2014).

At the same time that food production must be increased, the Convention on Biological Diversity (CBD), on its Target number 11, proposes to protect 10% of the entire ocean by 2020 with areas of particular importance for biodiversity and ecosystem services (CBD, 2018; Woodley et al., 2012). For that reason, a more coherent governance and effective planning between protected marine spaces and other maritime sectors and activities being performed within and around those areas must be well-studied at local levels, enlightening the most adequate decisions to be undertaken (Ruiz-Frau, 2015). An essential global approach to biodiversity conservation is to conciliate protected areas for conservation and food production (Rice and Garcia, 2011).

Aquaculture, unlike many people think, can be sustainable and aligned with conservation goals (Gouvello et al., 2017). Besides producing food resources, it can likewise restore and enhance threatened and endangered species (Olivotto, 2011; Froehlich et al., 2017), rebuild important shellfish habitats providing protection for several wild species (Brumbaugh, 2000; Coen, 2011), help to protect shoreline from erosion (Duarte et al., 2017), restore coral reefs (Pomeroy et al., 2006), produce marine baitfish (DiMaggio et al., 2009), provide ornamental species for aquaria (Olivotto et al., 2017), produce pharmaceuticals products, diminish fishing pressure under target species and avoiding destructive practices on benthic habitats as bottom trawling (Fish, 2018). Apart from conservation aquaculture, the modern organic aquaculture is rising up to tackle the conventional production, making use of best practices avoiding the use of antibiotics and off-farm inputs (Bergleiter and Censkowsky, 2010). It is necessary to enhance sustainable management practices in seafood production and maintain ecological harmony (Datta, 2012). Furthermore, aquaculture should be compatible and integrated at local contexts, recognizing potential economic activities that are coherent and sustainable in relation to conservation aims. More information about aquaculture production types can be found in Annex 1.

Oceanic islands face diverse development hindrances as connectivity, accessibility and limited land space. In a like manner, they suffer serious environmental issues that lead to relevant socioeconomic repercussions such as environmental degradation, loss of biodiversity, propagation of invasive alien species and climate change (Lopes et al., 2017). Strategic plans for islands have to take into account local context and do not use standardized mainland-based recommendations that do not address the spatiotemporal complexity of these environments (Chapman, 2011). Aquaculture rises as an opportunity to accelerate the Blue Growth in the European Outermost Regions whereas MPAs provide at local and regional levels significant ecosystem services and can incorporate multi-use areas. As an option to develop islander coastal communities, aquaculture can play a key role for food security, poverty alleviation and economic resilience of local communities, promoting synergies, diversifying local markets and livelihoods.

Considering spatial constraints and the possibility to incorporate aquaculture within multi-use areas inside MPAs come the opportunity to sustainably allocate resources and respective areas for the development of sustainable aquaculture practices within MPAs. Therefore, in order to promote and achieve strategic socioeconomic and environmental policies and goals is necessary to make a structured plan where aquaculture, in its different terms, can be aligned with marine protection steering plans in a case-by-case approach (Aguilar-Manjarrez et al., 2017). Coming with this purpose, the PLASMAR Project aims to analyze areas in the Macaronesia Region defining the scientific and technical basis to foster Blue Growth activities in the different archipelagos. In this way, project actions identify where new maritime activities can take place, understanding their possible conflicts, pressures and accumulated impacts, applying ecosystem approach, calculating a balance of the maritime development and ecological status defined by Marine Strategy Framework Directive 2008/56/EC with the Good Environmental Status of the ocean (GMR Canarias, 2017).

This thesis seeks to encompass main global targets as, Aichi Biodiversity Targets on aquatic species management (Target 6), sustainable aquaculture (Target 7), marine biodiversity protection (Target 11), as well as the Sustainable Development Goals (SDGs) from 2030 Agenda on poverty alleviation (Target 1), food security (Target 2), sustainable and inclusive economic growth (Target 8), inequality reduction (Target 10) and sustainable use of the oceans (Target 14). This study, rather than focus on target species and maximizing production and economic results, strived to clarify and emphasize a model where fisheries and aquaculture are part of integrated and ecosystem-based governance system across multiple sectors at local scale.

## 2) Aquaculture within MPA context

This chapter gives a glance of the most significant publications in the area of the study. For example: report on *Aquaculture and Marine Protected Areas: Exploring Potential Opportunities and Synergies* published by IUCN (2017), the scientific paper *Aquaculture and Marine Protected Areas Potential Opportunities and Synergies* from Gouvello et al., (2017), which stress the feasibility and compatibility to MPAs help aquaculture production in different terms. Besides, the report *Guidance about aquaculture and Nature 2000* from the European Commission (2012), brings more specifically the theme about aquaculture processes to these areas and how to mitigate impacts with good and bad practices guidance. Also, the *Guidelines for Applying Protected Area Management Categories* from Dudley et al., (2008) and the *Guidelines for Applying the IUCN Protected Area Management Categories to Marine Protected Areas* from Day et al., (2012), which have an extreme importance talking about MPAs management classifications and their specificities to human activities.

**2.1) Examples of MPAs and Aquaculture**

This sub-chapter presents few examples of countries, regions or specific MPAs to visualize what is already happening under this context. Some of them have a legislation already operating to have proper sustainable aquaculture within their marine protected areas.

- Australian's Great Barrier Reef Marine Park (GBRMP) for instance, which is the most iconic marine protected area in the world, only allows aquaculture in some zones in some parts of the Marine Park (the statutory Zoning Plan determines which zones). The proponent must apply for a permit which is then assessed against specified criteria. So, the process is effectively a case-by-case approach far from an automatic approval. It is likely that the Great Barrier Reef Marine Park Authority (GBRMPA) will be required to assess two basic types of aquaculture operation in the GBRMP: Extensive aquaculture that does not include the addition of feed or intensive aquaculture that does include the addition of feed. If a permit is issued, it will specify numerous conditions which must be adhered to; Depending on the proposed location and size, it may also require approval under the federal sea installations legislation too GBRMPA (2002).

- Mayotte, is a French Outermost region which created a large MPA, the Mayotte National Marine Park, comprising almost its entire EEZ. Joint creation of multiple-use MPAs with aquaculture operations. This situation is illustrated by the French Mayotte case, although the fact may be argued that some aquaculture productions farming non-native carnivorous fish (at a very small scale) pre-existed in this area, prior to the Mayotte National Marine Park creation. The pre-existing condition of the farm is, in fact, the main reason an aquaculture rearing system was authorized within the multiple-use MPA. The critical issues are related to how the decisions are made to allow such aquaculture production, how it will be monitored, and what project leaders envisage for the future (IUCN, 2017).

-Scottish planning permission is required for all new shellfish and finfish aquaculture developments, or change of use, and alterations to existing approved sites. As part of this process Scottish Natural Heritage, Scottish Environment Protection Agency and Marine Scotland Science are legal consultees. This process comprises the creation of an Environmental Statement which determines if an Environmental Impact Assessment (EIA) is required. An EIA is essential if the development is to take place in a sensitive area (such in the case of an MPA), or if a finfish production site that surpasses a certain dimension. In the case where the aquaculture development is within a Natura 2000 MPA, the EIA will trigger a Habitats Regulation Appraisal (HRA). This is undertaken under the Conservation (Natural Habitats) Regulations of 1994 which require all Competent Authorities to carry out an Appropriate Assessment where any activity within a protected area is likely to have a significant impact on a protected area. It has been believed that the HRA is the Appropriate Assessment for aquaculture development in MPAs in Scotland. The HRA must 'provide and analyses sufficient information to allow a competent authority to ascertain whether the plan or project will not adversely affect the sites integrity'. There is no assumption against aquaculture use within MPAs as long as the conservation objectives of the MPA are not compromised (Gouvello et al., 2017).

Several other countries also have aquaculture within MPAs, such as, Canada; Madagascar; China; Shetlands, Indonesia, between others. Furthermore, there are many well-known Natura 2000 areas in Europe where aquaculture activities are currently taking place sustainably, such as the Wadden Sea in the Netherlands, Arcachon in France, the Sado Estuary in Portugal, Doñana in Spain, Lanzarote Island in Canary Islands shellfish culture in England and Wales and several Lochs in Scotland.

## 2.2) European Context

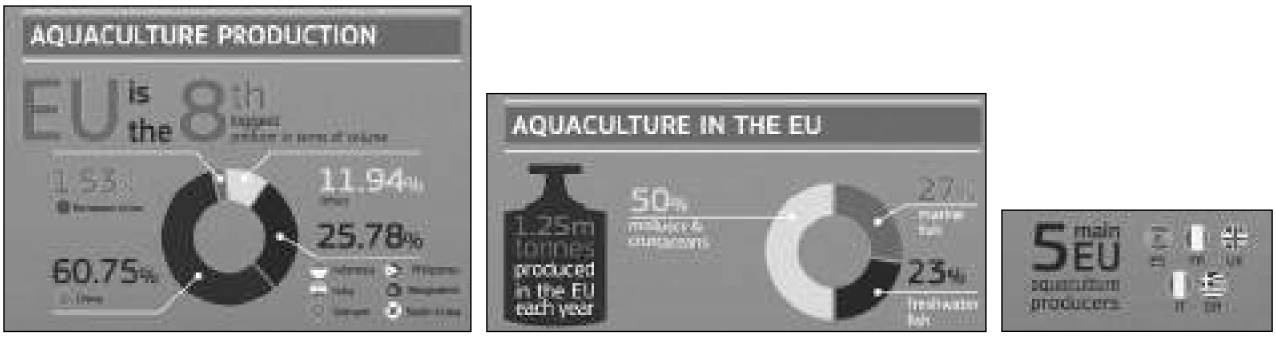
The EU’s Maritime Spatial Planning Directive 2014/89/EU has been adopted to provide framework for Member States in planning their seas, in order to deal with maritime sectors competition for marine space. This legislation also requires that planning of marine area is done through an ecosystem-based approach to ensure the sustainability of human activities with environment. Furthermore, species and habitats protected under the Birds and Habitats Directives have strict protection. Therefore, Member States need to identify the best areas for aquaculture sites ensuring that these conform to environmental standards and limit impact of aquaculture production at sea (Aquaculture Advisory Group, 2018).

### 2.2.1) *Current EU Statistics*

#### 2.2.1.1) Aquaculture

Currently, the EU aquaculture sector produces about 1.2 million tonnes of fish and shellfish with a total value of around EUR 4 billion. This represents slightly over 1% of the global aquaculture production. The sector is constituted in its majority of micro-enterprises (with under 10 employees) and provides employment to nearly 85,000 people. The seven most important farmed species in the EU are mussels, trout, salmon, oysters, carp, seabream and seabass. Where the 5 main EU aquaculture producer countries are Spain, France, UK, Italy and Greece (European Commission, 2016a).

Only 10% of EU demand for fish is supplied by EU aquaculture, whereas 30% is by EU fisheries, which means that the remaining 60% of wild and farmed fish consumed are imported from lower-income countries. The estimated projection for aquaculture production in 2020 is a growth of over 300,000 tonnes (25%) to a total of more than 1.5 million tonnes (European Commission, 2016a) Figure 2.



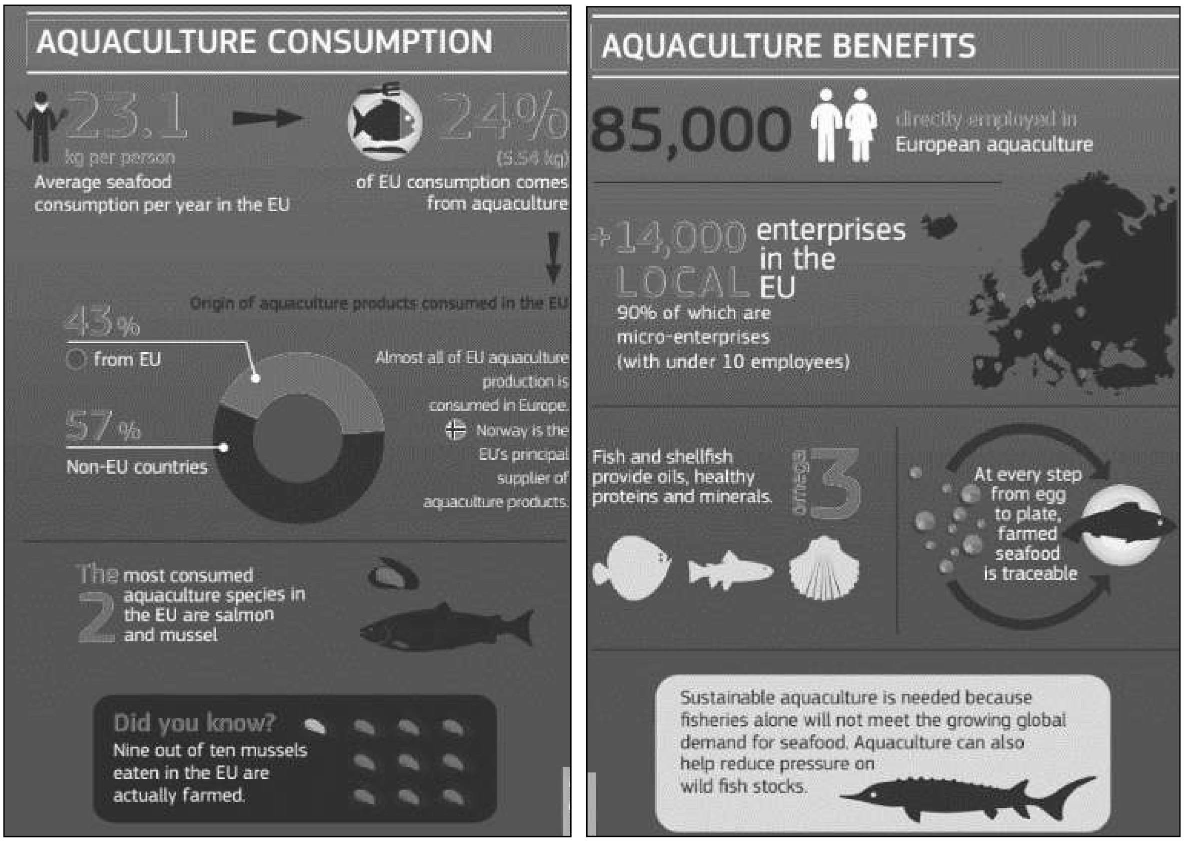



Figure 2. Europe's fast facts on aquaculture (Source: European Commission, 2018)

2.2.1.2) Marine Protection

In 2012, Europe had 5.9% of its seas covered by MPAs, whereas Natura 2000 areas are represented by 4% of the total European sea space as shown on the Figure 3. The Figure 4 shows the coverage of Natura 2000 areas by European regional seas, where Macaronesia had very small area compared to the other regions.

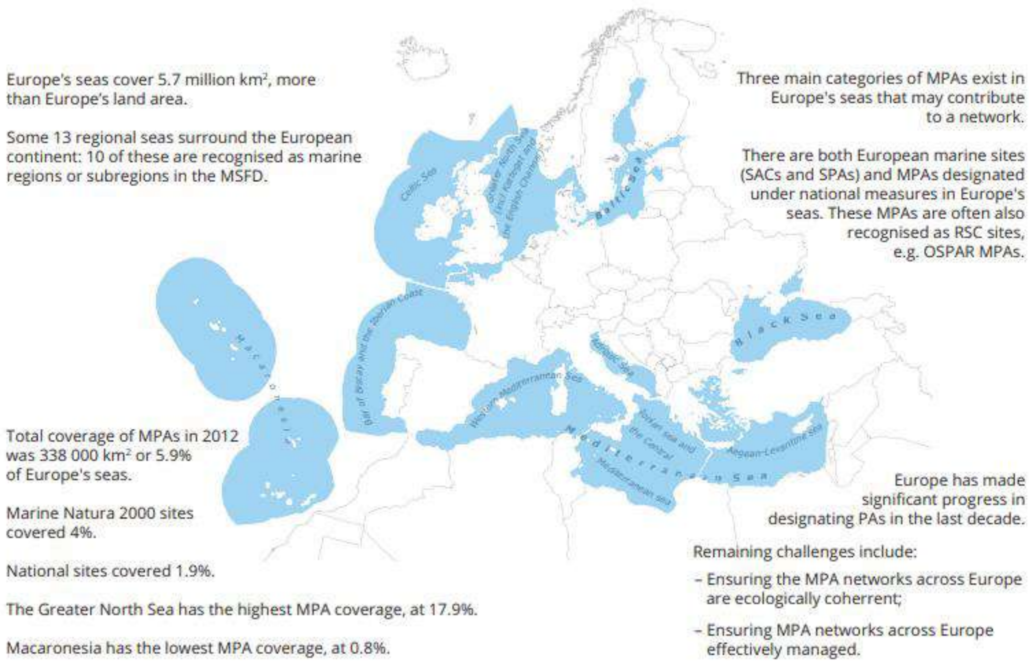



Figure 3. Europe's regional seas, and fast facts on EU MPA networks. (Source European Environmental Agency, 2015)

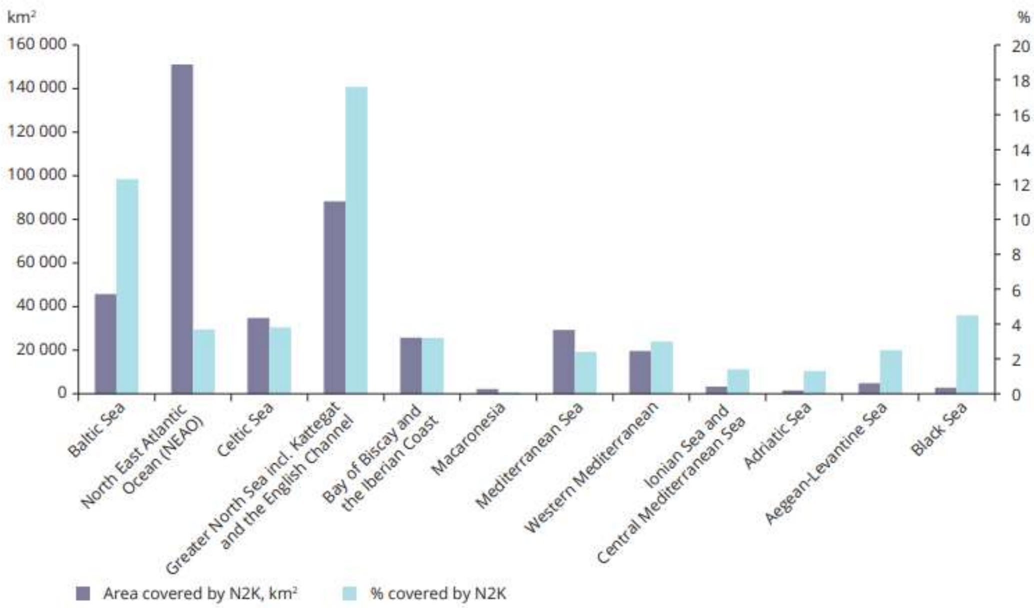



Figure 4. Coverage of Natura 2000 network in Europe's regional seas (Source European Environmental Agency, 2015)

### 2.2.2) *European Aquaculture Legislation*

Policies, strategies and frameworks published by EU Commission to foster the development of sustainable aquaculture:

- In 2013, the new Common Fisheries Policy introduced the Open Method of Coordination for the sustainable development of aquaculture. This method aims at spreading best practice and at giving practical answers to common challenges identified by Member States and stakeholders.

- In 2013, Strategic Guidelines for the sustainable development of EU aquaculture - COM/2013/229 Communication to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (29/04/2013)

- In 2014-2015, Member States developed Multiannual National Strategic Plans for the promotion of sustainable aquaculture. In these plans, Member States address the four priorities identified in the Strategic Guidelines for the sustainable development of EU aquaculture and propose concrete actions to address them.

The four strategic priorities of the Guidelines and Member State's plans are: reducing administrative burdens; improving access to space and water; increasing competitiveness; exploiting competitive advantages due to high quality, health and environmental standards (European Commission, 2016a).

2.2.3) *European Marine Protection Legislation*

- Natura 2000:

The Birds and Habitats Directives are the foundations of the EU's biodiversity policy. They empower all 28 EU Member States to work together, within a common legislative framework, to preserve Europe's most endangered, rare and representative species and habitat types across their natural range within the EU. Whilst the Birds Directive covers all naturally occurring wild birds present in the EU, the Habitats Directive focuses on a sub-set of ca 1500 other species, as well as ca 230 habitat types in their own right.

The two directives require Member States to guarantee that the listed species and habitat types are preserved and/or restored to a favorable conservation status throughout their natural range within the EU. The fact that a habitat or species is not facing a direct extinction risk does not necessarily mean that it is in a favorable preservation status.

To attain this goal, the directives require two types of provisions:

• Site designation and management measures: aimed at conserving core areas for species listed in Annex I of the Birds Directive and regularly occurring migratory birds, including internationally important wetlands (Special Protection Areas - SPAs) as well as habitat types and species listed in Annexes I and II of the Habitats Directive (Sites of Community Interest – SCIs);

• Species protection measures: involving the establishment of a general system of protection for all wild bird species in the EU and for species of special conservation interest listed in Annex IV and V of the Habitats Directive. These species protection measures apply across the entire natural range of the species in the EU and therefore also outside protected sites.

The first set of provisions has led to the creation of the Natura 2000 Network which currently includes over 26,000 terrestrial and marine sites across 28 EU countries. The SPAs and SCIs are often referred to collectively as Natura 2000 sites (European Commission, 2013).

Natura 2000 sites mostly overlap with nationally designated sites under IUCN categories I to IV, which aim to protect ecological processes and biodiversity. However, they also overlap with IUCN categories V and VI, supporting the idea that Natura 2000 is not restricted to nature reserves but also serves the broader principle of conservation and sustainable use (EEA, 2018).

Specifically, the 3 directives involved in the protection of the natural environment at the European sphere, are:

Habitats Directive - Directive 92/43/EEC
Ensures the conservation of a wide range of rare, threatened or endemic animal and plant species. Some 200 rare and characteristic habitat types are also targeted for conservation in their own right. Adopted in 1992, on the conservation of natural habitats and of wild fauna and flora aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements (European Commission, 2016b).

Birds Directive - Directive 79/409/EEC
Aims to protect all of the 500 wild bird species naturally occurring in the EU. It is the oldest piece of EU legislation on the environment. Europe is home to more than 500 wild bird species. But at least 32 % of the EU's bird species are currently not in a good conservation status. Habitat loss and degradation are the most serious threats to the conservation of wild birds. The Directive therefore places great emphasis on the protection of habitats for endangered and migratory species (European Commission, 2016c).

MSFD - Maritime Strategy Framework Directive 2008/56/EC
The Marine Directive aims to achieve Good Environmental Status (GES) of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. In 2017, on the Annex III of the Directive was amended to better link ecosystem components, anthropogenic pressures and impacts on the marine environment with the MSFD's 11 descriptors and with the new Decision on Good Environmental Status.

## 3) Objectives

This study is delivered within project PLASMAR, financed by the European Regional Development Fund, in the INTERREG Macaronesia framework, and aims to identify the best spatial scenario for allocation of sustainable aquaculture activities within Macaronesian MPAs, using for that the International Union for Conservation of Nature (IUCN) management classification (Dudley et al., 2008) and developing a tool to reach a better understanding of the marine plan composition. Not being a plan by itself, it aims to become one of the several steps within the marine planning process, necessary to allocate resources and their respective uses in a sustainable and cost-effective way through space and time, without jeopardizing conservation, the core purpose of any MPA. The specific objectives of the present work will be:

- Identify opportunities to develop sustainable aquaculture within Marine Protected Areas in the context of Macaronesia.
- Apply methodology developed by IUCN for Aquaculture within MPAs' site selection
- Give possible deploying areas for sustainable aquaculture activity in order to diversify and - Identify the percentage of area appropriate for sustainable aquaculture within the areas designated for protection classified by IUCN for Macaronesian Region

## 4) <u>Methodology</u>

### 4.1) Site Description

This study was held in the European Atlantic Islands, also known by the Macaronesia Region. It comprises 4 volcanic archipelagos under the jurisdiction of 2 different EU Member States (MS): Azores, Madeira and Selvagens from Portugal, and Canary Islands from Spain Figure 5.

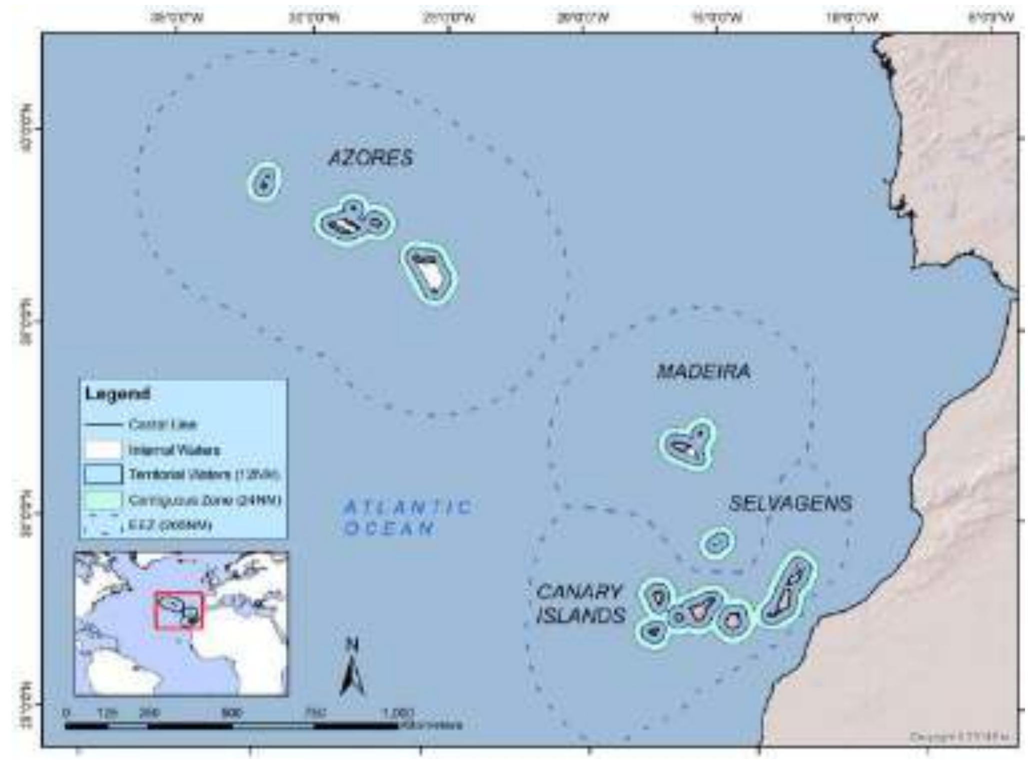



Figure 5. European Macaronesian Region: location within the North Atlantic Ocean: Azores, Madeira, Selvagens and Canary Islands (Source: Author)

Oceanic islands, in general have particular biogeographical and physical characteristics compared to the mainland and to continental islands. Usually the environments in oceanic islands present a more dynamic and dramatic oceanic and climatic conditions such as, higher waves, stronger currents, stronger winds, less nutrient input from rivers, narrow physical continental shelf which imply in less primary production and higher depuration capacity of the water compared to other European Seas. In addition, wild populations present particular evolutionary features as high level of endemism and speciation in some islands, and unique biodiversity. Macaronesia is characterized by a mixture of Mediterranean and Atlantic elements, to which are added some tropical ones (Whittaker and Fernández-Palacios, 2007; Whittaker, et al., 2007; Whittaker et al., 2008).

The area under study is the MPAs network in the European Macaronesian Region (Figure 6). Some MPAs were not considered suitable for the study due to their remoteness, such as some OSPAR protected areas and marine banks, as well as the Selvagens and Desertas Islands from Portugal.

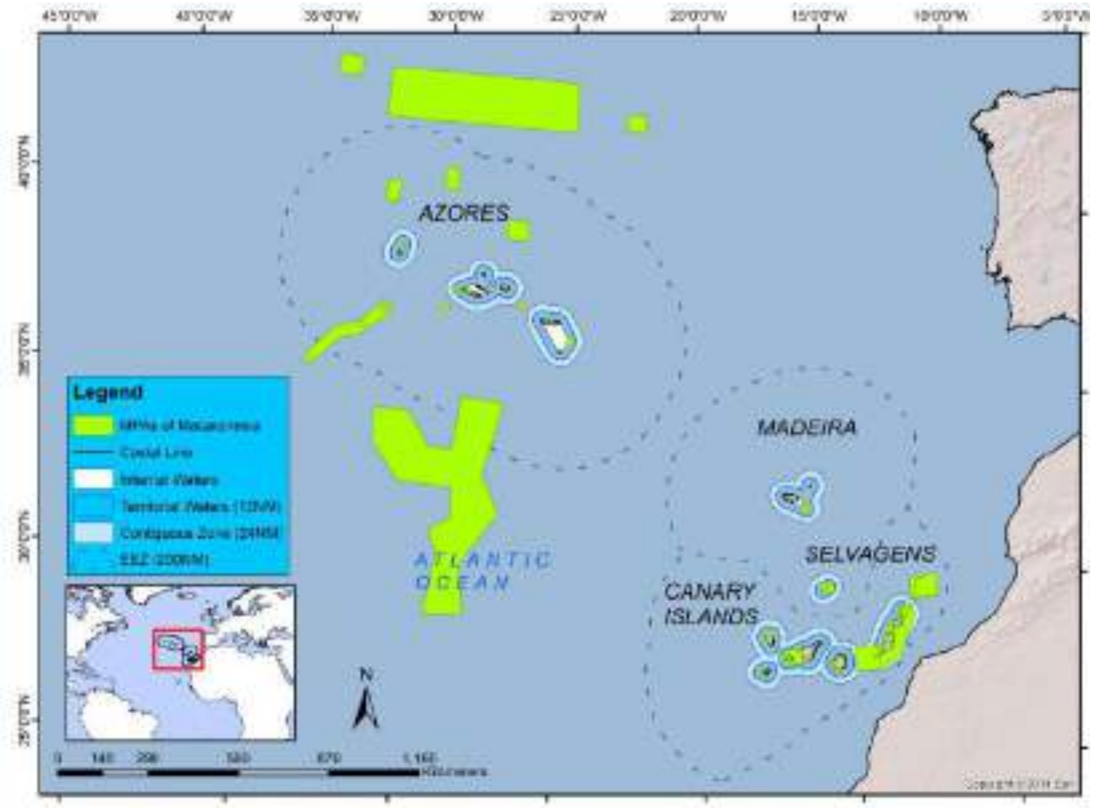



Figure 6. Map of all Marine Protected Areas in the region of Macaronesia (Source: Author)

## 4.2) Data Acquisition

Data were retrieved from the open data basis as EUNIS (European Nature Information System), CDDA (Common Database on Designated Areas), Natura 2000 and WDPA (World Database on Protected Areas). These repositories include several details, such as level of protection, biodiversity, important species and their estimated population sizes, important habitats, conservation status, marine surface area, threats and pressures, existence or not of a management plan and other data that were used to identify and analyze compatibilities between protected areas and sustainable aquaculture. Other data were gathered as bathymetry and maritime boundaries (Internal Waters, Territorial Waters, Contiguous Zones, Economic Exclusive Zones) from the Flanders Marine Institute (2018).

For the Canaries use case study, is used harmonized ‘Ecocartograficos’ data set on marine habitats. Dataset was retrieved from ECOAQUA, that deliver a harmonized product in 2018. ‘Ecocartograficos’ includes study for each of the islands, delivered in the early 2000s including the classification of the marine environment till 50 meters depth. As these studies were carried out by a total of 7 different companies without a common working methodology, it was difficult to interpret results on the level of archipelago. Within PLASMAR Project these datasets were, harmonized according to the INSPIRE principles (European data standard), including three classification standards¡:

1. IEHEM (Spanish Inventory of Marine Habitats and Species);
2. EUNIS;
3. MSFD.

### 4.3) MPA’s Classification

The IUCN management classification for protected areas from Dudley (2008) was used in order to identify MPAs where aquaculture will not conflict with their conservation goals. This classification divides Protected Areas within 7 different classes, as shown in the Table 1 and more specified in Annex 2.

Table 1. The main types of management categories (Dudley, 2008) (noting that while Ia and Ib encompass what is frequently referred to as no-take or marine reserves the other categories reflect a wider range of uses alongside conservation of nature)

| IUCN category | | Main objective or purpose |
|---|---|---|
| Ia | Strict nature reserve | Managed mainly for science |
| Ib | Wilderness area | Managed mainly to protect wilderness qualities |
| II | National Park | Managed mainly for ecosystem protection and recreation |
| III | Natural monument | Managed mainly for conservation of specific natural/cultural features |
| IV | Habitat/ species management area | Managed mainly for conservation through management intervention |
| V | Protected landscape/seascape | Managed mainly for landscape/seascape conservation and recreation |
| VI | Managed resource protected area | Managed mainly for sustainable use of natural ecosystem |

The present work idea was driven mostly by the IUCN publication about potential opportunities and synergies between aquaculture and MPAs (IUCN, 2017). This publication was complemented some months later by the study from Gouvello et al., (2017) which describes more specifically what was said by IUCN before. In both studies, authors expose the affinity aquaculture and conservation of marine areas might have. They use the definition of Dudley (2008) to classify MPAs by their type of management from I to VI. Day et al., (2012), developed a matrix with potential activities that might match to each different IUCN management category (Table 2). Considering that aquaculture can be implemented in MPAs within categories V and VI and even IV according to Day et al (2012) see Table 2, as long as production model, and aquaculture intensity would be compatible with the MPA’s objectives.

Table 2. Matrix of activities that may be appropriate for each IUCN management category (Day et al., 2012)

| Activities | Ia | Ib | II | III | IV | V | VI |
|---|---|---|---|---|---|---|---|
| Research: Nonextractive | Y* | Y | Y | Y | Y | Y | Y |
| Nonextractive traditional use | Y* | Y | Y | Y | Y | Y | Y |
| Restoration/enhancement for conservation (e.g. invasive species control, coral reintroduction) | Y* | * | Y | Y | Y | Y | Y |
| Traditional fishing/collection in accordance with cultural tradition and use | N | Y* | Y | Y | Y | Y | Y |
| Nonextractive recreation (e.g. diving) | N | * | Y | Y | Y | Y | Y |
| Largescale high intensity tourism | N | N | Y | Y | Y | Y | Y |
| Shipping (except as may be unavoidable under international maritime law) | N | N | Y* | Y* | Y | Y | Y |
| Problem wildlife management (e.g. shark control programmes) | N | N | Y* | Y* | Y* | Y | Y |
| Research: Extractive | N* | N* | N* | N* | Y | Y | Y |
| Renewable energy generation | N | N | N | N | Y | Y | Y |
| Restoration/enhancement for other reasons (e.g. beach replenishment, fish aggregation, artificial reefs) | N | N | N* | N* | Y | Y | Y |
| Fishing/collection: Recreational | N | N | N | N | * | Y | Y |
| Fishing/collection: Longterm and sustainable local fishing practices | N | N | N | N | * | Y | Y |
| **Aquaculture** | N | N | N | N | * | Y | Y |
| Works (e.g. harbours, ports, dredging) | N | N | N | N | * | Y | Y |
| Untreated waste discharge | N | N | N | N | N | Y | Y |
| Mining (seafloor as well as subseafloor) | N | N | N | N | N | Y* | Y* |
| Habitation | N | N* | N* | N* | N* | Y | N* |

Key:

N = No

N* = Generally no, unless special circumstances apply

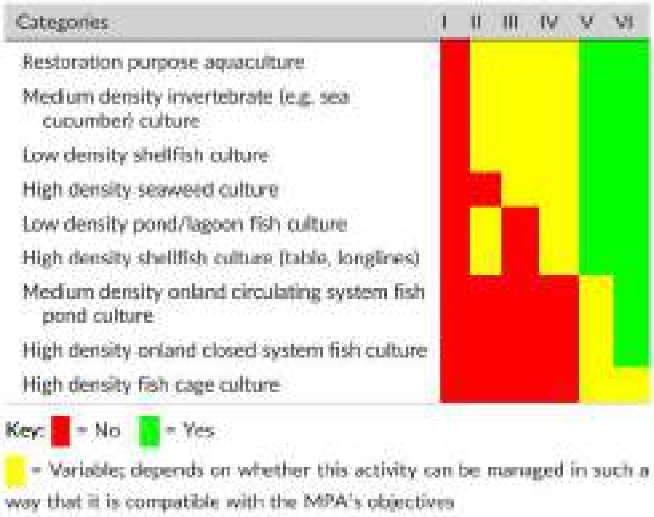
Y = Yes

Y* = Yes because no alternative exists, but special approval is essential

*= Variable; depends on whether this activity can be managed in such a way that it is compatible with the MPA's objectives

The different possible matches aquaculture systems can have for each protected area management class, are presented in Table 3, following IUCN (2017) and Gouvello et al. (2017). However, each aquaculture project is different and should be taken as a case-by-case approach due to the changeability character of its several variables (from the production system type and intensity to local environmental dynamics) as stressed by both IUCN (2017) and Gouvello et al. (2017), and what is presented in Table 3 should be changed if a specific condition that makes the activity compatible, or not, with MPAs' objectives, is set. For instance, a restoration aquaculture can be implemented within almost all IUCN classes, but avoided for Ia and Ib areas, whereas a high-density fish cage culture has to attend specific conditions from the MPA management plan to be accepted for the areas V and VI.

Table 3. Possible example of a risk matrix aquaculture systems and MPA categories (Gouvello et al., 2017)



| Categories | I | II | III | IV | V | VI |
|---|---|---|---|---|---|---|
| Restoration purpose aquaculture | No | Variable | Variable | Variable | Yes | Yes |
| Medium density invertebrate (e.g. sea cucumber) culture | No | Variable | Variable | Variable | Yes | Yes |
| Low density shellfish culture | No | Variable | Variable | Variable | Yes | Yes |
| High density seaweed culture | No | No | Variable | Variable | Yes | Yes |
| Low density pond/lagoon fish culture | No | Variable | No | Variable | Yes | Yes |
| High density shellfish culture (table, longlines) | No | Variable | No | Variable | Yes | Yes |
| Medium density onland circulating system fish pond culture | No | No | No | No | Variable | Yes |
| High density onland closed system fish culture | No | No | No | No | Variable | Yes |
| High density fish cage culture | No | No | No | No | Variable | Variable |

Key: = No = Yes

= Variable; depends on whether this activity can be managed in such a way that it is compatible with the MPA's objectives

For this study, IUCN classes V and VI were considered as the ones that could have aquaculture being operating within.

Data from protected areas of Natura 2000 (Site of Community Importance (Habitats Directive) and Special Protection Area (Birds Directive)) and OSPAR were not classified under the international IUCN classification. So, to standardize all MPAs from Macaronesia under the same classification, in order to check under the same conditions, these MPAs' management strategies were checked for allowance of human activities in the management objectives. According to Dudley et al., (2008) and Day et al., (2012), the primary management objective should apply to at least 75% of the protected area to classify that MPA as its major status. In those cases where there is no overlap between national protected areas and Natura 2000, since many marine Natura 2000 areas do not have a clear management plan, nor zonation within each area (core areas, buffer zones and transition area), it was taken into consideration that in general, Natura 2000 protected areas allow activities according to primary management objectives and MS are responsible for management, control and monitoring of these areas.

To overcome these difficulties, a methodology, presented in the flowchart in Figure 7 was developed in order to standardize Natura 2000 areas type of management into the IUCN classification.

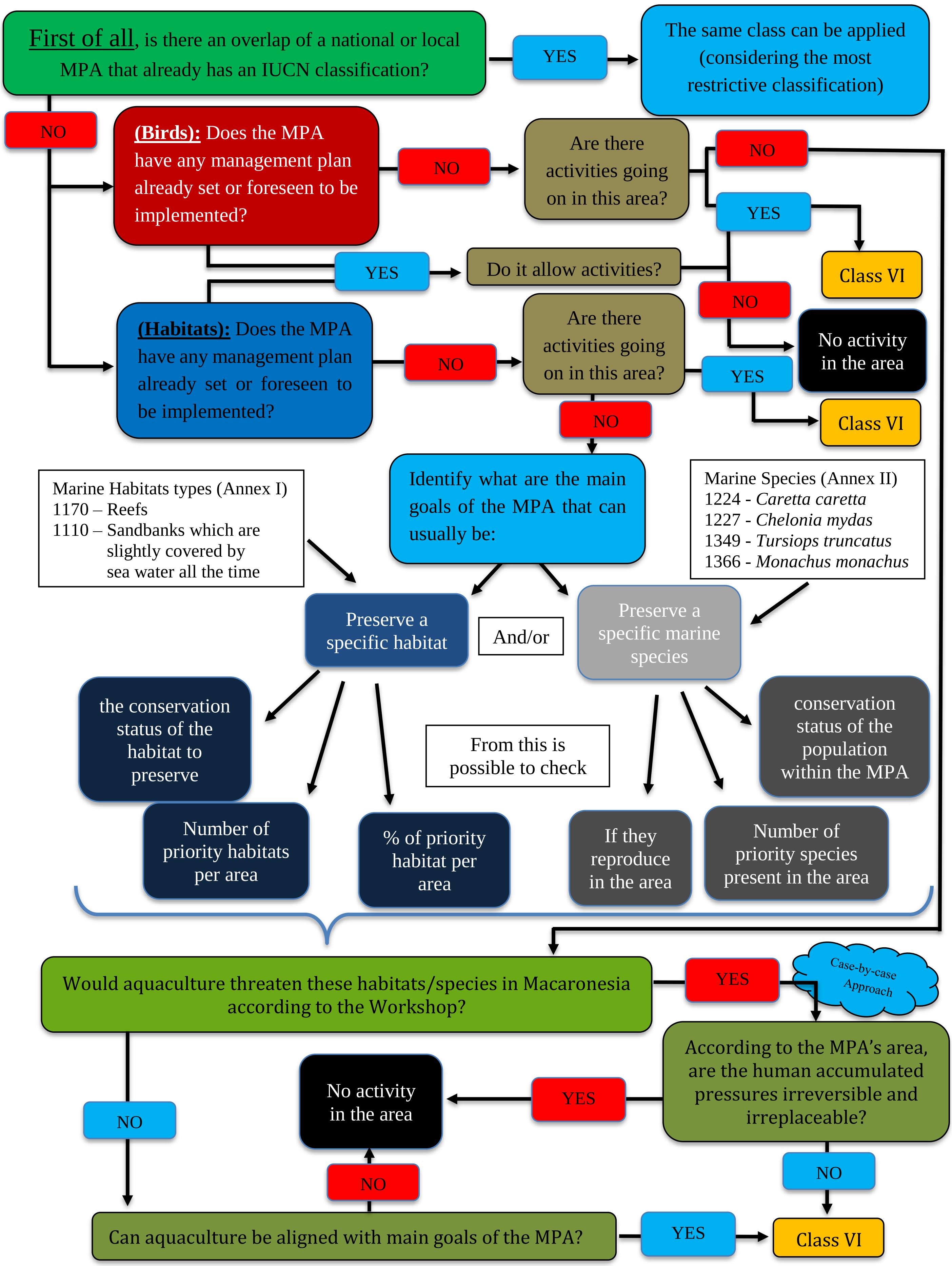

First of all, is there an overlap of a national or local MPA that already has an IUCN classification?
YES
The same class can be applied (considering the most restrictive classification)
NO
(Birds): Does the MPA have any management plan already set or foreseen to be implemented?
NO
Are there activities going on in this area?
NO
YES
YES
Do it allow activities?
Class VI
NO
(Habitats): Does the MPA have any management plan already set or foreseen to be implemented?
NO
Are there activities going on in this area?
No activity in the area
YES
NO
Class VI
Marine Habitats types (Annex I)
1170 – Reefs
1110 – Sandbanks which are slightly covered by sea water all the time
Identify what are the main goals of the MPA that can usually be:
Marine Species (Annex II)
1224 - *Caretta caretta*
1227 - *Chelonia mydas*
1349 - *Tursiops truncatus*
1366 - *Monachus monachus*
Preserve a specific habitat
And/or
Preserve a specific marine species
the conservation status of the habitat to preserve
From this is possible to check
conservation status of the population within the MPA
Number of priority habitats per area
% of priority habitat per area
If they reproduce in the area
Number of priority species present in the area
Would aquaculture threaten these habitats/species in Macaronesia according to the Workshop?
YES
Case-by-case Approach
According to the MPA's area, are the human accumulated pressures irreversible and irreplaceable?
No activity in the area
YES
NO
NO
NO
Can aquaculture be aligned with main goals of the MPA?
YES
Class VI

Figure 7. Methodological flowchart to standardize Natura 2000 areas type of management into the IUCN classification.

Methodology developed and applied in the project:

This methodology enables to deal with MPA and aquaculture potential and was applied and tested in the present study. It includes comparable steps to enable a decision on the possibility to include aquaculture in protected areas that do not have an IUCN classification.

1. The first step is to identify if the analyzed area has two or more protection designation and if any of them include an IUCN classification. If there is an area already classified under IUCN with classes less than V, so they will be classified as so. (example: "Ilhéu da Viuva" in Madeira where a SCI (Habitat Directive) overlaps with "Sítio da Rocha do Navio", an IUCN Class Ib site)

1.1- If yes, then the area is considered the same level as the most protective of the overlapped areas.

1.2- If not, the second step is to identify the existence of a management plan and, if the case, check if it allows activities in the area or not.

2. If yes, management plans, in general, bring the sorts of activities that are allowable or not within the area. Thus, is possible to check if aquaculture would be compatible to the studied MPA.

2.1. If yes, thus the compatibility allows the activity in the MPA.

2.2. But if there is no plan, check if there are activities already going on in this area. If not, with no plan and no activities or only very low impact and no intense activities, then the flowchart takes to another level of research;

3. At this moment, more data is required opening up to several other questions as whether the aquaculture could impact the area; if the aquaculture plan can be aligned with the MPA's goals as preserving or enhancing the priority habitats and species; moreover, about the accumulation of human impacts, if they could be (ir)reversible and (ir)replaceable. Furthermore, these questions would change depending on the type and intensity of production, for instance. Taking into account that in this step, doing nothing formally can also be considered as a measure taken by the authorities. No plan for a protected area is also a decision, although in many cases, unfortunately, is a lack of political will. Besides, relevant data from Natura 2000 can be very useful for this step.

3.1. If data is enough to make the activity to be aligned to the management practices of the area or the precautionary approach can be applied till a certain level where it is known that the environment will not be affected. Then, the area could be classified as level VI from IUCN, as this class gives the opportunity to activities operate inside a Marine Protected Area.

3.2. If data is not enough, then the precautionary approach would be applicable to restring the present MPAs

After having gone through the flowchart for each of the non-classified area and checking about overlapping classified MPAs, management plans, activities in the areas, present species, habitats and impacts, will give if the area will be classified under restrictive classification or a comparative to the class VI by IUCN. However, the conceptual model of accumulation of impacts relies on the type of aquaculture, intensity, species to be produced, local dynamics of the area among other variables in other words, a case-by-case assessment.

### 4.4) Identification of Suitable areas for Aquaculture

In this step, data from all MPAs were analyzed through the ArcGIS software, by selecting areas according to what is established as the most suitable conditions. By the most suitable conditions, the present study considered: marine areas mostly covered by water (area below the mean low tidal level), as our focus is on the production of organisms in water (nearshore and offshore); MPAs larger than 0.5 $Km^2$ (smaller areas were excluded from the analysis, once they all were rocks or islets around the islands or cliffy shores with almost no water surface); Marine Protected Areas from Natura 2000 and IUCN classes V and VI (OSPAR protected areas were not taken into consideration, once they already overlap other classified protected areas). Also, remote areas, sea mountains, banks were not considered as appropriate to have aquaculture, and thus not considered in the present analysis.

Further analysis, including other criteria as proximity to ports, shipping traffic, a maximum distance from the coast, waves intensity and more detailed locations of aquaculture areas inside every MPA regarding local hydrodynamics and habitats distribution, was not considered in this study, since it is foreseen to be done in the next steps of the PLASMAR Project. Other examples of important but not done analysis/criteria at this stage are economic cost benefit analysis and risk analysis from the activity, cumulative impacts, economic feasibility, social acceptance, urban concentrations, sewage or wastewater outlets, regions vulnerable to transboundary impact.

However, in addition to identify MPAs according to their management status, a more detailed analysis was produced for the Canary Islands, as the PLASMAR Project has access to the Ecocartografico data, which zoned the sea bottom habitats from Canary Islands until the bathymetry of 50m. In this way it was possible to identify avoidable sensible habitats. Besides, a buffer distance out of 100m from these habitats was produced in order to protect them from future human activities, in this case, sustainable aquaculture. This buffer zone of 100 meters is suggested to be followed by BOE (2011) and MAPAMA (2013) as good practices, even if the aquaculture production type requires no off-farm input, as feed. This is a protective measure that intends to keep boat traffic, that usually have duties as maintenance of the production, and the production mooring structures, essential for all sorts of nearshore or offshore production, away from sensible and important habitats.

According to the Annex I from the Habitats Directive, which tries to protect the biodiversity hot-spots of Europe, two habitats have the most importance in terms of surface distribution in the marine environment. The ‘Reefs’ (code 1170), which normally have seaweeds as Cystoseira spp. and Sargassum spp. associated to and ‘Sandbanks which are slightly covered by sea water all the time’ (code 1110), which have seagrasses as Cymodocea spp. and Halophila spp. commonly associated to.

Considered bottoms for the present study and their respective EUNIS code were: Cystoseira spp. on exposed infralittoral bedrock and boulders (A3.151); Maerl beds (A5.51); Kelp and seaweed communities on sublittoral sediment (A5.52); Macaronesian Cymodocea beds (A5.5311); Canary Island Halophila beds (A5.5321). Thus, a 100 meters buffer zone around aforementioned habitats was drawn, in order to avoid conflict between conservation and activity.

Map analysis: All areas of Natura 2000 and IUCN classes V and VI were merged to give a shapefile with a unique area. Therefore, all IUCN restrictive areas (Ia, Ib, II, III and IV) were also merged in another shapefile to the result of more protective areas. In both cases, only marine reserves with indeed marine spaces were considered. After that, the more protective areas shapefile was subtracted from the first mentioned one, in order to clip the present overlapping spaces common for distinct categories, as occurs to the "Archipélago de Chinijo" Natural Park, in the north of Lanzarote Island, in Canary Islands. Thereafter, main important seabed habitats according to Habitats Directive and classified by EUNIS were taken into account. In this last step is important to measure a 100 meters buffer zone distance in which aquaculture activities will be far from important seabed habitats as a good practice indicated by BOE (2011) and MAPAMA (2013).

From the maps made: the more protective layer; maps with the suitable MPAs for aquaculture; reproduction sites for the priority species *Tursiops truncatus* and maps for high and medium pressures and threatened MPAs.

### 4.5) Workshop with Experts

A workshop entitled "Good Environmental Status and Aquaculture", coordinated by the University Institute ECOAQUA from the Universidad Las Palmas de Gran Canaria (ULPGC) and the ARDITI from Madeira Islands, was held as part of the PLASMAR Project tasks. The working session was performed at the ECOAQUA facilities in the Marine Technological Science Park of Taliarte, in Gran Canaria.

The main aim of this workshop was to identify, together with experts from the ULPGC Aquaculture Research Group, potential pressures, impacts and potential solutions for the aquaculture activity in the Macaronesia Region. For this purpose, 11 quality descriptors listed by the Marine Strategy Framework Directive (MSFD) 2008/56/EC, defined with Commission Decision 2017/848/EU on Good Environmental Status (GES), were used to establish the criteria and methodological standards applicable to aquaculture in Macaronesian marine waters.

The workshop was organized in a dynamic and participatory way of collaboration amongst the participants. Initially, a general talk about the project was given. In a second part, to increase the level of the interaction with participants, the experts were asked to discuss questions about the influence of aquaculture over the 11 MSFD descriptors: biodiversity (D1), non-indigenous species (D2), commercial fish and shellfish (D3), food webs (D4), eutrophication (D5), seafloor integrity (D6), hydrographic conditions (D7), contaminants (D8), fish and seafood contaminants (D9), marine litter (D10) and energy including underwater noise (D11), which were hanged on the walls around the room (Figure 8). Each descriptor was very well explained, and diverse discussions arose (Png-Gonzalez et al., 2018).

Figure 8. “Workshop Good Environmental Status and Aquaculture” held by PLASMAR Project together with experts from ULPGC Aquaculture Research Group.

## 5) <u>Results</u>

This section contains the results of the processed data collected about the Macaronesian, both qualitatively and quantitatively. Maps from the 3 different studied archipelagos are shown, in order to have the visual location of the selected MPAs that are able to have aquaculture activity. Azores, Madeira and Canary Islands maps are presented together with their different conservation management status and suitability to aquaculture. Also, a more particular analysis about Canary Islands’ MPAs is presented to depict more likable spaces to have sustainable aquaculture activities and check priority marine habitats distribution, as much as priority marine animals and most threatened and pressured MPAs according to acquired data. Moreover, results from the workshop are shown to help discussion on significant impacts aquaculture might impose in the Macaronesia region.

### 5.1) Marine Protected Areas of Macaronesia

From the total number of 184 Marine Protected Areas in the region of Macaronesia, only 26 of them are classified as high protection areas according to IUCN classification (Ia, Ib, II, III and IV) and the remaining 158 as V or VI or in the other 4 classes: Birds Directive, Habitats Directive, RAMSAR Sites or OSPAR areas as shown on the Table 4.

Table 4. Total number of MPAs per classes and per archipelago in Macaronesia. Also, this table contains statistics about areas of MPAs, such as total area; mean marine area; minimum and maximum areas for each archipelago.

| *CLASS* | **NUMBER OF AREAS** | **CORE ZONE** | **AZORES** | **MADEIRA** | **CANARY** | **SELVAGENS** |
|---|---|---|---|---|---|---|
| *IUCN Ia* | **4** | - | 1 | 2 | - | 1 |
| *IUCN Ib* | **13** | - | 9 | 2 | 2 | - |
| *IUCN II* | **1** | - | - | - | 1 | - |
| *IUCN III* | **1** | - | - | - | 1 | - |
| *IUCN IV* | **7** | - | 7 | - | - | - |
| *IUCN V* | **-** | - | - | - | - | - |
| *IUCN VI* | **36** | 3 | 33 | - | 3 | - |
| *Birds Directive* | **42** | - | 10 | 2 | 29 | 1 |
| *Habitats Directive* | **71** | - | 19 | 3 | 48 | 1 |
| *OSPAR* | **8** | - | 8 | - | - | - |
| *RAMSAR Site* | **1** | - | 1 | - | - | - |
| *TOTAL NUMBER* | **184** | | **88** | **9** | **84** | **3** |
| *TOTAL AREA km²* | | | **250 188.2** | **850** | **25 932.3** | **1 252.5** |
| *MAEN AREA km²* | | | **2 885** | **124.2** | **405.7** | **480** |
| *MINIMUM AREA km²* | | | **0.03** | **3.76** | **0.005** | **94.6** |
| *MAXIMUM AREA km²* | | | **12 3661** | **767** | **14 393.2** | **1 252.5** |

Total surface of Marine Protected Areas from Macaronesian is: 278 223 km²

Comparing all the archipelagos regarding their protected surface and number of MPAs from the Table 4, the Azores Islands have the higher number of MPAs from the Macaronesia, 88 in total, from which 50 have the IUCN classification. At the same time, Azores is first in terms of protected surface, 250 188.2 km² in total, as occupies the notably leading position regarding the number of MPAs in different categories, 8 distinct classes of MPAs. Apart from this, Azores is the only archipelago to have OSPAR and RAMSAR sites, 8 and 1, respectively, and also is the unique in the region to have MPAs outside its Economic Exclusive Zone (EEZ).

In the following position about number of MPAs and protected surface come the Canary Islands with 84 MPAs protecting 25 932.3 km², of which only 7 have the IUCN classification. The Canary Islands have the largest number of Natura 2000 areas, 77 in total, being 48 under the Habitats Directive and 29 under Birds Directive.

Successively, the remote Selvagens Islands have 3 MPAs in which protect 1 252.5 km², having only one IUCN classified area. Finally, in the last position regard surface, Madeira Islands have much less space protected in comparison to the other previous two populated archipelagos, comprising a protected surface of 850 km² within 9 areas, in which 4 of them have the IUCN classification. Selvagens Islands belongs to Madeira Archipelago, in administrative terms, and due to its remoteness and a present sensitive political issue, this area is not in the further analysis.

*5.1.1) Most Protective MPAs*

From the total aforementioned 26 most protective MPAs that follow the IUCN management classification, it is important to mention 3 additional core zones from MPAs class VI, which are also restrictive areas and, thus, where most of human activities are not allowed. The total area from these 29 spaces is 113 396.5 km².

The Azores have the largest area from the more protective MPAs, a total of 112 655.25 km² comprised in the categories Ia, Ib and IV (Figure 9). From this area, 11 007.4 km² is within the Azorean EEZ. In other words, about 1.15% of its EEZ is not suitable for human uses or at least is suitable for limited uses. The western Azorean group of islands, the Corvo and Flores Islands, do not have any high protection MPA under the IUCN classification.

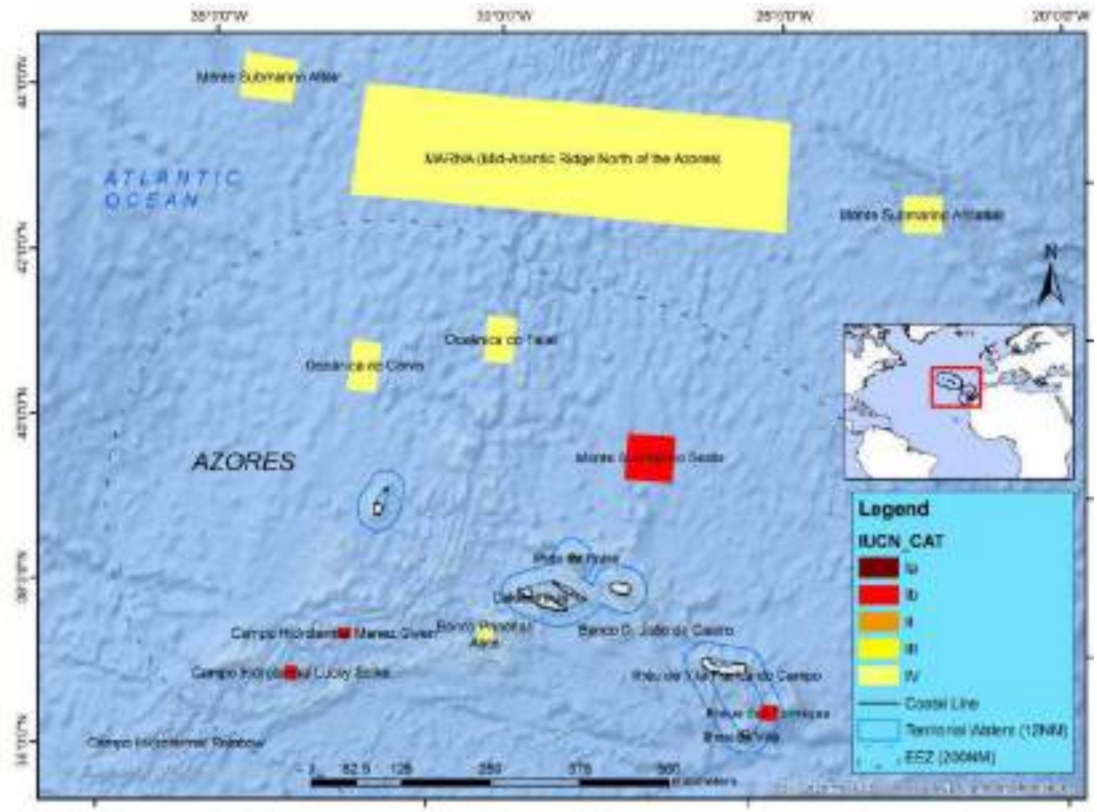



Figure 9. Levels of protection (IUCN Classification) of Marine Protected Areas in Azores Islands

Madeira (Figure 10) has 162.8 km² in total of its areas set as the 2 most protective levels of MPAs, 2 areas in Ia and the other 2 in Ib. In addition, Selvagens has 94.7 km² of its surface protected by the most restrictive class, the Ia. Therefore, their joint EEZ has 0.056% restricted for human uses.

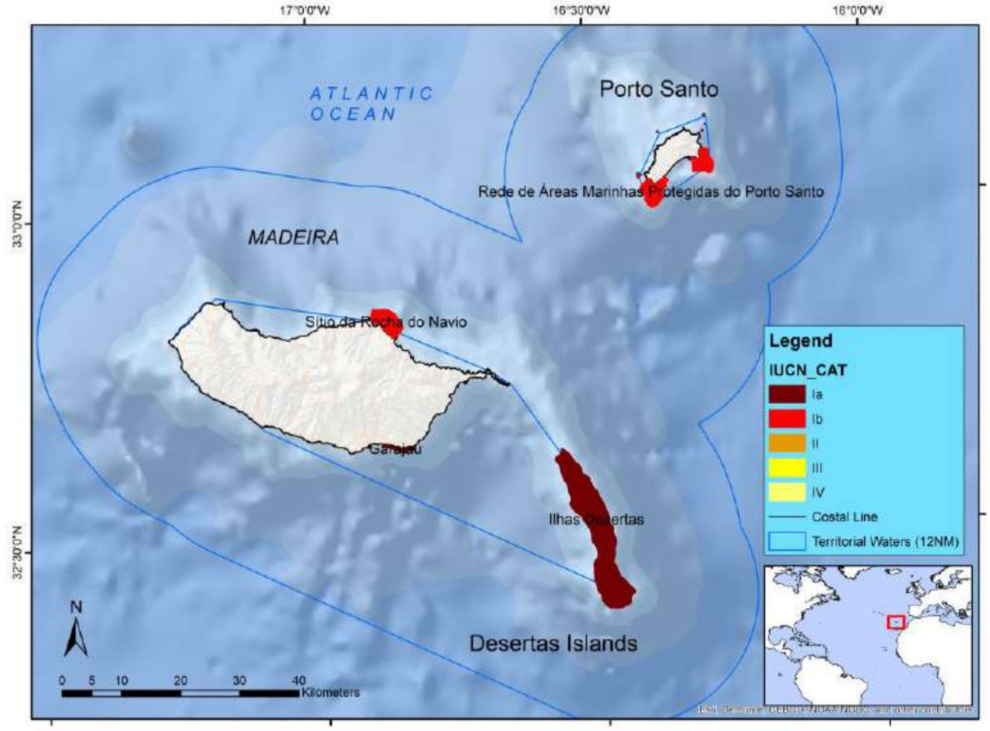



Figure 10. High Protection Marine Protected Areas in Madeira Islands

The Canary Islands (Figure 11 and 12), on the other hand, have 466 km² space classified in classes Ib, II and III, with "Archipélago de Chinijo Reserve" representing most of this value, 461.6 km². However, The Canary Islands also have 3 MPAs class VI that have core zones as part of their areas, which means 14.2 km² more to the account to protective surface, accounting in total 480.2 km². To put it another way, about 11% of Canary EEZ is restricted from human uses.

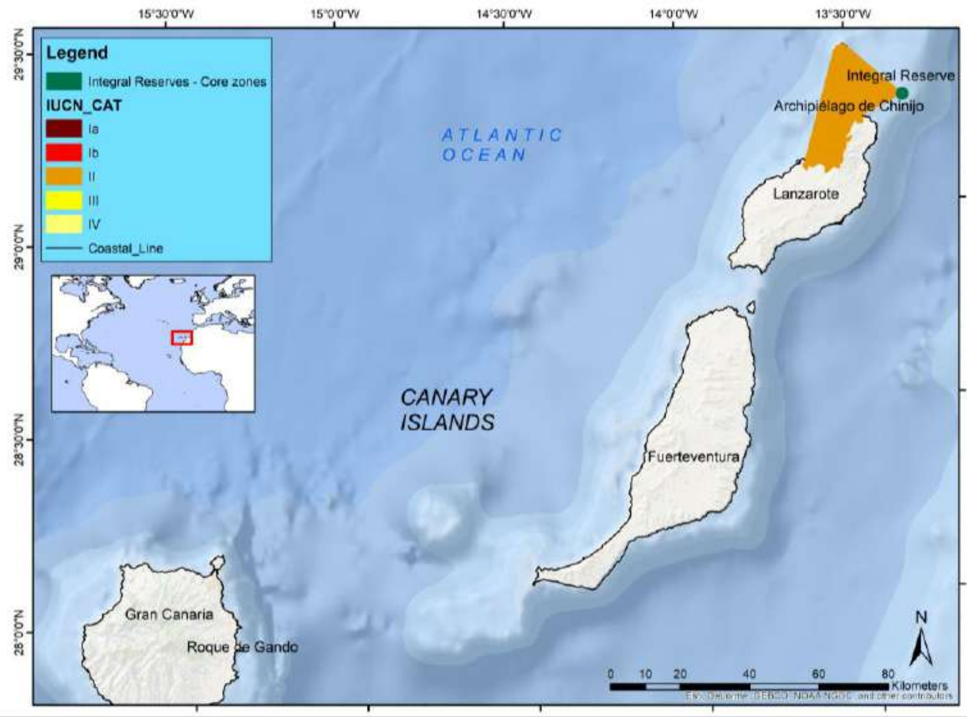



Figure 11. High protection Marine Protected Areas in the eastern group of Canary Islands

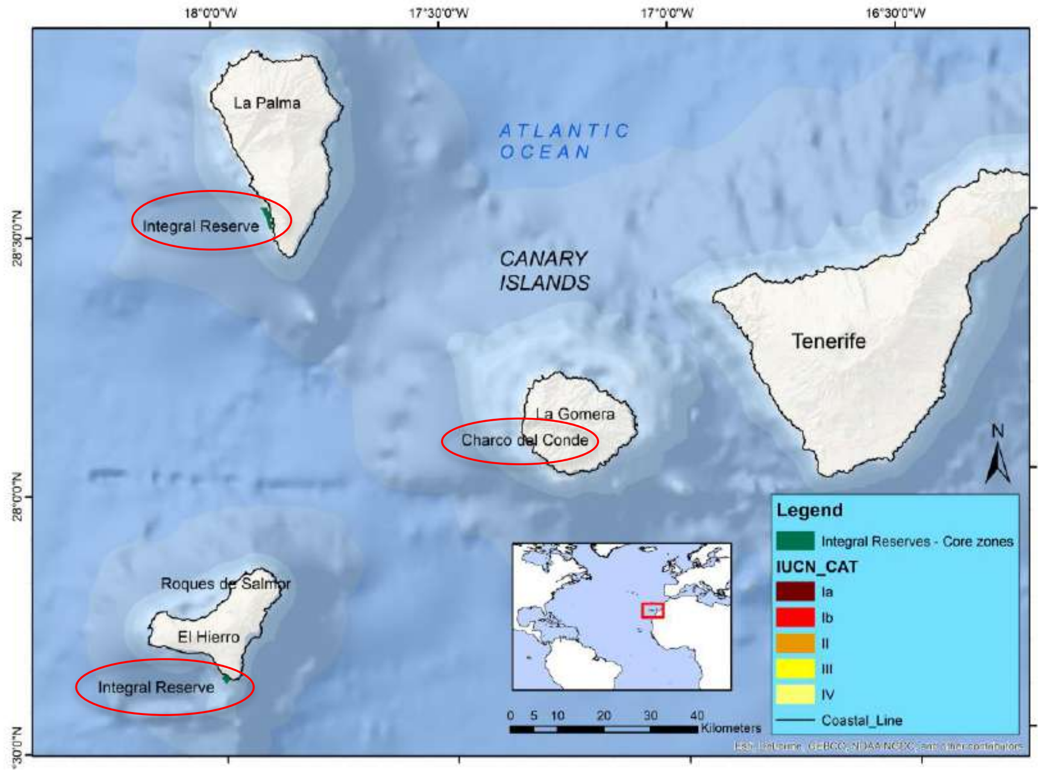



Figure 12. High protection Marine Protected Areas in the western group of Canary Islands

### *5.1.2) Compatible Areas for Aquaculture within MPAs*

After checking the management status of all Macaronesian MPAs through the flowchart aforementioned (Figure 7), it is possible to say that, apart from those overlapping areas by more restrictive classes, all the Natura 2000 are allowed to have activities according to their alignment to the MPA's management goals. Absolutely, it will depend on the way the use or activity is deployed. Natura 2000 is based mainly on the protection of certain priority habitats and species. Consequently, for instance, in a licensing process, if a project for a future human activity advocates for a care regime regarding the preservation of the priority habitats and respect species during its process of installation and operation means that the chances this comes to happen are very likely.

In Figure 18 is possible to observe the 27 suitable Marine Protected Areas for Azores Islands, which represent a total area of 722 km². All Azorean areas, but 1, are classified as Resource Management Protected Areas, which represent the IUCN class VI, where all activities can be performed in concordance to the MPA’s goals. Additionally, as most of the Azorean MPAs are large offshore areas, the percentage of total surface suitable for aquaculture become small, being considered as just 0.28% of the total Azorean MPAs (Figure 13).

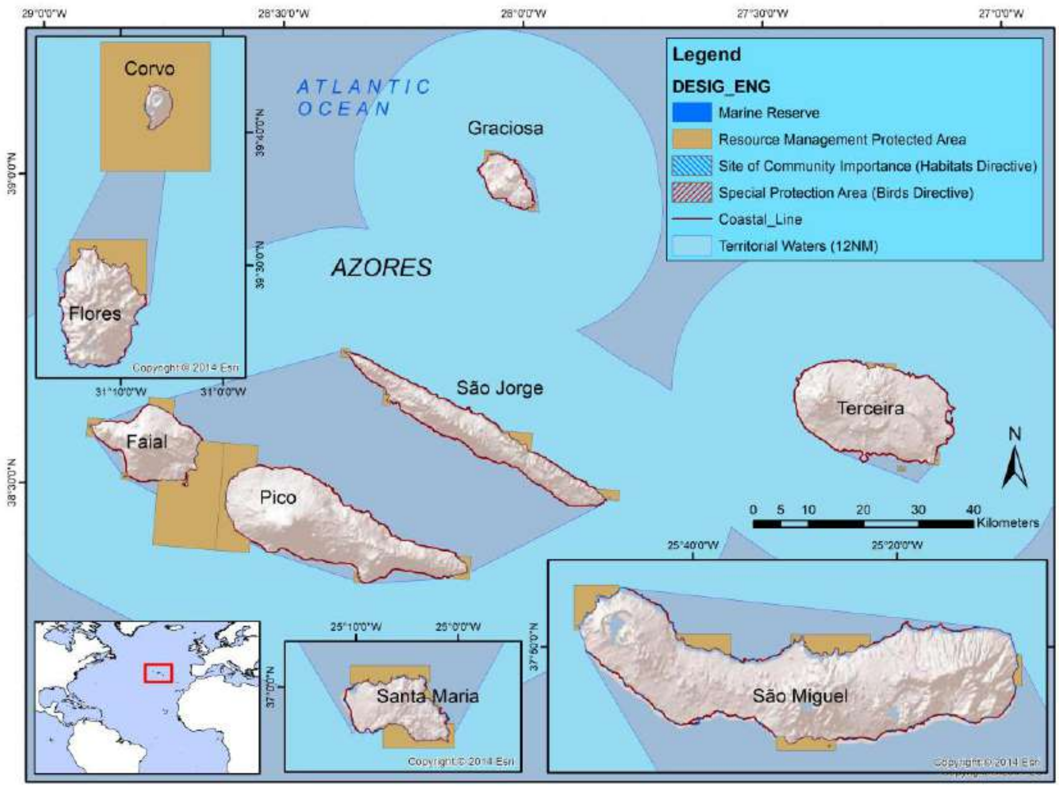



Figure 13. MPAs compatible for aquaculture in Azores

To the Canary Islands (Figures 14, 15, 16 and 17) is possible to observe the distribution of the 37 suitable MPAs that cover a total of 18 556.7 km²

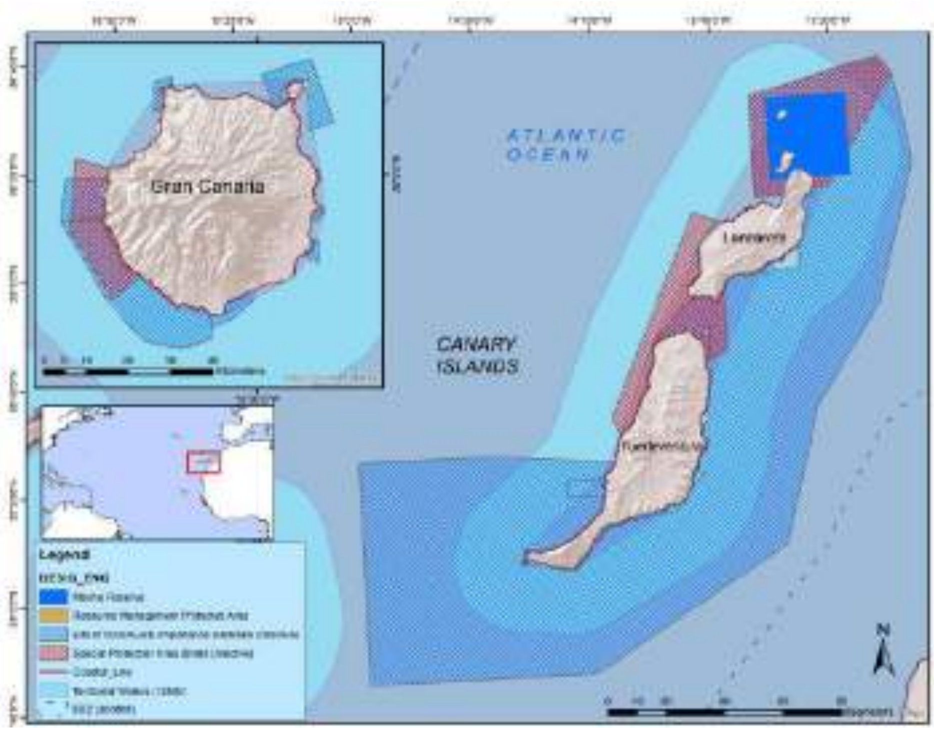



Figure 14. MPAs compatible for aquaculture in the eastern group of the Canary Islands

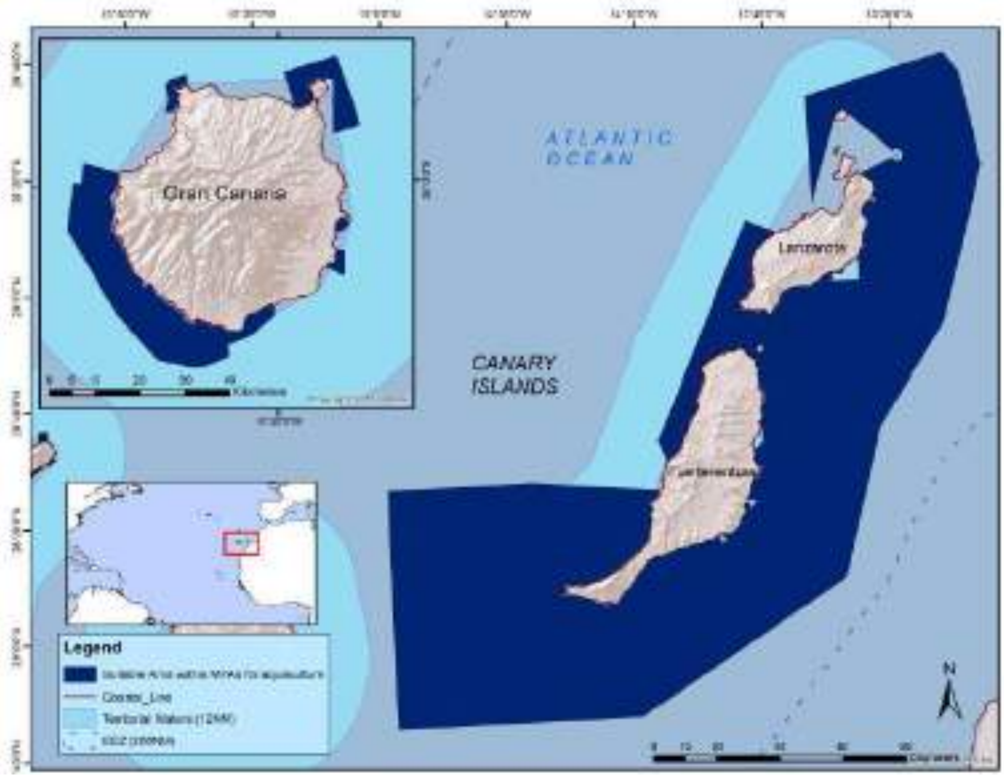



Figure 15. Total area of MPAs compatible for aquaculture in the eastern group of the Canary Islands

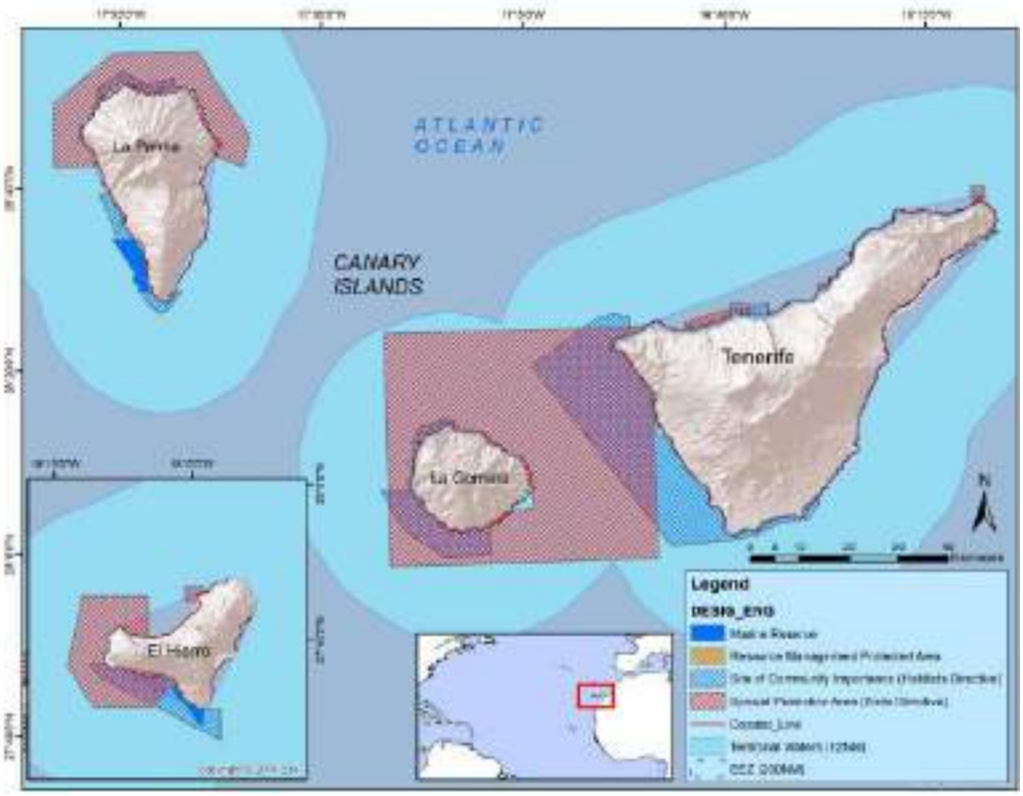



Figure 16. MPAs compatible for aquaculture in the western group of the Canary Islands

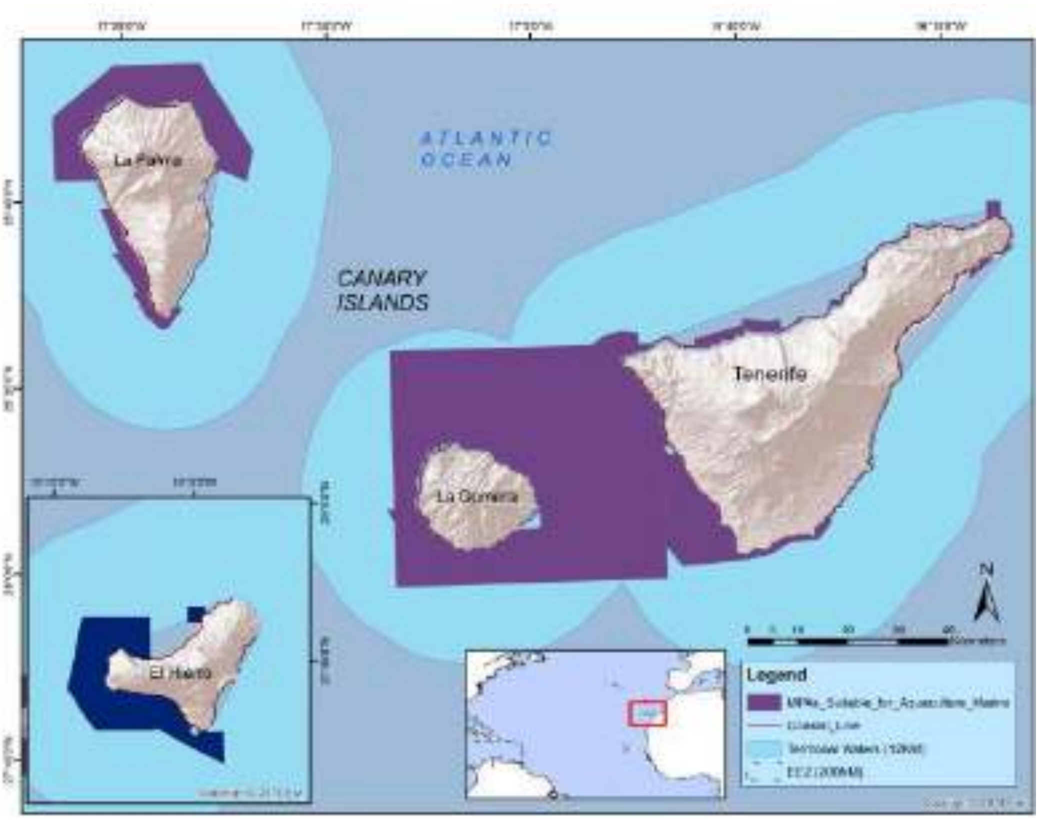



Figure 17. Total area of MPAs compatible for aquaculture in the western group of the Canary Islands

Table 5. Total number of MPAs and their different classes compatible for aquaculture and the total area for the activity within MPAs in Azores and Canary Island.

| | | **Azores** | **Canary Islands** | **Macaronesia** |
|---|---|---|---|---|
| *Total number of Suitable MPAs* | | 27 | 37 | 64 |
| *Total Suitable Area (km²)* | | 722 | 18 556.7 | 19 278.97 |
| *Total MPAs area* | | 250 188.2 | 25 932.3 | 278 223 |
| *Suitable MPAs for aquaculture (%)* | | 0.28 | 71.5 | 6.9 |
| IUCN | V | - | - | - |
| | VI | 26 | 3 | 36 |
| Natura 2000 | *Birds Directive* | - | 10 | 42 |
| | *Habitats Directive* | 1 | 24 | 71 |

In total, 64 different Marine Protected Areas can hold aquaculture uses in Macaronesia. In which, 33 areas in Portuguese Macaronesian waters and 37 in the Macaronesian Spanish ones. Finally, it was observed that only Azores and Canary Islands are able to receive the aquaculture activities according to their MPAs' management classification. All marine protected areas of Madeira have more restrictive categories, even the marine Natura 2000 areas have more protective spaces overlapping them, which make all their marine protected spaces not able to have such activity going on according to suitable conditions of this study.

In the Table 5 is possible to observe that most of MPAs in Canary Islands are able to receive aquaculture, 71.5%, which is mostly due to Natura 2000 areas.

### 5.2 The Canary Islands Case study

This sub chapter was created in order to deepen the analysis specifically for the Canary Islands. This was only possible due to the availability of spatial habitat data, harmonized ECOCARTOGRAFICOS sampled, and combined with data taken *in situ* for this archipelago, not modeled data as the dataset offered by EMODNET for the Macaronesia, which is not as precise nor accurate in terms of special distribution. Other reason for this analysis, was the fact that most of the MPAs from the Canary Islands are under the European Natura 2000 classification (Birds Directive or Habitats Directive). The Natura 2000 dataset brings several updated information about the status of the priority habitats and species, as much as human threats, pressures and uses and other information and, thus, most data from the Natura 2000 repository was able to be used for further analysis.

For this analysis, the 24 Habitats Directive areas, the 10 Birds Directive and the 3 MPAs classified as IUCN Marine Reserves class VI were taken into account. Essentially, the 18 556.7 km² classified as suitable MPAs to hold aquaculture activities, will be narrowed down, excluding the priority and sensible habitats and point out vital areas where priority species reproduce. In a like manner, attention will be called to threats, pressures and uses of the MPAs and possible impact they can have in the percentage of priority habitats per the respective Natura 2000 area.

#### *5.2.1) Priority Habitats in The Canary Islands*

At this sub-section, the Sea Bottom habitats with the priority status according to Natura 2000 will be shown as the example for Gran Canaria (Figure 18). With this information, was possible to further the analysis for the exclusion of sensitive bottom areas for Canary Islands until the isobath of 50m. Other reason for this analysis was the fact that most of the MPAs from the Canary Islands are under the European Natura 2000 classification (Birds Directive or Habitats Directive). This, gives the opportunity to know that the Sea Bottom Habitats classified are considered priority for the majority of MPAs in the archipelago.

Figure 28 depicts an example of the habitats distribution until the isobath of 50m depth for the Gran Canaria Island. On the same Figure MPAs compatible with aquaculture, are depicted in blue. It is possible to observe the greater amount of priority habitats patches in the south of the island, zone with large amount of sediment and more protected from ocean energy too. Also, this is the most touristic area of the island, which might imply more pressures on these habitats.

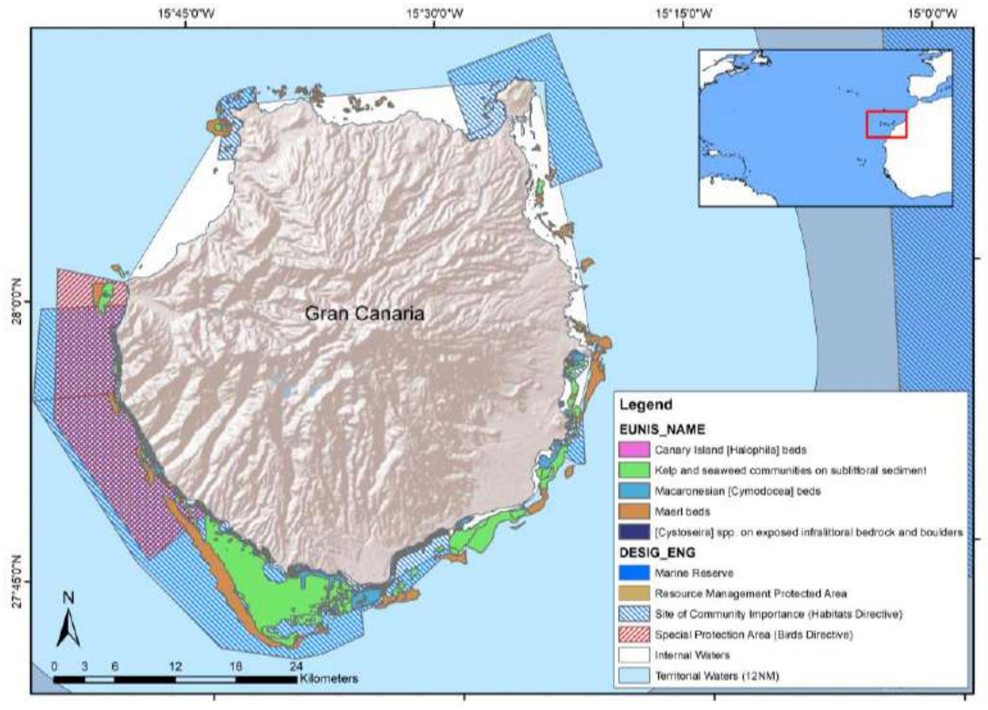



Figure 18. MPAs compatible for aquaculture in their different classes and the priority Sea Bottom habitats with priority status of Gran Canaria Island

### *5.2.2) Priority Animals*

Of the 4 priority marine species in the region, *Caretta caretta* (code 1224), *Chelonia mydas (*code 1227), *Tursiops truncatus* (code 1349) and *Monachus monachus* (code 1366), the dolphins *Tursiops truncatus* have a crucial importance in the 13 protected spaces (Figure 19) where they are known to reproduce. It is possible to observe that the reproduction sites are not the biggest MPAs, they are smaller compared to overall MPAs. Furthermore, reproduction areas are also the regions with denser area of the priority vegetation (seaweed, sea algae), which make these areas yet more important.

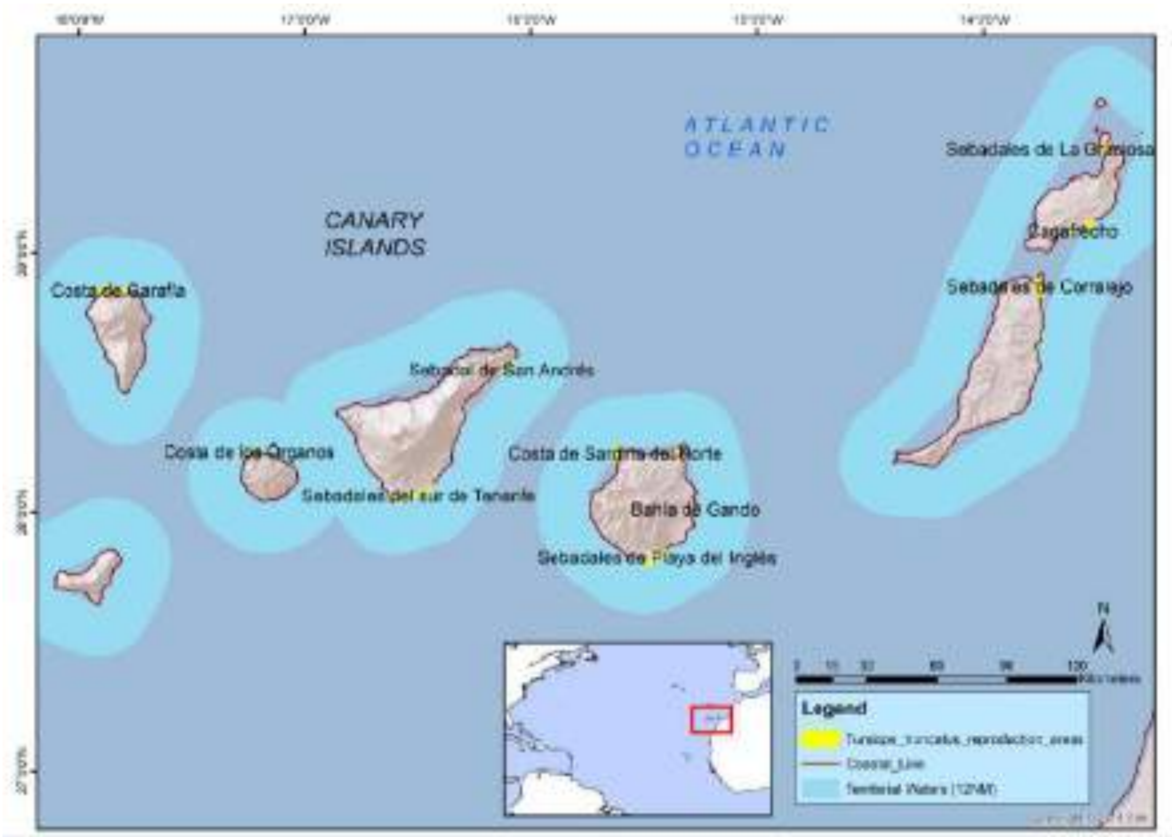



Figure 19. The 13 MPAs where the priority species *Tursiops truncatus* (bottlenose dolphin) reproduces in the Canary Islands

On the Table 6 is possible to identify all the 4 priority species and their conservation status according to the CDDA dataset for these 26 areas.

Table 6. The 4 priority marine species according to Annex III, Habitats Directive, their population type (if they reproduce, in red, if they are seen permanently in the region or if they concentrate sometimes), conservation and global assessment of these species per area in 26 MPAs of the Canary Islands.

| SITE NAME | SPECIES CODE | SPECIES NAME | SPECIES GROUP | POPULATION TYPE | CONSERVATION | GLOBAL ASSESSMENT |
|---|---|---|---|---|---|---|
| Área marina de La Isleta (ES7010016) | 1349 | Tursiops truncatus | Mammals | Permanent | A | A |
| | 1224 | Caretta caretta | Reptiles | Concentration | A | A |
| Bahía de Gando (ES7010048) | 1349 | Tursiops truncatus | Mammals | Reproducing | - | - |
| | 1227 | Chelonia mydas | Reptiles | Concentration | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | A | A |
| Bahía del Confital (ES7010037) | 1349 | Tursiops truncatus | Mammals | Reproducing | A | A |
| | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| Banco de la Concepción (ESZZ15001) | 1349 | Tursiops truncatus | Mammals | Permanent | B | A |
| | 1224 | Caretta caretta | Reptiles | Permanent | B | A |
| Cagafrecho (ES7011002) | 1349 | Tursiops truncatus | Mammals | Reproducing | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| Costa de Garafía (ES7020124) | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| | 1349 | Tursiops truncatus | Mammals | Reproducing | - | - |
| Costa de los Órganos (ES7020125) | 1349 | Tursiops truncatus | Mammals | Reproducing | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| Costa de San Juan de la Rambla (ES7020126) | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| Costa de Sardina del Norte (ES7010066) | 1349 | Tursiops truncatus | Mammals | Reproducing | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| Cueva de Lobos (ES7010014) | 1224 | Caretta caretta | Reptiles | Concentration | A | B |
| Espacio marino del oriente y sur de Lanzarote-Fuerteventura | 1349 | Tursiops truncatus | Mammals | Permanent | B | A |
| | 1224 | Caretta caretta | Reptiles | Permanent | B | A |
| Franja marina de Fuencaliente (ES7020122) | 1224 | Caretta caretta | Reptiles | Concentration | A | A |
| | 1349 | Tursiops truncatus | Mammals | Permanent | A | A |
| Franja marina de Mogán (ES7010017) | 1349 | Tursiops truncatus | Mammals | Permanent | B | B |
| | 1227 | Chelonia mydas | Reptiles | Concentration | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | A | A |
| Franja marina Santiago-Valle Gran Rey (ES7020123) | 1224 | Caretta caretta | Reptiles | Concentration | A | A |
| | 1349 | Tursiops truncatus | Mammals | Permanent | A | A |
| Franja marina Teno-Rasca (ES7020017) | 1227 | Chelonia mydas | Reptiles | Concentration | - | - |
| | 1349 | Tursiops truncatus | Mammals | Permanent | B | A |
| | 1224 | Caretta caretta | Reptiles | Concentration | A | A |
| Mar de Las Calmas (ES7020057) | 1349 | Tursiops truncatus | Mammals | Permanent | A | A |
| | 1227 | Chelonia mydas | Reptiles | Concentration | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | A | A |
| Playa de Sotavento de Jandía (ES7010035) | 1349 | Tursiops truncatus | Mammals | Permanent | A | A |
| | 1227 | Chelonia mydas | Reptiles | Concentration | - | - |
| | 1224 | Caretta caretta | Reptiles | Permanent | A | A |
| Playa del Cabrón (ES7010053) | 1227 | Chelonia mydas | Reptiles | Concentration | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| Sebadal de San Andrés (ES7020120) | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| | 1349 | Tursiops truncatus | Mammals | Reproducing | - | - |
| Sebadales de Antequera (ES7020128) | 1349 | Tursiops truncatus | Mammals | Reproducing | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| Sebadales de Corralejo (ES7010022) | 1349 | Tursiops truncatus | Mammals | Reproducing | A | A |
| | 1227 | Chelonia mydas | Reptiles | Concentration | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | A | A |
| Sebadales de Guasimeta (ES7010021) | 1349 | Tursiops truncatus | Mammals | Reproducing | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| Sebadales de Güigüí (ES7011005) | 1349 | Tursiops truncatus | Mammals | Concentration | B | C |
| | 1224 | Caretta caretta | Reptiles | Concentration | A | C |
| Sebadales de La Graciosa (ES7010020) | 1349 | Tursiops truncatus | Mammals | Reproducing | A | A |
| | 1227 | Chelonia mydas | Reptiles | Concentration | - | - |
| | 1224 | Caretta caretta | Reptiles | Concentration | - | - |
| Sebadales de Playa del Inglés (ES7010056) | 1349 | Tursiops truncatus | Mammals | Reproducing | B | C |
| | 1224 | Caretta caretta | Reptiles | Concentration | A | A |
| Sebadales del sur de Tenerife (ES7020116) | 1224 | Caretta caretta | Reptiles | Concentration | A | A |
| | 1349 | Tursiops truncatus | Mammals | Reproducing | - | - |
| | 1227 | Chelonia mydas | Reptiles | Concentration | - | - |

*5.2.3) The Main Threats, Pressures and Activities within the Natura 2000*

Human activities occur very often inside all Natura 2000 areas, either around the limits of the area or both inside and outside the area. The activities (shown on Table 7) that promote or are considered high or medium level pressure or threat according to Natura 2000 are expressed in distinct color shades. The areas that have more activities are darker and consequently, have a stronger tendency towards be impacted, in the Figures 20 and 21.

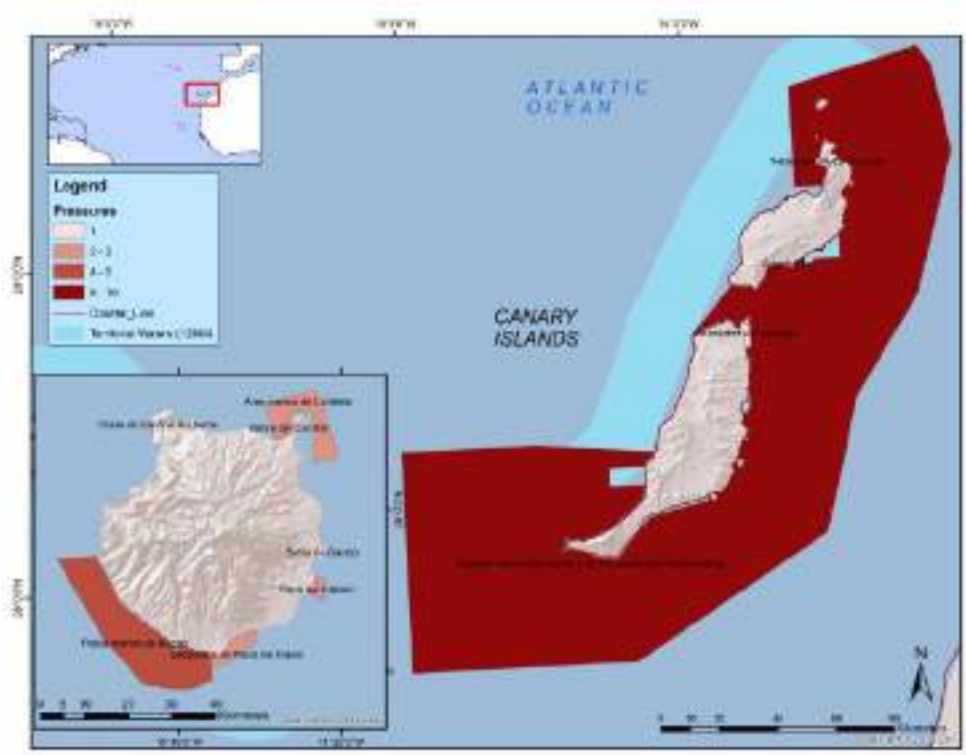



Figure 20. Number of medium and high pressures and threats in the eastern group of the Canary Islands

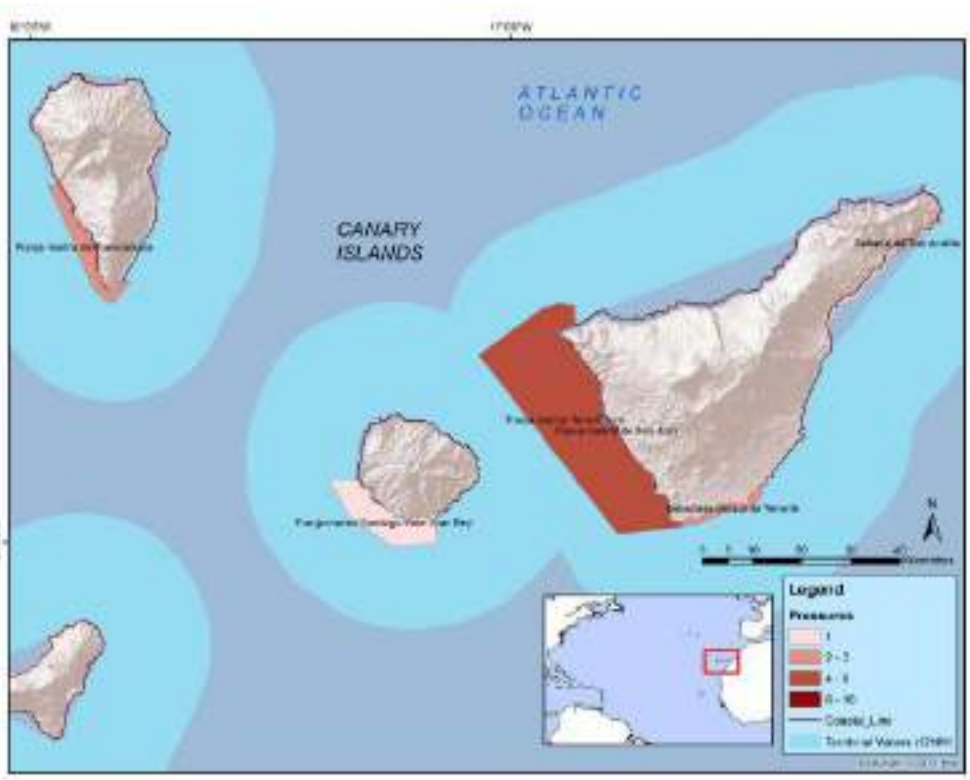



Figure 21. Number of medium and high pressures and threats in the MPAs of the western group of the Canary Islands

The higher number of pressures is associated to larger areas, where the largest area, "Espacio marino del oriente y sur de Lanzarote-Fuerteventura”, from southwest of Fuerteventura to the north of Lanzarote (Figure 20), has the higher number of activities from all MPAs of Canary Islands, according to Natura 2000 database.

On the Table 7, bellow, it is possible to identify the most pressured and impacted Natura 2000 areas and the percentage area of their respective priority Sea Bottom Habitat with the specific threats for each priority habitat.

Table 7. Medium and high threats, pressures and activities within the Natura 2000 areas in the Canary Islands. 4 priority marine species according to Annex III, Habitats Directive, their population type (if they reproduce, if they are seen permanently in the region or if they concentrate sometimes), conservation and global assessment of these species per area in the Canary Islands.

| SITENAME AND SITECODE | AREA (HA) | HABITATS | COVER(HA) | HABITAT (%) | GLOBAL ASSESMENT | THREATS PREASSURES AND ACTIVITIES | INTENSITY | OCCURRENCE |
|---|---|---|---|---|---|---|---|---|
| Área marina de La Isleta (ES7010016) | 8562.09 | Reefs | 708.23 | 8.3 | B | Noise nuisance, noise pollution<br>Shipping lanes | High | IN |
| | | Sandbanks | 405.84 | 4.7 | B | | | |
| | | Sea Caves | - | - | B | | | |
| Franja marina de Mogán (ES7010017) | 29993.09 | Sandbanks | 12077.921 | 40.2 | B | Marine water pollution, | Medium | IN/OUT |
| | | | | | | Invasive non-native species, | Medium | IN/OUT |
| | | | | | | Noise nuisance, noise pollution, | High | IN |
| | | | | | | Marine macro-pollution<br>(i.e. plastic bags, styrofoam), | High | IN |
| | | | | | | Wildlife watching | High | IN |
| Sebadales de La Graciosa (ES7010020) | 1192 | Reefs | 28019 | 23.5 | B | Invasive non-native species | Medium | IN/OUT |
| | | Sandbanks | 843.82 | 70.8 | | | | |
| Sebadales de Corralejo (ES7010022) | 1946.69 | Reefs | 737.83 | 38 | B | Scubadiving, snorkelling | High | IN |
| | | Sandbanks | 929.28 | 47.7 | | | | |
| Bahía del Confital (ES7010037) | 634.27 | Reefs | 389.68 | 61.4 | A | Modification of water flow<br>(tidal & marine currents)<br>Scubadiving, snorkelling | High | IN |
| | | Sandbanks | 207.13 | 32.6 | C | | | |
| Bahía de Gando (ES7010048) | 477.77 | Sandbanks | 435.68 | 91.2 | B | potting | High | IN |
| | | Reefs | 20.49 | 4.3 | | | | |
| Playa del Cabrón (ES7010053) | 956.2 | Sandbanks | 690.28 | 72.2 | A | Removal for collection purposes<br>Scubadiving, snorkelling | High | IN |
| | | Reefs | 120.11 | 12.5 | A | | | |
| | | Sea Caves | - | - | - | | | |
| Sebadales de Playa del Inglés (ES7010056) | 2721.58 | Sandbanks | 2644.53 | 97.6 | B | marine macro-pollution<br>(i.e. plastic bags, styrofoam) | High | IN |
| | | | | | | intensive fish farming, intensification | High | IN |
| | | | | | | Professional active fishing | Medium | IN/OUT |

| SITENAME AND SITECODE | AREA (HA) | HABITATS | COVER(HA) | HABITAT (%) | GLOBAL ASSESMENT | THREATS PREASSURES AND ACTIVITIES | INTENSITY | OCCURRENCE |
|---|---|---|---|---|---|---|---|---|
| Costa de Sardina del Norte (ES7010066) | 1426.56 | Reefs | 529.98 | 37 | B | scubadiving, snorkelling | High | IN |
| | | Sandbanks | 756.2 | 53 | A | | | |
| | | Sea Caves | 14.26 | 1 | B | | | |
| Cagafrecho (ES7011002) | 633.17 | Sea Caves | - | - | B | scubadiving, snorkelling | High | IN |
| | | Reefs | 62.09 | 9.8 | B | | | |
| | | Sandbanks | 186.24 | 29.4 | B | | | |
| Franja marina Teno-Rasca (ES7020017) | 69489.68 | Reefs | 1666.72 | 2.4 | B | Intensive fish farming, intensification<br>Noise nuisance, noise pollution<br>Professional active fishing<br>Wildlife watching<br>Shipping lanes, ports, marine constructions | High | IN |
| | | Sandbanks | 3825.07 | 5.5 | B | | | |
| | | Sea Caves | - | - | - | | | |
| Sebadales del sur de Tenerife (ES7020116) | 2692.68 | Reefs | 298.61 | 11 | - | Removal for collection purposes<br>Noise nuisance, noise pollution | High | IN |
| | | Sandbanks | 1547.35 | 57.4 | B | | | |
| | | Sea Caves | - | - | - | | | |
| Cueva marina de San Juan (ES7020117) | 0.78 | Sea Caves | 0.7 | 89.7 | B | Scubadiving, snorkelling<br>Removal for collection purposes<br>Marine water pollution | High<br>High<br>Medium | IN<br>IN<br>IN/OUT |
| Sebadal de San Andrés (ES7020120) | 582.79 | Reefs | 14.14 | 2.42 | B | Invasive non-native species<br>Noise nuisance, noise pollution | Medium<br>High | IN/OUT<br>IN |
| | | Sandbanks | 325.33 | 55.8 | B | | | |

| SITENAME AND SITECODE | AREA (HA) | HABITATS | COVER(HA) | HABITAT (%) | GLOBAL ASSESMENT | THREATS PREASSURES AND ACTIVITIES | INTENSITY | OCCURRENCE |
|---|---|---|---|---|---|---|---|---|
| Franja marina de Fuencaliente (ES7020122) | 7055.25 | Sea Caves | - | - | B | Professional active fishing<br>Marine macro-pollution (i.e. plastic bags, styrofoam)<br>Fertilisation | Medium<br>High<br>High | IN/OUT<br>IN<br>IN |
| | | Reefs | 2481.99 | 35.2 | A | | | |
| | | Sandbanks | 649.05 | 9.2 | - | | | |
| Franja marina Santiago-Valle Gran Rey (ES7020123) | 13139.09 | Reefs | 323.11 | 2.46 | B | Professional active fishing | Medium | IN/OUT |
| | | Sandbanks | 2505.55 | 19 | B | | | |
| | | Sea Caves | - | - | - | | | |
| Espacio marino del oriente y sur de Lanzarote-Fuerteventura (ESZZ15002) | 1432842.48 | Reefs | 113852.33 | 8 | A | Demersal longlining<br>Seismic exploration, explosions<br>Geotechnical survey<br>Leisure fishing<br>Wildlife watching<br>Outdoor sports and leisure activities, recreational activities<br>Other sport / leisure complexes<br>Shipping lanes, ports, marine constructions<br>Point source or irregular noise pollution<br>Marine macro-pollution (i.e. plastic bags, styrofoam) | Medium | IN/OUT |
| | | Sandbanks | 1501.76 | 0.1 | - | | | |

5.2.4) *Suitable Analysis of Aquaculture until 50m in The Canary Islands*

At this sub-chapter, it will be shown the suitable areas for aquaculture, excluding habitats taken into consideration to be avoided from Canary Islands with a buffer zone (100m) until the bathymetry of 50m. The total size area suitable for aquaculture, according to this analysis is 999.2 km², which represents 0.05% of the total Canary Islands MPAs would allow the activity.

It is possible to observe that in the group of western islands (El Hierro, La Gomera, La Palma and Tenerife, on Figure 23) the bathymetry is much steeper and practically there is no continental shelf. This implies that on these islands, the area suitable for aquaculture is restricted to a narrow strip. On the other hand, on the eastern islands (Gran Canaria, Fuerteventura and Lanzarote, on Figure 22) there are more sediments around them on wider continental shelves, therefore, displaying larger areas suitable for aquaculture until further from the coast.

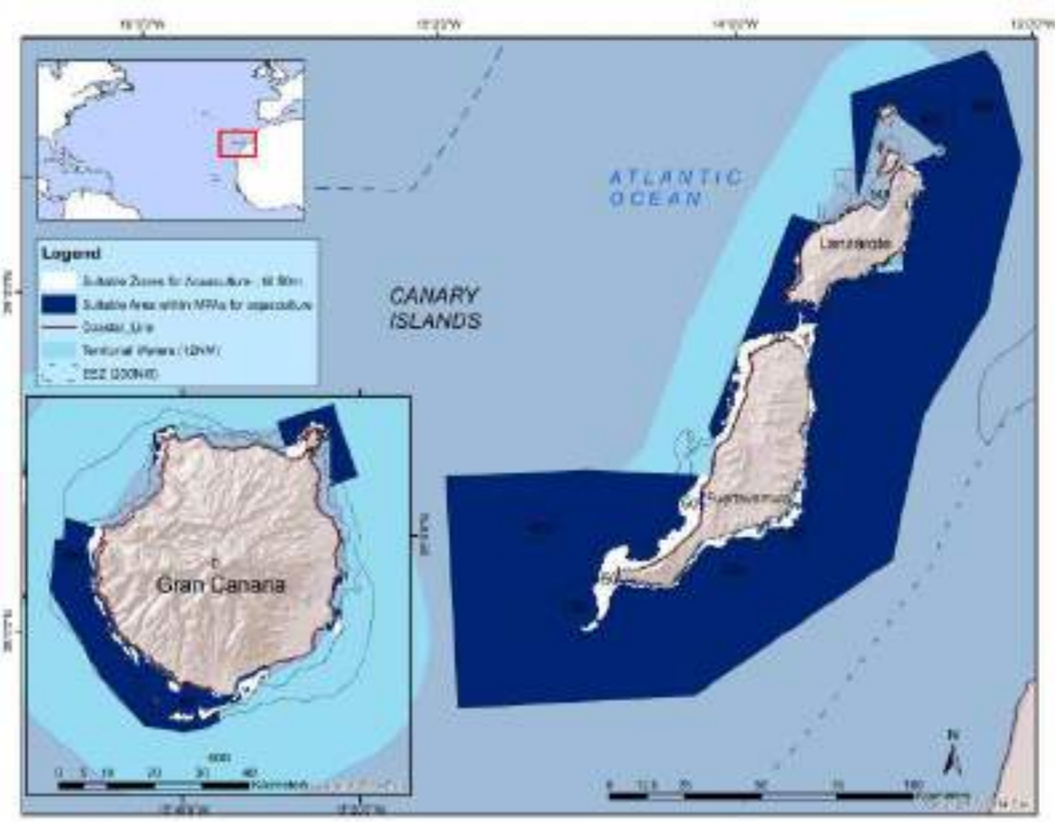



Figure 22. Suitable areas for aquaculture within MPAs in the eastern group of the Canary Islands until 50m. A buffer zone (100m) and bathymetry (50m, 100m, 200m, 500m). In white, is represented the suitable areas for aquaculture through the deeper analysis. In dark blue is the total area of suitable MPAs for aquaculture from the previous analysis.

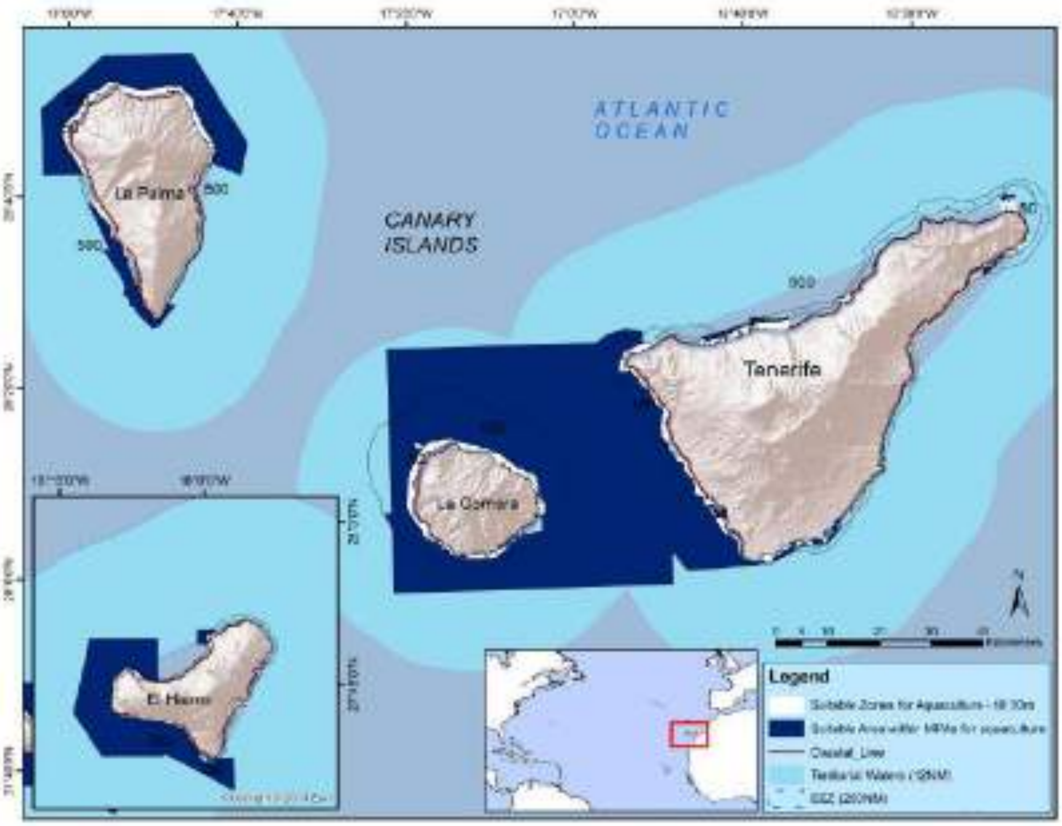



Figure 23. Suitable areas for aquaculture within MPAs in the western group of the Canary Islands until 50m. A buffer zone (100m) and bathymetry (50m, 100m, 200m, 500m). In white, is represented the suitable areas for aquaculture through the deeper analysis. In dark blue is the total area of suitable MPAs for aquaculture from the previous analysis.

5.2.5) *Comparison with the new PROAC*

Very recently, in July of 2018, the Canarian regional government approved the Regional Aquaculture Management Plan for Canary Islands (PROAC) which stipulated aquaculture areas in Canary Islands. According to the plan, there are no stipulated areas for aquaculture in La Gomera nor in El Hierro Islands and Tenerife and La Palma have very narrow stripes destined to the activity. Besides that, almost all areas from Lanzarote and Fuerteventura are delimited already inside Habitats Directive areas, as well as in Tenerife. La Palma has part of its only area inside a Birds Directive area. Gran Canaria, on other hand, has almost no aquaculture areas delimited within MPAs.

Although the distribution of the areas is available online and it is possible to identify the areas designated to the activity through the map bellow (Figure 24), it is not possible to check the area size as necessary data were not provided. The numbers on the map refer to current fish cage farms in the zone, which represent 13 near-coastal aquaculture units, in which Lanzarote and Tenerife have 1 and 5 cage farms, respectively.

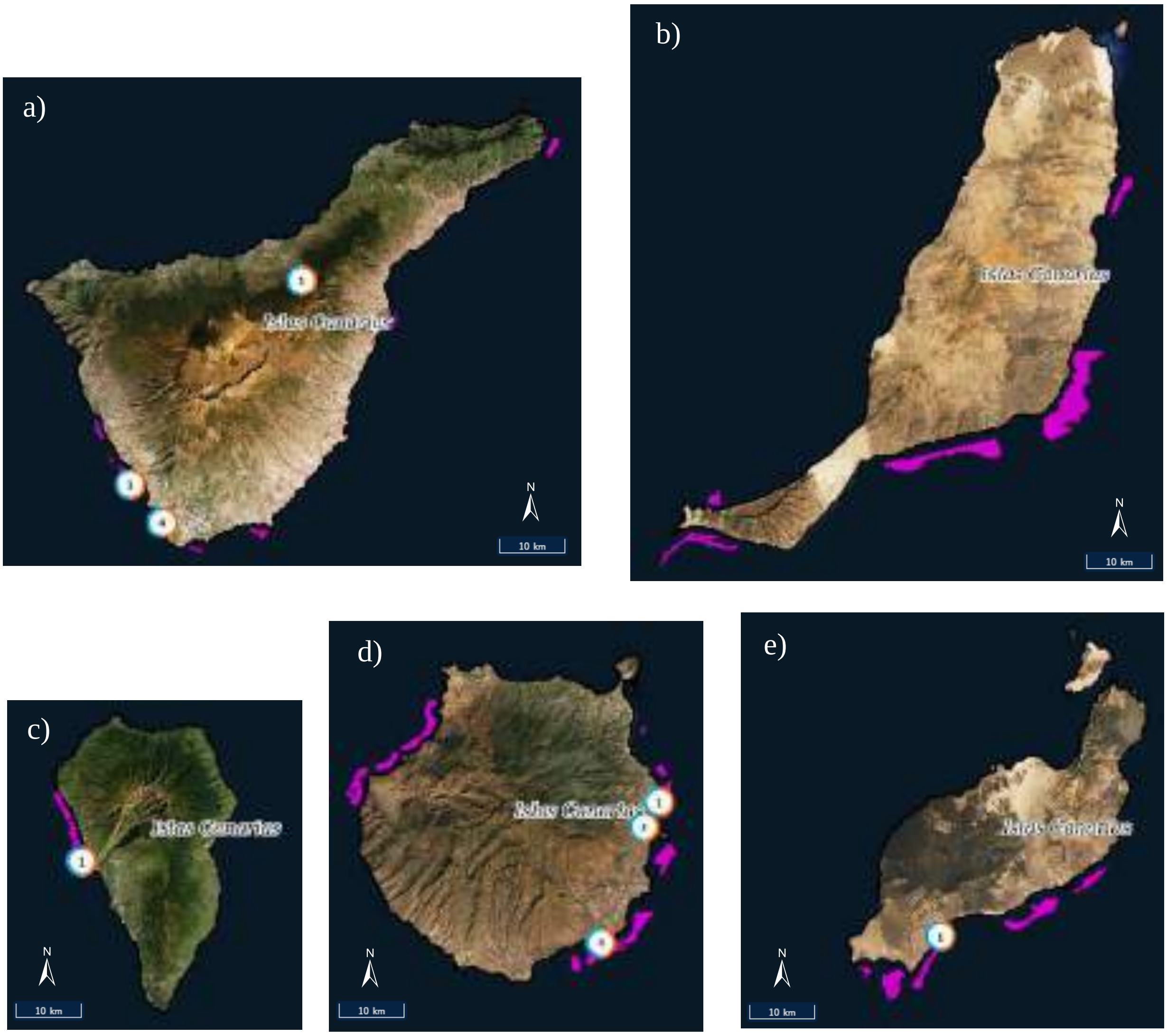



Figure 24. The new Regional Aquaculture Management Plan for Canary Islands (PROAC) areas, approved in the middle of July 2018 with the number and location of the current marine aquaculture farms. a) Tenerife; b) Fuerteventura; c) La Palma; d) Gran Canaria; e) Lanzarote. PROAC does not set areas for aquaculture activity in the Islands of La Gomera and El Hierro. (Source: https://servicio.pesca.mapama.es/acuivisor/)

### 5.3) Workshop Results

After very productive discussions about the subject, experts agreed about implications of aquaculture in Macaronesia according to the 11 MSFD descriptors. This workshop had extremely importance to identify what are the main impacts aquaculture can have in the surrounding environment. In the case of the present study more specifically, takes account that the influence of these issues become even more sensible within MPAs. Besides, outcomes from the Workshop "Good Environmental Status and Aquaculture" will be shown to demonstrate the most several impacts from aquaculture in the Macaronesia environment. At the end, results from the PLASMAR decision supporting system for MSP zoning, web application INDIMAR (http://www.geoportal.ulpgc.es/indimar/).

According to the workshop, experts stressed the fact that depths greater than 40m there is practically no influence from intensive aquaculture to the bottom, once nutrients are carried away and dissolved from the strong currents of oceanic islands. So, in this case, within MPAs, no intensive production should be performed. However, if an intensive aquaculture unit is up to be implemented within an MPA, it is possible to use a precautionary approach. In this way, until 50m depth the "Ecocartografico" analysis of the priority bottom habitats (Figure 22 and 23) presented the compatibility of places to have aquaculture within MPAs. And from 50m depth onwards, it would be possible to have, in a general way, most of the aquaculture types of production.

For Birds Directive, according to the workshop, it is possible to receive aquaculture, once does not directly contribute in the seabirds change behaviors. During breeding seasons, mitigation management practices can be adopted to avoid seabirds change their foraging patterns.

The same occur for Marine Mammals, as there are no many studies about that, it is assumed that the impact still not significant for entanglements. Thus, would not even significantly impact the behavior of local dolphins.

## 6) Discussion

Aquaculture is a fast-growing activity worldwide. Its production is vital to help feeding the world and supplying other resources, as energy, industrial substances and others in the current proportion population is demanding from natural resources. Thus, the sustainability of this activity is crucial to the maintenance of a Good Environmental Status of several different habitats and species. The possible coexistence with Marine Protected Areas must give floor to a research intensification and to evolve to a more holistic approach, in order to identify the functionality of the system from local to regional scale, give birth to carrying capacity technology analysis encouraging single-species to ecosystem-level considerations, as stressed by Froehlich et al., (2017).

Sustainable aquaculture can enhance coastal communities as a key role for food security, poverty alleviation and economic resilience, as well as promoting synergies, diversifying local markets and livelihoods. Likewise, it is even possible involve local communities in the steering process of the MPA, promoting community-based aquaculture and conservation. There are many opportunities and several of them can be strictly aligned with conservation goals. Enhance, restore and replace species and habitats through sustainable production is key to change paradigms that will help to improve local communities, supply world's future necessities and ameliorate ecosystem services.

However, more research is necessary to fill the gaps about conservation and aquaculture interactions. Collaborative projects that unite industries, scientists, local communities and governments should bring innovation and technologies to increase knowledge about workable synergies, promote health ecosystems and change the way seafood and other resources from aquaculture are supplied. Especially due to Aichi targets and CBD, the focus of the conservation nowadays is becoming more inclusive, taking into account people's activities, thus becoming a solution instead of the problem.

Aquaculture, if well planned, offers a huge synergistical potential not just for producing food for a growing planet, but provide livelihoods to coastal communities and, in the case of shellfish or seaweed culture, help even recover lost ecosystem services in degraded zones generating protection areas for juveniles and small species, for instance.

Absolutely this activity has to respect the capacity of the system and make all the possible to avoid any possible impacts that could hindrance conservations goals. Alien species, escapees, input of nutrients, antibiotics trophic level of the species produced, are some among many of the current issues science and private companies try to tackle, in order to make the sector more profitable and sustainable. A good management plan, following the diverse good practices guidelines is crucial to ameliorate the quality of the production and the environment functionality. Good practices of management of aquaculture are crucial for the maintain or improve the GES. Recommendations such as: not allow any type of spill or littering from a vessel or platform located in the sea; ban the anchoring over seagrass meadows, understanding the anchoring as the fixing of an anchorage system on the seabed; Avoid the installation of cages of marine cultures in areas of known distribution of the species *Tursiops truncates* or very close to priority habitats (MAPAMA, 2013; Borg, 2016).

Similarly, it is possible that different activities coexist on the same space. Aquaculture might bring tourists to visit the farming sites, taste the local products and learn from the benefits of the activity, at the same time that produces food or any other resource. Also, the local wild species will bring a larger community that can be found around the farm and, thus, other kind of tourism is attracted, the ones interested in the live bellow water.

By setting a space for seafood production might reduce the available fishing areas within MPAs, which can improve the protection status of the determined zone within an MPA. With the rotation of people in a certain frequency for maintenance of the farms also might have an indirect effect in helping avoid Illegal, Unreported and Unregulated fishing (IUU) by making the community responsible for physicalizing these spaces for the benefit of all. In other words, engage locals to help in the protection of the MPA.

The question of site selection is well documented in the literature and should take into account environmental as well as aquaculture technical and socio-economic issues (IUCN, 2007, 2009a; Aguilar-Manjarrez et al., 2017). If socio-economical sustainability of local fisheries accepts levels of sustainable capture on wild stocks within MPAs, these levels of compliance depending on the sensitiveness of coastal habitats should similarly allow aquaculture co-development in some MPAs. Clearly the species being considered for cultivation will be a major issue if it is non-native that could disrupt native populations. Some guidance on aquaculture and MPAs for the Natura 2000 sites has been developed within the European community and can be an example of interest for other countries as it explains in detail a step-by-step procedure for a full impact assessment (European Commission, 2012; Gouvello et al., 2017)

The vital parameters to study will depend in a straight line on the characteristics of the site in question, on how urgently the data are required and on the type of aquaculture to be developed. The site characteristics to be examined, aside from those relating to the environment, include the traditional activities carried out in the area, interference with other activities in terms of use, and the particular socioeconomic elements present.

It is arguably suggested the seasonal farming where production (of certain algae, for instance) takes place during winter, while tourism (for example) can use more space during the summer, or vice versa, for instance. Changes in water temperature and salinity could influence it. Maybe it could cope with seasonal fishing closures. Many other governance measures can take the floor and improve local communities. Also, temporally closures or changes in the behavior of the consumers will have to change too.

Apart from that, other suggestions would promote more sustainable aquaculture systems as IMTA, which tend to be more balanced for the environment, at the same time that diversify produced species. Also, avoid many activities in areas and seasons of breeding, spawning, nursery and migration of priority species. Maintenance activities would have to be reduced to avoid impact a priority species.

A good governance practice would involve a couple of principles and practices, in which the knowledge, the participatory approach, social acceptability, the precautionary principle, the scale approach, the adaptive approach, economic aspects, the legal framework, administrative procedures, sectoral planning, private sector, organizations, integrated coastal zone management (ICZM), the site selection process, the ecosystem approach, carrying capacity, indicators and models, environmental impact assessment (EIA), environmental monitoring programme (EMP), Geographical information systems (GIS) are all of extremely important in the different steps of the planning process. Nowadays the Ecosystem Approach to Aquaculture (EAA) and ecological aquaculture by Costa-Pierce (2013) state that farms are "aquaculture ecosystems" intended to deliver both economic and social profit using ecological principles.

Investing in an aquaculture production might propitiate the development of other steps of the production as creating land-based hatcheries facilities that fulfill grow-out necessities and even open doors for exportation and, consequently, diversifying local market and increasing livelihoods. FAO,2010; Kapetsky et al., 2013

Macaronesia has an enormous potential to perform aquaculture within diverse MPAs according to their management status. Now is part of the future studies tell how this interaction should take place in a local scale.

All the information created for this thesis will become database for PLASMAR project. More specifically, this data will be inserted in the decision supporting system for MSP zoning-web application INDIMAR, which will go further to the next steps of analysis regarding the impacts of human activities.

### 6.1) Limitation of the study or difficulties faced in the analysis process

The main limitations of the present study were the lack of data, outdated data, expansive data or non-available data due to governmental/institutional bureaucracy and timelines. More investment in research is necessary as very little is still known about species and habitats and their ecological functions. For instance, no data exist for spawning areas of turtles is available. Even data about current aquaculture sites or current areas determined for aquaculture is not free for download. The new Regional Aquaculture Management Plan for Canary Islands (PROAC) was approved at the middle of July but no data was updated till the end of this work. Distribution of human activities, data of fishing areas, current aquaculture sites and planned areas for example, ability to monitor progress towards such targets has been constrained by a lack of robust data in marine protected areas.

### 6.2) Future studies suggestion

It is indispensable consider local contexts when studying oceanic islands. For that, study accumulative human impacts and the carrying capacity of the system as much as to check whether they are irreversible and/or irreplaceable is essential to the better understanding of the relation of the activity (in its different intensities and types) with the environment. Studies as modelling of nutrient distribution per site or per aquaculture zone area are important to better estimate nutrient distribution from an aquaculture farm within an MPA and its implications to the local and regional scales. Besides, it is also important to study how aquaculture increases the functionality of the system.

## 7) Conclusion

- It is possible to associate aquaculture production and marine conservation within marine protected areas;
- Aquaculture activity must be aligned with the local conservation management plan;
- Good practices of management of aquaculture are crucial to maintain or improve the GES and ensure ecosystem services;
- Macaronesia has many spaces where sustainable aquaculture could be implemented;
- Good governance is essential to have better coordination between different activities, avoiding conflicts and increasing synergies;
- Aquaculture within MPAs is an opportunity in Macaronesia to enhance coastal communities as a key role for food security, poverty alleviation and economic resilience, diversifying local market and livelihoods;
- Sustainable aquaculture production can be diversified and give place to conservation aquaculture within MPAs;
- There is no approach as the panacea to adapt an aquaculture production in MPA, each aquaculture project is different and should be taken as a case-by-case approach;
- Each aquaculture project is different and should be taken as a case-by-case approach due to the changeability character of its several variables (from the production system type and intensity to local environmental dynamics);
- More studies are necessary to conciliate conservation and aquaculture.

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ANNEXES

Annex 1 – Description of the most widespread aquaculture production systems

-Species and Trophical Level (Seaweeds, Molluscs, Crustaceans, Finfishes)

- Growing Phases / Life Cycle (Hatcheries, Broodstock, Larval Rearing, Nursery, Grow-out)

- Farming Systems (Cages/Ponds, Suspended Culture, Vertical or Rack Culture, Bottom, Ponds, Recycling Aquaculture Systems (RAS), Integrated Multitrophic Aquaculture (IMTA), Aquaponics)

- Intensity (Intensive, Semi-intensive, Extensive)

- Aquaculture Site (Land-based Aquaculture, Inland or Inshore, Nearshore or Coastal, Offshore or Open-Sea)

Nearshore: This coastal area comprises depths that range from 20 to 50 metres. Closeness to the shore and shallow water imply a greater concentration of uses, as this is the area traditionally used for tourism, coastal navigation, etc.

Offshore: This is aquaculture carried out in exposed areas offshore (more than 3 nautical miles from the coast), and also includes floating or semi submerged shellfish and fish farming systems. In these areas there is much less interference from other uses, since they are farther from shore and therefore more difficult to reach and have more complex environmental and oceanographic conditions. On the other hand, obtaining environmental information about these areas is more difficult and more expensive, which is why they are often less well known

(Source: IUCN, 2017 and others)

## Annex 2 – IUCN Management Categories

Table 8. Definition and Primary Objectives of IUCN Protected Area Categories (Dudley, 2008)

| IUCN Category | Definition | Primary Objective |
|---|---|---|
| Ia | Category Ia are strictly protected areas set aside to protect biodiversity and also possibly geological/ geomorphological features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring. | To conserve regionally, nationally or globally outstanding ecosystems, species (occurrences or aggregations) and/ or geodiversity features: these attributes will have been formed mostly or entirely by non-human forces and will be degraded or destroyed when subjected to all but very light human impact. |
| Ib | Category Ib protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition | To protect the long-term ecological integrity of natural areas that are undisturbed by significant human activity, free of modern infrastructure and where natural forces and processes predominate, so that current and future generations have the opportunity to experience such areas. |
| II | Category II protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities. | To protect natural biodiversity along with its underlying ecological structure and supporting environmental processes, and to promote education and recreation. |
| III | Category III protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine caverns, geological feature such as caves or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value. | To protect specific outstanding natural features and their associated biodiversity and habitats. |
| IV | Category IV protected areas aim to protect particular species or habitats and management reflects this priority. Many category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category. | To maintain, conserve and restore species and habitats. |
| V | Category V protected areas are where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation and other values. | To protect and sustain important landscapes/ seascapes and the associated nature conservation and other values created by interactions with humans through traditional management practices. |
| VI | Category VI protected areas conserve ecosystems and habitats together with associated cultural values and | To protect natural ecosystems and use natural resources sustainably, |

| | | |
|---|---|---|
| | traditional natural resource management systems. They are generally large, with most of the area in natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area. | when conservation and sustainable use can be mutually beneficial. |