UNITED NATIONS

EP

UNEP/MED WG.509/39

UN environment programme | Mediterranean Action Plan Barcelona Convention

30 August 2021
Original: English

Meeting of the MED POL Focal Points

Videoconference, 27-28 May and 6-7 October 2021

Agenda item 14: Review of assessments for development of three new Regional Plans in accordance with Article 15 of the LBS Protocol for the biennium 2022-2023

Assessment of aquaculture practices in the Mediterranean and their impact on the marine environment

UNEP/MAP
Athens, 2021

Note by the Secretariat

The 21st Meeting of the Contracting Parties to the Barcelona Convention COP21 (Napoli, Italy, 2-5 December 2019) adopted Decision IG.24/10 which endorsed the main elements for development/ update of six new Regional Plans related to the urban wastewater treatment, sewage sludge management, agriculture management, aquaculture management, storm water management in addition to updating the current Regional Plan for Marine Litter Management in the Mediterranean. COP21 also approved the way forward proposing the time frame for the development, negotiation and adoption of the six Regional Plans. With regard to the Regional Plan on the Prevention and Reduction of Pollutant Releases in the Mediterranean Sea from Aquaculture, the Meeting approved submission of the new Regional Plan to COP 23 (December 2023). In preparation for the development of this Regional Plan, the Programme of Work (PoW) and Budget for the biennium 2020-2021, which was adopted in Decision IG.24/14, mandated MED POL in Activity 2.4.3.1(c) to undertake an "assessment of status and impacts of aquaculture on the marine environment."

The present assessment, produced in coordination and support of Plan Bleu Regional Activity Centre, provides an overview of the aquaculture sector in the Mediterranean; state of play of aquaculture facilities and current practices in the Mediterranean; impacts of significant aspects of the aquaculture sector in relation to practices common to onshore and offshore aquaculture; culture practices in onshore and offshore aquaculture; legal and institutional measures in place for regulating the onshore and offshore aquaculture; and currently applied Best Available Techniques (BAT) and Best Environmental Practices (BEP) in Mediterranean aquaculture. The assessment includes an evaluation of current and potential level of implementation (or non-implementation) of proposed measures included in the main elements for the Regional Plan on Aquaculture Management including recommendations for additional complementary measures and proposals to improve BAT and BEP for onshore and offshore aquaculture.

The assessment on aquaculture practices in the Mediterranean and their impact on the marine environment was discussed during the Meeting on National Baseline Budget Methodologies, Assessments of new Regional Plans and Evaluation of National Action Plans under the LBS Protocol in April 2021. The Meeting agreed with the findings and recommendations of this assessment and requested the Secretariat to proceed with submission to the Meeting of the MED POL Focal Points.

The Meeting of the MED POL Focal Points is expected to review this draft assessment and to provide its comments with the aim of approval as a background information document for further elaborating the new Regional Plan for Aquaculture Management in the Mediterranean during the biennium 2022-2023.

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List of Abbreviations / Acronyms

ADCP	Acoustic doppler current profilers
AZA	Allocated Zones for Aquaculture
BAT	Best Available Techniques
BC	Barcelona Convention
BEP	Best Environmental Practices
CCRF	Code of Conduct for Responsible Fisheries
DHA	Docosahexaenoic acid
DIN	Dissolved inorganic nutrients
DNA	Deoxyribonucleic acid
DO	Dissolved oxygen
EAA	Ecosystem Approach to Aquaculture
EC	European Commission
EIA	Environmental Impact Assessment
ELV	Emission Limit Values
EMP	Environmental Monitoring Programme
EPA	Eicosapentaenoic acid
EQS	Environmental quality standards
EU	European Union
EUMOFA	European Market Observatory for fisheries and aquaculture
FAO	Food and Agriculture Organization
FCR	Feed Conversion Ratio
GES	Good Environmental Status
GFCM	General Fisheries Commission for the Mediterranean
IAS	Invasive Alien Species
ICZM	Integrated Coastal Zone Management
IMRAS	Integrated Multi-trophic Recirculating Aquaculture Systems
IMTA	Integrated multi-trophic aquaculture
LBS	Land Based Sources
MEDPOL	Mediterranean Pollution Control and Assessment Programme
MSFD	Marine Strategy Framework Directive
MSP	Maritime Spatial Planning
NPK	Nitrogen:Phosphorus:Potassium
OECD	Organisation for Economic Co-operation and Development
Poly-APSs	Polymeric 3-alkylpyridinium salts
POM	Particulate organic matter
RAS	Recirculating aquaculture systems
SEA	Strategic environmental assessment
SQS	Sediment quality standards
TSS	Total suspended solids
UK	United Kingdom
UNEP/MAP	United Nations Environment Programme / Mediterranean Action Plan
UV	Ultra-violet
WFD	Water Framework Directive
WQS	Water quality standards
WSN	Wireless sensor networks

1. Overview of the Aquaculture Sector in the Mediterranean

1. The Mediterranean is a large, semi-enclosed sea bordered by 22 countries, with two distinct basins divided by a narrow, relatively shallow channel between Sicily in the north and Tunisia in the south. The areal division of the sea between the western and eastern basin is roughly 1/3:2/3. The eastern basin is somewhat more saline than the western basin, especially in the vicinity of the Suez Canal (Angel, 2013). Despite its impressive biodiversity, biomass is relatively low, mainly due to low primary production. The total length of the Mediterranean coasts is approximately 45 000 kilometres. It is highly populated region with numerous and varied activities, including tourism, which strongly compete for sea space with the aquaculture industry (Cardia et al, 2007).

2. In the Mediterranean region, aquaculture plays a major role in food security, jobs creation and economic growth while reducing dependence on overexploited wild stocks. Mediterranean aquaculture is experiencing remarkable steady growth since 1980, especially with adoption of modern grow out technologies. Aquaculture contributes 47% of the total fish production (2016). The total aquaculture production (comprising fish, shellfish and crustaceans farmed in marine, brackish waters) increased from 643 thousand tonnes in 2000 to 1,144 thousand tonnes in 2010, continuing up to 1,575 thousand tonnes in 2016. Turkey (31%), Greece (25%), Italy (24%) and Spain (7%) contributes 87% of the total production. In 2016 Mediterranean marine fish production reached approximately 334,000 tonnes, with total value of US$2 billion. Turkey receives the highest annual revenues, of about US$670 million. The main species produced are sea bass (42%) and sea bream (41%). The sector plays an important socioeconomic role in coastal communities, as it provides more than 313,000 jobs in Mediterranean and Black Sea countries (Bolognini et al, 2019). This rapid growth poses serious challenges including environmental impacts on marine and coastal ecosystems and associated biodiversity.

2. State of play of aquaculture facilities and current practices in the Mediterranean

3. This section presents the state of play of aquaculture facilities and current practices in the Mediterranean. This also includes commonly applied practices; pollutants and contaminants discharged from onshore and offshore aquaculture facilities; related regulatory framework and institutional frameworks in the Mediterranean; as well as existing BAT and BEP for onshore and offshore aquaculture.

2.1 Commonly applied practices in the aquaculture sector

Culture systems

4. Bolognini et al (2019) categorised the Mediterranean Aquaculture on the basis of intensification of farming systems:

   a. **Lagoon culture** is a traditional form of extensive fish aquaculture that originated in the Mediterranean, using coastal lagoons, salt ponds and large brackish areas in transitional waters. It relies on natural fry recruitment or controlled seeding of hatchery fingerlings, and management of water in-flow inside channels and barriers of farming areas. Fish are prevented from returning to the sea by complex permanent capture systems and fish barriers. These systems are typical of the northern Adriatic Sea (e.g. the seasonally based ‘valliculture’).

   b. **Land-based ponds**, mainly shallow earthen basins where modern systems ensure water supply, are used for seabass and seabream in Portugal, southern Spain and Italy. Farms use various levels of intensification and pond size, but in general these are semi-intensive systems covering large areas, with individual ponds ranging from one to several hectares.

   c. **Land-based tank** systems are an intensive solution for culturing high-value fish. Most systems used for hatchery production are recirculated closed systems (RAS), separated from the external environment by physical filters and drains. These allow the control of water parameters and environmental conditions, which are of paramount importance for rearing eggs, larvae and juveniles. The use of temperature controls frees the activity from local environmental climate constraints. In the Mediterranean, land-based tanks are used mainly along Italian coasts and are equipped with flow-through sea water systems.

d. **Sea net pens** is the most common aquaculture system in coastal and open waters. It uses large pocket-shaped nets anchored to the bottom and maintained on the surface by a rectangular or circular floating framework. These net pens are widely used for rearing finfish, such as sea bass and sea bream and to a lesser extent trout, in coastal and open waters. The openness of the farming system makes it vulnerable to external influences (pollution events and physical impacts), as well as exposing marine ecosystems to potential pressures from farming activities (use of chemicals, nutrients and effluent release, spread of pathogens etc).

Species composition

5. The main cultivated finfish species in the region are gilthead sea bream (*Sparus aurata*), European sea bass (*Dicentrarchus labrax*), and flathead gray mullet (*Mugil cephalus*). Sea bream and bass are predominantly reared in net cages in coastal waters, whereas mullets are generally reared in ponds.

2.2 Pollutants and contaminants discharged from onshore and offshore aquaculture facilities

6. The mariculture effluent mainly consists of organic matters and nutrients (originated from fertilizers, feeds, and metabolic processes) and chemicals (comes from therapeutants and antifouling paints). Xinyan et al (2020), described the composition and source of the pollutants in Table 1:

Table 1: Composition and main source of mariculture effluents in cage systems

Composition	Main Source	
Organic matter and nutrients	Organic carbon	Uneaten feed, feaces
	Urea	Excretion
	Uric acid	Excretion
	Nitrogen (N)	Uneaten feed, feaces
	Phosphorus (P)	Uneaten feed, feaces
Chemicals	Antibiotics	Uneaten feed, feaces and biliary excretion
	Pesticides	Uneaten feed, feaces and biliary excretion
	Parasiticides	Uneaten feed, feaces, biliary excretion and water column (bath)
	Algaecides	Water column (bath)
	Disinfectants	Water column (bath)
	Hormones	Uneaten feed, feaces and biliary excretion
	Zinc	Feed, algaecides and pesticides
	Copper	Antifoulant paints, algaecides and pesticides
	Lead	Antifoulant paints

2.3 Related regulatory framework and institutional measures in the Mediterranean

UNEP/MAP Barcelona Convention System

7. The UNEP/MAP–Barcelona Convention system is the comprehensive institutional, legal and implementation framework that the Contracting Parties have adopted for concerted action to fulfil the vision of a healthy Mediterranean Sea and Coast that underpin sustainable development in the region. The Barcelona Convention and its seven Protocols constitute a unique and advanced multilateral legal framework for the protection of the marine and coastal environment and sustainable use of their resources in the Mediterranean. The Land-Based Sources (LBS) Protocol is a very relevant one which proposes “to take all appropriate measures to prevent, abate and eliminate to the fullest extent possible

pollution of the Mediterranean Sea by from land-based sources and activities, by the reduction and phasing out of substances that are toxic, persistent and liable to bioaccumulate listed in the Protocol."

8. The Protocol on Integrated Coastal Zone Management (ICZM) is another Protocol of relevance which was adopted the Contracting Parties to the Barcelona Convention in 2008. Under this Protocol, the Parties are committed to establish a common framework for the integrated management of the Mediterranean coastal zone and to take the necessary measures to strengthen regional cooperation for this purpose. The Protocol aims to provide a framework under which countries can better plan and manage their coastal zones and deal with emerging coastal challenges.

9. To this end, the urgent implementation of short, medium and long-term measures is required in order to address the challenges currently facing the aquaculture industry, including market competition, environmental issues, allocation of space in coastal areas for aquaculture farms, and competition among the different users of the coastal space and resources. In this context, the establishment of Allocated Zones for Aquaculture (AZAs) is to be considered within the framework of ICZM and against the background of Mediterranean Sea governance, with regulations and/or restrictions assigned to each zone in accordance with their suitability for aquaculture activities and carrying capacity limits, and it should be supported by a multidisciplinary and multi-stakeholder approach, in coherence with the principles of sustainable development (Macias et al, 2019).

FAO/GFCM Strategy and Technical Guidelines

10. There are a number of strategies and guidelines from FAO/GFCM among which Code of Conduct for Responsible Fisheries (CCRF), Ecosystem Approach to Aquaculture (EAA), Marine Spatial Planning (MSP), Allocated Zones for Aquaculture (AZAs) are relevant.

EU Regulations

11. The Mediterranean aquaculture is governed in EU Member States which are Parties to the Barcelona Convention by a number of EU regulations. Regulation (EU) No 1380/2013 of the European Parliament and the Council of 11 December 2013 on the Common Fisheries Policy, Strategic Guidelines for the sustainable development of EU aquaculture (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee of the regions -2013) and Regulation (EU) No 708/2007 of the European Parliament and of the Council amended by Regulation (EU) 304/2011 of 9 March 2011 concerning use of alien and locally absent species in aquaculture are very relevant. The recent EU Farm-to-Fork Strategy fixed a number of targets in line with Sustainable Development Goals, among which two are relevant for aquaculture - i) reduce the sale of antimicrobials for farmed animals and in aquaculture by 50% and ii) 25 % of total farmland being used for organic farming.

Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD)

12. In EU-Member States which are Parties to the Barcelona Convention, the WFD and MSFD are applied. The WFD aims to improve and protect the chemical and ecological status of surface waters and the chemical and quantitative status of groundwater bodies throughout a river basin catchment. This extends from rivers, lakes and ground-waters through to transitional (including estuaries) and coastal waters. Whereas the MSFD aims to achieve good environmental status (GES-MSFD) in marine waters. Its scope of application extends to coastal waters on aspects of environmental status which are not already addressed by the WFD or other Community legislation, as well as the full extent of Member States territorial waters over which they have or exercise jurisdictional rights (MSFD, Article 3.1). To help achieve GES-MSFD, eleven descriptors of the state of the environment have been defined: biodiversity, non-indigenous species, commercial fish, food webs, eutrophication, sea-floor integrity, hydrographical conditions, contaminants, contaminants in fish and seafood, litter, and underwater energy such as noise.

2.4 Existing BAT and BEP in the Aquaculture Sector commonly found in the Mediterranean

Recirculating aquaculture systems (RAS)

13. RAS are land-based aquaculture facilities – either open air or indoors – that minimise water consumption by filtering, adjusting, and reusing the water. Compared to traditional pond or open water aquaculture, the water recirculation process in RAS makes it possible to control the culture conditions and collect waste. In addition, land-based aquaculture avoids escapees and limits external transmission of diseases and parasites. RAS gives promise of more sustainable food production with healthier fish, lower consumption of fresh water, and shorter transport distances, as fish can be grown closer to the markets (EUMOFA, 2020). The present-day RAS generally consists of (i) devices to remove solid particles from the water which are composed of fish faeces, uneaten feed and bacterial flocs, (ii) nitrifying biofilters to oxidize ammonia excreted by fish to nitrate and (iii) a number of gas exchange devices to remove dissolved carbon dioxide expelled by the fish as well as/or adding oxygen required by the fish and nitrifying bacteria. In addition, RAS also use UV irradiation for water disinfection, ozonation and protein skimming for fine solids and microbial control and denitrification systems to remove nitrate (S. Goddek et al., 2020).

Integrated multi-trophic aquaculture (IMTA)

14. IMTA is one of the most promising pathways in the evolution of aquaculture systems. IMTA is based on the integrated cultivation of aquatic organisms belonging to different and complementary trophic levels. Inorganic and organic wastes from fed aquaculture organisms (e.g. finfish) are assimilated by respectively, autotrophs (phytoplankton, macroalgae, plants) and heterotroph species (oysters, mussels, sea cucumbers) that are co-cultured with the fed organisms. IMTA systems are designed in order to:

a. Decrease the dependence on external inputs, and increase the system efficiency by optimizing the use of nutrients and energy in the production loop,
b. Decrease the waste effluent and bio-deposit impacts by limiting the loss of nutrients (in water, sediments and air)
c. Diversify farm- products and generate a more robust source of income (less dependent on mono-product markets)
d. Generate and use different types and levels of ecosystem services

15. In general, an IMTA includes the combination of fed aquaculture (e.g. finfish) with suspension organic extractive aquaculture (e.g. shellfish), taking advantage of the enrichment in small particulate organic matter (POM), while inorganic extractive aquaculture (e.g. seaweeds) benefit from the increased availability of dissolved inorganic nutrients (DIN). Simultaneously, deposit organic extractive aquaculture (e.g. echinoids, holothuroids, decapods and polychaetes), make use of the enrichment in large POM, and faeces and pseudo-faeces (F & PF) from suspension-feeding organisms. The bioturbation and microbial mineralization on the bottom regenerates more DIN, which become available to the seaweeds (Chopin et al., 2008).

Biofloc technology

16. Biofloc Technology is considered as new “blue revolution” since nutrients can be continuously recycled and reused in the culture medium, benefited by the minimum or zero-water exchange. It is an environment friendly aquaculture technique based on in-situ microorganism production. Biofloc is the suspended growth in ponds/tanks which is the aggregates of living and dead particulate organic matter, phytoplankton, bacteria and grazers of the bacteria. It is the utilization of microbial processes within the pond/tank itself to provide food resources for cultured organism while at the same time acts as a water treatment remedy. Thus, this system is also called as active suspension ponds or heterotrophic ponds or even green soup ponds.

3. Impacts of significant aspects of the aquaculture sector on the Mediterranean marine environment

17. Further to the significant aspects identified in the previous section, impacts of these aspects are assessed in this section in relation to practices common to onshore and offshore aquaculture; culture practices in onshore and offshore aquaculture; legal and institutional measures in place for regulating the onshore and offshore aquaculture; and currently applied Best Available Techniques (BAT) and Best Environmental Practices (BEP) in Mediterranean aquaculture.

3.1 Practices common to onshore and offshore aquaculture in the Mediterranean

Impacts of feeding practices, uneaten feeds and excreta

18. A large portion of feed applied remains uneaten by fish which is majorly factored by in-efficient feeding practices. The improper feeding ration and feeding frequency are the main reasons for this. The fish do not take feed if supplied in an excess rate than its ability to take; if the pellet is not in detectable condition and the feed is of inferior quality (high solubility, bad smell, less digestibility etc. resulting low Feed Conversion Ratio (FCR). The feed intake also depends on the feeding behaviour of the respective species. Hence, the proper feeding practice is of utmost importance to minimise the nutrient release in the system. At present, different types of feeding system are practiced, including manual feeding, self-contained underwater feeders and an automated remote-controlled feeding system. The latter two produce less organic matter than the former one. In the tuna penning industry, as those are fed whole (preferably oily) fish such as sardine, anchovy, and mackerel, the water around the pens often has an oily film and emits a strong smell, resulting the poor water quality.

19. According to Xinyan et al. (2020), the most significant negative environmental impacts of intensive mariculture are those related to high loads of organic matter, including nutrients and solids. Organic matter contributes to nutrient pollution, which further leads to hypoxia and eutrophication through fertilized aquatic plant growth and respiration. Significant concentrations of organic matter and nutrients cause the excessive growth of phytoplankton, which reduces the transparency of the water column, affecting the photosynthesis of aquatic plants and impairing the balance between primary and secondary productivity. Li et al. (2011) found that eutrophication and high levels of organic matter lead to low dissolved oxygen concentrations in the water column, resulting in a reduction of wild fish populations which have detrimental impacts on other aquatic organisms as a result of deteriorated habitat quality. Ballester et al. (2017), highlighted that in contrast, the uneaten feeds are also used as resources to the biofouling communities attached to the cage structures and the wild fish in the surrounding waters. This can result in the aggregation of fish or other trophic creatures around the cage facilities, stimulating biological activity. The benthic environment is also affected remarkably. Martinez et al (2012) showed that Organic and nutrient enrichment may also change the physicochemical compositions of seabed sediments and further affect the abundance, biomass and biodiversity of the benthic communities. An increase of total organic carbon accumulation in the sediment would be harmful to benthos due to decreasing oxygen availability. On the contrary, the enrichment in lipid content due to the accumulation of uneaten food pellets on seabed would become nutrient resources to promote microbenthic algal growth. (Xinyan et al, 2020).

Impacts of medicines/antibiotics

20. A variety of chemicals is used for disinfection and disease outbreak treatment in aquaculture. In addition, pharmaceuticals and other contaminants of emerging concern are not completely removed during wastewater treatment processes, these contaminants are actively discharged to surface water bodies (Bodik et al., 2016; Golovko et al., 2014a, 2014b; Yang et al., 2017) when wastewater are reused for aquaculture. Environmental impacts of chemical compounds depend on toxic effect of the compound, pathogens sensitivity to antibiotics, therapeutics and active time zone of the chemical in the environment. Most of the medicines were adapted from the poultry and cattle husbandry and their possible effect on the marine environment isn't fully investigated (Illhan et al, 2017). As the medicines are generally applied through mixing with feed or by bath, most of the treatment results in direct release of chemicals into water column and sediment. Similarly, indiscriminate use of antibiotics for

fish health management is one of the major problems in aquaculture. Unmetobolized antibiotics are often passed to the aquatic environment by uneaten antibiotic treated feed and by faeces as these are consumed by the fishes or filter feeders or it passes to the sediment. In both water column and sediment, different classes of antibiotics have different half-life. Effects of bioactive matters on environment can be categorised as i) substances with inhibitory effect last long in animal tissue, ii) release of substances with inhibitory effect to the aquatic environment, iii) development and transmission of the antibiotic resistance gene in microorganisms (Illhan et al, 2017).

Impacts of heavy metals

21. The increased concentration of heavy metals and chemical compounds are affecting the adjacent water column and seabed sediments. The accumulated heavy metals are incorporated into several biological and chemical cycles of the benthic sediments. Besides, high concentrations of zinc, copper, or other metal elements are toxic to macrobenthic fauna and microalgae, which are crucial elements in the food-chain for natural fisheries production (Xinyan, et al).

Impacts of cage cleaning

22. Net cleaning is labour-intensive and costly. It releases significant amounts of cleaning waste into the surrounding environment, depending on local conditions and season. The release of biofouling particles is presently the norm during net cleaning operations and presents a multitude of risks, including the transmission of associated fish pathogens, gill and skin damage to the fish, organic deposition and contamination below fish farms and the spread of Non-indigenous Species (Nina and Oliver, 2020).

Impacts of antifouling agents

23. Sampson et al (2020) reviewed and stated that biocides are the active ingredients that prevent the settlement, adhesion, and growth of organisms to a painted surface and are arguably the second most hazardous ingredient to tributyltin which is a major component. Antifouling paints leach into the marine environment after application, thereby destroying aquatic life like killing of barnacles and other marine organisms. This resulted in a total ban in early 2008 following a resolution from governments in many countries.

3.2 Culture practices in onshore aquaculture

Impacts of installation of settlement tanks and drum filters

24. In pond-based system, the provision for settlement tanks/ponds reduces the space of fish culture as takes it requires a large space. In RAS, installation of settlement tanks and drum filters has improved efficiency remarkably in treating the effluents. But high installation and operation cost have failed to attract the small producers.

Impacts of discharge of effluent water

25. Abundant loads of organic wastes, nutrients, and chemicals in the effluent are discharged into the receiving waters, and are subsequently transported in the water column and settle on the seabed, impacting the adjacent area (near-field) and beyond (far-field). These can cause significant environmental and ecological issues such as low levels of dissolved oxygen (i.e., hypoxia), eutrophication, heavy metal pollution, and habitat destruction (Xinyang et al, 2020). One of the early water quality problems associated with Mediterranean fish farms was the presence of an oily film around the cages. This was generally related to the large percentage of dust (pulverized feed pellets) in the pelleted food, which is not available to the farmed fish. This causes considerable loss to the farmers, and reduced water quality (stimulated bacterial growth also depletes the water of essential dissolved oxygen) (Angel 2013).

3.3 Culture practices in offshore aquaculture

Impacts of cage locations, its specifications and management

26. Cardia et al, (2007) emphasised that the proper care should be given to identify the site on which the cages will be set up and their suitability with regard to (i) exposure to potential sea storms, (ii) seabed characteristics and depth, (iii) prevailing sea conditions, and (iv) visual impact. An exposed site and an increased risk of heavy storms will require cages, nets and mooring systems designed to resist the maximum registered storm strength. If the site is somewhat sheltered, a simplified mooring system and lighter rearing structure will reduce the cost of the initial investment. The submerged or low visual impact models are considered if any negative interactions are encountered with the coastal tourism.

27. The water depth, in combination with the average current speed and direction, can determine the concentration of waste sediment in the area around the cages. Uneaten feed pellets have a higher density compared with faeces; thus, their displacement will be more concentrated. Given a constant current, the deeper the site the larger the displacement will be, both for uneaten pellets and fish faeces. Thus, a shallow site will result in the need to use short nets and, consequently, cage volumes will be smaller than in a deeper site. It also impacts the farm footprint, mooring design and diving inspections. During any project development, the water depth should be studied on a marine chart and then properly verified through an extensive field survey (Cardia et al, 2015).

Impacts of escape of non-indigenous species

28. Angel (2013) summarised that there are many factors that may lead to loss of the farmed stock, including storms that may physically damage the net cages, predators (e.g., sharks, dolphins, bluefish, seals) that may bite the nets in their attempt to eat the enclosed fish, human error (e.g., during replacement of net cages or during harvest), poachers that cut the nets to catch fish, collision of ships with cage farms, etc. All of these generally result in the release of farmed fish to the surrounding environment, involving financial loss to the farmer and potential environmental problems related to genetic and ecological interactions of the escapees with the wild fish. Because many Mediterranean countries do not require farmers to report escapes, there are no reliable data on the frequency of escapes, however, it is assumed that the percentages of escapees are similar to those reported in Norway, ranging between 0% and 6%. Daimont (1997) pointed that in addition to genetic "pollution" of the wild-stock gene pool, the escapees also compete with the wild fish over the same habitat and food resources and there are instances of disease transmission from farmed fish to wild fish populations.

Impacts of discharge of effluent water

29. Price et al (2013) carried out a detail review on the impacts of cage culture on the environment and stated that usually there are no measurable effects on water quality 30 meters beyond the cages when farms are sited in well-flushed waters. Nutrient spikes and declines in dissolved oxygen sometimes are seen following feeding events, but there are few reports of long-term risk to water quality from marine aquaculture. In respect of benthic effects, well-managed farms may exhibit little perturbation and, where chemical changes are measured, impacts are typically confined to within 100 meters of the cages. Benthic chemical recovery is often rapid following harvest.

3.4 Legal and institutional measures in place for regulating the onshore aquaculture

Monitoring programmes for measurement of discharged pollutants

30. The environmental protection criteria for land-based farms are covered by legislation, which requires an approved special waste disposal study including recommendations for the treatment of effluents before their discharge. The treatment procedure consists of mechanical filtration, sedimentation, plus biological filtration and disinfection (Papoutsoglou, 2000). In practice, adherence to all these regulatory obligations is not so well, may be due to bureaucratic complexities, diversity of information required and continuous appearance of new regulatory orders. Rosa and Marta (2011)

pointed that lack of continuity of political and economic processes is the main problem which challenges countries and generates instability. This issue puts off aquaculture investors because many projects are slow-progressing businesses.

Regulatory measures including permitting conditions for onshore aquaculture facilities

31. The legal framework for aquaculture and the number of bodies/authorities involved in the license granting process may vary widely from country to country. The licensing requirements generally cover environmental protection, secure navigation, shipping rules, commercial fisheries protection, public health protection, archaeological sites protection and tourist activities. They are also associated with social, economic and political conditions which exist in terms of avoiding the disturbance of public peace and scenic views, taking into consideration the locally existing use of land and public environmental sensitivities and in terms of avoiding politically sensitive regions. The most common agencies involved in the licence granting process are Fisheries, Environment, Physical planning and public works, Merchant Shipping or navigation, culture and heritage, National defence, Industry and Labour Authorities (Rosa and Marta, 2011).

3.5 Legal and institutional measures in place for regulating the offshore aquaculture

Monitoring of pollutants in sediments and the water column

32. LBS Protocol, Annex I Chapter A, defines “Aquaculture” as a sector of activity which clearly requires an issuance of an authorization i.e., permit for the discharges of wastes stemmed from this activity referred to in Article 6 to the LBS Protocol. Moreover, Annex II of the LBS, clearly defines the characteristic of such discharges and characteristic of discharge site and receiving environment to be taken into account.

33. Regarding monitoring of pollutants in sediments and the water column from aquaculture activities, it should be noted that the Monitoring Guidelines have been prepared for IMAP Ecological Objective 5 Common Indicators 13: Concentration of key nutrients in water column and 14: Chlorophyll-a concentration in water column, as well as for IMAP Ecological Objective 9 Common Indicators 17: Concentration of key harmful contaminants measured in the relevant matrix; 18: Level of pollution effects of key contaminants where a cause and effect relationship has been established and 20: Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels in commonly consumed seafood. These guidelines are created to support technical personnel of IMAP competent laboratories of the Contracting Parties for the implementation of standardized and harmonized monitoring practices related to application of sampling methods, sample preservation and transportation, sample preparation and analysis in seawater, biota and sediment, along with quality assurance and reporting of monitoring data. They present a summary of the best available known practices employed in marine monitoring bringing together integrated comprehensive analytical practices to ensure the representativeness and accuracy of the analytical results needed for generation of quality assured monitoring data.

Regulatory measures including permitting conditions for offshore aquaculture facilities

34. Almost same permitting conditions are followed for the offshore aquaculture. The average time taking in licencing process is 14 months and the whole until to get the first sale is 2.5 to 3.5 years (Rosa and Marta, 2011).

35. Papoutsoglou (2000) found that the following permitting conditions ensure a satisfactory installation and management level for environmental protection: distance between farms; sufficient and permanent seawater currents; proper orientation of the main axis of the net-cages blocks in relation to the existing water currents; proper mooring of the net-cages blocks; identification of the minimum water depth beneath the bottom of the cages; scientific coverage for the operation and management of the farms; limits on the relation between area occupied by net-cages versus maximum annual production; stocking density limits; proper feeding application (food conversion ratio, food dispersion technique); regular removal of dead fish; regular monitoring of the water and bottom sediment quality, as well as the benthic communities of the area; sanitary measures. The

Environmental Impact Assessment is considered a common practice for licencing aquaculture activities in many countries in order to lease the site and obtain permission for the operation of a fish farm, together with production management details and a description of the specific area in terms of the physical, chemical and biological parameters of the water body (Papoutsoglou 1996, Papoutsoglou et al. 1996, Karakassis et al. 1998). Unfortunately, almost all of the data needed are usually obtained from published sources (if they exist), rather than from specific measurement programmes at individual sites. So, the impact of all these regulations are not to the level as desired.

Maritime spatial planning

36. Maritime Spatial Planning (MSP) has been identified as a key instrument for spatially allocating maritime uses in the sea space avoiding spatial conflicts between activities, and between activities and the environment. MSP incorporates the ecosystem-based approach (EB-MSP) to balance both socio-economic and environmental objectives, in line with the Marine Strategy Framework Directive, where applicable.

37. UNEP/MAP has taken some remarkable initiatives to support the implementation of MSP processes, including cross-border cooperation in MSP initiatives which among others also contributed to the implementation of the EU-MSP Directive, where applicable, as well as the implementation of the ICZM Protocol to the Barcelona Convention and the achievement of Good Environmental Status of the Mediterranean Sea and Coasts, building also on the long-standing experience within the UNEP/MAP system in designing and implementing ICZM tools and MSP processes in some countries. The two completed projects, namely "Supporting implementation of MSP in the Western Mediterranean region (SIMWESTMED)" and "Supporting MSP in the Eastern Mediterranean (SUPREME)" call for special mention in this regard (UNEP MAP, 2021).

3.6 Currently applied Best Available Techniques (BAT) and Best Environmental Practices (BEP) Mediterranean aquaculture

Benthic and nutrients input to the marine environment as a result of feeding practices and other operational aspects

38. Though BAT and BEP reduces the benthic and nutrient input considerably still a small portion is reaching to the marine environment. Besides, as a part of other operational aspects, deployed many modern gadgets (like different under water sensors etc.) reduce or hinder the free movement of other species which may affect the biodiversity.

Recirculating closed systems and reusing/recycling water for irrigation purposes in onshore aquaculture

39. RAS facility tends to be quite expensive. Investment costs are high, and the recirculation technology consumes vast amounts of energy and requires to be controlled and managed by a skilled workforce. RAS have a long history in freshwater environments; but the technology remains to prove its viability on large-scale production, especially concerning saline water environments. Fish welfare is not necessarily ensured in RAS, and several projects have experienced mass mortality, due to design errors or technical difficulties of the water recirculation. Despite technological developments in recent years, there are still many risks associated with intensive large-scale RAS operations.

40. In arid regions, where fresh water is scarce, aquaculture wastewater is an alternative water resource. Irrigation with aquaculture wastewater may affect the soil microbial community composition and functional diversity. Consequently, the changes in the soil environment would be significant (Chen et al, 2021).

Using environmentally benign antifouling agents for cleaning of cages

41. Even though various compounds with strong activities against typical biofoulers produced by marine microorganisms have been obtained since 1995, there is little information on the field tests of these compounds. Therefore, it is necessary to evaluate highly effective compounds in field assays for

the spectrum of their antifouling activity, which will provide critical data for the marine coating industries. With the increasing ecological problems of heavy metal and organotins-alternative biocides, the acute and chronic toxicity towards non-target organisms and degradation kinetics of potent antifouling agents in the marine ecosystem needs to be considered before commercialization. Especially for more complex compounds, some of them are not easy to break down in the marine environment, and may cause biological accumulation for marine organisms, which will induce long-term physiological impacts on the food chain. At the same time, it is very necessary that the toxicities of degradation products of those complex compounds should be evaluated to guide their intelligent usage (Kai-Ling et al, 2017).

Preventing escapees and Invasive Alien Species (IAS)

42. If not controlled very strictly, the entry of very few individual Invasive Alien Species also can create a massacre, resulting in great losses to the native biodiversity.

Reusing fish offal as fertilizer and disposal

43. The inconsistency in NPK fertilizer contents may create confusion in deciding the doses to be applied and may not give the desired result. Moreover, if the ingredients are taken from dead and diseased fishes, it may harm the agricultural field.

4. Proposed measures to minimize impacts from onshore aquaculture and recommended improvement measures

44. The main elements for the Regional Plan for Aquaculture Management in the Mediterranean (Decision IG.24/10) call for minimization of impacts from onshore aquaculture which may include alternative efficient feeding practices; installation of settlement tanks and filters; optimization of discharge systems; establishment of monitoring programmes based on local oceanographic conditions; establishment of recirculating closed systems; planting blue catch crops; reuse/recycle of water for irrigation purposes; establishment of treatment of nutrients from effluents; conducting environmental impact assessments of aquaculture facilities; and permitting for aquaculture installations. These issues are discussed below.

4.1 Adoption of alternative efficient feeding practices

45. Feeding efficiency includes optimizing the composition of the feed (optimal digestibility) to maximize growth and minimize waste at the lowest possible cost, as well as feed delivery. Feed delivery includes the optimal feeding regime whereby feed is provided to the caged fish in suitable portions and at the correct intervals to both maximize growth and health and minimize loss to the surrounding waters. High-tech feed delivery systems include feeding programs that are computerized and customized to each individual cage to optimize delivery of feed to the stock. Another sophistication is the use of submerged Doppler systems (e.g., Doppler Pellet Sensor) that detect when fish stop feeding (increase in the flux of pellets to the bottom of the cages), and send signals to cause the automated feeders to cease feeding. Many of the above are technologies are used in Mediterranean (Angel, 2013), but universal is needed.

46. There have been a lot of improvements in feed composition now-a-days. Feed is manufactured with the use of specific essential nutrients and feed additives (depending upon the ingredients used), including limiting essential amino acids (i.e., lysine, methionine, threonine, etc.), essential fatty acids (i.e., DHA, EPA, etc.), and/or trace elements (these essential nutrients having been previously supplied by using high-quality fishmeals and fish oils), and more recently specific feed enzymes (i.e., phytase, protease, xylanase, etc.), emulsifiers (i.e., lecithin derivatives, taurocholic acid), acidifiers (i.e., organic acids), and prebiotics and/or probiotics depending upon the cultured species (Huan et al., 2018; Novelli et al., 2017; Tacon, Hasan, & Metian, 2011). Feeding the improved feed with modern system will increase the feeding efficiency.

4.2 Installation of settlement tanks and filters

47. RAS removes solid wastes through sedimentation and screen filters (Ebeling & Timmons, 2012). The sedimentation tanks remove the larger particles (more than 100 µm) whereas the smaller particle are removed by screen filters. Though RAS can remove a large portion of solid wastes through sedimentation, it is not effective in removing fine solids from the system (Piedrahita,2003), hence, the need for a supplementary screen filter along with the sedimentation technique. Generally, screen or floating bead filters have better solid removal efficiency compared to sedimentation basins, though total solid removal is not also possible with screen filters (Patterson, Watts, & Timmons, 1999).

4.3 Optimization of discharge systems

48. Development of submarine pipeline systems: Now there are a couple of newly developed outfall designs (in addition to surface discharge) are available to maximise the initial dilution of the discharge especially in the mixing zone. Discharge through submarine pipelines provides better flexibility in meeting the design goal.

49. Definition of appropriate sea depth: As a rule of thumb and depending on the current velocity, the cage net depth should be no deeper than one-third of the site's depth and at least 15 meters should be left between the net base and the sea bed (at low tide), to permit a wider and better dispersion of cage waste particulate (Cardia et al, 2015). Sophisticated models are now available for siting net pen farms based on the local current velocity, depth, loading rate, and other factors that minimize adverse benthic impacts. (Boyed et al, 2020).

50. Installment of diffusers at the end of the pipelines and pumps: Submerged diffusers allow the effluent to be directed at different angles to the ambient flow to maximize the initial dilution. Multi-port submerged diffusers provide more dilution than single outlets. These provide ample momentum to dilute the concentration as quick as possible.

51. Improved abatement measures for the collection of oily residue: The problem was rapidly addressed and most of the pelleted feeds are now extruded to improve pellet integrity and reduce feed loss and feed dust is collected and recycled (Angel, 2013). Storing the feed in cool place and for a short time is also helpful (Susanne et al, 2019).

4.4 Monitoring nutrients Emission Limit Values (ELVs)

52. Many countries (Norway, Australia, UK etc.) have adopted the concept of the mixing zone for mariculture effluent which is defined as the area immediately around the cage culture system where the effluent is physically mixed and dispersed into the surrounding environment. Emission limit values (ELVs) and environmental quality standards (EQSs) – Water quality standards (WQS) and sediment quality standards (SQS) are established in the mixing zone for important contaminants present in the effluent, which apply to the water quality at the end of point-source and within the receiving environment, respectively. Once these standards are established, monitoring measures to assess the mariculture compliance is also required to be put in place. This concept may be adopted to have a robust monitoring programme.

53. Xinyang et al (2020) reviewed that mariculture effluent monitoring techniques have developed rapidly from traditional manual point sampling techniques (e.g., visual diver surveys) to cover increased monitoring areas using more time-efficient and cost-effective approaches (e.g., remote sensing, video monitoring). Wireless sensor networks (WSNs) have been recently adopted to provide continuous monitoring of water quality at high spatial and temporal resolutions. These systems allow a large number of water quality sensors to be installed around the mariculture site for detailed monitoring of dissolved oxygen (DO), salinity, total suspended solids (TSS), temperature, water level, and ammonia nitrogen. In addition, in-situ video surveys are used to monitor changes to benthic communities resulting from mariculture without the need for destructive sampling, as well as the feed uptake by fish stocks within the mariculture cages themselves. Biochemical tracing (fatty acid

analysis, stable isotopic signatures and soya DNA) and biological indicators (macro algae and protistan group) are also being used as effective monitoring tools to trace mariculture waste in the water column or benthic system.

4.5 Recirculating closed systems

54. There has been a continuous technological improvement in all operational aspects of RAS, be it in respect of Main flow oxygenation, nitrifying biofiltration alternatives, fine solid control, ozonation, denitrification, microbial control or energy efficiency. Efforts have been made to classify biofilters and to document their performance in order to help farmers and designers specify systems with a better degree of reliability. The moving bed bioreactor, the fluidized sand filter bioreactor and the fixed-bed bioreactor are examples of attached growth biofilter designs which have become standard in modern commercial RAS. Fine solids control strategies used in modern RAS include ozonation, protein skimming, floatation, cartridge filtration and membrane filtration. The most appropriate type of RAS facility is dependent on the species to be farmed, feed, production volume, temperature and local factors such as water access, emissions levels, access to land, buildings and heating (S. Goddek et al., 2020). The modern RAS system with novel technologies should be adopted.

4.6 Planting blue catch crops (e.g. mussels)

55. Parallel farming of blue catch crop (extractive species) is an effective measure to deal with emissions of nutrients from fish farming, as it absorbs nutrients from the water by filtering or eating nutrients bound to particles (mussels/oysters, detritivores), or by assimilating dissolved nutrients (algae) and thereby acting as catch crops (Buck et al. 2018, Troell et al. 2009). This may take place directly adjacent to fish farms or in the same water zone (defined differently depending on the location) to achieve a nutrient balance in emissions from fish farming. Mussels, ascidians and algae are the catch crops farmed commonly whereas many more species have the potential to operate as catch crops. The number of catch crops can be defined on the basis of mass balance models where the amount of nitrogen and phosphorus released from fish farming is balanced out by farming of extractive species designed to absorb a corresponding amount of nitrogen and phosphorus (Susanne et al, 2020).

4.7 Reuse/recycle of water for irrigation purposes

56. Aquaponics (or IMRAS –Integrated Multi-trophic Recirculating Aquaculture Systems) is best emerging technology in this line which supports integrated aquaculture with vegetable production. It combines two production systems by recirculating nutrient rich aquaculture water through standard hydroponic growing beds. All of the nutrients required by the plants are supplied through the fish wastes, thereby eliminating the need for fertilizer. The plants clean the water for the fish, thereby eliminating the need for water exchanges. Hence, it is a labor-saving technique, also saving traditional agriculture work such as ploughing, tilling and digging.

57. The effluent water can also be used to irrigate plants, if national regulations allow such a practice. Despite the benefits of the aforementioned method, the high concentration of ions in aquaculture effluent may lead to soil salinization and groundwater contamination (Beltrán 1999; Miranda et al. 2008). Therefore, using it for irrigation of tree species in seedling nurseries might be a better alternative to avoid such problems in agricultural fields (El-Kady and Suloma 2013). Liete et al (2017) showed that the saline aquaculture effluent can be reused to irrigate tree species (Enterolobium contortisiliquum), enabling a successful integration of aquaculture and agriculture and reducing environmental impacts of improper effluent disposal.

4.8 Treatment of nutrients from effluents

58. RAS employs a biological system for management of nitrogen in the culture system. It uses the nitrification process to convert toxic ammonia to less toxic nitrate (Avnimelech, and Defoirdt, 2007). There are generally two types of filters are available now and research is on to have the better

quality. The emerged fixed-film filters include rotating biological contactors and trickling filters, while submerged fixed-film filters include fluidized bed filters and bead filters (Dauda et al., 2014; Malone & Pfeiffer, 2006). Biofilters provide a surface for the growth of microbes that come in contact with the wastewater and convert the toxic ammonia to nitrate (Ebeling & Timmons, 2012). The granular media or foam fractionator filters may also be better option (Waller, 2001). RAS system with this facility may be established and research on further development may be encouraged.

4.9 Adopting measures to ensure environmental impact assessment

59. FAO (2009) had carried out a detailed review on environmental impact assessment and monitoring in aquaculture and summarised some useful steps to strengthen the EIA procedure. Those include: i) developing a synthesis document specific to aquaculture based on a review of all EIA Guidelines; ii) developing better/more consistent screening criteria and scoping guidelines; iii) streamlining EIA procedures; iv) making sure small producers are not disadvantaged or excluded, minimizing barriers to entry of small producers into aquaculture; v) undertaking better analysis of socio-economic issues; and vi) and exploit scientific research, if necessary, to assess impacts of aquaculture on the marine environment. EIA and SEA may also be used as effective analytical tools. Country specific guidelines may be developed through all these measures, strict implementation of which through capacity building of all stakeholders will ensure proper EIA report ready for issuance of consent.

4.10 Stringent grant permit for aquaculture installations

60. Instead of having a number of grant permit obligations in place, there is immense scope of improving the legislative framework for better contributing for aquaculture development in the region. A common policy document for the whole region may be developed. The local government may be given more power to implement all the legislations very methodically and the whole process should be more streamlined. The capacity of all the stakeholders may be built up to make the process fast, hassle free and followed very strictly, which in return may invite more investment in the sector.

5. Proposed measures to minimize impacts from offshore aquaculture and recommended improvement measures

61. The main elements for the Regional Plan for Aquaculture Management in the Mediterranean (Decision IG.24/10) call for minimization of impacts from offshore aquaculture which may include establishing criteria to be met in the selection of aquaculture sites; applying Marine Spatial Planning for establishment of aquaculture plants; implementing permitting schemes; identifying alternative efficient feeding practices; controlling discharges through monitoring; establishing Multitrophic Aquaculture Systems; controlling escapes for prevention of harmful aquatic organisms; using new environmentally friendly antifouling agents (TBT-free, preferably also copper free); ensuring regular movement of cages in aquaculture sites; promoting alternative disposal/ re-use of offal; and ensuring the establishment of appropriate monitoring programmes. These issues are discussed below.

5.1 Establishing criteria for aquaculture site selection

62. Major considerations should be given to: i) **marine habitat mapping -** distribution of marine habitats and information about their level of legal protection and sensitivity to increase of organic pollution; ii) **oceanographic conditions and carrying capacity:** current and wave analysis, profiles of temperature and salinity, nutrients and chlorophyll levels; iii) **interaction with fisheries:** fishery grounds and interactions with wild fish; and iv) **negative impact from other users:** sources of organic and chemical pollution and other risks such as maritime transport activities and oil spills. In line with an ecosystem approach to aquaculture (EAA), the ecological carrying capacity (along with physical, production and social) plays a key role in aquaculture site selection.

5.2 Maritime Spatial Planning

63. The optimal siting of offshore aquaculture is a complex MSP problem requiring comprehensive (balancing existing and emerging sector objectives), coordinated (planning multiple emerging sectors simultaneously), and strategic planning (optimized using an analytically defined objective function that explicitly considers the objectives) across the seascape (E. Menera et al.). S.E. Lester et al (2018) demonstrated and tested the value of a MSP analytical model that strategically identifies the location, size, and type of offshore aquaculture farms in relation to a suite of existing ocean activities and environmental concerns in Southern California Bight, USA, an area with strong interest in and concerns regarding offshore aquaculture development. In a number of Mediterranean countries, MSP processes have been started, and they are in different stages of early phase. This type of zone-specific model may be considered where applicable.

5.3 Permitting schemes setting operational conditions

64. The Environmental Monitoring Programme (EMP), as part of licence conditions, represents an important tool to supervise the potential polluting effects of any given fish farm. This way, inclusion of all the operational conditions into licencing regime as EMP in respect to Chemical pollution, organic matter discharge, Visual alteration of scenic places, fish escape etc. will be of immense help. The MOM model (Modelling-Ongrowing fish farm monitoring, Stigebrandt et al. 2004) in Norway and Volledenwieder OECD are popular models for calculating point source emission and monitoring aquatic environment.

5.4 Efficient feeding practices

65. Improved feeds that leach less nutrients to the water and are better assimilated by the fish minimize waste and improve the efficiency of feed utilization, benefiting both the environment and the farm's bio-economic results. Almost all the modern techniques described above for increasing feeding efficiency in onshore-aquaculture are applied in the case of off-shore aquaculture.

5.5 Controlling discharges to Sediments and Water column through monitoring

66. In addition to sophisticated monitoring devices mentioned earlier, a number of others are available now which may be applied to control the discharges. The application of remote sensing in mariculture monitoring is widely conducted using an array of optical (e.g., Landsat Thematic Mapper (TM), China–Brazil Earth Resources Satellite (CBERS)-3/4 and Sentinel-2A), and radar-based space-borne instruments (e.g., CosmoSkyMed, Radarsat and Sentinel-1A), to measure and monitor water quality parameters such as chlorophyll-a, suspended particulate matter, turbidity, and colored dissolved organic matter at varying spatio-temporal scales. Acoustic doppler current profilers (ADCP) combined with free-fall multi-parameter profiler could be used to monitor the flow structures and water quality parameters such as conductivity, temperature, fluorescence, turbidity, and dissolved oxygen to show the possible distribution of effluent materials (Xinyan et al, 2020).

5.6 Multitrophic Aquaculture Systems

67. Bela et al. (2020) reviewed the existing IMTA practices in offshore aquaculture and found that the existing methods for farming extractive species, like seaweeds and invertebrates, in coastal and sheltered areas need to be customised precisely for offshore operations to be able to withstand drag forces from strong currents, waves and swell typical of more exposed environments. While it is likely that higher growth rates will be recorded in the vicinity of offshore fish farms, there is also a need to identify risks (e.g., social, economic, and environmental) and to understand and communicate the bioremediative roles of extractive species. Employing IMTA within multiple-use offshore systems has the potential to provide commercially valuable organisms representing different trophic levels, and a variety of ecosystem services, that could sustain each other and participate in the bioremediation and protection of the marine environment, whilst providing a sustainable avenue for future food production from the oceans. The location specific species mix models are to be developed to make the system

neutral, both temporally and spatially. Farmers need to choose the right combination of species providing the greatest benefits for the locality. This requires an in-depth knowledge of local conditions such as water depth, topography, currents, spatial and temporal changes in nutrients, temperature, salinity and oxygen levels, as well as freezing. (Susanne et al, 2019).

5.7 Prevention of escapes of harmful aquatic organisms and pathogens

68. Applying more effective confinement technique is more logical than trying to protect the wild population, though complete prevent is not possible realistically. Storm damage to farm systems is one of the major causes of escapes and employment of a reliable standard, as practiced in Norway (NS 9415 – requirements for design and operation of marine fish farms) is a promising approach to reduce such risks. Submersible cage systems designed for open sea conditions, such as the Sub-flex system and the Ocean-Spar system are an option to reduce mechanical stress to net cages in high-energy environments (Angel, 2013). Reporting escapes is also another effective measures which is not practiced in Mediterranean region. Any legislation / directives regarding this will be of help. Tracing the escaped fish with molecular marker also useful to assess the impact. The semi-closed and closed system is obviously of help.

5.8 Use of new environmentally friendly antifouling agents

69. Synthesis of effective and novel eco-friendly compounds from natural resources has got momentum due to the ban of tributyltin and other booster biocides. Diverse natural products have been successfully employed as starting materials in the development of antifouling paints. Notably, eco-friendly natural antifouling agents are found in seaweed, bacteria, algae, corals, sponges, and terrestrial plants. Natural antifoulants work through various physical and chemical control mechanisms, including low drag, low adhesion, wettability, micro-texture, grooming, sloughing, and chemical secretion. They are comprised of higher biofiber, which would perform analogous antifouling like other conventional coatings, thus minimizing the more toxic base polymer proportion. Some of the Green antifouling natural products used globally at present are Zinc tannate(plant), Isocyanotempenes (sponges, Nudibranchs); 5,6-Dichloro-1-methylgramine (DCMG) (plant), Poly-APSs (linear 3-octylpyridinium polymers) (Marine sponges). The use of this environment friendly biocides should be encouraged (Sampson, 2020).

5.9 Ensuring regular movement of cages in aquaculture sites

70. Fallowing refers to the practice of relocating marine fish cages or delaying restocking of cages to allow the sediment below to undergo natural recovery, both geochemically and ecologically, from the impacts of nutrient loading. This management tool is implemented around the world for preventing long-lasting damage to the benthic environment and for decreasing risks to farms of pathogens and parasites (Price and Morris, 2013).

5.10 Alternative disposal/ re-use of offal

71. Fish offal are reused in different ways to produce a varied kind of products like animal feed, compost, biodiesel/biogas, natural pigments, food industry/cosmetics, proteases, fish skin etc. It is profusely used as a feed ingredient, as it represents a valuable source of high-quality protein and energy (New, 1996; Gabrielsen & Austreng, 1998). The recovered carotenoids from shrimp, lobster, crab, crayfish, trout, salmon, redfish, red snapper and tuna can be effectively used instead of synthetic carotenoids in aquaculture feed formulations, and the residue available after extraction may be used for the preparation of chitin/chitosan (Sachindra et al., 2006). A number of useful compounds are isolated from seafood waste including enzymes, gelatin and proteins that have antimicrobial and antitumor capabilities. Chitosan, produced from shrimp and crab shell, has shown a wide range of applications from the cosmetic to pharmaceutical industries.

5.11 Establishing appropriate monitoring programmes

72. Humbrey (2009) synthesised summary of many review papers and country reports and summarised the recommendations for establishing appropriate monitoring programmes. Focus should be given on introducing effective monitoring of wider environment related to both identified risks and potential management responses, pursuing an appropriate balance between farm level monitoring and monitoring of the wider environment, ensuring value of information on more focused fewer parameters, ensuring efficient analysis and reporting of monitoring data, and feedback into individual farm or sector management, defining and monitoring sustainability indicators, establishing sampling standards and protocols, making monitoring more locally relevant, creating national and regional information systems for aquaculture monitoring information.

6. Proposed additional BAT and BEP measures for onshore and offshore aquaculture

73. The main elements for the Regional Plan for Aquaculture Management in the Mediterranean (Decision IG.24/10) call for development of a guidance document on BAT and BEP for the aquaculture sector (onshore and offshore) addressing benthic impacts and nutrients, efficient feeding practices, settlement tanks (to collect suspended soils) and filters (drum filters), regular movement of cages, optimization of discharge systems, blue catch crops (e.g. mussels); water: recirculating closed systems and reuse/recycle of water for irrigation purposes in onshore aquaculture; disease and parasites; chemical discharges: use of environmentally benign antifouling agents; escapees and prevention of Invasive Alien Species (IAS); physical impacts, disturbance and predator control; and alternative disposal/ re-use of offal. In this section, specific proposals are provided for each of these aspects with the aim to provide further information that can be included in this guidance document.

6.1 Benthic impacts and nutrients

74. <u>Efficient feeding practices:</u> The better food digestibility can lower the Feed Conversion Ratio thereby increase the feed efficiency. Optimisation of the digestion process is crucial for sustainable fish farming and depends on a series of integrated physiological processes including ingestion, secretion, digestion, absorption, motility and evacuation. Fish species specific field trial may be carried out.

75. <u>Settlement tanks (to collect suspended soils):</u> Singh, Ebeling, and Wheaton (1999) reported no differences in water quality between RAS with screen filter and that of settling basins, though the needed make-up water volume was significantly higher in RAS with settling basins. Further research for increasing the water use efficiency may be helpful.

76. <u>Filters (drum filters):</u> In drum filter, the dirty water moves through the screen which traps solids and then the screen moves to a back flush area where clean water is sprayed from behind the screen to clean it. This continual back flushing requires that more water be diverted down the drain with the waste. Also, they typically do not remove as small a particle as granular media. Further research may be carried out to increase the efficiency.

77. <u>Regular movement of cages:</u> Research may be carried out to investigate the correlations between farm site characteristics and the required duration and effectiveness of recovery which would aid development of fallowing guidance for the mariculture industry.

78. <u>Optimization of discharge systems:</u> Use of semi closed system with soft shell or hard shell will be useful, in which the water is passed from the production system through a central bottom pipe, where sludge (deposited material) and dead fish also accumulate and are separated out. Different structures separate off sludge and dead fish in different transport systems.

79. <u>Blue catch crops (e.g. mussels):</u> Uptake of nutrients varies for the different organisms. Emphasis should be given species specific condition where they can work as a special sink – i.e. absorb more than is released – for any of the nutrients.

6.2 Water

80. Recirculating closed systems: Recent studies (B-V Chang et al. 2019) demonstrated the benefits of integrating IMTA and RAS to develop a novel multitrophic recirculating aquaculture system (IMRAS) which may be explored. More studies may be carried out to make RAS viable, especially in large scale in marine environment more investment friendly and viable.

81. Reuse/recycle of water for irrigation purposes in onshore aquaculture: Although aquaponics has developed considerably over recent decades, there are a number of key issues that still need to be fully addressed, including the development of energy-efficient systems with optimized nutrient recycling and suitable pathogen controls.

6.3 Disease and parasites

82. Regular fish health monitoring, pathogen diagnosis and prompt correct treatment are essential. The feed supplemented with probiotics and prebiotics is useful to increase the immunity of fish. The development of resistant variety of the pathogen is a serious problem now. More research to develop preventive medicine will be helpful. Adoption of semi-closed or closed system reduces the chance of infection.

6.4 Chemical discharges: use of environmentally benign antifouling agents

83. A promising technological solution to these problems is the use of copper alloy netting. These alloys are inherently biofouling-resistant, have higher strength and resistance to biting than polymer nets and have advantageous hydrodynamic properties. This may be explored.

6.5 Escapees and prevention of Invasive Alien Species (IAS)

84. Boudouresque et al (2002) recommend that steps be taken at once to slow down the rate of introduction of non-native species. In particular, it seems necessary to implement national legislation, to set up quarantine conditions (aquaculture), to control the flow of ballast waters and the aquarium trade and to ban all species, which prove to be invasive in other parts of the world (‘‘black list’’ or ‘‘dirty list’’). The technology used for the treatment of ballast water in the shipping sector can be applied to the aquaculture sector. National level list of IAS may also be prepared for better management.

6.6 Physical impacts, disturbance and predator control

85. The submerged cages and installing cages in AZA will overcome the physical impact. The closed and semi-closed system will be helpful to the control the predator.

6.7 Alternative disposal/ re-use of offal

86. There are emerging technologies to produce varied enzymes food industries like proteases for meat tenderisation, milk-clotting, etc. which may be explored further.

7. Conclusions and Recommendations

87. The findings of the assessment indicate that aquaculture in Mediterranean is experiencing a good improvement in technological aspect and it is going through almost on the right track, though there are scopes for further improvement. There is a high need of robust legal framework and governance structure with distinct accountability map for strict implementation of the available legislations to minimize the environmental impacts. Further research, more importantly field level testing, is needed to see the effectiveness of the novel technologies developed across the globe and to assess the condition for replicability and transferability of available BATs and BEPs. Circular economy should be considered as the overarching conceptual framework underlying any aquaculture developments. Creating a Mediterranean long-term vision of the sector is key to push forward a

sustainability transition. These aspects should be reflected in the new Regional Plan for Aquaculture Management in the Mediterranean.

88. With regard to proposed measures, emphasis should be given on utilisation of novel technologies which may encompass a broad area starting from aquaculture zoning, site selection to production aspects. For onshore and offshore aquaculture, in general, including the BATs and BEPs, the scope will be aimed at increasing the production efficiency (through novel feed ingredient and innovative feeding practices) as well as reducing the environmental impact (through use of closed or semi-closed system, improved recirculation technologies, mitigating diseases effectively, improving energy efficiency). Exclusively for offshore aquaculture, the innovative technologies for the site selection as well as suitable cage structure which withstand at different physical conditions of the sea should be given preference. For onshore farming, solid waste and effluent management should be given priority. Adoption of all of these innovative technologies along with effective collaboration at all levels with all the stakeholders will establish aquaculture as an important sector for blue economy in the region.

Annex I
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