GUIDELINES FOR MARICULUTRE DEVELOPMENT (MUSSEL AND OYSTER FARMING) IN MONTENEGRO

Definition of the FOOD4HEALTH guidelines addressed to producers (A.T1.5)

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Introduction

Aquaculture is a dynamic industry with annual growth rate of around 10.8%, with a high profit rate, particularly in developed countries (FAO, 2012). World mariculture production (18.3 million tonnes) comprises marine molluscs (75.5 percent, 13.9 million tonnes), finfishes (18.7 percent, 3.4 million tonnes), marine crustaceans (3.8 percent,3.9 million tonnes) and other aquatic animals (2.1 percent, 0,33 million tonnes). The share of molluscs (mostly bivalves, e.g., oysters, mussels, clams, cockles, ark-shells, and scallops) declined from 84.6 percent in 1990 to 75.5 percent in 2010, reflecting the rapid growth in finfish culture in marine water, which grew at an average annual rate of 9.3 percent from 1990 to 2010 (seven times faster than the rate for molluscs (FAO, 2012). World per capita apparent fish consumption increased from an average of 9.9 kg in the 1960s to 19.2 kg in 2012 (preliminary estimate). World food fish aquaculture production expanded at an average annual rate of 6.2 percent in the period 2000–2012 (9.5 percent in 1990–2000) from 32.4 million to 66.6 million tonnes (FAO, 2014).

Considering the intensive growth of the human population worldwide and that food availability in many countries is decreasing, it is necessary to intensify the production of healthy food in existing areas and also to identify additional locations. Experiences of many coastal countries in the process of production of healthy food in the sea resulted in the fact that mariculture today is a strategic development industry. Mariculture provides opportunity for producing protein rich food and economic development of the area in which the farming activity is done. Considering that development of this sector in the Boka Kotorska Bay is limited in terms of development of industrial production in mariculture, potential threats to marine and coastal diversity of species are negligible (Mandić *et al*., 2016).

Although the Fishery Strategy of Montenegro 2015-2020 provides for an increase in production of autochthonous species, particularly as regards bivalves, the production growth is still limited, considering the natural potential, but long-term prospects are quite good. Over the past few years, the global production in aquaculture has been increased and reached a point above 50% of commercial fish catch in fishery. Farming of fish and other marine organisms in Montenegro is done based on the following: the Law on Marine Fishery and Mariculture, the Spatial Plan for Special Purpose Area for the Coastal Zone, the Law on Environment, the Law on Environmental Impact Assessment**,** the Law on Nature Protection, and secondary legislation applicable based on the abovementioned laws.

Current State of Montenegrin marine aquaculture – species, technologies, production

Marine aquaculture in Montenegro includes fish farming (sea bass and sea bream) and farming of two species of bivalves – mussels (*Mytilus galloprovincialis*) and oysters (*Ostrea edulis*). Bivalve farming (Figure 1) is at a relatively low level, considering the natural potential available. In 20 farming sites on the territory of the Boka Kotorska Bay, the current annual mussel production is 228 tons (MONSTAT, 2019), while the quantity of oyster farmed is negligibly low, (about 17 tons) considering that the first farming site was set up in 2009. Sale is done mainly through direct supply, while lately retail chains have begun placing this product on the market.

Figure 1. Mussel farming in Boka Kotorska bay (long-line system)

When comparing the total length of the coast of the Boka Kotorska Bay (105 km) with the length of the sea area occupied by farms (about 100 meters per farm), it is obtained that in spatial terms shellfish farming in Montenegro occupies less than 2% of the coastline of the Bay. Given that it is the production of healthy food in a clean environment, which is extensive in type and does not involve the intake of food, antibiotics, agents against predatory or fouling species, this type of production must be preserved, branded, and improved.

One of the biggest problems in this sector is the lack of a Center for dispatch and purification of live shellfish (lack of sanitary and hygienic conditions necessary for export), as well as the

lack of an organized market. Given that shellfish farming is done in the traditional way and that they are actually small family farms, the only way for their survival is reflected in the stimulation by the state in order to provide basic infrastructure conditions (electricity, water, sewage systems), transfer of new farming technologies and branding. product. In relation to the Strategy for the Development of Fisheries and Mariculture, it is clear that production in mariculture is stagnant and that it is far from strategic development goals.

What is certainly missing is the Strategy for marine aquaculture development of Montenegro that would clearly define all the key development goals and enable the implementation of certain activities.

Technology for mussel and oyster farming in Montenegro

History of mariculture in Montenegro (Mandić *et al*., 2016)

Initial exploration on the possibility of mussel (*Mytilus galloprovincialis*) and oyster (*Ostrea edulis*) farming in Boka Kotorska Bay goes back to the early sixties of the last century. Farming process implied three stages of cultivation for oysters and two phases of mussels farming. Bundles of branch, so-called "fašine", were placed in the sea, and young oysters were caught on them after six months. Then oyster fries were extracted from the sea for second phase. Second phase implied processing and beam forming braids with diluted branches. The third phase involved the removal of branches, cementing and interference in the final braids.

Mussel farming was somewhat easier compared to oyster farming, and it implied two stages – collecting young on old ropes, so-called "kadena" that were placed horizontally below the surface. Collecting the fries was followed by a second phase - the removal of young mussels from *kadena* and involvement in braids, which have been positioned on the floating park in the space of 35-40 cm. Breeding parks and piers were a steel structure, and these experimental parks were placed in positions with a very shallow depth (5-10 m).

Total time of oysters growing lasted from 28-30 months, while mussel reaching market size in 2-3 years, depending on the size of the individual (Stjepčević, 1974).
Farming technology had involved stationary parks for mussels and oysters (Figure 2), as well as oyster cementing using a methodology similar to that still used in most of Adriatic and Mediterranean countries (Figure 3). Former appearance of stationary parks in countries of the region is presented in Figure 4 and Figure 5.

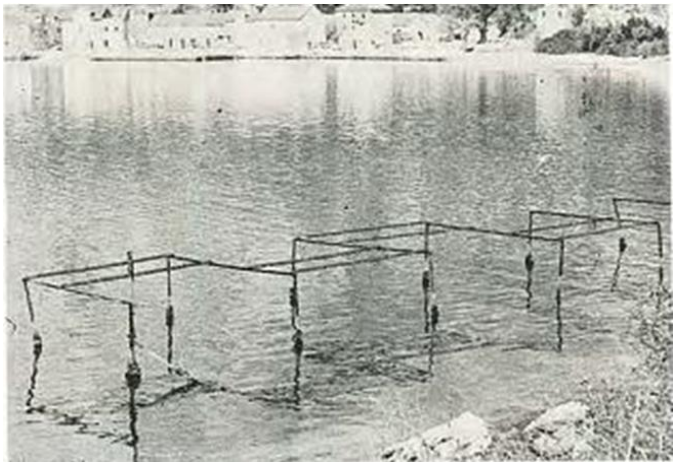

Figure 2. Former appearance of the experimental stationary park (Orahovac, Montenegro) (Stjepčević, 1974).

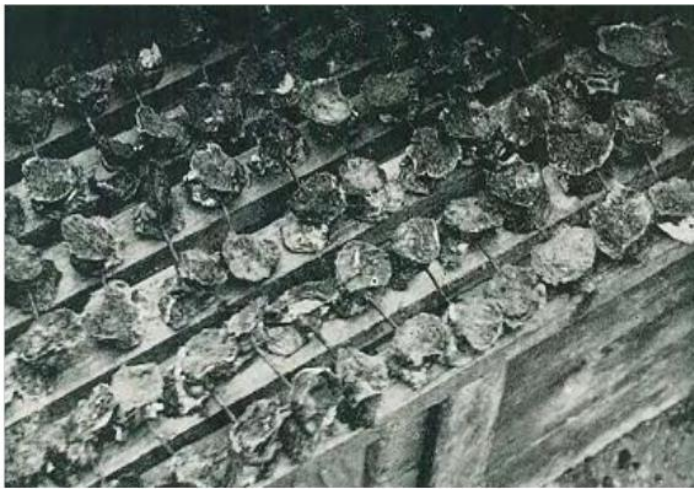

Figure 3. Oyster cementing method in the first investigations on possibility for farming in the Boka Kotorska Bay (Stjepčević, 1974).

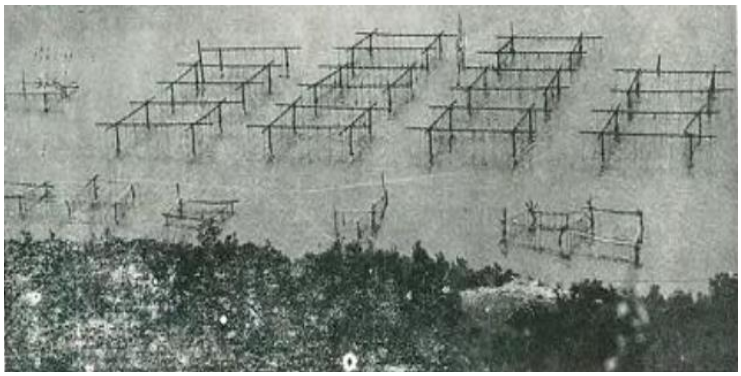

Figure 4. Former appearance of the stationary park for oyster and mussel farming, the Malostonski Bay, Croatia (Stjepčević, 1974).

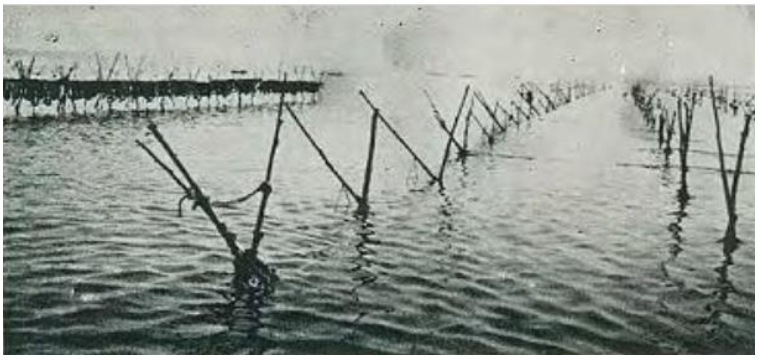

Figure 5. Former appearance of the stationary park for *M. galloprovincialis* farming, the Taranto Bay, Italy (Stjepčević, 1974).

Several decades after the initial surveys, commercial mussel farming on the area of the Boka Kotorska Bay began to develop in the second half of 1980s and it implied introduction of the floating parks methodology, used even today, while commercial oyster farming began as late as in 2009. Today, the farming technology of mussels and oysters in the Boka Kotorska Bay uses long-lines system, which proved that it meets all the necessary conditions for safe production (Mandić, S., 2008).
In the period of the first surveys until today, additional research activities and experiments have been made in order to explore the possibilities for the Pacific oyster (*Crassostrea gigas) and rainbow trout (Oncoryhynchus mykiss*) farming in the sea. One of very important segments of marine aquaculture is technology transfer, and in that regard activities were conducted with colleagues from Spain, Italy, Norway and China. Many plans such as farming of salmon, brine shrimps Artemia salina, eel (*Anguilla anguilla*), mullet (Mugil sp.), as well as development of lagoon farming are still in the conceptual phase because of lack of funds.

There are two basic systems of mussel and oyster farming - the system of long-lines (floating parks – Figure 6 and Figure 7) and the "raft" system. Each system involves an extensive type of breeding, and several breeding phases. The breeding phases are identical for both types of cultivation, while the difference is in the materials used, the method and the amount of production.

Figure 6. Technology of mussel farming in Montenegro

Figure 7. Technology of oyster farming in Montenegro

Plastic buoys are placed at about 3.5-4 meters distance and are connected twice with ropes 12 mm thick. The number and weight of anchorages depends on the size of the floating park, but to a greater extent on the characteristics of the site. Namely, if the farm is exposed to significant waves or winds, in that case a larger number of heavier anchorages are set up. Having in mind the position of the location where the cultivation is planned, it is enough to place 4 anchors of 1000 kg each and one of central weight of 500 kg.

The method of tying buoys and their placement in the sea is illustrated in Figures 8, 9 and 10. Anchors are concrete blocks weighing from 500 to 1000 kg, where the area occupied by the anchors is significantly larger than the area occupied by the floating platform, because the anchors are placed at a certain angle. The greater the depth at which the farm is located, the

greater the difference in area, i.e. the angle at which the anchors are placed. The floating park (platform) must be properly marked, and according to the Law on Marine Fisheries and Mariculture, fishing or other activities that interfere with breeding activities may not be performed within 100 meters from the farm.

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Figure 8. Buoy binding method

Figure 9. Setting up one line of floating park

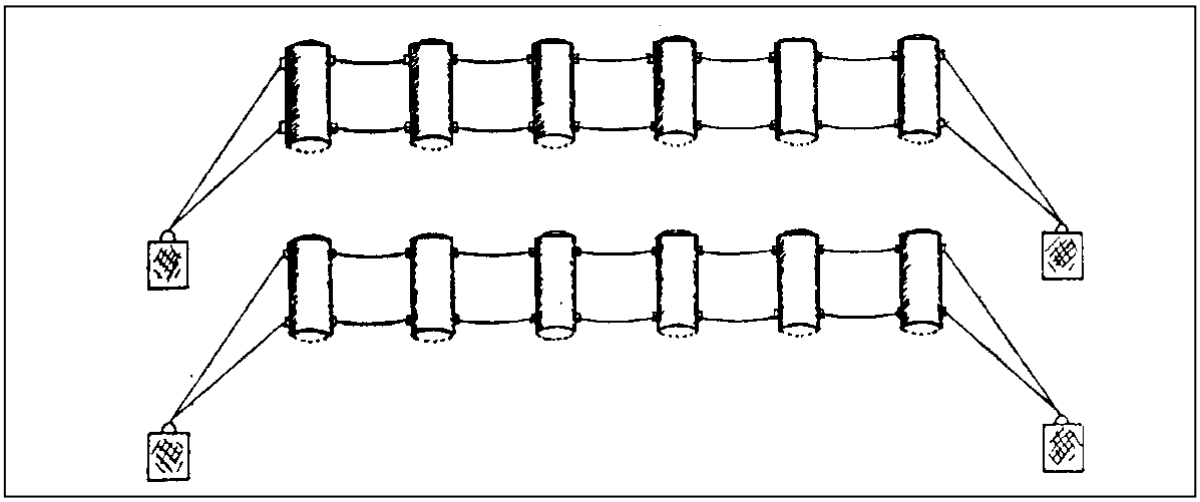


Figure 10. Schematic presentation of a part of the floating park

Approach to address the issues related to mussel farming

Definition and acceptance of new zones for mussel farming in Montenegro

Analysis of the suitability and attractiveness of the Boka Kotorska Bay area for the development of shellfish farming was done based on preconditions for defining mariculture sites that are accepted as a recommendation of the General Fishery Commission for Mediterranean (GFCM) of which Montenegro is a member. The analysis was performed using data on pressures on mariculture (fishing areas, eutrophication, contamination, important marine habitats, coastal type, urbanization) and based on environmental data (climatology, exposure to the open sea, seabed characteristics, water quality, trophic status, organographic conditions , coast type).

The results of the analysis of the Bay's suitability for mariculture confirmed that all existing shellfish farms are in locations that are suitable for mariculture development, but also that a significant part of the Boka Kotorska Bay is very suitable but not used for the mariculture programme. Potentially suitable locations obtained by the analysis should be part of the new spatial plans for coastal zone management (Figure 11). The analysis was done only for Bivalve farming, since fish farming have a significant negative impact on the environment, and thus represents an additional type of pressure, especially in semi-enclosed systems such as the Boka Kotorska Bay where water changes, especially during the summer, are very weak.

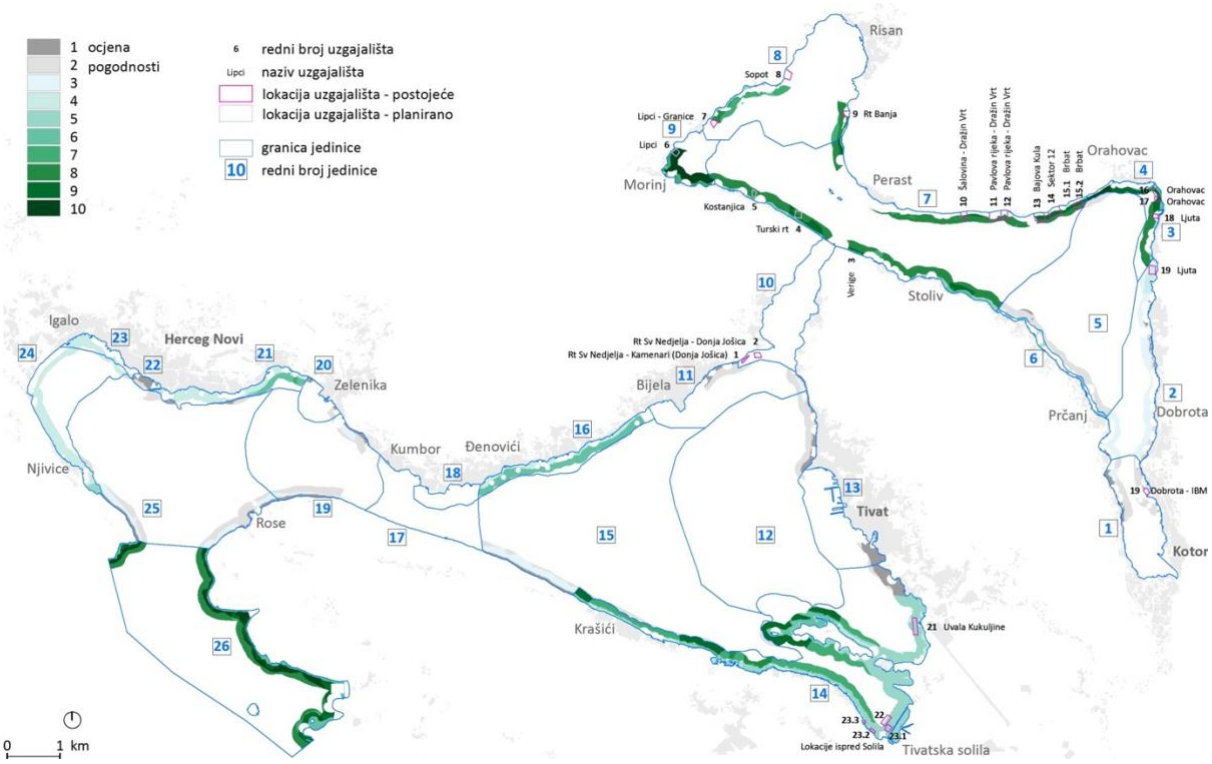


Figure 11. Analysis of suitability for mariculture development in Boka Kotorska Bay – for Bivalve farming (suitable areas are presented as green zones) – PAP/RAC, MORT, 2017.

Analyses of the possible new zones for fish farming in Montenegro

In accordance with the recommendations for the development of new zones for open sea mariculture (defined in the Spatial Plan of the special purpose area for the coastal zone of Montenegro), from January 2019 the Institute of Marine Biology (University of Montenegro) began a detailed study of several zones in accordance with the FAO concept "AZA (Allocated Zones for Aquaculture) ". The AZA concept implies very detailed research of various parameters and criteria that are indicators for defining new locations for mariculture (especially for fish farming). The study is done in accordance with the Environmental Quality Standards for the aquaculture sector, the principles of defining aquaculture zones (Allocated Zones for Aquaculture), the principles of defining zones of effect (Allowable Zone of Effect) and Sustainable Development Indicators of aquaculture in the GFCM region (InDam). This program is funded by the Ministry of Agriculture, Forestry and Water Management of Montenegro.

Fish farming in Montenegro (Figure 12 and 13) implies a closed farming cycle in floating cages in the sea. Although it shows a mild growth over the past few years, it is still at a low level, particularly in comparison with countries with relatively small production (Croatia, Albania, Morocco or Tunisia). Two fish farming sites on the territory of the Boka Kotorska Bay have annual production of around 120 t (MONSTAT, 2019). Production shows growth in recent years, thanks to decisive management of one of the two existing farms. However, the development of this sector is stagnant, as there are no defined locations for aquaculture in the open sea of the Montenegrin coast, which should be an integral part of the spatial plan of the coastal zone management and which should constitute security for investors to invest in cage farming.

There is a growing interest in recent years by various investors for growing not only sea bass and sea bream, but also for Atlantic bluefin tuna (*Thunnus thynnus*). Poor development of aquaculture in Montenegro contributes to the conflict of this sector with tourism and ecology, and ignorance of the actual situation and the possibility of linking these sectors. Although fish farming can significantly affect the ecological and biological condition of water, proper and sustainable management of production, regular monitoring of the environment and regular control to prevent the risk and disease could make the development of this sector viable and environmentally sound (Mandić *et al*., 2014).

Figure 12. Fish farming in Montenegro (floating cages)

Figure 13. Fish farming in Montenegro (floating cages)

Principles of good production practice

Good aquaculture practices, in the context of this guideline, can be defined as considerations, procedures and protocols designed to foster efficient and responsible aquaculture production and to help ensure final product quality, while protecting and improving the environment. Bivalve cultivation (especially mussels and oysters) has been proposed as a means to reduce the effects of eutrophication within coastal waters of Montenegro.

A low culture density is offering a rich source of active substances (e.g. antioxidants), minimize ecological stress along the grow-out period and increase resistance to diseases, ultimately reducing the risk of disease spreading to wildlife.

Combination of mariculture activities with other maritime uses may be considered as an option for fostering the sector's development. Due to growing pressure on the sea space and having in mind the on-going technology development in planning the sea space, the multi–use concept may become an important trend that shall be considered in the planning process.

Collection of seed for mussel and oyster farming

The first phase of cultivation involves the collection of seeds either from the natural environment or from installed collectors. Ropes about 40 mm thick are usually installed as collectors. Although the largest number of seed is collected from the natural environment, the installed collectors can collect about 30-40% of the seed necessary for the production cycle.

The second phase of cultivation begins after the seeds have been attaced for collectors reach a size of about 2-3 cm. After reaching the mentioned size, the young are transported into plastic mesh bags (braids or pergolas) 2-3 meters long (Figure 14) and 2-3 cm in diameter, with the average weight of one braid being about 4 kg.

Figure 14. Seeds collected on ropes and collectors

Handling of mussel and oyster seed

During the process of preparation of seeds for next phase, it is important to take into account the following:

- Mussel seed should be collected during late evening or early morning to avoid direct sunlight
- Desiccated, stunted, unhealthy seed in the intertidal exposed area should be avoided/ discarded
- The seeds attached to adult mussels in subtidal collections should be gently detached without damaging the byssus threads
- The harvested seed should be kept under shade, kept cool, under wet conditions, transported quickly, handled gently and avoiding dropping/ throwing while loading and unloading (Figure 15).

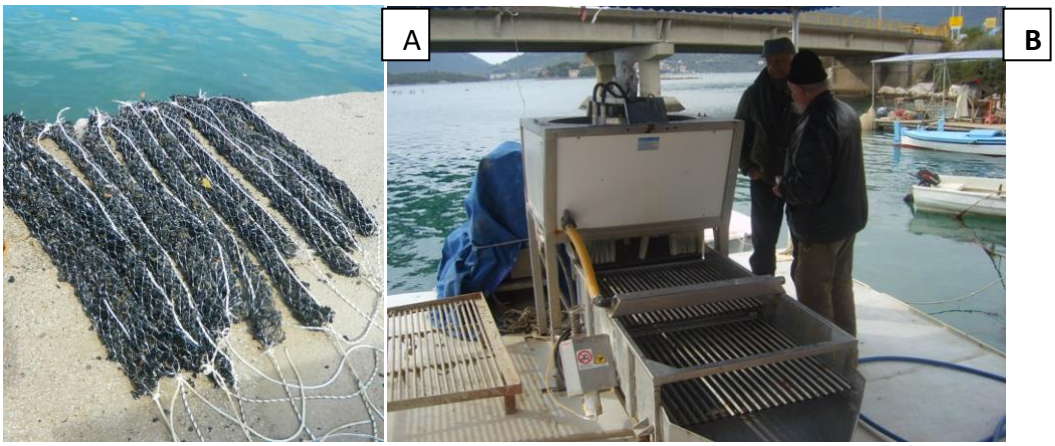
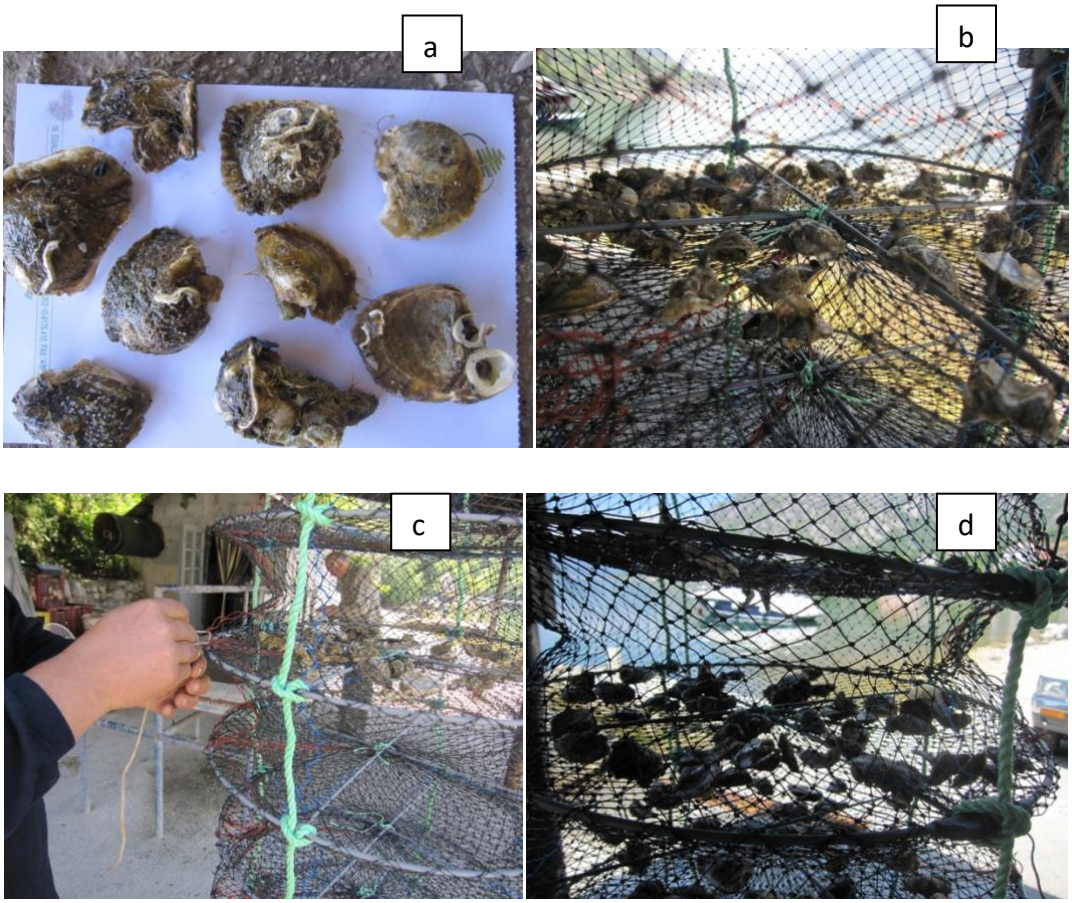
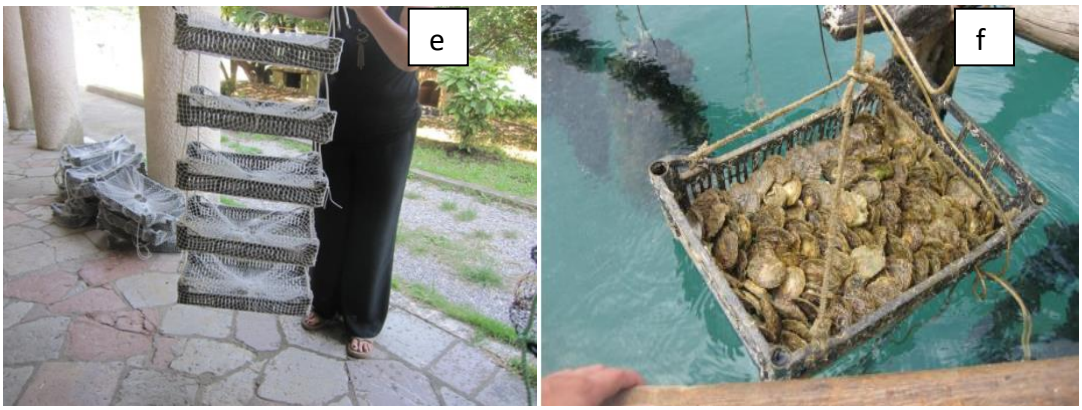


Figure 15. Mussel seed prepared for growing

Pergolars planted in this way (Figure 15 A) are placed on breeding lines (long-lines) at a distance of 30 to 50 cm, where they either grow to market size, or, in certain cases, require the next phase (rarefaction in cases of high density).

Various solid objects can be used as collectors for young oysters, but also old pergolas of mussels, rubber plates, plastic nets, oyster shells, etc. After collection of seeds, oysters can be grown in plastic boxes, lanterns or can be cemented (Figure 16).





Slika 16. (a-f). Method of planting young oysters in lanterns (a-d) and plastic boxes (e-f)

Regular cleaning activities of sea bottom

Quantities of marine litter originating from the fisheries and mariculture sector significantly exceed the quantities estimated during all previous research activities and projects. The problem of marine litter (ML) under shellfish and fish farms is higher than expected, since most ML assessment and clean-up activities were focused on ML outside the farm areas. In order to apply good practices when it comes to protection and preservation of the environment, it is necessary to carry out clean-up activities at least once a year (nets, ropes, plastic boxes and all pieces of equipment that inadvertently reach the seabed) (Figure 17).

Figure 17. Mussel nets collected under the mussel and oyster farm

European strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030.

The European Commission has adopted new strategic guidelines for a more sustainable and competitive EU aquaculture (https://ec.europa.eu/oceans-and-fisheries/ocean/blue-economy/aquaculture/aquaculture-guidelines_en).
These guidelines provide the Commission, the Member States and stakeholders with a common vision for the development of the sector in a way that directly contributes to the European Green Agenda, and in particular the field-to-table strategy. The guidelines will strengthen the competitiveness and resilience of EU aquaculture and increase environmental and climate performance

Main objectives of EU Strategy is engaging all relevant stakeholders in the development of the EU aquaculture as a sector that supplies nutritious and healthy food with a low environmental and climate footprint, that creates economic opportunities and jobs, and becomes a global reference for sustainability and quality. In particular, the guidelines have the following objectives.

The strategic guidelines identify 13 areas where further work is needed to promote the sustainability, competitiveness and resilience of EU aquaculture:

1. Building resilience and competitiveness
2. Access to space and water
3. Regulatory and administrative framework
4. Animal health and public health
5. Climate-change adaptation and mitigation
6. Producer and market organisations
7. Control
8. Diversification and adding value
9. Participating in the green transition
10. Environmental performance
11. Animal welfare
12. Ensuring social acceptance and information to the consumer
13. Increasing knowledge and innovation

In order to provide assistance for the implementation of the measures defined in the Strategy, the Commission will establish an EU mechanism for assistance in the field of aquaculture. This mechanism should assist the Commission, Member States, industry and other stakeholders

in developing further guidance and gathering examples of best practice in the areas covered by this Communication.

Key goals of mariculture development

- Encouraging sustainable economic development and creating business opportunities and creating new jobs in "blue" economic sectors - fisheries and mariculture. This especially refers to the definition of new locations for mariculture on the open sea of the Montenegrin coast as well as the development of land-based fish farming (in recirculation systems-RAS)
- sustainable development and improvement of mariculture as a support to the development of tourism in the Coastal region (obtaining a certificate on organic shellfish farming, product branding, formation of clusters and new tourist offers closely related to fisheries and mariculture)
- increasing the capacity of innovative technologies in the process of cultivation, diffusion and transfer of technologies and technological knowledge, improvement of technological processes
- establishment of an innovative network between academic research centres and government bodies in order to form a cluster of producers of traditional products, including mariculture products
- promoting cross-sectoral innovative capacities of the fisheries, mariculture and tourism sectors in the micro-regions of coastal municipalities through the establishment of a knowledge network on the importance of mariculture with the task of improving innovation, competitiveness, internationalization, sustainability and inclusive development of these two sectors.

Recommended indicators for future monitoring of plan implementation

- Development of shellfish farming in the Boka Kotorska Bay area (supplementing spatial plans, defining new suitable zones for shellfish farming)
- Number of new, active fish farms on the open sea of the Montenegrin coast
- Annual production in mariculture (growing trend)
- Development of land-based fish farming (recirculation systems) - number and production capacity

- Progress in product branding and number of organic production certificates
- Number of offered services/new tourist offers closely related to mariculture
- Number of new jobs in the mariculture sector
- Progress in the formation of producer clusters

Conclusion

In general, it can be concluded that during many years of work and cooperation with Mediterranean countries, significant progress has been made in the field of mariculture development in Montenegro. In addition to the progress of exchanging experiences, introduction of new technologies, application of FAO AZA principles has contributed to such development of an approach in defining new locations for mariculture that will provide security for investments and contribute to achieving some of the strategic goals of mariculture sector development in Montenegro.

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