ANALYSIS OF INTERACTIONS BETWEEN DIFFERENT TYPOLOGIES OF AQUACULTURE PRACTICES AND THE TRENDS OF ADRIATIC FISH STOCKS, HIGHLIGHTING BOTH POSITIVE AND UNWANTED EFFECTS OF AQUACULTURE ON MARINE HABITATS AND SPECIES

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"Analysis of interactions between different typologies of aquaculture practices and the trends of Adriatic fish stocks, highlighting both positive and unwanted effects of aquaculture on marine habitats and species"- (ARGOS-S-03)

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ABBREVIATIONS

ZP	Zoning plan
SLP	Spatial Landscaping Plan
ZC	Zadar County
Study	Study on the use and protection of the sea and submarine
PCA	Protected Coastal Area

1. ABSTRACT

Implementation of the project "ARGOS" within the Cross-border Cooperation Program Italy Croatia 2014-2020, includes the development of starting points for analysis of the relationship between different forms of aquaculture and trends in fish stocks in the Adriatic Sea, with emphasis on positive and negative effects of aquaculture on marine habitats and species and analysis of the relationship between different forms of aquaculture and trends in fish stocks in the Adriatic Sea, with emphasis on positive and negative effects of aquaculture on marine habitats and species .

The first part of the study provides an insight into previous activities and existing documents, as part of previous mariculture activities in the Zadar County.

The second part presents an analysis of the relationship between different forms of aquaculture and trends in fish stocks in the Adriatic Sea, with emphasis on the positive and negative other effects of aquaculture on marine habitats and species, but also the impact on mariculture, and after the general part White fish farming and tuna farming with emphasis on:

• interaction with species in the environment
• interaction with catches of the same species in fishing
• habitat interaction

then measure in shellfish farming by emphasizing:

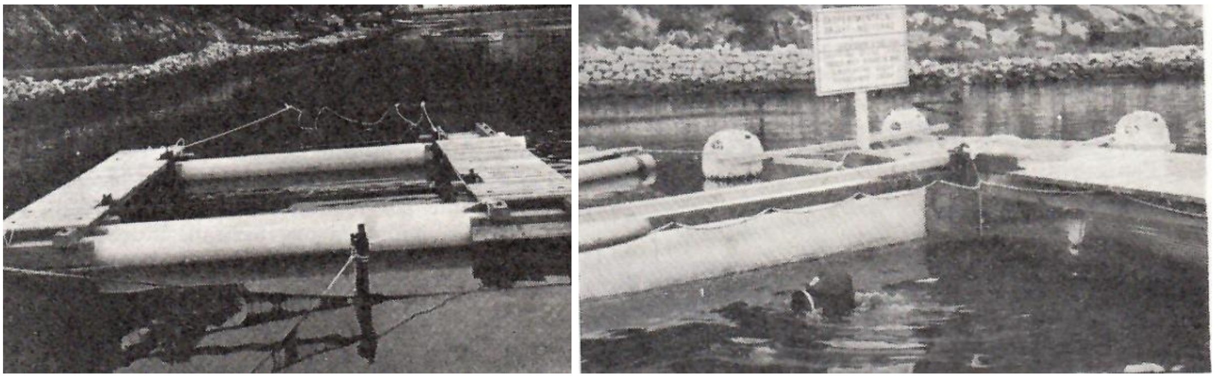
• interaction with species in the environment
• interaction with natural shellfish settlements

Emphasis is also placed on open issues related to the breeding of other marine organisms, through proposed measures and recommendations for the implementation of measures. Proposals for measures and recommendations for the implementation of measures should include aspects of data collection and spatial planning at sea in a way that contributes to the adoption of a framework for the new programming period in the EU.

2. INTRODUCTION

Zadar County has a long tradition of breeding marine fish and shellfish, which is the case along whole Dalmatia. The first documented activities related to the cultivation of marine organisms (fish and shellfish) date back to Roman times. The first Dalmatian fishponds date back to the 1st century. In the Middle Ages, fish and oyster farming developed near coastal monasteries, and this trend was joined by feudal landowners who for centuries appropriated and exploited the best locations for fish and shellfish farming. Fishponds were used to raise mullets, gilthead bream, sea bass and eels.

Experimental breeding of sea bass in floating cages in Zadar County began with the purchase of juveniles from a hatchery that was on the island of Pellestrina, which is forming a barrier between the southern Venetian Lagoon and the Adriatic Sea. The cage was set up in the Novigrad Sea in 1978.



Figures 1 and 2. The first experimental cages for mullet and sea bass farming.

It was the first CBC (Cross border cooperation) related to fish farming established between Croatia and Italy. After encouraging results, fish farming company, "Cenmar" was established. In 1981 it set up the first cage for commercial seabass farming in the world, in the bay of Lamjana on the island of Ugljan. Further cooperation soon began, which resulted in the KNOW HOW project for the construction of a hatchery. It commenced its operation in 1983, and 80% of the equipment was produced in Zadar County. The first catch from its own hatchery was in 1986. At the World Conference on Aquaculture in Venice (1981), information about the first successes of seabass farming in floating cages was released.

Due to the high prices and increased demand for tuna in the Japanese market, there has been significant fishing pressure on this species. The consequences were first seen in the southern hemisphere, and then in our country, which resulted in catch restrictions, ie the introduction of tuna catch quotas at the international level. This was the incentive for the start of caged tuna farming.

Cultivated tuna farming was among the first to be started by Australian Croats in Port Lincoln in the early 1990s. In South Australia, our Croatian fishermen managed to store the caught tuna in cages, feed them and thus increase the price of farmed tuna by selling them on the Japanese market. Our fishermen transferred this new experience in cage tuna farming, which achieved exceptional results, to Croatia. Several of our emigrants decided to invest their capital in, at the time unknown branch of mariculture, tuna farming in cages. The caged tuna farming project also started in the Zadar area at the end of 1995, on their own initiative thanks to several emigrants from Kali on the island of Ugljan.

With an initial capital of two million Australian dollars and another five million dollars spent on cages, tuna boats and the construction of onshore infrastructure, in 1995, Kali tuna was founded. It was the first company in this part of the Mediterranean to start tuna farming. Since then, the tuna business has been extremely important for Croatian mariculture and is one of the most successful Croatian export projects. Kali tuna started experimental production in 1996 in its tuna farm near the island of Iž. In those first years, they farmed and placed the first 39 tons of tuna on the Japanese market. Tuna is primarily intended for the specific Japanese "sushi" and "sashimi" markets. Following the example of Kali tuna, several other companies started growing tuna. Shellfish farming as a production segment from Mariculture has started to expand to new locations in the Zadar aquatorium.

3. SPATIAL PLANNING OF AQUACULTURE IN ZADAR COUNTY

In the period from 1995-2001 the activities of drafting the Spatial Plan for the area of Zadar County took place. It was finalized in April 2001 and was published in the Official Gazette no. 2/01. The development was led by the Institute for Physical Planning of Zadar County.
Article 119 of the Spatial Plan prescribes the need to prepare special studies and expert bases for permanent monitoring of changes in space, and, among other things, the **Study on the use and protection of the sea and seabed**. The study should cover the sectors of maritime economy and marine protection. In the maritime economy sector, the study had to be based on a comprehensive analysis and valorization of the development of all industries related to the sea. The Spatial Plan also ordered, "in order to create a data bank and the necessary basis for the preparation of spatial planning documentation", the establishment of the **Cadastre for the Use of Maritime Property** for the entire Zadar County.

The need to produce the Study arose because already then, ie in 2000, symptoms were noticed (eg overload and damage to the coastline by unplanned construction, sea pollution with untreated wastewater, excessive exploitation of renewable resources, conflicts between the mariculture and tourism sectors) which clearly indicated the **need to improve the planning and management system** as soon as possible, to a level that will allow existing growth (naturally caused by the attractiveness of county resources) to be gradually shaped into sustainable development.

The study, as **an expert basis for initiating the process of Integrated Coastal Zone Management of Zadar County** (ICZM), was a significant step in formulating a quality response to the described need. This was actually the **beginning of spatial planning at sea**.

Mariculture was a frequent topic of open debate in public dialogue and the media at the time. This increased the interest in determining this significant activity in a better spatial way, so the Mariculture Sector was dealt with in great detail in the Study. The topic of mariculture was burdened with a number of contradictory information, inaccurate information and semi-information, and the ICZM's mission was to try to remedy such a situation with a systematic and reasoned description of the sector.

The description is structured into several parts, describes its state and trends in the global context, description of the state and trends in mariculture in the Republic of Croatia and Zadar County, and a discussion on the impact of mariculture on the environment and its relationship with other sectors.

4. ZONING OF THE COASTAL AREA OF ZADAR COUNTY

Within the Study, Zoning of the Coastal Area of Zadar County was created for strategic designing of the spatial aspect for mariculture develompemnt, in order to:

1. ensure that individual decisions are a part of the long-term sustainable and optimal usage of existing resources;
2. show conducted and presented analysis as an example of planning, ie analytical support to planning in the context of ICZM, which takes into account and uses criteria such as space suitability, receiving and carrying capacity of the environment, and the existence and interests of other activities or users.

The implemented zoning divides the county area into **four** legally prescribed (OG 08/99) types of **zones**:

• **zone Z1** - areas designated for mariculture. Any other activity that may be developed must not be harmful to the farming conditions of fish and shellfish.
• **zone Z2** - areas where mariculture has a high priority, but other activities are allowed.
• **zone Z3** - areas where, under certain conditions, limited forms of mariculture are allowed and it serves as a supplement to other dominant activities.
• **zone Z4** - areas that are not suitable for mariculture

The zoning of the coastal area for mariculture purposes takes into account the suitability of the area for that activity, the receiving and carrying capacity of the environment, the interests of other activities in the area and suggests the following activities:

- determination of criteria for assessing the suitability of the area for mariculture activities, in accordance with legal requirements and recommendations
- determining the impact of the activity on the environment
- recognizing the interests of other sectors
- multicriteria spatial analysis, which as a result divides the analyzed area into zones of different credit rating, given their suitability for performing mariculture activities.

During the implementation of measures and objectives set by the Study, in 2005 the Program for Monitoring the State of the Environment and Pollution of the Coastal and Marine Areas of Zadar County was developed and adopted, as the main program and the Program for Monitoring the State of the Environment for Mariculture in Zadar County. The Environmental Monitoring Program for the port area for public transport and special purpose ports, as the second sectoral subprogram, and the last sectoral subprogram, the Program for monitoring the environmental status and pollution of the coastal and marine area with wastewater in Zadar County, were developed in 2006.

In order to efficiently evaluate the results of individual measurements of sectoral programs, especially its correct interpretation, it was necessary to establish reference points. Reference points are places where reference samples are taken continuously.

Reference points / monitoring stations and bearings:

4.1 Urban Zadar region

- Nin Bay (station P1 / Nin bay)
- Area from Privlaka to Zadar (station P3 / Petrčane)
- Zadar area (stations P4-T4 / Kolovare and station P5 / Gaženica)
- Area from Zadar to Drage (station P6 / Pašman Canal)

4.2 Zadar - Biograd islands

For the purposes of the Program, the division was made according to geographical location in four island groups, and as an additional criterion "sea current presence" and development factor were considered.

- Group I: Vir, Ošljak, Ugljan, Pašman, Babac (station P1 / Nin bay, station P2-T2 / Vir, station P3 / Petrčane, station P4-T4 / Kolovare, station P5 / Gaženica, station P6 / Pašman canal, station P7 / Vrgada, station P8 / Iž and station P9, T9 / Sestrunj)
- Group II: Vrgada, Košara, Žižanj, Gangaro (station P7 / Vrgada)
- Group III: Iž, Lavdara, Rava, Rivanj, Sestrunj, Tun, Zverinac, Dugi otok (station P8 / Iž, station P9 T9 / Sestrunj and station P15 / Open sea)
- Group IV: Silba, Molat, Ist, Škarda, Premuda, Olib, Maun (station P10 / Silba canal and station P11 / Maun)

4.3 Island of Pag (area of the island belonging to Zadar County)

One of the largest Adriatic islands is administratively divided into two counties. Maritime domain belonging to Zadar County is divided into four units:

- First unit (station P11 / Maun): cape Straško-cape Prutna
- Second unit (stations P1 / Nin Bay and station P14 / Ljubač Bay)
- Third unit (station P12 / Velebit Canal): from Ljubač to Pag
- Fourth unit (station P12 / Velebit kanal): coastal belt of the Bay of Pag.

4.4 Velebit Canal Area

• Velebit canal (station P12 / Velebit canal)
• Novigrad sea (station P13 / Novigrad Sea)
• Ljubač bay (station P14 / Ljubač Bay)

4.5 Open sea (station P15 / Open sea)

It covers County's open sea. The borders of this region are the Zadar-Biograd region, ie islands and the state border of the Republic of Croatia, which is 45 nautical miles, ie 83.43 km.

With the program for monitoring the state of the coastal and marine environment at these stations, the following potential sources of pollution: wastewater, pollution from tourism, mariculture, maritime transport, nautical tourism, ports, docks, industry, urbanism and agriculture were monitored.

General and physico-chemical indicators for each of the potential sources of pollution were monitored.GENERAL: Hydrometeorological conditions; PHYSICO-CHEMICAL: Dissolved Oxygen, Oxygen Saturation, Salinity, Turbidity, Suspended Substances, Total Organic Carbon (TOC), Nutrients, Metals, Organic Compounds, Microbiology.

The program for monitoring the state of the environment and pollution of the coastal and marine area of Zadar County included determining the state and movement, identifying the causes and sources of pollution, prioritizing and implementing quality management programs and developing programs in case of sudden pollution. Samples were collected and tested, and pooled physical, chemical, biological, and radiological parameters were determined.

For the area of Zadar County, Operational implementation (monitoring) of all programs, ie testing of monitoring indicators in the water column and sediment at given reference points, has been carried out continuously since 2007.

In the next chapter, we will conduct an analysis of the implemented monitoring programs related to mariculture in the Zadar County with a preliminary analysis of the Zadar County plan related to mariculture.

5. ANALYSIS OF THE SPATIAL PLAN OF ZADAR COUNTY

According to the valid Spatial Plan of Zadar County (Official Gazette of Zadar County No. 2/01, 6/04, 2/05, 17/06, 3/10, 15/14, 4/15) and Article 29 based on the Study of the Use and Protection of the Sea and Seabed in the Zadar County and subsequent audits, areas of mariculture locations were determined for each currently existing individual type of mariculture. That is why the County area is divided into four prescribed types of zones (Regulation on criteria for suitability of parts of maritime property for fish and other marine organisms „Narodne novine", No. 8/99, 56/12):

Zone Z1 - areas designated for mariculture:	Any other activity that would be developed must not be harmful to the conditions of fish and shellfish farming (Košara-Žižanj).
Zone Z2 - areas where mariculture has a high priority, but other activities are allowed:	Fish farming: Fulija-Kudica, Mrđina-Lamjana, Dugi otok – from cape Gubac to cape Žman, Zverinac, Gira, Iž - Srednji otok, Iž - Vela Sveža, Velo Žalo i Vrgada, Dinjiška – the wider area of cape Fortica, Lukar. At these locations, shellfish farming in polyculture with fish is also allowed, in accordance with the applicable regulations for shellfish farming. Shellfish farming: Novigrad Sea - excluding Karin and including Novsko ždrilo, Velebit canal – the area from Modrič to cape Pisak - Seline, Ljubač Bay, NE coast of Pag island – from Goluberje to Čiker from Srbljina, parts of Dinjiška bay and parts of Stara Povljana bay, Pakoštane-Draga area, NE from the islets of Veliki and Mali Žavinac to the mainland coast. In zones Z1 and Z2, farming capacity will be determined by special regulations governing the protection of the environment and nature.
Zone Z3 - areas where limited forms of mariculture are allowed under certain conditions and where it serves as a supplement to other dominant activities:	Kablin, Dumboka, Olib, Vičija bok - Rava, Velebit canal from Šilje Žetarica bay to cape Kozjača and from cape Dugi to County border. In addition to the existing locations, it is possible to locate white fish and shellfish family farms at depth in accordance with the regulations governing the criteria on the suitability of parts of

	the maritime domain for farming of fish and other marine organisms. (…)
Zone Z4 - areas not suitable for mariculture.	Accordingly, the capacities of individual locations were estimated. The capacities of individual locations where cultivation will take place in quantities for which the preparation of EIA is mandatory, will be determined through the environmental impact assessment procedure.

5.1 Environmental Impact Assessment

When determining the location conditions for starting a farm, measures within the competence of environmental protection (Environmental Protection Act NN 80/13, 153/13, 78/15) and nature protection (Nature Protection Act NN 83/13) are determined. Environmental protection regulations require the initiation of assessment procedures regarding the need to assess certain environmental interventions or the initiation of an assessment of certain environmental interventions. Regulations in the field of nature protection require the assessment of the acceptability of interventions on the ecological network, which is most often carried out as part of environmental protection procedures.

Criteria for conducting an environmental impact of aquaculture interventions is given by special regulations (**Table 1**).

Table 1 Criteria prescribed by the Regulation on Environmental Impact Assessment (NN 61/14, 03/17).

ENVIRONMENTAL PROTECTION SECTOR PROCEDURES
ZAPROCEDURES FOR WHICH THE ENVIRONMENTAL IMPACT ASSESSMENT IS MANDATORY
1) Marine farms:
a) white fish farms in a protected coastal area of the sea with an annual production of more than 100 tons
b) fish farms outside the protected coastal area, up to a distance of 1 NM with an annual production of more than 700 tons
c) fish farms outside the PCA, which are more than 1 NM away from the shore with an annual production of more than 3,500 tons
2) Mariculture zone in PCA planned for several white fish farms

3)	Shellfish farms in PCA with an annual production of more than 400 tons
ASSESSMENT PROCEDURE ON THE NEED FOR THE ENVIRONMENTAL IMPACT ASSESSMENT - Environmental Protection Study	
	• White fish farms in a protected coastal area (PCA) with an annual production of less than 100 tons

Environmental impact assessment (EIA) procedure

For all farm sites for which an environmental impact assessment procedure has been carried out, the existing good practice is to analyze key indicators in the sediment to be able to create Environmental Impact Study. After the assesment, the Ministry issues the prescribed Monitoring Program.

Assessment procedure on the need for the environmental impact assessment

If we are talking anout a new farm or a farm where farming quantities and the method of cultivation are changing (increase or decrease of farminging fields) that do not require an EIA procedure, conducting field research or analysis of indicators in the sediment is not a practice.

6. REVIEW OF IMPLEMENTED MONITORING PROGRAMS

Depending on the increase in capacity, location of the farm, and the type of farming, environmental impact assessment procedures have been carried out, and for some sites several environmental impact assessment procedures and /or assessments of the need for assessment have been carried out over the years.

The analysis of the implemented procedures and monitoring programs was made according to the zoning for setting up farms in the Zadar County, which is defined by the spatial plan.

Zone Z1

In the area of this zone there is only one, white fish farm that has been farmed for many years. Since this is a farm where a Usage Program, and two Environmental Impact Assessments (EIA) have been developed, a monitoring program is also being implemented, which includes monitoring of organic carbon concentration, total amount of nitrogen and phosphorus in stations in the farming area and reference stations in the surface layer of sediment up of 5 cm depth, as well as the redox potential profile from the surface layer of sediment to a depth of 10 cm (every 1 cm). It also includes the review of marine habitats on transects monitoring the condition of marine habitats of the coastal zone once a year and, Carlit method (Nikolić et al., 2013). The sediment and habitat monitoring program is carried out once a year at the time of greatest impact (late September / early October), except for the Carlit method, which needs to be implemented in the spring. During 2019, a monitoring program according to the Aquaculture Stewardship Council (ASC) standard has been launched at the farm.

Zone Z2

Tuna farms

Within zone Z2 tuna is farmed at a total of 5 locations, one of which is not in currently functional for farming, although an environmental impact assessment procedure has been carried out for it. At the remaining sites, environmental impact assessment (EIA) procedures were carried out, which defined environmental monitoring programs. Similar to marine sediment farms, monitoring includes tracking the concentration of organic carbon, total amount of nitrogen and phosphorus at stations in the farm area and reference stations in the surface layer of sediment to a depth of 5 cm, including redox potential profile from the surface layer of sediment to a depth of 10 cm (every 1 cm). In earlier sediment studies, focus was monitoring of organic nitrogen and organic phosphorus, while more recent studeis concluded that monitoring of total nitrogen and total phosphorus is a more reliable indicator. A more recent study prescribes monitoring the condition of coastal zone marine habitats and monitoring of antibiotics in bivalve molluscs from cage overgrowth in tuna farms.

Table 2 Overview of indicators monitored in tuna farms

INDICATORS	ZVERINAC	GIRA	MRĐINA	KUDICA
Sea water: sea transparency, dissolved oxygen, ammonia and chlorophyll	Yes	Yes	Only chlorophyll and oxygen saturation	No
Marine sediment: redox potential, organic carbon, total nitrogen and total phosphorus	Yes (concentrations of organic nitrogen and organic phosphorus)	Yes (concentrations of organic nitrogen and organic phosphorus)	Yes	Yes (concentrations of organic nitrogen and organic phosphorus)
Biological-diving examination	Yes	Yes	Yes	Yes
Visual determination of the influence of fat on mediolittoral biocenoses	Yes	Yes	No	Yes
Carlit method	No	No	Yes	No
Antibiotic analysis	No	No	Yes	No

White fish farms

White fish is farmed at a total of 11 locations. There are smaller farms in five locations (or farms) that, due to their capacity, were not subject to the environmental impact assessment procedure, therefore do not have prescribed monitoring programs. The remaining 6 were subject to environmental impact assessment procedures that defined monitoring programs and their frequency. Monitoring programs (at almost all farms) include monitoring of organic carbon, total nitrogen and total phosphorus concentrations in marine sediment in farm areaa and reference stations in the sediment surface layer to a depth of 5 cm, and a redox potential profile from the sediment surface layer to a depth of 10 cm (each 1 cm). It also includes the review of marine habitats on transects once a year in several transects and monitoring the condition of marine habitats of the coastal zone, Carlit method (Nikolić et al., 2013). The sediment and habitat monitoring program is carried out once a year at the time of greatest impact (late September / early October), except for the Carlit method, which needs to be implemented in the spring. At most farms, the condition in the seawater column is monitored, as well as the monitoring of antibiotics in shellfish from fouling on the cage.

Table 3 Overview of indicators on white fish farms

INDICATORS	LAMJANA	VELO ŽALO	ŽMAN	VRGADA	LAVDARA	MAUN
Sea water: sea transparency, dissolved oxygen,	Yes	Yes	Yes	Yes	No	No

INDICATORS	LAMJANA	VELO ŽALO	ŽMAN	VRGADA	LAVDARA	MAUN
ammonia and chlorophyll						
Marine sediment: redox potential, organic carbon, total nitrogen and total phosphorus	Yes	Yes	Yes	Yes	Yes	Yes
Biological-diving examination and/or seabed imaging	Yes	Yes	No	Yes	Yes	Yes
Carlit method	Yes	Yes	Yes	Yes	No	Yes
Antibiotic analysis	Yes	Yes	Yes	Yes	No	No

Shellfish farming

For two sites where there are multiple poducers, for which the assessment procedures on the need for environmental impact assessment have not been carried out and, given the existing practice, no monitoring programs are implemented.

Zone Z3

White fish farming

For two locations, assessment procedures on the need for assessment were carried out, and no environmental monitoring programs were prescribed for these farms.

Table 4 Overview of mariculture zones and implemented environmental impact assessment procedures and assessments of the need for assessment and environmental monitoring programs

ZONE / No.	MARICULTURE ZONES	EXCRACT FROM A CARTOGRAPHIC ILLUSTRATION 1.1. USE AND PURPOSE OF SPACE	SPATIAL PLAN OF ZADAR COUNTY	IMPLEMENTED ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES / ASSESSMENT OF THE NEED FOR ASSESSMENT	MONITORED PARAMETERS IN FARMING AREA	REMARKS
Z1	Area designated for mariculture - fish and shellfish farming					
	Košara-Žižanj		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county.	Oikon (2008): Space Use Program Oikon (2009): Environmental Impact Study Green Infrastructure (2018) Environmental Protection Study Environmental impact study (2020): increasing the capacity of white fish farms from 2,400 to 3,700 tons per year.	• In 2019, measurements of physicochemical parameters in the sea column were performed (temperature, density, salinity, transparency with Secchi plate, visual inspection of the sea, pH, dissolved oxygen, oxygen saturation, ammonium, nitrites, nitrates, inorganic nitrogen, total nitrogen, orthophosphates, total phosphorus, silicates total organic carbon), also biological indicators were recorded (chlorophyll α). Aquaculture Stewardship Council (ASC) standard. Allowable Zone of Effect (AZE). 1) In marine sediment: concentration of organic carbon, total nitrogen and total phosphorus at stations S1, S2, S3, S4, S5, S6, R1 and R2 in the surface layer of sediment up of 5 cm depth, as well as the redox potential profile from the surface layer of sediment to a depth of 10 cm (every 1 cm). 2) Monitoring of marine habitats on transects once a year T1, T2, T5, T6 and TR-S1 and TR-S2 3) Monitoring the condition of marine habitats in coastal belt with Carlit method (Nikolić et al., 2013) on the outer side of the island of Košar facing the farm and the inner side of the island of Košar towards the farm. 4) The environmental monitoring program should be implemented once a year at the time of the greatest impact (end of	-

ZONE / No.	MARICULTURE ZONES	EXCRACT FROM A CARTOGRAPHIC ILLUSTRATION 1.1. USE AND PURPOSE OF SPACE	SPATIAL PLAN OF ZADAR COUNTY	IMPLEMENTED ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES / ASSESSMENT OF THE NEED FOR ASSESSMENT	MONITORED PARAMETERS IN FARMING AREA	REMARKS
					September/beginning of October), except for the Carlit method, which should be implemented in the spring.	
Z2	Areas where mariculture is of high priority, but other activities are allowed Areas for fish farming with shellfish in polyculture					
1	Dinjiška – wider area of cape Fortica	/	The zone is specified only in Regulations, it is not marked in cartographic illustration 1.1 (located within the wider zone for shellfish farming Z2 Dinjiška III).	Ekotop (2017): Environmental protection study - Expansion of white fish and shellfish farming in Dinjiška Bay, island of Pag	Monitoring is not carried out on the farm.	The ZZ monitoring station is located in the immediate vicinity of the farm.
2	Gira	/	The zone is specified only in Regulations, it is not marked in cartographic illustration 1.1 (located within the wider zone Z2 Vrgada 11).	Oikon (2008): Environmental impact study for expanding tuna farm capacity near the island of Gira	1) In sediment: redox potential, concentration of organic carbon, organic nitrogen and organic phosphorus at positions P1, P2 and P3 in the surface layer of sediment to a depth of 5 cm. The measurement should be performed twice a year, at the time of the lowest (June), and at the time of the highest food intake (August/September). 2) Biological (diving) inspection of three transects (TR1, TR2 and TR3). Examination should be done twice a year (at the same time when sediment samples are taken). 3) Determination of the influence of fat on mediolittoral biocenoses, once a year (at the same time when	-

ZONE / No.	MARICULTURE ZONES	EXCRACT FROM A CARTOGRAPHIC ILLUSTRATION 1.1. USE AND PURPOSE OF SPACE	SPATIAL PLAN OF ZADAR COUNTY	IMPLEMENTED ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES / ASSESSMENT OF THE NEED FOR ASSESSMENT	MONITORED PARAMETERS IN FARMING AREA	REMARKS
					water and sediment samples are taken).	
3	Lukar		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county.	No data on preformed procedures are available.	There is no information on the implementation of the monitoring program on the farm.	-
4	Zverinac		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county.	Oikon (2006): Environmental impact study of a tuna farm at Zverinac	1) Measurement of basic properties of sea water: transparency of the sea, dissolved oxygen, ammonia and chlorophyll at stations VM1, VM2 and R at depths of 0.5 m, 20 m, and along the bottom. Measurements should be carried out once a year, in September or October (at the time of the highest food intake, ie at the time of the greatest impact). 2) Measurement of basic parameters in sediment: redox potential, organic carbon, organic nitrogen and organic phosphorus, at positions S1, S2 and R in the surface layer of sediment to a depth of 5 cm. The measurement should be performed twice a year, in June and in September. 3) Perform a biological-diving inspection of the bottom under the existing farm at the end of the first year after the cages are moved to a new location. 4) As part of the periodic inspection (once a year), perform a biological inspection of the anchor structure and fouling by recording with an underwater camera under the farm, on the basis of which the interpretation of the state of	

ZONE / No.	MARICULTURE ZONES	EXCRACT FROM A CARTOGRAPHIC ILLUSTRATION 1.1. USE AND PURPOSE OF SPACE	SPATIAL PLAN OF ZADAR COUNTY	IMPLEMENTED ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES / ASSESSMENT OF THE NEED FOR ASSESSMENT	MONITORED PARAMETERS IN FARMING AREA	REMARKS
					phyto- and zoo-benthos will be performed. 5) Visual determination of the influence of fat on mediolittoral biocenoses in September / October at the time of greatest influence. Make photo documentation.	
5	Iž - Srednji otok		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county.	INSTITUTE FOR SAFETY IMPROVEMENT d.d., (2015): Environmental protection study – Building a white fish farm near the island of Iž with a capacity of 690 tons per year. Green infrastructure (2016): Environmental protection study – Building a white fish farm with a capacity of up to 200 tons of consumable fish per year, in the part of the waters northwest of the island of Iž	Monitoring is not carried out on the farm.	The ZZ monitoring station is located in the immediate vicinity of the farm.
6	Iž - Vela Savež a		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county.	Zelena infrastruktura (2018): Environmental protection study Increasing the capacity of white fish farms to 85 tons per year near the island of Iž (Vela Svežina bay) Zelena infrastruktura (2019): Increasing the capacity of white fish farms up to 700 tons per year near the island of Iž (Vela Svežina bay)	Monitoring is not carried out on the farm.	The ZZ monitoring station is located in the immediate vicinity of the farm.

ZONE / No.	MARICULTURE ZONES	EXCRACT FROM A CARTOGRAPHIC ILLUSTRATION 1.1. USE AND PURPOSE OF SPACE	SPATIAL PLAN OF ZADAR COUNTY	IMPLEMENTED ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES / ASSESSMENT OF THE NEED FOR ASSESSMENT	MONITORED PARAMETERS IN FARMING AREA	REMARKS
7	Mrđina-Lamjana		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county.	Oikon (2016): Environmental Impact Study - Increasing the production capacity of white fish farms at the Lamjana location in zone Z2 in Zadar County	1) In marine sediment: concentration of organic carbon, total nitrogen and total phosphorus at stations M VŠ1, M VŠ2, M VŠ3, MG, MB and M REF in the surface layer of sediment to a depth of 5 cm and redox potential profile from the surface layer of sediment to depth 10 cm (every 1 cm), 2) In the seawater column: oxygen saturation and chlorophyll concentration at stations M VŠ1, M VŠ2, M VŠ3, MG, MB and M REF, 3) monitoring the condition of marine habitats of the coastal zone by the Carlit method (Nikolić et al., 2013), 4) analysis of antibiotics: concentrations of sulfadiazine, trimethoprim, flumequine and oxytetracycline in shellfish from cage fouling in which the juvelines are housed (station M VŠ1 and MG), 5) inspection of the seabed under all farming areas and in their immediate vicinity. 6) Implement the environmental monitoring program once a year at the time of greatest impact (end of September/beginning of October).	
				Oikon (2004): Environmental impact study for farm capacity up to 1,500 tons per year Zelena infrastruktura (2019): Environmental Impact Study - Increasing the capacity of tuna farms at the location below Mrđin, on the southwest side of the island of Ugljan	1) In marine sediment: concentration of organic carbon, total nitrogen and total phosphorus at stations P1, P2, T2, T3, in the surface layer of sediment to a depth of 5 cm and redox potential profile from the surface layer of sediment to depth 10 cm (every 1 cm), 2) In the seawater column: oxygen saturation and chlorophyll concentration at stations P1, P2, T2, T3 at a depth of 0,5 m, 10 m, 20 m and on the seabed.	

ZONE / No.	MARICULTURE ZONES	EXCRACT FROM A CARTOGRAPHIC ILLUSTRATION 1.1. USE AND PURPOSE OF SPACE	SPATIAL PLAN OF ZADAR COUNTY	IMPLEMENTED ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES / ASSESSMENT OF THE NEED FOR ASSESSMENT	MONITORED PARAMETERS IN FARMING AREA	REMARKS
					3) Overview of fouling on farming installations and nets. Overview of marine habitats on transects TR1, TR2, TR3. 4) Review of the spread of oil spots (distribution and impact on the mediolittoral). Monitoring the state of marine habitats of the coastal zone, Carlit method (Nikolić et al., 2013) at a length of about 600 m. 5) The environmental monitoring program should be implemented once a year, at the time of the greatest impact (end of September/beginning of October), except for the Carlit method, which should be implemented in the spring.	
8	Fulija - Kudica	Two separate zones 	The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county.	Oikon (2015): Environmental protection study - White fish farm in the Iška channel - Target capacity up to 700 tons per year	Monitoring is not carried out on the farm.	
				Oikon, (2007): Study on the environmental impact of tuna farms between the islands of Fuli and Kudice Zelena infrastruktura (2019): Environmental study - Tuna farm with a capacity of 500 tons per year at a location between the islets of Fulija and Kudica in the Iška Channel	1) In sediment: redox potential, concentrations of organic carbon, organic nitrogen and organic phosphorus, at positions S1, S2 and R in the surface layer of sediment to a depth of 5 cm. Measurements should be taken twice a year, in June (before the introduction of the new generation of tuna) and in August (at the time of greatest impact, ie at the time of greatest food intake). 2) Biological-diving inspection of the bottom on four transects (TR1, TR2, TR3 and TR4) twice a year, in June (before the introduction of the new generation of tuna), and at the time of the strongest feeding (at the same time when the	

ZONE / No.	MARICULTURE ZONES	EXCRACT FROM A CARTOGRAPHIC ILLUSTRATION 1.1. USE AND PURPOSE OF SPACE	SPATIAL PLAN OF ZADAR COUNTY	IMPLEMENTED ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES / ASSESSMENT OF THE NEED FOR ASSESSMENT	MONITORED PARAMETERS IN FARMING AREA	REMARKS
					sediment is sampled). On the transect TR3, the impact will be monitored after the cessation of cultivation on the old concession field A. Along the island of Iž, the settlement of Posidonie will be mapped before the first installations of the farm are set up, in the summer of 2008. 3) Visual determination of the influence of oils on mediolittoral biocenoses in September/October at the time of greatest influence. Make photo documentation.	
9	Velo Žalo		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county..	Oikon (2007): Environmental impact study of sea bass and gilthead bream farms at the location "Velo Žalo" in the Rava Channel Oikon (2017): Environmental Impact Study - Whitefish farm with a capacity of 1,101 tons a within the protected coastal area at the location Velo žalo on Dugi otok	1) in marine sediment: concentration of organic carbon, total nitrogen and total phosphorus at stations M1, M2 and R in the surface layer of sediment up to a depth of 5 cm and redox potential profile from the surface layer of sediment to a depth of 10 cm (every 1 cm), 2) in the seawater column: oxygen saturation and chlorophyll concentration at stations M1, M2 and R, 3) monitoring the condition of marine habitats of the coastal zone by the Carlit method (Nikolić et al., 2013), 4) analysis of antibiotics: concentrations of sulfadiazine, trimethoprim, flumequine and oxytetracycline in shellfish from cage fouling in which the juvenile is housed (Ø 16 m) (station M1), 5) inspection of the seabed under all farming areas and in their immediate vicinity. 6) Implement the environmental monitoring program once a year at the time of greatest impact (end of September / beginning of October).	

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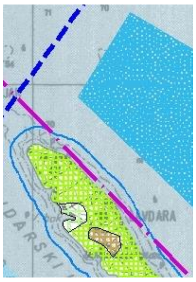
10	Dugi otok – from cape Gubac to cape Žman		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county..	Oikon (2015): Environmental protection study - White fish farm along Dugi otok between capes Žman and Gubac with a target capacity of up to 700 tons per year Zelena infrastruktura (2018): Environmental Impact Study - increasing the capacity of white fish farms along Dugi otok - between Capes Žman and Gubac - up to 3,000 tons per year	1) In marine sediment: concentration of organic carbon, total nitrogen and total phosphorus at stations M1 and REF, in the surface layer of sediment to a depth of 5 cm and redox potential profile from the surface layer of sediment to a depth of 10 cm (every 1 cm). 2) In the seawater column: oxygen saturation and chlorophyll concentration a at stations M1 and REF, at depths of 0.5 m, 10 m and bottom. 3) Monitoring the condition of marine habitats of the coastal zone by the Carlit method (Nikolić et al., 2013) from Cape Gubac to Cape Žman (about 2.3 km). 4) Analysis of antibiotics: concentrations of sulfadiazine, trimethoprim, flumequine and oxytetracycline in fouling of caged shellfish (station M1),	
11	Vrgada		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county.	Oikon (2016): Environmental Impact Study - Increasing the production capacity of farms near the island of Vrgada in Zadar County to 2,145 tons of fish and 220 tons of shellfish	1) in marine sediment: concentration of organic carbon, total nitrogen and total phosphorus at stations M1, M2, M3, M REF, in the surface layer of sediment to a depth of 5 cm and redox potential profile from the surface layer of sediment to a depth of 10 cm (every 1 cm), 2) in the seawater column: oxygen saturation and chlorophyll concentration a at stations M1, M2, M3, M REF, at depths of 0.5 m, 10 m and bottom. 3) monitoring the condition of marine habitats of the coastal zone by the Carlit method (Nikolić et al., 2013), 4) analysis of antibiotics: concentrations of sulfadiazine, trimethoprim, flumequine and oxytetracycline in fouling of	

ZONE / No.	MARICULTURE ZONES	EXCRACT FROM A CARTOGRAPHIC ILLUSTRATION 1.1. USE AND PURPOSE OF SPACE	SPATIAL PLAN OF ZADAR COUNTY	IMPLEMENTED ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES / ASSESSMENT OF THE NEED FOR ASSESSMENT	MONITORED PARAMETERS IN FARMING AREA	REMARKS
					caged shellfish (station M1, M2, M3), 5) inspection of the seabed below all farming areas on the transect passing through the middle of the farm from one edge to the other and in their immediate vicinity. 6) Implement the environmental monitoring program once a year, at the time of the greatest impact (end of September/beginning of October), except for the Carlit method, which needs to be implemented in the spring.	
12	/		The zone along the island of Lavdar is marked in the cartographic illustration 1.1., but is not listed in the Spatial plan of Zadar county.	Oikon (2008): Environmental impact study of the Atlantic tuna farm on the site near the island of Lavdar Vela in the Middle Channel Zelena infrastruktura (2017): Environmental protection study - conversion of tuna farms 1 and 2 near the island of Lavdar Vela into a common field for white fish farming Dvokut Ecro (2019): Environmental study for the conversion of farming fields 5 and 6 from tuna farming to white sea fish farming and relocation of farming fields 1 and 2 at the Lavdara farm	1) In sediment: redox potential, concentrations of organic carbon, organic nitrogen and organic phosphorus, at each of the six farms (S1, S2, S3, S4, S5, S6), and at reference station - R, in the surface layer of sediment to depth 5 cm. Measurements should be taken twice a year, in June (before the introduction of the new generation of tuna) and in September (at the time of greatest impact, ie at the time of greatest food intake), except at the reference station where measurements should be taken once a year, either in June or in September. 2) Biological-diving bottom inspection to be performed on three transects (TR1, TR2 and TR3) once a year, in June. Special attention should be paid to the condition of the lower edge of the Posidonia settlement (TR2 and TR3). 3) Review of the possible impact of oils from the farm on the mediolittoral once a year during the strongest feeding near the beginning of the TR2 transect on the northeast coast of Lavdara,	

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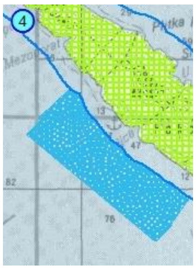
					and on the northwest coast of the islands Božikovac and Balabra in the weather situation when the west wind blows. Make photo documentation.	
13	/		The zone along the island of Maun is marked in the cartographic illustration 1.1, but is not listed in the Spatial plan of Zadar County.	Dvokut Ecro (2020): Environmental impact study White sea fish farm at a location near the island of Maun with a capacity of 5,000 t per year.	1) Determination of the quality of the coastal sea by examining the communities of macroalgae on the rocky bedrock by the Carlit method from Mezoporata to the bay Koromačna (about 3.7 km); 2) Determination of the concentration of organic carbon, total nitrogen and total phosphorus at stations S1 (below the active cage), S2 (at the edge of the concession area) and REF (reference point), in the surface layer of sediment to a depth of 5 cm and redox potential in the surface layer of sediment . 3) Diving inspection and assessment of the condition of benthic communities on the transect from the shore to the first cages. 4) Implement the environmental monitoring program once a year at the time of greatest impact (September), except for the Carlit method, which needs to be implemented in the spring.	
Z2	Areas where mariculture has a high priority, but other activities are allowed - shellfish farming areas					
I	Novigrad sea (with Novski ždril, without Karin		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county.	There is a farm, but no environmental impact assessment procedures have been carried out.	There is no information on the implementation of the monitoring program on the farm.	

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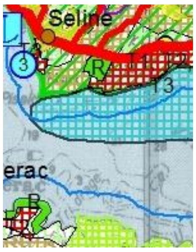
	sko sea)					
II	Velebit canal – area from Modrića to cape Pisak – Seline		The zone is marked in cartographic illustration 1.1. and listed in Spatial plan of Zadar county.	There is a farm, but no environmental impact assessment procedures have been carried out.	There is no information on the implementation of the monitoring program on the farm.	
Z3	Areas where, under certain conditions, limited forms of mariculture are allowed while it serves as a supplement to other dominant activities in fish and shellfish farming areas					
1	Kablin	/	The zone (bay near the island of Sestrunj) is listed only in the Regulations, it is not marked in cartographic illustration 1.1.	Zeleni servis (2017): Environmental protection study with a request for assessment of the need for environmental impact assessment for the project: "White fish farm in the waters of Kablin Bay on the island of Pasman"	Monitoring is not carried out on the farm.	The ZZ monitoring station is located in the immediate vicinity of the farm.

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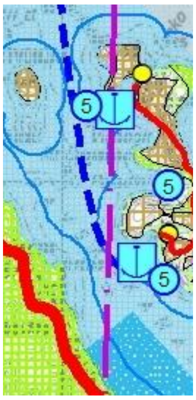
2	Vičija bok - Rava		The zone is listed in the Regulations, but is not specifically marked in cartographic illustration 1.1. (a bay in the west of Rava), but is located within the larger zone Z3, which includes the waters around the entire island of Rava.	Oikon (2015): Environmental study - White fish farm in the bay Vića bok (island of Rava) with an annual capacity of up to 100 tons	Monitoring is not carried out on the farm..	The ZZ monitoring station is located in the immediate vicinity of the farm.

7. MONITORING PROGRAMS IN ZADAR COUNTY

7.1 Monitoring program: Quality of farmed marine organisms and the sea in which they are farmed

In the area of Zadar County, the indicator *Quality of cultivated marine organisms and the sea in which they are grown* is monitored at 3 stations OB23 Rovanjska, OB08 Novigrad sea, OB22 PAG- Dinjiška bay (http://baltazar.izor.hr/azopub/bindex) for many years.

- The indicator monitors the sanitary quality of shellfish and the sea in which they are grown, and it is direct indicator of marine ecosystem pollution.

The analysis of the quality of farmed marine organisms and the sea in which they are farmed was conducted at 27 farms in the Adriatic area during 2019. Out of 27 farms tested, 19 of them had concentrations of E. coli below 230 in all analyzed samples, E.coli/100g of homogenates and interstitial fluids, which clasifies them in class A.

Detailed results from previous years are available at stations OBO8 and OB23, while for station OB22 it is possible to search results only on an annual basis on the total display of all stations.

Figure 3 Stations in Zadar county (Source: http://baltazar.izor.hr/azopub/bindex)

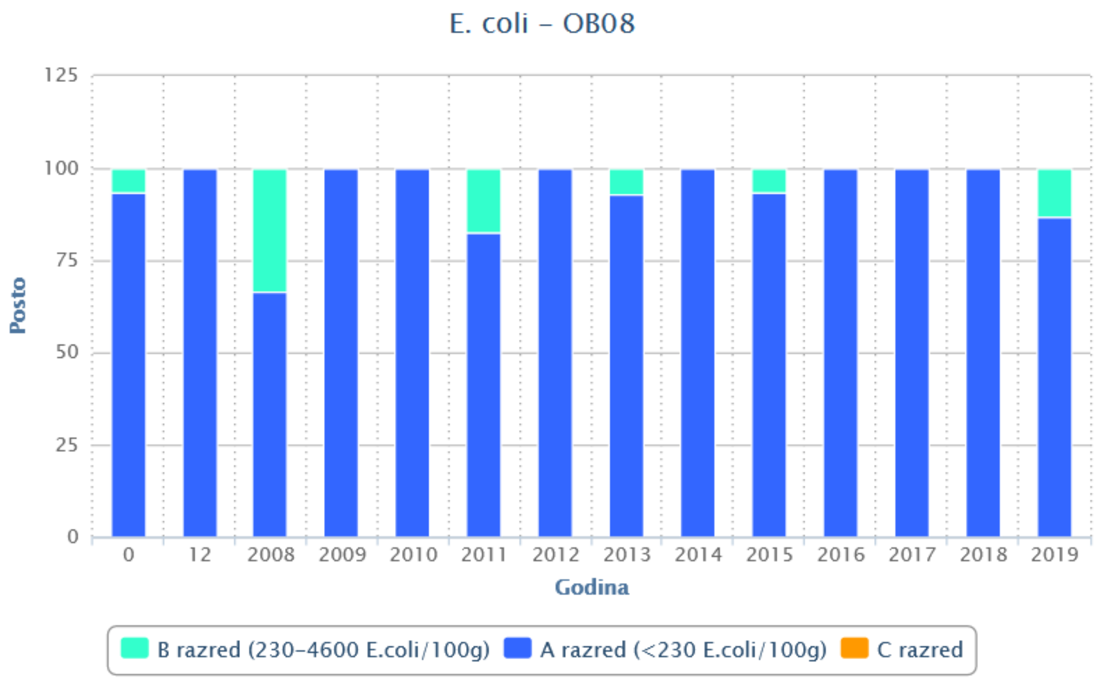


Figure 4 Values of the measured indicator at the station OB08 Novigrad sea

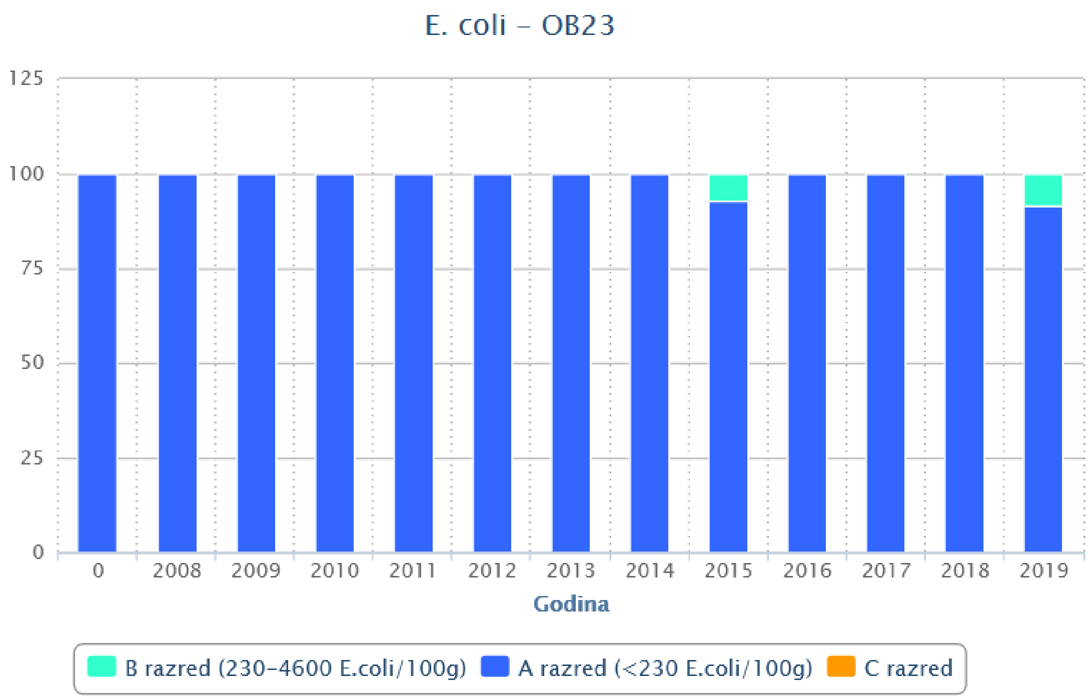


Figure 5 Values of the measured indicator at the station OB23 Rovanjska

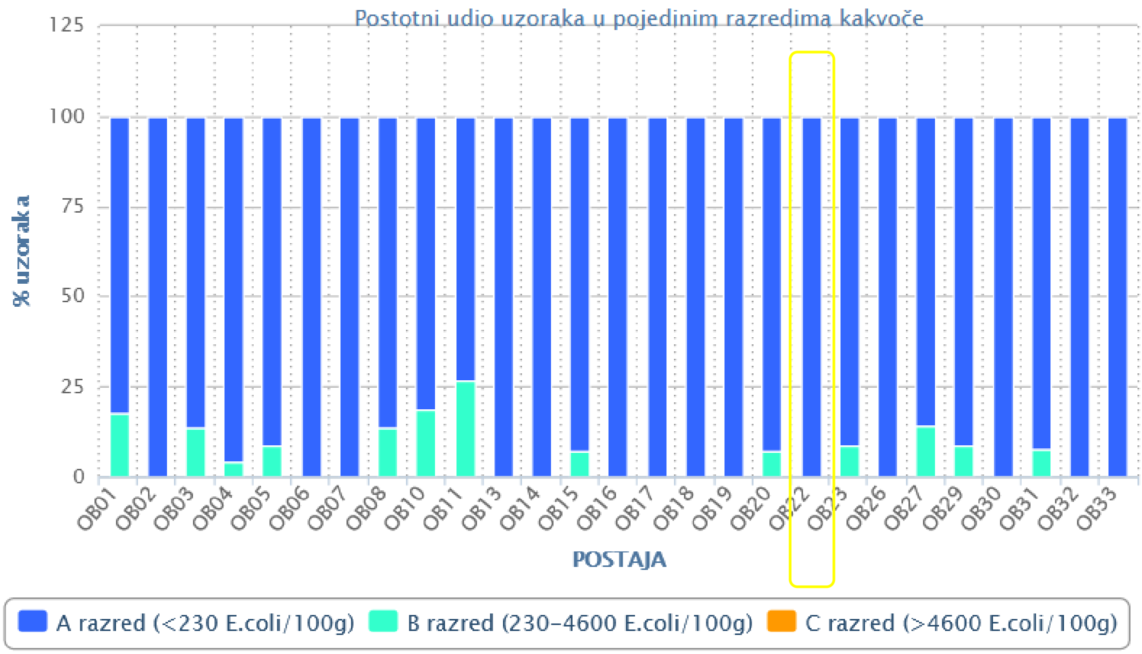


Figure 6 Overview of the status of indicators at all stations along the Adriatic (marked station OB22)

7.2 Zadar County Monitoring Program

In addition to the indicators of the seawater column, at stations where the impact of aquaculture on the marine environment is monitored, sediment tests are performed at points T2, T3, T4, T5, T6, T9, T10, T12, T13, T14, T15, T16 and T18. Following indicators are monitored: total nitrogen, total phosphorus, total organic carbon and redox potentia. Furthermore, monitoring is done on reference stations P2, P4, P6, P9, P13 at a county level.

As for the selected indicators in the sediment, they are used as indicators of sediment load of organic matter as a consequence of cultivation.

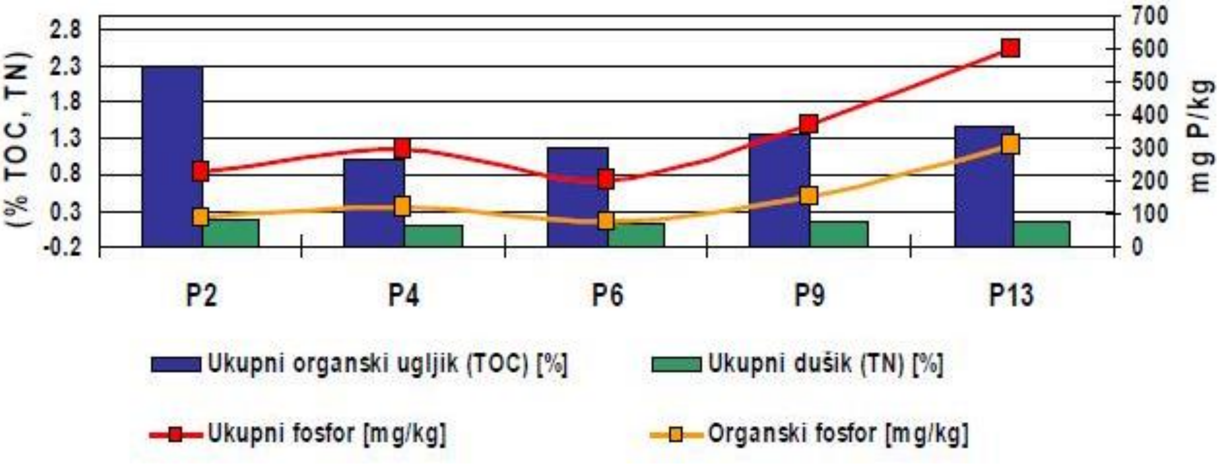
Total organic carbon (%): just like organic matter, it is associated with the sedimentation of fish droppings and unused food near fish farms but also with the natural deposition of organic material, for example: from primary production in a water column (CAQ, 2012). Organic carbon in marine sediment appears as a result of metabolic processes of organisms living in the sea column (dead phytoplankton, zooplankton, and fecal pellets of zooplankton), on and in sediment, and as carbon contained in biogenic carbonate minerals (calcite and aragonite). The accumulation of organic matter in sediment depends on water column production, terrestrial inputs, and sedimentation efficiency.

Total phosphorus (%): as is the case with organic carbon or organic material, phosphorus is released in the form of particles (fish droppings and unused food) and is deposited below and near the farm. High levels of phosphorus sedimentation were measured near the fish farm and distribution patterns found around the fish farm were observed. Phosphorus has been proposed as a useful indicator of farm waste accumulation and has also been proposed as an indicator of a farm's impact on Posidonia oceanica habitat (CAQ, 2012).

Total nitrogen in sediments (%): Total nitrogen concentrations in sediments are expressed in % and are used in the calculation of the C: N ratio as an indicator of carbon quality.

Redox potential (mV): Oxidation-reduction conditions in surface sediment depend on the degree of organic enrichment and, accordingly, redox potential measurements can serve as an intermediary for calculating organic load. The redox potential decreases with depth and the concentration of O2 in the interstitial water. The negative redox potential is associated with anaerobic conditions, ie the decomposition of organic matter by anaerobic bacteria, which use sulfate as an electron acceptor in marine sediment and release hydrogen sulfide.

The results of sediment analysis at measuring stations from the monitoring program (organic carbon, total nitrogen and phosphorus content) at T stations (for 2013, 2015, 2017, 2019) were compared with the range of values determined for the sediment of the Central Adriatic coastal area (Matijević et al., 2006, 2008, 2009, 2012) and the open sea, according to the research of Faganelli et al. (1994) and Matijević (2008, 2012). According to these studies, the phosphorus values recorded on the coastal area are in the range of 119.0 - 1,392.0 mg P / kg, the amount of total nitrogen is from 0.01 to 0.15%, while the amount of organic carbon is from 0, 28 to 1.40%.
The values of organic carbon at T stations are slightly elevated or are at the upper limit of the range that was previously stated for total organic carbon over the years. Regarding the state of this parameter, it was increased for the observed period at the reference stations for sediment P. The values of total phosphorus and nitrogen at stations T and P were in the range as stated in the literature.



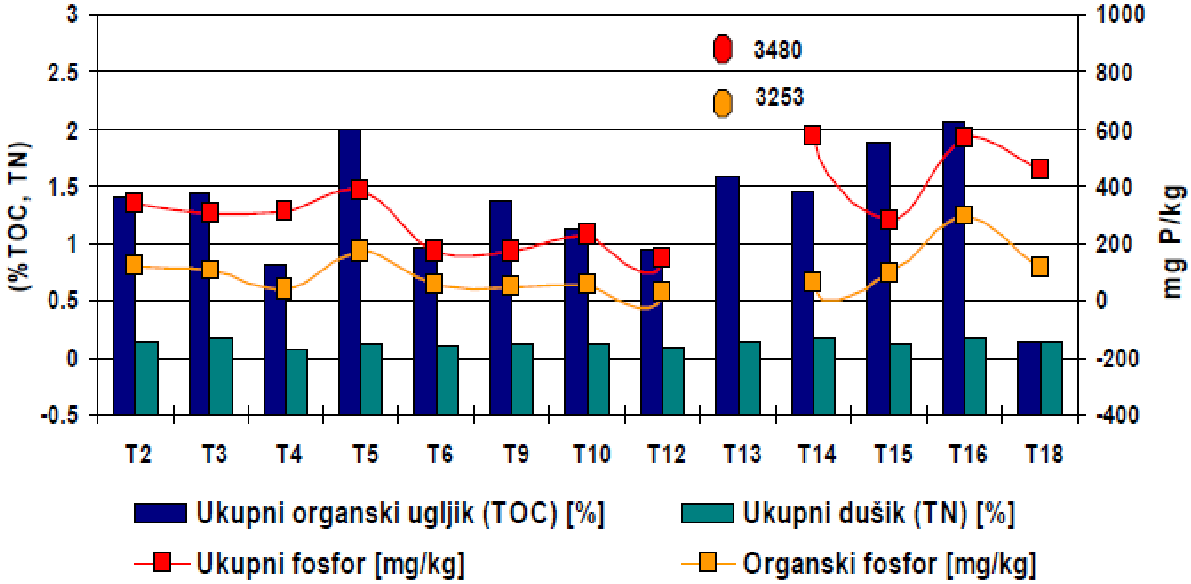


Figure 7 Total organic carbon (TOC) content, total nitrogen (TN) and total phosphorus (TP) in sediment at reference stations P (above) and of farm stations T (below) in the Zadar County in September 2011.

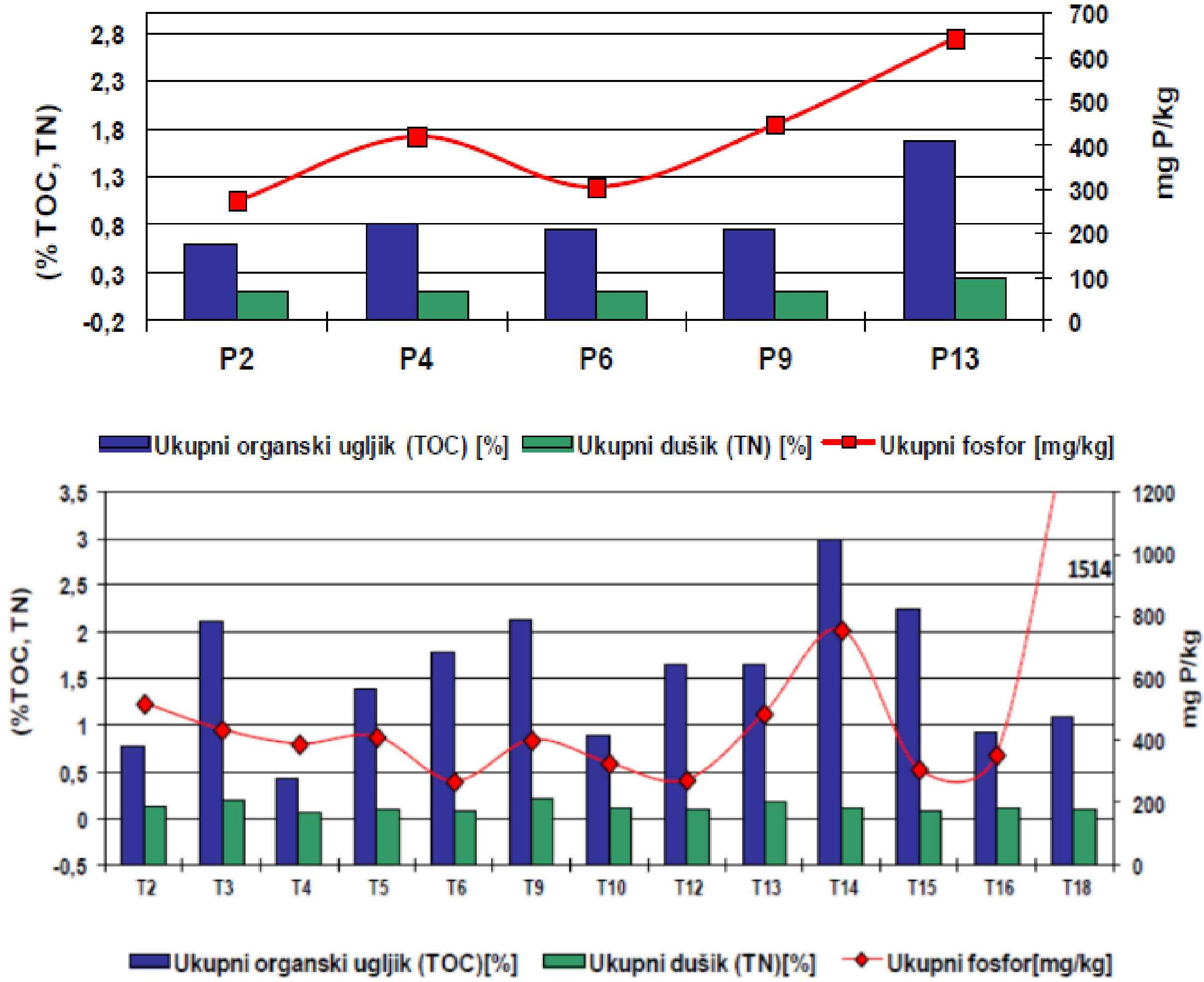
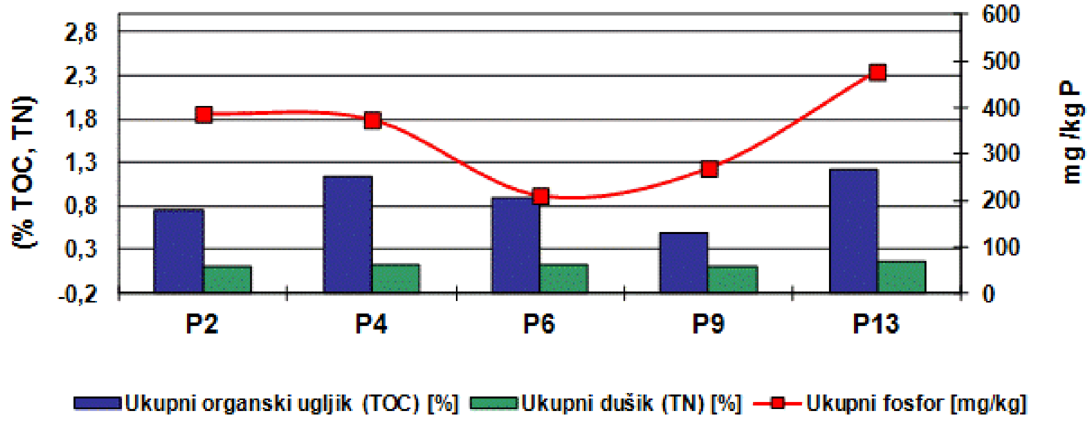


Figure 8 Total organic carbon (TOC) content, total nitrogen (TN) and total phosphorus (TP) in sediment at reference stations P (above) and of farm stations T (below) in the Zadar County in June 2013.



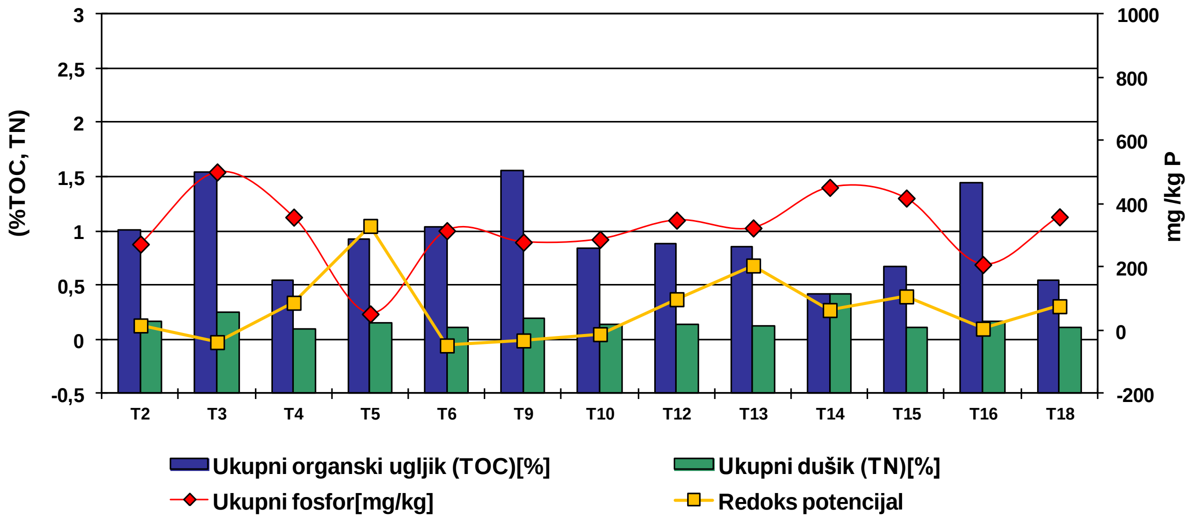


Figure 9 Total organic carbon (TOC) content, total nitrogen (TN) and total phosphorus (TP) in sediment at reference stations P (above) and of farm stations T (below) in the Zadar County in 2015.

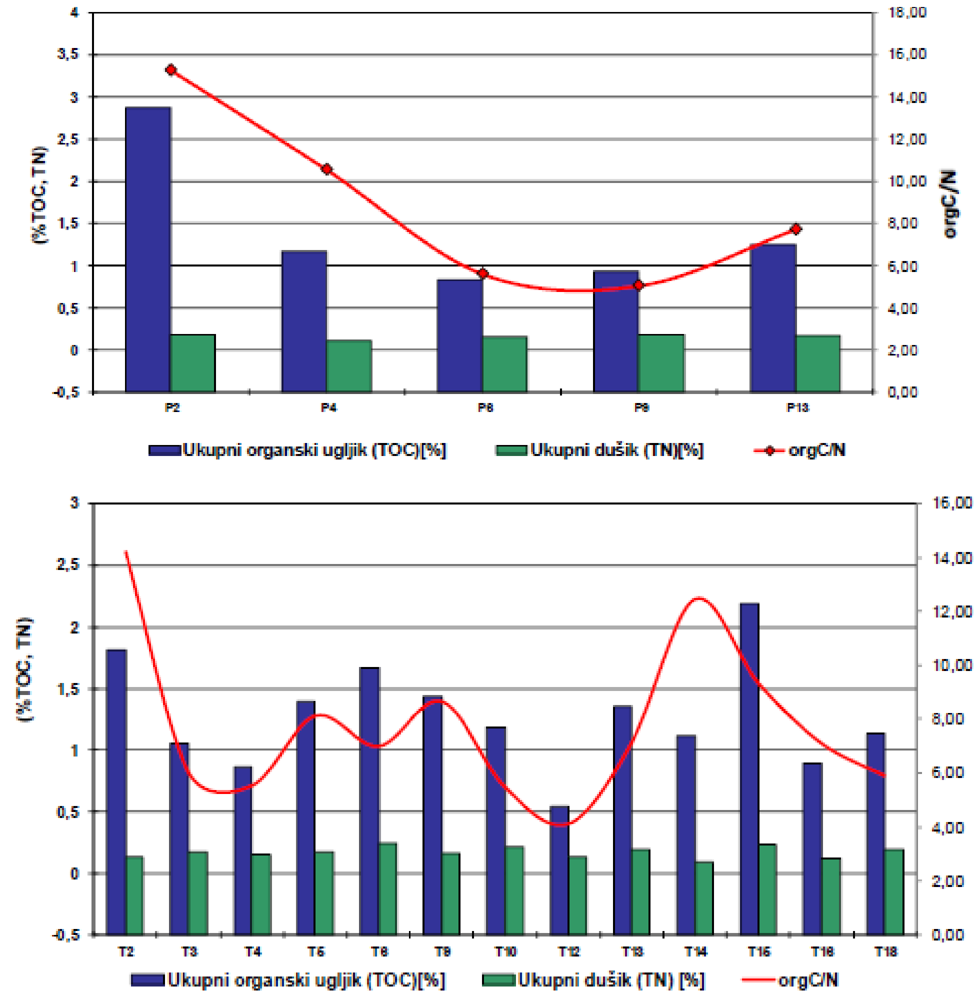


Figure 10 Total organic carbon (TOC) content, total nitrogen (TN) and organic C/N in sediment at reference stations P and of farm stations T in the Zadar County in 2017.

Pokazatelji	P2	P4	P6	P9	P13
Ukupni organski ugljik-TOC (%)	1,13	0,753	0,994	0,488	1,39
Ukupni dušik-TN (%)	0,13	0,089	0,138	0,059	0,137
Ukupni fosfor (mg/kg P)	199,9	306,09	154,1	229,3	348,9
TOC:TN	8,69	8,46	7,20	8,27	10,15
TOC:TP	56,5	24,6	64,5	21,3	39,8

Pokazatelji	T2	T3	T4	T5	T6	T9	T10	T12	T13	T14	T15	T16	T18
Ukupni organski ugljik-TOC (%)	0,887	1,21	0,63	1,66	1,78	1,2	0,755	0,421	0,656	0,425	0,55	1,35	0,984
Ukupni dušik-TN (%)	0,121	0,123	0,078	0,122	0,122	0,105	0,128	0,056	0,089	0,057	0,066	0,122	0,102
Ukupni fosfor (mg/kg P)	273,2	472,1	764,2	457,9	293,1	234,2	273,7	141,6	332,6	199,8	279,3	301,47	370,6
TOC:TN	7,33	9,84	8,08	13,61	14,59	11,43	5,90	7,52	7,37	7,46	8,33	11,07	9,65
TOC:TP	32,5	25,6	8,2	36,3	60,7	51,2	27,6	29,7	19,7	21,3	19,7	44,8	26,6

Figure 11 Total organic carbon (TOC), total nitrogen (TN) and total phosphorus (TP) including TOC : TN i TOC ratio in sediment at reference stations P and of farm stations T in the Zadar County in 2019.

Redox potential

If we observe the data on redox potential in the context of the latest available data according to the Zadar County Monitoring Program (ZZJZ, 2017 and 2019), the redox potential in the sediment at the reference measuring stations (P) ranged from -298.6 (P4 - Kolovare) to - 49.8 mV (P2 - Vir).

At the measuring stations on the farm T, the redox potential was measured in the range from -338.4 (T6 - Svitla bay-island of Ugljan) to +100 mV (T3 - Vela Rava). Negative values of redox potential were noticed at most stations, which indicates the decomposition of organic matter in the sediment without the presence of oxygen (ZZJZ, 2017)

Regarding the redox potential values in the sediment at the reference measuring stations (P), it ranged from -265.8 mV to 196.4 mV and the redox potential values at the measuring stations T ranged from -202.8 mV to 199.3 mV. Almost all values were positive.

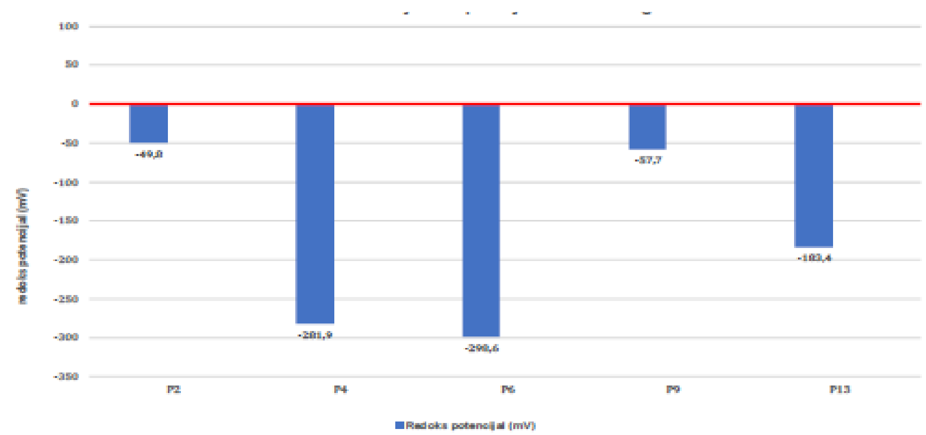


Figure 12 Redox potential value in sediment at reference stations P in Zadar County in 2017.

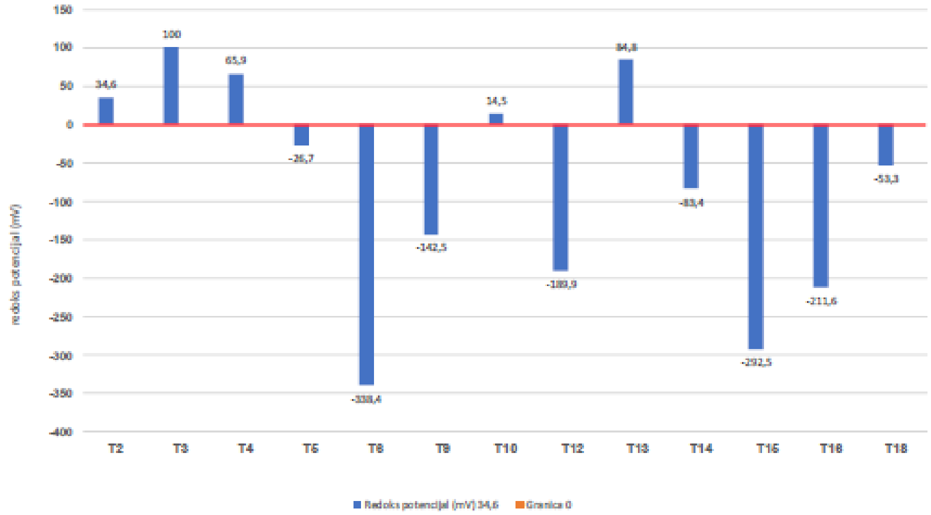


Figure 13 Redox potential value in sediment at farming stations T in Zadar County in 2017.

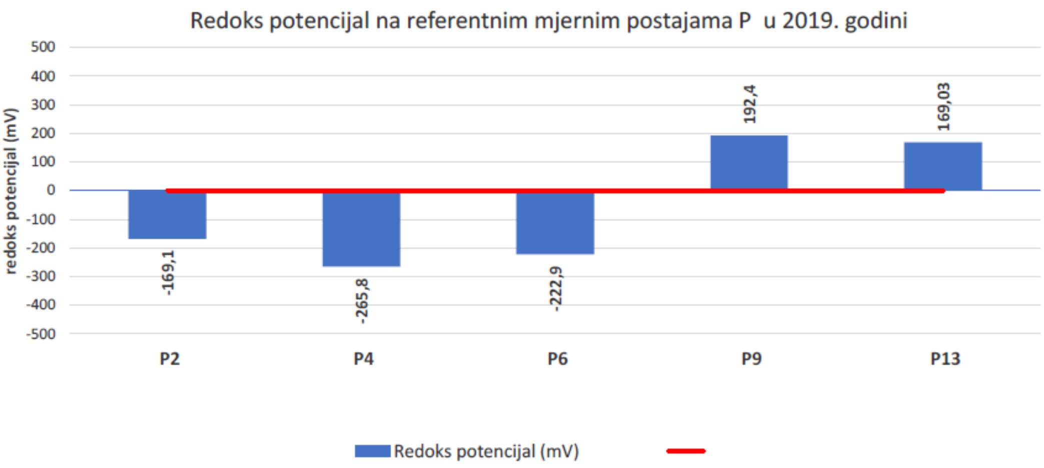


Figure 14 Redox potential value in sediment at reference stations P in Zadar County in 2019.

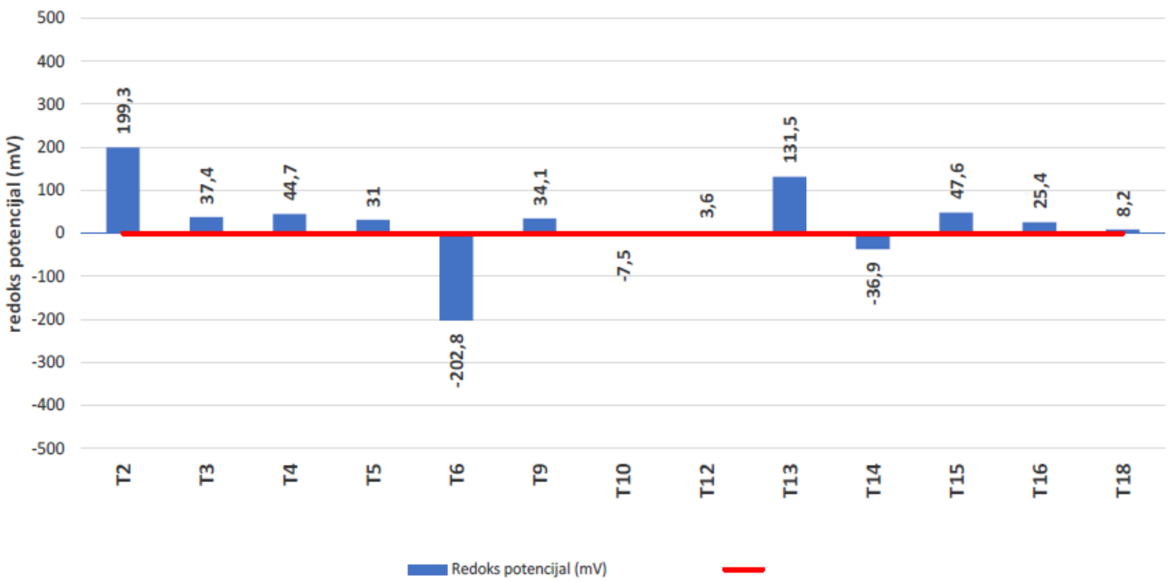


Figure 15 Redox potential value in sediment at farming stations T in Zadar County in 2019.

7.3 II - DISPLAY 1.1. Use and purpose of the area: area for development and arrangement

On the map 1.1. Use and purpose of the area: area for the development and arrangement of ZP ZC, zones for mariculture are marked, in the following categories: (1) Z1 - zone designated for mariculture; (2) Z2 - high priority zone of mariculture; (3) Z3 - zone of limited form of mariculture; (4) Z4 - zone unsuitable for mariculture; (5) outdoor cultivation; and (6) Z2 - shellfish farming zone.

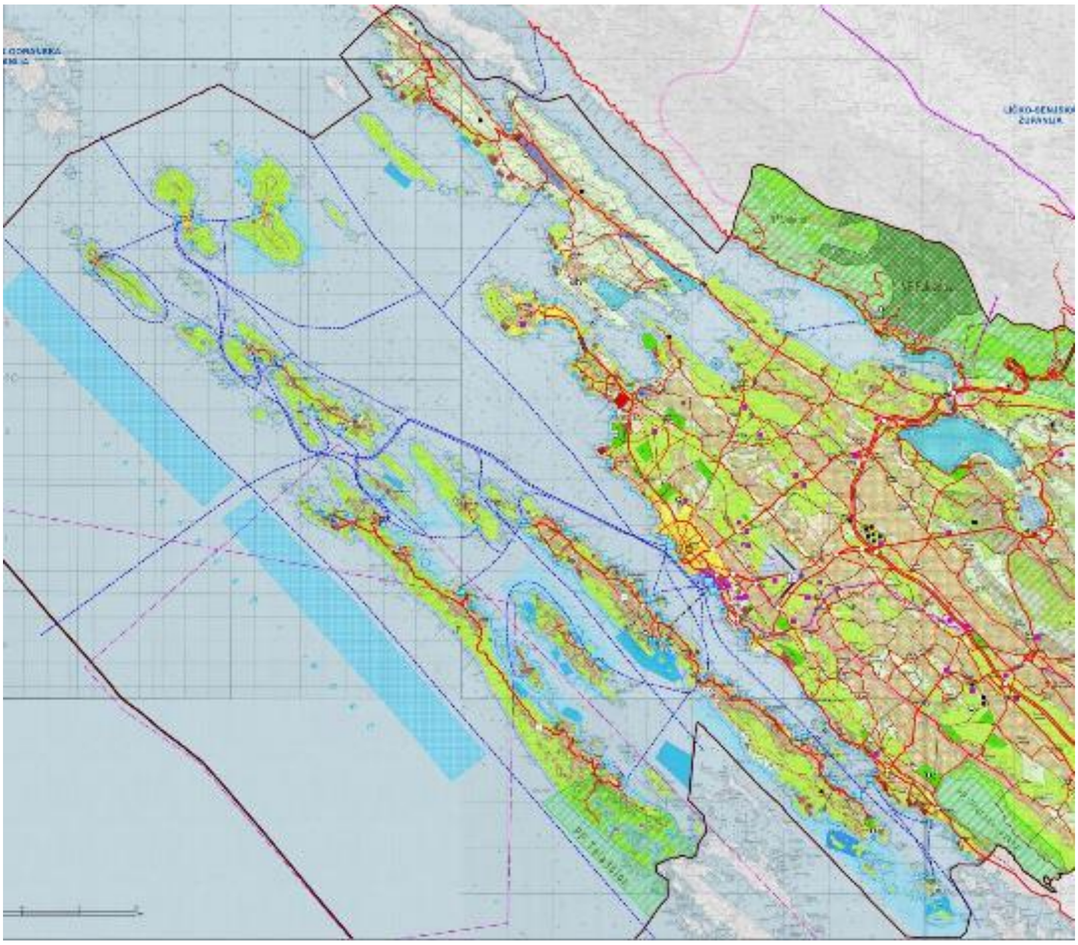
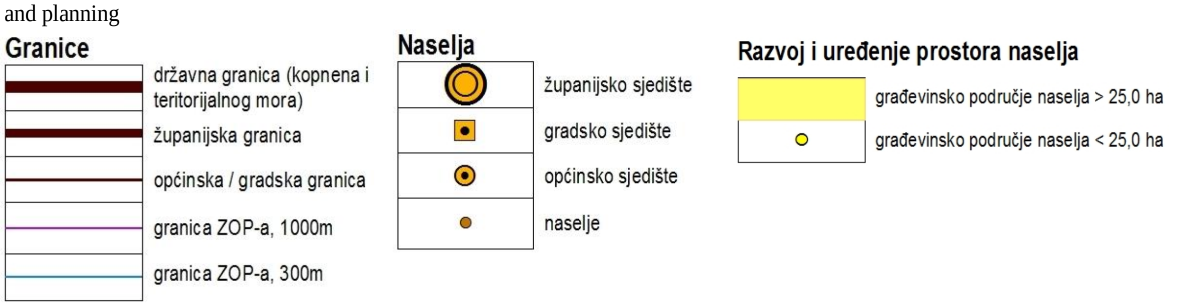


Figure 16 Extract from the Cartographic overview of the spatial plan of Zadar County 1.1. Use and purpose of space: area for development and planning



Razvoj i uređenje prostora izvan naselja

Gospodarska namjena:

- proizvodna
- lučko-industrijska zona
- iskorištavanje mineralnih sirovina:

površine za eksploataciju morske soli

površine za istraživanje i eksplotaciju "Benkovačkog arhitektonskog kamena"

potencijalne površine za eksploataciju arh.-građevnog kamena

- marikultura:

Z_1- zona određena za marikulturu

Z_2- zona visok. prioriteta marikulture

Z_3- zona ograničenog oblika marikulture

Z_4- zona nepogodna za marikulturu

uzgoj na otvorenom moru

H Z_2- zona uzgoja školjaka

T T
- ugostiteljsko-turistička namjena
T1 - hotel, T2 - turističko naselje, T3 - kamp

Sportsko - rekreacijska namjena

R
R1 - golf igralište, R2 - jahački sport,
R3 - zimski sportovi, R5 - vodeni sportovi,
R6 - auto-moto sport,
R7 - sportski aerodrom s pratećim turističkim sadržajima

PN posebna namjena

zrakoplovno vježbalište

Poljoprivredno tlo:

- osobito vrijedno obradivo tlo
- ostala obradiva zemljišta

šumsko zemljište

ostalo poljoprivredno tlo, šume i šumsko zemljište

Zaštićeni dijelovi prirode

PP park prirode

NP nacionalni park

Cestovni promet:

autocesta

brza državna cesta

ostale državne ceste

županijske ceste

lokalna cesta

nerazvrstana cesta

most

tunel

podmorski tunelski most - potencijalni

raskrižje cesta u dvije razine

Pomorski promet:

Morska luka otvorena za javni promet:

- međunarodni gospodarski značaj
- županijski značaj
- lokalni značaj
- nerazvrstane luke

1 **Morska luka posebne namjene za djelatnosti:**

1 - industrijska luka, 2 - brodogradilište, 3 - luka nautičkog turizma,
4 - interventni privez, 5 - sidrište, 6 - sportska luka,
7 - ribarska luka, 8 - privez u funkciji marikulture

Plovni put:

- međunarodni
- unutarnji

Riječni promet:

luka i pristanište

Željeznički promet:

pruga velike propusne moći / potencijalna

ostale željezničke pruge za međunarodni promet

željeznička pruga od značaja za regionalni promet

žičara panoramska

Zračni promet:

zona zračne luke Zadar

zračna luka za međunarodni i domaći zračni promet

zračno pristanište

helidrom

navigacijski sustavi

uzletno-sletna staza

Obrada, skladištenje i odlaganje otpada

regionalni centar za gospodarenje otpadom Zadarske županije

pretovarna stanica

neusklađena odlagališta

građevina za sabirno mjesto opasnog otpada

8. INTRODUCTION

WP3 sets out a common governance framework in which the partnership of Adriatic institutions responsible for fisheries and aquaculture operate as a whole. In this sense, the aim is to establish comprehensive management driven by scientific research and reccomendations. The current emphasis on the shared fishing resources, generated by the project, has been extended to the entire Adriatic ecosystem. When it comes to aquaculture, it is primarily refered to the harmonization of criteria for its pressure on the marine environment and harmonization with socio-economic effects, all in accordance with the framework of the Common Fisheries Policy and the Water Framework Directive.

To this end, the project envisages a series of studies that should provide a basis for concrete improvements in fisheries and aquaculture management. As part of this work package, Zadar County (P8) is participating with a study that analyzes the interaction between different typologies of aquaculture practice and trends in Adriatic fish stocks, highlighting both the positive and adverse effects of aquaculture on marine habitats.

Farming technologies in aquaculture can be divided into:

- **Farming in open water container system**

Water flow ensures the exchange of water to cultivated organisms. Water brings dissolved oxygen and drains metabolites. When growing filter feeders, it also brings food.

- Cultivation of organisms in pools with gravity inlet and outlet
- Cultivation of organisms in cages (most often fish)
- Cultivation on fixed and floating parks (shellfish or other animals that feed on filtration. Algae cultivation.)
- Growing on the seabed (shellfish, echinoderms)

- **Cultivation in a closed breeding system – cultivation in pools**

Water is brought and drained from the pool with cultivated organisms. Water can be taken to a greater or lesser extent from a natural water body and discharged into a natural recipient. Multiple use of the same water in swimming pools is called recirculation.

- Cultivation in pools with controlled farming conditions (temperature, light, oxygen, salinity ...)
- Cultivation in pools where only water flow is controlled

In the context of the "ARGOS" project, the interactions of different typologies of aquaculture practices with regard to environmental effects, at the moment, are primarily related to aquaculture farming technologies implemented in the open farming system. These primarily refer to cage fish farming and various filter feeders farming technologies (predominantly shellfish) in the open farming system.

In an open breeding system, the interaction of cultivated organisms with the environment is immediate, and management comes down to predicting the expected interactions between environmental conditions and those organisms in cultivation. In a broader sense, this includes the interaction of farming installations and the position of the farm in the area with the environment in which the farming takes place.

Zadar County has a long experience in cage fish farming and at the moment over 50% of farmed fish in the Republic of Croatia are farmed in its waters. This is the result of recognizing favorable orographic, climatic and hydrogeographical conditions in most of the county's maritime domain and the long-term application of aquaculture in that area. Moreover, shellfish farming has also been initiated, which is located in smaller areas suitable for their farming. In addition to entrepreneurial initiatives, Zadar County creates conditions for the development of aquaculture through integrated coastal zone management, which includes monitoring the ecological parameters in its waters. Fishing and the fish processing industry are also very developed in Zadar County. Overall, this forms a significant basis and presupposes significant experiences related to aquaculture, fishing and the environment as well as the effects of aquaculture on marine habitats in the area of application.

In accordance with the experience of Zadar County, this study will primarily focus on the interaction of cage fish farming and the marine environment and on the studies and challenges related to the interaction of shellfish farming in the marine environment.

9. ANALYSIS OF THE RELATIONSHIP BETWEEN DIFFERENT FORMS OF AQUACULTURE AND TRENDS IN FISH STOCKS IN THE ADRIATIC SEA

9.1 Enviromental, man's and animal influence on farms

The legislator has prescribed in advance that the farming activity can be performed only in suitable areas, where the environmental impact is favorable. It also prescribed (**Ordinance on the criteria for determining areas for aquaculture within the maritime domain NN 106/2018**) areas where aquaculture is excluded. These are the areas where it predominates:

- severe pollution - urban centers, port and industrial centers, etc.,
- unsatisfactory hygienic and sanitary conditions,
- unfavorable hydrodynamics,
- flowering of toxic phytoplankton species risk,
- intensive maritime transport,
- intensive recreational activities,
- areas of greater economic importance,
- other areas where restrictions on aquaculture are prescribed by special regulations governing spatial planning, regulations governing water management, as well as regulations governing environmental and nature protection.

Due to exceptional sensitivity of shellfish farming, in terms of food safety, to assess the suitability of the area for farming it is mandatory:

- making a list of pollution sources of human or animal origin that are likely to be a source of contamination in the production area,
- examining the amounts of organic pollutants that are released at different periods of the year, depending on the seasonal variations of humans and animals in the catchment area, rain readings, wastewater treatment, etc., and,
- determining the characteristics of the circulation of pollutants based on current samples, bathymetry and tides in the production area.

"In addition to the criteria of suitability, and in regard to the water quality standard and areas suitable for shellfish farming, when determining new areas for aquaculture, it is necessary to take into account already granted water use/wastewater dischagre rights for which data must be obtained from „Hrvatske vode“ (Croatian waters)."

9.2 General Abiotic and Biotic factors affecting fish and shellfish farming

9.2.1. Abiotic physical factors

The most important physical environmental factors for the cultivation of aquatic organisms are temperature, light, movement of water masses (waves and currents) and turbidity. Salinity is often included in the physical parameters, but as a function of the density of water masses.

Ambient temperature is one of the fundamental limiting factors for the growth, development and survival of each species. Thus, each species has its own optimum temperature, at which it spends its life, but also the minimum and maximum temperature, which it tolerates (tolerance interval). The closer the temperatures are to the tolerance limits, the more stressed the organisms are, and the greater production loss certainty for the grower. Temperature determines the growth rate and energy consumption of cultivated organisms, which is reflected on economic indicators concerning production. Sea temperature is not the same at all depths, and it depends on the distance from the shore, wind exposure, freshwater inflow, sea currents, seabed configuration and seasonal changes. Thermocline, i.e. the occurrence of water column stratification where a layer of water of higher temperature stays on the surface and lower temperature at the bottom, occurs during the warmer part of the year, in areas where there is no intensive mechanical mixing (waves, wind, current, tides, etc.). Placing cages of different dimensions can bring cultivated organisms to different temperature conditions, especially in the period when the thermoclimate is shallower than the maximum depth of the cage.

Additionally, sea temperature is affected by climate change also. The increase in sea temperature due to climate change is insignificant (1-3 ^{o}C) in relation to the differences in sea temperature at different farming locations. Nevertheless, this growth could be significant in lagoons and areas where ranges of temperature changes are already higher. Climate change is likely to affect a number of extreme weather conditions such as droughts, floods, storms or strong wind periods. These occasional occurrences can cause damage. In Southeast Asia, which is one of the largest areas of the aquaculture sector, farming is expected to decline by 30% by 2050 due to global temperature rise and ocean acidification (source: https://www.theguardian.com/environment/2019/jun/05/climate-crisis-and-antibiotic-use-could-sink-fish-farming-industry-report).

Light directly affects the cultivation of marine organisms by changing the metabolic rate and spawning of cultivated organisms, and indirectly through the impact on primary production associated with the production and consumption of oxygen and the production of shellfish food. The amount of light that reaches the breeding organisms affects, among other things, the color of their body. Given the fact that the fish adapt their color means the less light, the darker the pigment.

Sea water as a farming medium is in motion (thanks to sea currents) and transmits vibrations. Therefore, maintaining the position in water requires muscle work which is reflected in energy consumption, growth and the overall development of the musculoskeletal system. Exposure to mechanical energy is important for the development of the muscular and skeletal system of animals because mechanical stimulation causes muscle activation and stimulates the formation of a stronger skeleton. This is significant for shellfish farming as the hardness of the shell and the strength of the adductor muscles contribute to longer survival and longer shelf life. Sea currents cause water exchange in the farming area, carrying away metabolites and CO_2, and bringing oxygen. In shellfish farming, sea currents can also bring food. Moderate flow has a positive effect, while excessively strong currents can cause stress and increased energy consumption in farming organisms. Vibration (underwater noise) can cause significant stress to cultivated organisms.

Taking into account physical parameters, like the amount of particles in seawater is important because it affects sedimentation and transparency. A large amount of tiny particles in the water column (increased turbidity) can coat the gill epithelium and significantly reduce oxygen transfer to the body, even to the point of causing suffocation. The high concentration of particles in water that is not edible to shellfish poses a burden to the filtration system which can significantly or catastrophically affect their production in mariculture.

In the physical sense, salinity can significantly affect mariculture when increased inflow of fresh water into the farming area occurres. Fresh water is lighter and is found in the surface layer. The depth of the halocline then depends on the dynamics of inflow and outflow of fresh water and on the conditions for vertical mixing of the water column. Such areas are most often estuaries that can bring large amounts of fresh water and bring down salinity to a level of significant stress for cultivated organisms. For successful cultivation, it is important to monitor the hydrographic conditions and the inflow of fresh water to the farm. Cold fresh water clouded by soil particles found in the surface layer can cause death of shellfish if it occurs suddenly and at short intervals. The only solution in such cases is to lower the lines with pergolas to a greater depth, which is unfortunately not possible in the case when the farming area is shallow.

9.3 Analysis and trends of the interrelation between abiotic physical factors in fish farming (white fish and tuna)

Exposure to light during the night affects the metabolism and circadian rhythm of fish, and sudden and intense flashes of light can cause stress. This happens during night lightning storms. Fish can panic, swim fast, collide and injure themselves. Stress can also cause eating disorders, decreased immunity and increased metabolic rate. Sometimes, underwater lamps are used during the storm to reduce the possibility of causing this type of stress.

Excessive exposure to sunlight, such as in shallow cages, can cause skin damage due to UV radiation.

Fish are cold-blooded or poikilothermic animals, so their body temperature depends on the ambient temperature. The speed of metabolism and digestion directly depends on body temperature. In the natural environment, fish move and select areas in the water column where the temperature corresponds to their life cycle and sources of available food, but when they are caged, they are forced to stay at the temperature that is in the cage (source: Manual and guide for good manufacturing practice-Cage cultivation of sea bass and gilthead bream, L. Bavčević, Advisory Service, Zagreb 124).

The optimal temperature for organisms' cultivation is the one with the highest growth rate in relation to the energy cost of maintaining the organism and feeding expences. For example, the ideal temperature for gilthead bream farming is considered to be 24^{o}C.

If the farm is located in the area exposed to sudden changes in temperature due to shallow sea depths or sea currents, rising seabeds or freshwater inflows, these temperature changes will certainly affect farming, growth rate and cause stress to farmed animals.

Knowing the exact temperature at all depths of the farm id important for determining daily energy consumption and needed amount of food.

Climate temperature changes

Climate change that is a consequences of global warming has an important impact on sea warming. Due to the complex orographic characteristics and oceanographic conditions, it is not easy to predict changes in sea temperature at certain locations intended for aquaculture. At Mala Lamjana on the island of Ugljan is located the oldest commercial cage farm for sea bass and gilthead bream. Sea temperature has been measured daily since 1986. By analizyng available dana, sea temperature in shown at a depth of 5 meters.

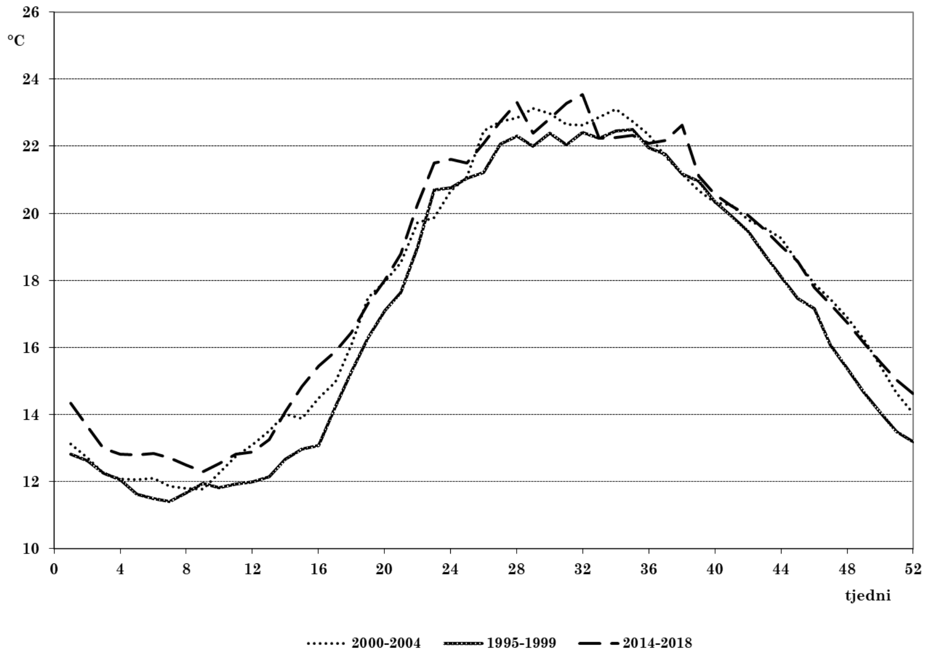


Figure 1. Representation of average weekly sea temperatures at the cage farm in Mala Lamjana on the island of Ugljan. The figure shows the movement of the average weekly sea temperature for the three five-year periods 1995-1999, 2000-2004. and 2014-2018.

Measurements indicate an increase in the average weekly sea temperature after year 2000, but according to complex oceanographic conditions this cannot be unambiguously quantified.

In order to gain insight into the importance of sea temperature on farming processes, that are also reflected on the interaction of cultivation with the environment, two simulations of growth, oxygen consumption and fecal carbon emissions of gilthead bream were made (estimation methods from SUO Košara, 2021). The first simulation is based on the conditions of the current annual temperature regime (obtained by nonlinear regression analysis), and the second on a linear increase in the average weekly sea temperature by only 1% throughout the year.

Figure 2 shows the effect of temperature on the growth rate of gilthead bream. The figure shows that the total cumulative effect of the linear increase in temperature, at the end of the second calendar year of cultivation is at the level of + 11%. That means the gilthead bream reaches a size of 350 grams and average weight 12 weeks earlier.

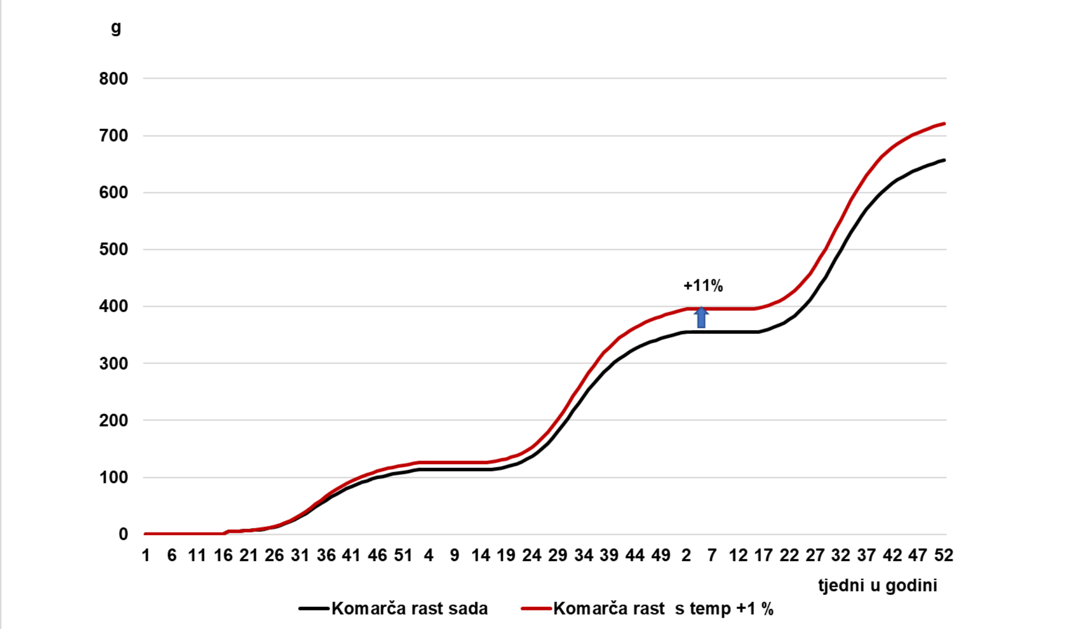


Figure 2. Representation of gilthead bream growth in cage farming in two scenarios, the first is in the temperature regime that simulates the current situation, and the second is with an increase in weekly average temperature by only 1%.

The change in growth rate has repercussions on the growth of biomass in cages where the consumption of dissolved oxygen and the emission of metabolites from the cage are accelerating. A comparison of the oxygen consumption through the farming cycle in the cage with 250,000 gilthead breams, for the two aforementioned scenarios is shown in the picture above. An increase in oxygen consumption is visible in the summer months (+ 13%), when due to the increased sea temperature and lower oxygen solubility in the sea. In the second calendar year, an increase in oxygen consumption in the summer months is shown, (+ 13%) when oxygen solubility is lower due to increased sea temperature.

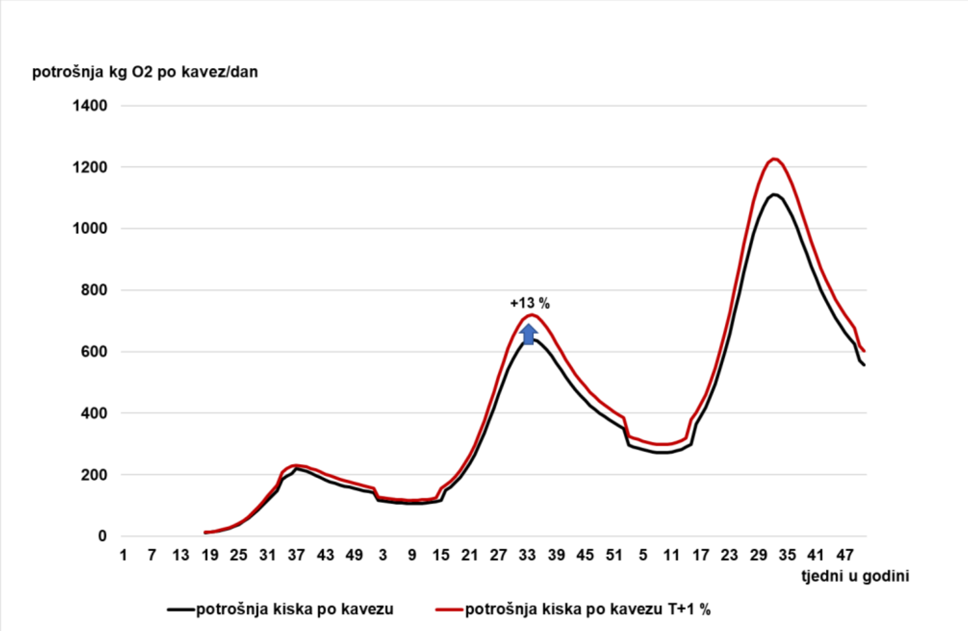


Figure 3. Representation of estimated oxygen consumption per cage per day, for two sea temperature scenarios in gilthead bream cage in which 250,000 pieces of fish were placed. The first scenario is based on average weekly temperature in the last period, and the second is based on an increase of weekly average by only 1%.

The first scenario is an estimate based on current temperatures, and the second scenario is based on an increase in average weekly temperature by 1%.

A similar situation is found in the faecal carbon emission simulations on cage with 25,000 gilthead breams. Accelerated growth due to the increase in sea temperature by 1%, increases the emission of fecal carbon in the summer of the second calendar year by 12%.

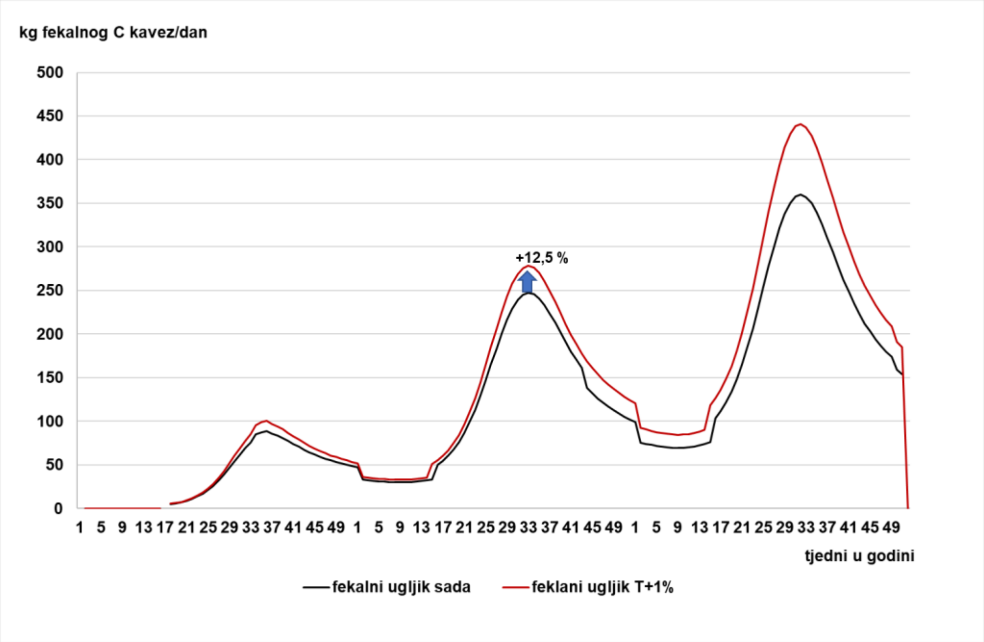


Figure 4. Representation of the increase in daily faecal carbon emissions for two sea temperature scenarios, for gilthead bream cage in which 250,000 pieces of fish were placed. The first scenario is based on average weekly temperature in the last period, and the second is based on an increase in the weekly average by only 1%.

Accordingly, this shows a loss of ecological capacity of the farm, but there are many technological solutions which are in line with the business strategy, and relate to the caged fish farm policy, accelerating production cycles, using favorable temperatures to achieve maximum growth or entring the „big fish" farming market. This means that in the future we should turn to adaptive management that is not rigidly limited by annual production at a particular location.

The farm can also be set up on a location where the ambient temperature is artificially changed (near thermal power plants or hot springs) and in this way can speed up the time required for cultivation.

Fish can move, so they will choose the water temperature that suits them best, while in shellfish farming, individuals at different depths will be exposed to different temperatures, which can result in unequal growth rates.

9.4 Analysis and trends of the relationship between abiotic physical factors in shellfish farming

Shellfish, especially oysters, are sensitive to very high and very low sea temperatures, as well as to salinity below 23 ‰ and can die during major floods. The optimal salinity for oyster farming is 25-35 ‰, and the temperature from 2 to 22 ° C.

In the northern Adriatic, mussels spawn from October to June, and the development of larvae in plankton lasts 10-20 days (Zavodnik, Šimunović, 1997). After internal fertilization, in the case of flat oysters, the larvae are incubated in the mantle cavity for about 8-10 days and then released into the sea. The larvae spend an additional 7-20 days in the planktonic stage after which they stick to a rock or other surface. The time of spawning and larval development is particularly sensitive to sea temperature.

Oyster farming technology is determined according to environmental conditions and the characteristics of the farming area. Thus, for example, in areas of large tidal amplitudes, bottom cultivation technology is applied. Growing at the bottom results in harder shelled oysters which is a desirable characteristic. Disadvantages of bottom cultivation are higher mortality due to parasites and sludge retention. In contrast to bottom farming, sea column farming is applied, which is suitable in areas of smaller tidal amplitudes, which is a characteristic of the Adriatic Sea. Nets, cages or ropes are used for growing in the sea column. The advantage is smaller losses because the oysters are protected in the nets. These methods require much more maintenance and cleaning of fouling. Another disadvantage is that such oysters sometimes have a softer shell and become brittle, so breeders use various techniques to strengthen them (for example, turning the cage).

Farming in a water column can bed one by using cages, baskets, bags, floating bags, and in areas where there is a large difference in tides, these cages stay above the surface for part of the day. Floating bags or cages are a good way to grow because the movement of the waves shakes the oysters and makes them firmer. In addition, fouling is easily removed from the bags by turning the bags and exposing the fouling to the air for 48 hours (source: http://oystergro.com). Bags that are hung on poles in an area where of high tides have the advantage that fishermen turn them when the sea rises and falls.

Figure 5. Various oyster farming technologies (source: http://www.pangeashellfish.com/blog/the-different-methods-of-growing-oysters)

Oysters grown in deep water can be "trained" before hunting by exposing to the tides. In this way the oyster is forced to open and close the shell so it strengthens the adductor muscle and survives longer out of the water.

As for oysters, selection of mussel farming technology is determined primarily by the characteristics of the farming area. For example, in the province of Galicia in Spain, a well known area for mussel farming, most suitable tehnique is bay farming, where high primary production is conditioned by the large amplitude of the tides (4m) and the constant movement of the bottom layers of sea water rich in nutrient salts. Under such conditions, mussels grow faster and reach 8-10cm in size after 8-9 months. Cultivation is done using farming platforms (rafts) of 100-500 m^2 on which ropes for mussel farming are hung.

Mussel farming in the Adriatic Sea is most often carried out on farming lines that are part of floating parks for shellfish farming. Growing on lines exposes mussels in pergolas to the influence of waves which then indirectly cause mechanical stimuli. Excessive exposure to mechanical stimuli is not good as it can cause shell damage or weaken and loosen byssus threads in mussels. The possible impact of maritime traffic that generates waves which then generate stress in farmed shellfish should also be considered. Mussels on the lines are growing in net pergolas (coils), which can also adapt to environmental conditions.

There are several types of net pergolas on the market today. In addition to the usual gillnets, there are also those with double netting (http://www.romplastica.net/en/project-type/reti-per-mitilicoltura-en/). On double nets, one net is thicker and larger in diameter, and the other is thinner and smaller in diameter. This thin net can be made of cotton that decomposes in the sea after a few weeks. The thin net serves to keep the small mussels from falling out while the pergola is placed in the sea. A thicker net strengthens the mussels, which is especially important when growing in more open locations where there is a greater impact of waves which can cause the mussels to break off. In lagoon farming where the sea is calm, ropes can be used around which a cotton net is placed that later decomposes so that the mussels remain attached only to the rope.

a) b) c)

Figure 6. Different types of pergolas: a) with side reinforcements, b) double pergola, c) cotton pergola (Source:http://www.romplastica.net/en/prodotti/dualnet/, http://godeepaquaculture.com/mussels/cotton-bisect-square-mesh-mussel-socking/)

Mussel farming in the Adriatic Sea, and especially on its eastern coast, is carried out in areas along the coast. Such a position significantly determines the possible impact of inflows from the mainland into breeding areas. Rainwater brings significant amounts of detritus that enters the farming areas directly or indirectly through watercourses (rivers, streams) and flows into the shellfish farming zone. In addition to the inedible suspended particles, which was mentioned earlier, the inflow of inland waters also brings detritus.

The yield of detritus by water inflows from the mainland can have positive effects on shellfish growth if the organic particles are nutritious to the shellfish. Increased total degradation of organic matter that consumes oxygen dissolved in seawater, may contribute to hypoxia and stress for farmed bivalve molluscs. The risk of hypoxia is greater the higher the density of farmed shellfish that also consume oxygen for digestion of food. Shellfish farmers are aware of the problems that arise with increased rainfall intensity. In addition to the sharp decline in salinity, rainwater brings large amounts of mud (Novigrad sea, Limski and Raški bay), which results in the death of shellfish.

9.5 Abiotic chemical factors

Marine organisms are surrounded by an aqueous medium and they receive oxygen from it, but their body fluids are greatly influenced by the composition of seawater. Osmotic conditions, pH, the amount of carbon dioxide and the presence of chemical compounds in seawater are very quickly reflected in the composition of body fluids of cultivated individuals that are spending additional energy to maintain homeostasis.

Salinity

Cultivated organisms have a salinity tolerance interval. Many organisms benefit from the conditions of light sweetening of sea water. Fish like this because it reduces the osmotic pressure on body fluids, so in these conditions they often give better production results. For shellfish farming, this usually means that is provides nutrient salts that support photosynthesis and food production for shellfish. In extreme cases this means bad weather, extreme salinity changes and stress for farmed organisms. Salinity may vary more in river mouth areas or near springs. Salinity in the Adriatic ranges between 38 and 40 ppm, while in areas of fresh water inflow it can fall below 7 ppm.

Amount of dissolved oxygen

In most natural habitats of the oligotrophic sea, such as the Mediterranean, the concentration of dissolved oxygen reaches 90-100% of possible saturation. Such locations, with sufficiently strong current in the farming area, ensure a supply of oxygen for the successful cultivation of organisms. Oxygen saturation of water is an indicator of the total metabolism in the water column, while the concentration of dissolved oxygen is a measure of the limit value tolerated by cultivated organisms. For fish, the most common lower limit of dissolved oxygen concentration, which allows a concentration gradient on the gill epithelium sufficient for normal respiration, is between 4 and 5 mg per liter.

Metabolites of farmed organisms

Fish metabolism results in the emission of ammonia, urea, carbon dioxide and other metabolites. Ammonia in certain concentrations is a poison that negatively affects all the desired effects of cultivation itself. The younger the organisms, the greater the toxicity. The risk of toxic effects is higher in closed farming systems, especially if the intensity of metabolism is so high that it is necessary to introduce additional oxygen into the farming medium.

Eutrophication/primary production - nutrient concentration - agriculture

The degree of trophicity of the farming area is determined by physical parameters - temperature and light and chemical parameters such as nutrient salts and micronutrients. The most common limiting factor of trophic level in the Adriatic Sea is the concentration of biologically available phosphorus in the water column. In addition to the increase in trophicity initiated by primary production, it is also possible to increase the trophicity of the area by direct inflow of organic matter. Natural systems with added energy, such as estuaries or areas with inland water flow, are natural habitat for shellfish, but they are also the most common choice for establishing shellfish farming areas. Anthropogenized mariculture systems, such as habitats where intensive farming of heterotrophic organisms (cage fish farming) has been established for the long run, pose a challenge to establishing the ecologically sustainable farming. The increase in the trophicity of the sea under the influence of agriculture causes leaching of agricultural land and achieves the highest intensity as a result of yields with inland waters. Today, we know very little, for example, to what extent the disappearance of agricultural activities on the islands has affected ecological changes in the habitats along the coast of these islands.

Toxins - herbicides and insecticides used in agriculture, microplastics

As previously stated, in areas with severe pollution - urban centers, port and industrial centers ori n areas with unsatisfactory hygienic and sanitary conditions, the possibility of aquaculture is excluded.

The use of pesticides in agriculture in areas that can directly or indirectly emit pesticides into coastal waters poses a threat to the hygiene of marine organisms as food for humans. This applies to both fishing and farming organisms, if farming takes place in areas exposed to such emissions.

The result of industrial development is microplastic that is already found in seawater and animals in accumulate it in their digestive system. When consuming most species of fish, their digestive system is removed, thus avoiding contamination of humans with microplastics.

The origin of microplastics in the sea is mostly from wastewater and inadequate disposal of plastic waste that ends up in the sea and degrades and decomposes into small pieces. Although significantly less than fishing, plastic structures on farms also degrade over time and release microplastics into the surrounding sea. Degradation is accelerated by fouling organisms, for example isopod shrimps that drill holes in plastic buoys.

Marine pollution, accidents and damages

Petroleum and petroleum products from maritime transport (cargo, fuel, lubricants) as a result of negligence or accident can be an additional source of toxins in the environment. Tar and larger quantities of fuel oil can completely coat farming installations to the extent that they become unusable, and at the same time cause immediate mortality of farming organisms.

9.6 Analysis and trends of the relationship between abiotic chemical factors in whitefish and tuna farming

The salinity of body of farmed fish is around 10 ppm, so fish farmed the sea (more than 35 ppm) are exposed to a constant loss of body water, which is enhanced by feeding dry pellets. Such conditions are stressful to farmed fish, and, along with other stressors, can easily lead them to a state of weakened immunity. Farmed fish can to some extent control the salt concentration in body fluids. The salt concentration in the body fluids of fish is about 0.9 ‰ while in the seas it ranges between 34 and 39 ‰. Since liquids in contact tend to equalize the concentration of dissolved ions, farmed fish are under constant pressure of losing water from the body. To prevent this from happening, fish regulate the concentration of salt in the body by consumating the energy obtained from food. Therefore, some species, such as sea bass, when grown in brackish waters, achieve less conversion of food into growth than when grown in the sea. In brackish waters, there is usually a danger of salinity falling to zero when farmed fish cannot escape and are prone to water penetration into the body. Even then, some species can withstand a significant drop in salinity for a long time, but consume significant amounts of energy to maintain balance among body fluids.

Sea bass is more tolerant to changes in salinity than gilthead bream, and with the salinity of the surrounding water between 20 and 30 ppm it achieves significantly better growth with more efficient food conversion. Such conditions, however, can be found in a very small number of locations, and there are also high risks of excessive salinity drop which poses stress to farmed fish.

Fish takes oxygen from the environment in dissolved form. Oxygen is taken up by the gills, where carbon dioxide is released from the blood into the water (sea), and dissolved oxygen is taken into the blood. The difference in dissolved oxygen concentration between seawater and blood is required for successful oxygen transfer. The higher the metabolic activity, the higher the body's demand for oxygen. The rate of metabolic activity is fundamentally determined by the ambient temperature and the size of the fish. In addition to the above-mentioned parameters, the rate of metabolism on a daily basis is significantly affected by the relative feeding intensity. As the ambient temperature rises, the metabolic activity of farmed fish generally increases, along with the growth potential, which requires more frequent feeding. On the other hand, with temperature increase, the solubility of oxygen in seawater decreases, so there is a turning point when the increase in temperature no longer contributes to the overall growth increase in the farm. The recommended minimum dissolved oxygen concentration for successful cultivation should not fall below 5 mg/l. Lower concentrations over time can act as a stressor and cause lower food utilization, i.e. an increase in the conversion index.

In cage farming, generally, there are no dangerous concentrations of ammonia and carbon dioxide. Farms in recirculation are much more sensitive to this problem, especially if they add oxygen to the farming medium. On the other hand, other substances released into the environment can reduce the quality of seawater, which needs to be eliminated in the process of selecting a breeding site.

Fouling organisms on the cage mesh reduce the circulation of water in the cage which can lead to a decrease in the dissolved oxygen concentration. In these circumstances, the expected production results are also disrupted.

Fish can also bioaccumulate toxins, even though their food does not come from the environment. Toxins enter the body through the skin and gills and reach other tissues through the bloodstream, where they can accumulate.

9.7 Analysis and trends of the relationship between abiotic chemical factors in shellfish farming

Shellfish, and especially oysters, are sensitive to salinity lower than 23‰ and can die during major floods. The optimal salinity for oyster farming is 25-35 ‰, and the temperature is 2-22 ° C.

Inflow of detritus by water from the mainland can have positive effects on shellfish growth if the organic particles are nutritious to the shellfish. Otherwise, it increases filtration and energy consumption for filtering and removing inedible particles. Detritus is made up of particles of organic matter inhabited by bacteria that decoposes them. Increased total degradation of organic matter that consumes oxygen dissolved in seawater may cause hypoxia and stress to farmed shellfish. The risk of hypoxia is greater the higher the density of farmed shellfish that consume oxygen for metabolizing food. Metabolites lower the pH of seawater. Reduced pH adversely affects shellfish calcification. The normal pH of seawater is about 8.2 while a reduced pH of about 7.8 and 7.6 significantly affects calcification and especially the stages of larvae development.

Shellfish growth rate is significantly affected by the amount of food available. Food amount is not necessarily proportional to the density of prey in the medium in which they feed, but it depends on the availability of food per unit of time. This means that in areas with lower food density, provided that the seawater is sufficiently flowable, sufficient food for growth and development of shellfish can be provided through farming facilities (flux or inflow of food).

A large enough and frequent enough supply of nutrientive salts ensures the growth of shellfish, but more importantly, a greater edible shell mass. In areas where fish are raised nearby, the supply of nutritive salts comes from the metabolic breakdown of food in fish. In coastal areas with a constant or intermittent inflow of fresh water, nutritive salts are dissolved in fresh water and, upon arrival at sea, support the growth of phytoplankton. Nutritive salts in rainwater can be derived from the leaching of agricultural land or wastewater from human settlements. Such areas may have higher productivity, but greater risks related to hygienic safety are, so farming process in such zones has an increased risk.

In eutrophic areas, there is much higher fouling on installations and on shells of shellfish. Fouling can have such a negative impact that it nullifies the positive impact of a larger amount of shellfish food.

Shellfish are a particularly risky food category because they are filter feeder animals and therefore, accumulate various substances in their body, including bacteria, viruses, biotoxins, heavy metals, other toxic substances, and even microplastic particles.

However, shellfish, unlike fish, are consumed whole and are thus one of the main ways of ingesting microplastic in humans. By consuming one serving of mussels (225g) according to some research, a person would intake 7µg of plastic into his body, which is negligible (<0.1%) in relation to the total daily exposure to chemical compounds such as PBT (Persistent, bioaccumulative and toxic substances) and plastic additives (source: Microplastic in seafood). This calculation is based on the assumption that the largest measured amount of microplastics in shellfish from China averages 4 pieces of microplastics/g of meat. 225g of meat has about 900 pieces of microplastics, and according to the dimensions and density of polyethylene, it is calculated that 900 pieces have a mass of 7µg. However, in the work of C. L. Murphy from 2018, is stated that 5 to 650 pieces of microplastic per gram of shellfish meat were measured, which indicates that the amount of microplastic in a portion of shellfish can be significantly higher (650pcs x 225g x 0.007 = 1,137µg). This study also demonstrated significantly higher concentrations of microplastics in farmed mussels and oysters compared to wild individuals.

9.8 Biotic factors

Predators – birds, bluefish, tuna, sharks, dolphins, gilthead breams, starfish, (direct damage but also cause of stress)

Farming in aquaculture involves large amount of individuals that are food not only for humans but also for other marine animals. The presence of food attracts predators and causes them to change their natural patterns of behavior and adapt to the exploitation of this new potential food source. In doing so, predators are doing damage.

Farmed fish are very well protected from predators. However, fish that gatheres around the cage can attract predators (large fish and mammals) to the wider area around the cage, and the very presence of predators can be a stressor for the caged fish.

Sharks, dolphins and bluefish have strong enough teeth able to bite through the thicker mesh of the cage causing more damage and allowing escape of farmed individuals. In Scotland, sea lions have become a major problem for salmon farming because they can bite through the cage net. In Canada, growers are forced to invest in special polyethylene nets with steel cables that surround entire farms, which requires greater investment. Source: https://thefishsite.com/articles/the-predator-thats-killing-500-000-scottish-farmed-salmon-a-year

In addition to marine predators, which are a minor problem in the Adriatic Sea, in mariculture we often encounter predation from fish-eating birds. The fish in the cages are protected from birds by placing a safety net. Birds often find a way to catch the occasional fish from the cage despite protection by a safety net, especially when it comes to freshly dead fish. In such cases, bird predation is a problem because it is not possible to accurately record death, and it may cause the spread of the disease due to significant damage to small fish.

The presence and abundance of potential shellfish predators may pose a risk to production. A predator is, for example, a mussel-eating starfish. Cultivation on floating parks prevents access to starfish and their presence in that case has no effect on farming. Predators are murex shellfish that pierce the shell of shellfish and feed on the edible part as well as octopuses that open shellfish and eat soft tissue, which can be a problem for farming on the seabed. When growing in sediment, the growing surfaces are covered with nets to protect them from predators.

Pergolas that do not normally touch the bottom can elongate over time. In a few months, the mussels pass through the openings of the pergola net, so the net is inside, and the mussels are outside. As the net collapses, it also lengthens, and the pergola gets longer with time. This needs to be taken into account in case the farm is in a shallow sea, so that the pergola does not touch the bottom. Some newer types of pergolas have sewn-on side ropes that serve as reinforcements and at the same time prevent elongation of the pergola.

Lately, there has been more and more talk about the gilthead bream predation over mussels and oysters. The gilthead bream has strong jaws with which it crushes the shell of the shellfish. The farms attract gilthead breams due to the large amount of food, and can cause significant damage. There are special nets for pergolas (so-called Spanish nets) that prevent gilthead bream predation, however they reduce the flow of seawater and increase the cost of farming and labor. Fouling accumulates on the nets and needs to be cleaned regularly, and such nets make it even more difficult to work with pergolas.

Figure 7. Protective nets against predation (Source: http://www.romplastica.net/en/prodotti/fishnet-fish-guard-net/)

Assessment of bird damage in fish farms

Many fish farms not only provide birds with fresh food, but also large quantities of pelleted fish food and a resting place. Birds like to rest on buoys and other structures located on the open sea or ponds. The very presence of birds has many negative effects on the growth of farmed fish including predation on farmed fish, predation on food, fecal contamination and injuries and stress of farmed fish.

Birds can catch and eat significant amounts of fish from farms. The high density of farmed fish facilitates fishing so the birds hunt with great success. With their diet, birds reduce the amount of farmed fish and destroy the product that brings income to the owner of the farm. For example, one bird can eat 100-500g of fish per day, meaning 100 birds can eat about 50 kg of fish per day, which is more than 18 tons of fish per year (Opačak et al., 2004). The biggest damage is to small fish, which are easier for birds to catch and swallow. The Great cormorant is known to feed exclusively on fish and can dive to a depth of 35m in search of food. The prey they feed on depends on the species that live in nearby waters (Suter, 1995) and mostly consume prey lighter than 500g, but are able to eat fish of 800-900 g (Steffens, 2010). Some studies show that cormorants can eat more than 500g of fish per day per individual: average 672g, range 441-1095g/day (Carss et al. 1997, Gremillet et al. 2003).

Fish food is expensive and the part of the food that does not reach the water will, therefore not reach the fish and thus will not increase the biomass of farmed fish. Some farmers claim that birds eat up to 5% of total fish food (Gorenzel et al, 1994).

During hunting, the birds will injure a larger number of fish that may die from the injuries. Consequentally, injuries and mortality may increase the risk of infection in the rest of the flock. Injured fish that survive, however, are more susceptible to disease and secondary infections due to reduced immunity and thus contribute to the spread of the disease (Schreckenbach et al., 1988; Kortan et al., 2008; Fijan, 1989).

Additionally, due to the long-term presence of fish-eating birds, fish are kept in deeper layers of water where is less food and oxygen, which will result in reduced growth rate of farmed fish, gradual weight loss and aliment of general condition (Treer et al., 1995). The birds stay around the farm where they feed and rest. In doing so, they leave their droppings everywhere: on farming structures and water in which fish live which leads to contamination with coliform bacteria (Gorenzel et al., 1994). Contamination can lead to a decrease in oxygen concentrations in the water. The feces can also contain parasites that birds can transmit from other infected areas. The appearance of coliform bacteria is especially dangerous if there is a shellfish farm nearby.

Fouling

One of the problems in aquaculture is the settlement of organisms on farming installations and on the mesh of the cage, which we simply call „fouling“. Fouling communities in the farming area are all organisms that spend their lives attached to a solid base. These include numerous algae, among which there are species that encrust limestone, then sponges, cnidarians, other shellfish, polychaetes, among which are species that build limestone houses (worms and bryozoans). If farming facilities are not maintained regularly, mobile species such as crabs, sea urchins, starfish, snakes and fish also be found in fouling communities. The producer is obliged to clean the farming installations from fouling and shellfish that accumulate at least once a year. This is primarily done to prevent damage to the ropes, buoys and anchors.

Fouling communities on farmed shellfish are a problem for breeders because:

- They burden the framing instalations
- They close the openings on breeding installations through which seawater brings food and oxygen to farmed shellfish and removes pseudofeces and metabolites.
- Fouling on shellfish themselves reduces their commercial value
- It creates conditions that support the development of diseases of farmed shellfish

Figure 8. Oysters with barnacle fouling (The Balanomorpha). Source: http://www.ag.auburn.edu/fish/image_gallery/details.php?image_id=313&sessionid=eb4e832e58fada

By transferring shellfish intended for farming from one production area to another, it is possible that fouling organisms get transfered which creates additional difficulties in farming in the area.

After sellfish has been growing on farming installations for several months, they need to be sorted by size and replanted in order to avoid excessive density and optimize their growth rate. In addition, during replanting, shellfish are cleaned of fouling and of juveniles that may have attached on them and on farming installations. Cages and nets protect shellfish from predators and fouling, which results in a higher survival rate and lower marketing expences. In those cages oysters can remain growing until they reach commercial length.

Plankton for shellfish feeding

The growth rate of shellfish significantly determines the duration of the farming cycle. For shellfish farming, the most important thing is to determine the duration of cultivation, ie the time of growth to a size suitable for placing on the market. The most common time from juvenile collection to market placement is between 18 and 30 months. The farming cycle can be shorter if larger (older) shellfish are collected for the plantation, which does not change the real growth rate of a particular species. Growth rate can also be significantly affected by food quantity and sea temperature. The amount of shellfish food is not necessarily proportional to the density of prey the medium in which they feed, but depends on availability of food per unit of time. This means that in areas with lower food density, provided that the seawater is sufficiently flowable, sufficient food for growth and development of shellfish can be provided through farming facilities (flux or inflow of food).

The increase and index of **mussel** condition vary depending on a number of environmental factors (Gavrilović, A., 2008; Gavrilović, A. et al., 2011). The mussel feeds by filtering seawater from which it extracts various planktonic organisms. The most suitalbe for growing are areas with strong currents due to the bigger inflow of fresh water from the land which is rich in nutrients. Therefore, it is most often grown in estuaries and bays where pergolas are also sheltered from large waves and storms. Mussels grow the fastest when they have the most food, and that is at temperatures of 10-20°C.

Oysters feed on organic detritus, bacteria, diatoms, dinoflagellates and small planktonic shrimp. When the concentration of organic particles is very high, the oysters cannot feed and close the shells. In addition, oysters are sensitive to very high and very low sea temperatures, as well as to salinity below 23‰ and die during major floods. Mortality can be caused by anoxia and sedimentation. The optimal salinity for cultivation is 25-35‰, and the temperature is 2-22°C.

Diseases

Cultivated organisms also suffer from viral, bacterial, fungal and parasitic diseases. Farming conditions can favour the emergence and spread of these diseases.

Parasites and pathogens are mostly found in wild populations, and when they reach farmining individuals, they begin to spread very quickly due to densely distributed individuals of the same species. Parasites cause stress, mortality, and the additional medical cost. It is estimated that about 20% of farmed salmon in Norway die due to parasite infection. About 10-15% of them die due to stress caused by the treatment, and about 5% from the infection itself. Parasitic diseases of sea bass and gilthead bream are becoming more common, and with continuous cultivation it will become an increasingly important economic and environmental problem in cultivation. Borrego et al (2017) list over twenty known species of parasites found in gilhead bream farms. Most farming parasites come from natural habitat in the farming area. For example, the isopod shrimp Ceratothoa oestroides, which is obligate parasite on natural fish habitat, can cause significant damage in sea bass and gilthead bream farming. In juveniles, it causes deaths, and in adults, deformities and growth retardation. There is a great danger of the transmission of parasites from other areas, which is suppressed by strict veterinary regulations and the measures.

Parasites in shellfish can cause incalculable damage. An example of this is the import of Pacific oysters to France with the parasites *Marteilia refringens* (affecting oysters and mussels) and *Bonamiom ostreae* (affecting oysters), which later caused large deaths of flat oysters. Mussles are attacked by the parasite *Mytilicola intestinalis*, which caused significant losses in mussels farming in the 1950s in Germany. The development of production areas for shellfish farming increases the possibility of the occurrence and spread of the disease, so it is necessary to ensure preventive measures against disease transmission and monitoring the health status of shellfish.

In the 1970s and 1980s, flat oyster populations were further wiped out by the emergence of two diseases (zoonoses *Marteilia refringens* and *Bonamia ostrea*) due to which the cultivation of this species in Europe never recovered. Flat oyster production in Europe has thus fallen from 30,000 tons in 1961 to around 6-7,000 tons from 2000 to the present.

Animal health in aquaculture is governed by European legislation of Council Directive (2006/88/ EZ) on the animal health requirements applicable to aquaculture animals and on the prevention and control of certain diseases in aquatic animals. In accordance with the Regulation, farms must be under the supervision and must implement good hygiene practice.

In Croatian legislation, this Directive is implemented on the basis of the Ordinance on animal health conditions applicable to aquaculture animals and the prevention and control of certain diseases of aquatic animals (NN 132/2014). All aquaculture farms should provide traceability records for all organisms they farm. This record must contain information on all movements of aquaculture animals to or from shellfish farms; for deaths in each epidemiological unit by type of production and the results of a risk-based animal health monitoring program. Authorized processing establishments shall keep records of all movements of aquaculture animals to or from those establishments, and in the case of transport of aquaculture animals, transporters shall keep records of deaths: during transport, in farms, in shellfish farming areas, in processing establishments where trasporting vehicle entered, and while replacing the water during transport.

The owner of the farm and personell caring for aquatic animals, including personell accompanying aquaculture animals during transport, veterinarians, other experts involved in aquatic animal health monitoring services, veterinary inspectors, and heads of veterinary or other official or private laboratories have the obligation to report to the competent authority any suspected existence of a disease listed in Part II. Annex IV of this Ordinance or if the presence of such a disease in aquatic animals has been confirmed and if increased mortality of aquaculture animals occurs.

Presence of biotoxins in shellfish and „blossoming of the sea“ in aquaculture zones

Shellfish are a particularly risky food category because they are filter feeder animals and therefore, accumulate various substances in their body, including bacteria, viruses, biotoxins, heavy metals, other toxic substances. In addition, their meat is rich in water, protein and unsaturated fats and very quickly begins to spoil after dying. Since shellfish digestive tract is not removed before consumption (exception are some types of scallops), digestive enzymes further accelerate the breakdown of shellfish meat and spoilage. However, since shellfish can survive a few days out of the water if kept cold and moist, this process can be somewhat delayed. An additional risk in shellfish consumation is that they are often eaten raw or with minimal heat treatment that fails to destroy the bacteria in them. Also, if shellfish are contaminated with biotoxins, heat treatment does not help. Namely, biotoxins are not degraded at high temperatures.

Biotoxins are produced by algae in phytoplankton and are toxic to humans. They are accumulating in the meat of shellfish due to their diet- filtration (Paralytic Shellfish Poison -PSP, Diarrhetic Shellfish Poison -DSP).

Due to the high-risk nature of this product and to enhance consumer safety, regulations governing food safety pay special attention to the production of shellfish and their market placement. The control of shellfish production is performed by sampling the surrounding sea water, sampling of shellfish meat from the farms and control on the vessel and other vehicles, dispatch and purification centers.

The blossoming of toxic microalgae can cause mortality in cultivated organisms. In Norway, 8 million farmed salmon died in 2019 due to the flowering of toxic microalgae, in just a few days. The loss amounted to more than 200 million euros. This phenomenon is thought to be related to sea warming and climate change. Norway is investing in phytoplankton monitoring systems to avoid such cases in the future. It is planned to move the fish to more suitable locations in case the occurrence of toxic phytoplankton is spotted (source: https://thefishsite.com/articles/norway-invests-10-million-kroner-to-combat-algal-blooms).

10. ANTHROPOGENIC INFLUENCE

Cultivated organisms, together with organisms in natural habitat make up the renewable sea resources. Various forms of anthropogenic activities can result in pollution that reduces the natural and economic value of renewable resources. Holdgate (1979) defines pollution as man's „input of substances or energy into the environment that can harm human health, damage living communities and ecological systems.“ Mason (1981) divides pollutants into:

- acids and alkalis
- anions (sulphides, sulphites, cyanides, etc.)
- detergents
- household and farm waste
- food processing waste (including farm waste)
- gases
- heat
- metals
- nutrient salts
- organic toxic waste
- pathogenic organisms
- pesticides
- polychlorinated biphenyls
- radionuclides.

The cultivation of aquatic organisms has been known for thousands of years. The increase in the human population was accompanied by the need to conserve drinking water resources, which shifted the need for food production to the sea area. At the same time, the shift of industry to the coastal belt is becoming a threat to the usability of natural resources. It is known, for example, that under the pressure of development, Japan today grows organisms in polluted and densely populated areas. Recently, there is an increasing danger of latent poisoning caused by marine organisms. The impact of intensive agricultural production, the impact of industrial production, the impact of larger settlements and cities in the context of pollution cause danger to the usability of renewable resources, including cultivated organisms. The danger of undesirable changes in the Adriatic Sea (eutrophication or poisoning) stems from the fact that its surface area is approximately 1/20 of the surface area of the Mediterranean Sea, and it is affected by a third of inland waters exiting into the Mediterranean. These waters bring urban and industrial wastewater and some water that washes away from agricultural soils (herbicides, insecticides, fungicides, nutrient salts, etc.). The northern Adriatic is experiencing increase in phytoplankton blooms, especially in the summer months, and the occurrence of toxic phytoplankton species consisting mainly of dinoflagellates is also increasing. At the bottom of the Venetian lagoon, about 1.8 million cubic meters of waste has been deposited, which is associated with the danger from release of highly toxic compounds (dioxin, etc.). Microbiological contamination is especially dangerous for the quality of the filter feeders (shellfish, etc.) and creates a possible danger from poisoning with microorganisms, biotoxins and especially a dangerous hepatitis infection. In this sense, our by-laws are stricter than Directive EZ 91/492/EEC. Among the dangers in quality of farmed organisms for human consumption should be included poorly managed fish farming. The danger of using inadequate food can endanger the producer himself (penalties or closure of the farm), which is very unlikely in our country, because it is very well covered by veterinary prevention. Improper use of food reduces the ecological value of the environment, and thus the economic and ecological profitability of granting concession for cultivation. This approach is especially important in “declared areas” for mariculture where one producer can influence the production capabilities of another producer.

Nautical tourism – fecal pollution

The presence of *E. coli* in shellfish and water is taken as an indicator of faecal contamination. With human and animal faeces, other types of bacteria (such as fecal coliforms) which live the intestine, can enter the farm waters. Due to unregulated sewage disposal systems, nautical tourism greatly causes pollution.

Nature protection measures – Natura 2000 Ecological Network

The Habitats Directive and the Birds Directive together provide a framework for the establishment of the Natura 2000 network, and are applicable both on land and at sea, which may lead to limited use of technology that can be applied to aquaculture in Natura 2000 areas.

Pollution from underwater discharges of wastewater

Contamination of the farming area with wastewater is possible if there are sewage systems (that discharge wastewater into the sea) nearby. Pollution by industrial wastewater or wastewater hazardous to human health is contraindicated for mariculture.

In the coastal area, we most often find wastewater from urban settlements, which carries potential fecal pollution and the possibility of introducing pathogenic organisms into cultivated organisms. The introduction of pathogenic microorganisms into the environment is especially dangerous when consuming farmed shellfish. Therefore, it is important to control the discharge of wastewater especially in areas that have been declared as shellfish production areas. As a direct consequence, treated wastewater can result in nutrient uptake and eutrophication of the area.

Noise – sound, vibrations

Maritime transport noise creates stress for farmed fish that feel all the vibrations in the marine environment with their latheral line. Underwater earthquakes, seismic surveys or bottom drilling can affect fish health. Since noise is often used to drive away predators, these sounds can also cause stress to fish.

Stress caused by technological processes in cultivation

Divers enter the cage during its cleaning and during the catch which creates stress to remaining fish. Fish communicate with each other by releasing chemicals (chondroitin) that signal stress. In this way, fish of the same species „know“ that it is time to escape, while the same chemical can also attract predators. These chemicals are excreted from the skin of fish and are also found in mucus on the skin. Other fish detect it with olfactory organs (nostrils). Fish may react differently to this type of alarm by squeezing the flock, swimming faster, jumping out of the water, hiding, or even panic and freeze swimming, as is the case with tuna (A.S. Mathuru et al. 2012).

Stress caused by educational and tourist activities on farms

Recently, the activity of aquaculture has been associated with educational and tourist activities. Tourists and guests are transported by boat to the farm where they are introduced to farming process. Increased number of people and vessels around the farm can have a significant impact on the farm and cause additional stress to the cultivated organisms. In Spain, tourists can even swim and dive with tuna in cages.

11. THE IMPACT OF FARMING SITES ON THE ENVIRONMENT, PEOPLE AND OTHER LIVING BEINGS

Aquaculture can potentially affect the ecosystem by emitting substances, energy and living organisms into the environment. The substances emitted are:

- nutrients that support plant growth (phytoplankton, algae, and sea flowers)
- organic particles from feces and uneaten food, which are rich in energy, and which are most often broken down by microorganisms
- substances used to maintain farmding installations
- substances used to treat cultivated organisms
- maintenance of the farm results in the generation of waste and the producer is obliged to properly dispose in order to avoid pollution.

11.1 Physical impact

Visual – aesthetic impact

Sea farms occupy large areas and have certain surface structures that can be seen from the shore. Moreover, there are supporting facilities on the coast that are often located near beaches or tourist centers and in that way can conflict with tourist attractions.

Figure 9. Norway farms in poorly accessible locations, Source: Norwegian Seafood Council (2011)

Due to the relocation of farms to areas offshore areas where the influence of waves and sea currents is greater, cage systems have been developed that are periodically submerged and have automated feeding systems. However, it is important to mention that this technology is not fully developed, it is not cheap and it is not completely safe to be applied on a wider scale.

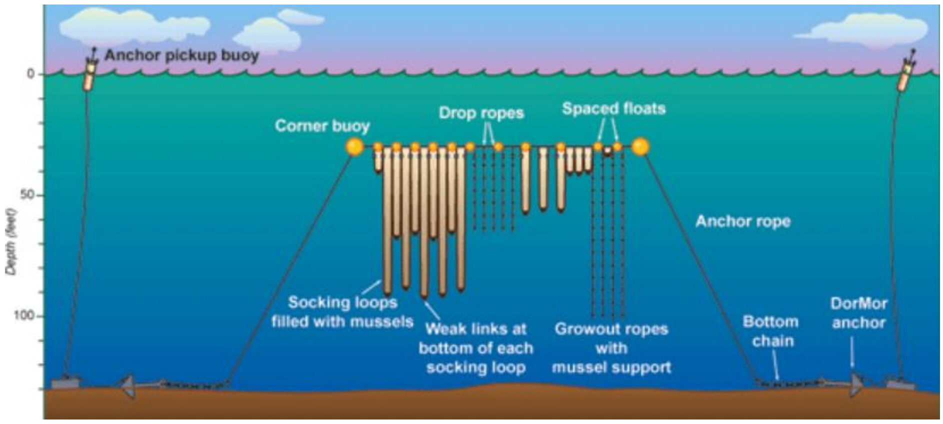


Figure 10. Submerged cages, Source: Woods Hole Oceanographic Institution,
https://www.whoi.edu/oceanus/feature/down-on-the-farm---raising-fish

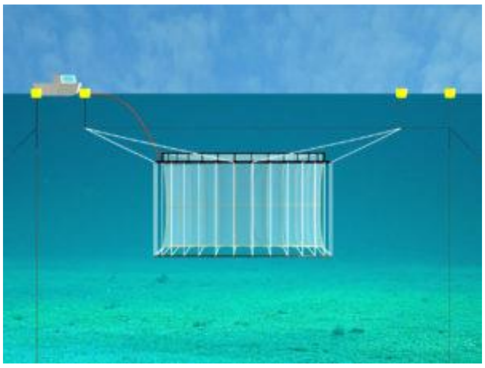


Figure 11. Submerged cages, Source: Badinotti Group,
www.badinotti.com/productos/acuicultura/submersible-cages/

Impact on maritime transport

There are certain restrictions for passage of boats and anchoring around the farm. Since farms are often located within bays, the space for safe anchoring of nautical vessels is reduced. There is a possibility of collision of ships with farming installations.

Closure of certain areas of the sea for other activities (recreation, fishing, traffic)

Areas where marine organisms are grown are prohibited for other activities, which can lead to dissatisfaction of the local community that wants to preform these activities.

Reduction of circulation at the micro location

Farming installations represent a physical barrier and reduce or alter natural currents in the area. This restriction also reduces the inflow of water into the farming system, which significantly reduces the production results, therefore, solving this problem is of mutual interest to all users of the maritime domain.

Shading the seabed

Farming installations prevent light from reaching the bottom, which grately impacts the sea flowers. For this reason, the placement of cultivation in protected areas of sea flowers is avoided.

Fish and other animals often gather under the farming installations because it provides shelter. Fish are gathering under floating objects because in that way they are not visible to the predators that are below them.

Impact of anchoring the farming installations into the seabed

Farming installations must be anchored with concrete blocks or screws. Such interventions destroy demersal species. If the anchorage has longer chains, during low tide the chains can go down to the bottom and scrape it, damaging demersal organisms.

Burying the bottom with detritus – sedimentation

Fecal emission of cultured organisms creates detritus that settles to the bottom below the cage, except in the case of extremely strong currents that carry detritus and spread it over a larger area. Sedimentation disturbs marine organisms such as coral and marine flowering plants. In a poorly managed farm, the accumulated detritus in some areas can be as deep as 50 cm. In addition to fecal detritus below the farm, there is accumulation of detritus that occurs when fouling organisms fall from the breeding installations to the bottom. The problem of detritus poses an important challenge to a sustainable breeding technology management ecosystem.

Creation of new habitat for species – new fouling surface

Farming installations and organisms themselves represent a new free surface for the reception of sedentary organisms. Concrete blocks, ropes, bridges, and other parts of the farm are habitats that are quickly inhabited by marine organisms. The consequence of cultivation is therefore the emergence of a new anthropogenic ecosystem that needs to be brought into balance with the surrounding habitats.

Filtration – increasing the water column transparency

It is necessary to raise awareness of the ecological importance of shellfish farms and their contribution to the regulation of ecosystems through filtration, biodiversity, habitat structure and food chain dynamics. It is especially important to restore the natural shellfish habitats and give the opportunity to natural habitats to function as nurseries and mini protected areas. Shellfish filter significant amounts of seawater while assimilating nitrogen and phosphorus, contributing to the quality and purity of the sea.

Farm waste

If the shellfish farm anually produces less than 400 tons and is not located in protected area, the producer himself needs to take care of the waste and environmental protection measures.

According to the Law on Sustainable Waste Management, producer is obliged to store and dispose of the produced waste on-site, separately by type of waste. In addition to proper sorting and storage of waste, producer is obliged to hand over the waste to a company that has an appropriate waste management permit or a certificate from the competent authority. The process of shellfish farming results in the waste production, which can be divided into: packaging waste, municipal waste and hazardous waste (related to the fleet of ships that is in the service of the farm). While growing shellfish, it is possible to generate a certain amount of plastic waste (collectors for juveniles, plastic cases). A smaller amount of municipal waste is generated on the farm. This waste is independent of the breeding activity, ie it is caused by the people working on the farm. Hazardous waste means waste generated on ships and boats in the aquaculture. In general, vessels that perform this work are also active in the absence of farming activities and generate waste from vessel maintenance (motor oils, oily materials, etc.). The collection of packaging, municipal and hazardous waste is carried out in accordance with Articles 44, 47 and 54 of the Sustainable Waste Management Act (NN 94/13).

11.2 Chemical influence

Release of microplastics from farming installations

The origin of microplastics in the sea is mostly from wastewater and inadequate disposal of plastic waste that ends up in the sea and degrades and decomposes into small pieces. In addition, all the plastic structures that make up the farm itself also degrade over time and release microplastics into the surrounding sea. Fouling organisms accelerate degradation, like isopod shrimps that drill holes in buoys. To minimize microplastic pollution, the farm should replace plastic structures with metal or wood, and ropes and nets with biodegradable materials (cotton and coconut fibers).

Release of antibiotics and drugs from food into the marine environment

Sometimes farmed organisms need to be treated with drugs, such as antibiotics. Medicines are usually given through food and can enter the marine environment in two ways - either directly through uneaten food, or indirectly through metabolites. Antibiotics can affect good bacteria and organisms that are found in the marine environment. It is known that only about 20% of antibiotics are retained in the body of fish, while about 70-80% are transmitts into the environment. Antibiotics in the environment encourage the formation of resistant strains of bacteria.

Oxygen consumption

Organic particles emitted by aquaculture decompose with the consumption of oxygen and thus reduce the concentration of dissolved oxygen in the sea, which is undesirable for the environment and for cultivated organisms. Animals use oxygen dissolved in water for breathing and thus reduce its concentration, especially during feeding or while stressed. Given the high concentration of dissolved oxygen in the farming environment is a production priority, it is important to manage cultivation in such a way as to ensure conditions for normal respiration of organisms throughout the farming area. The exception may be the occasional drop in oxygen concentration at the bottom below the cage, which is not transmitted to the surrounding areas.

Increasing the concentration of CO_2 in the farming environment

The metabolism and respiration of farmed animals produces carbon dioxide that is dissolved in seawater. Increased amounts of CO_2 lower the pH, which is especially important in closed farming systems with added oxygen. In open farming systems, this can occur as a result of catastrophically poor management that inevitably results in producer's economic collapse.

Increased nutrient concentration due to metabolite excretion

Nutrients are various salts, mostly nitrogen and phosphorus, that support the growth of photosynthetic plants. If the current in the farimg area is not strong enough, nutrient retention results in accelerated fouling of phytoplankton and algae on farming installations. At night, when there is no photosynthesis, all these organisms are reducing the concentration of dissolved oxygen, which can endanger all organisms, especially cultivated ones.

In addition, when farming and feeding fish, the surrounding sea is enriched with nutrients. Setting up farms in an insufficiently flowed area can lead to eutrophication and increased algae development. For this reason, the area may be unsuitable for recreational activities.

Release of chemicals used to maintain farming installations

Maintenance of breeding devices includes cleaning, washing and disinfection when necessary. Cleaning, washing and disinfecting agents can end up in the environment which should be avoided if possible. Moreover, it is necessary to use environmentally friendly products.

11.3 Biological influence

Escape of organisms from cultivation

Monitoring fish losses over three years on a sample of 6 countries revealed a loss of over 9 million fish (Jackson et al. 2015). Most of the waste is caused by improper anchoring and by selection of inappropriate anchoring equipment or cage installations and nets.

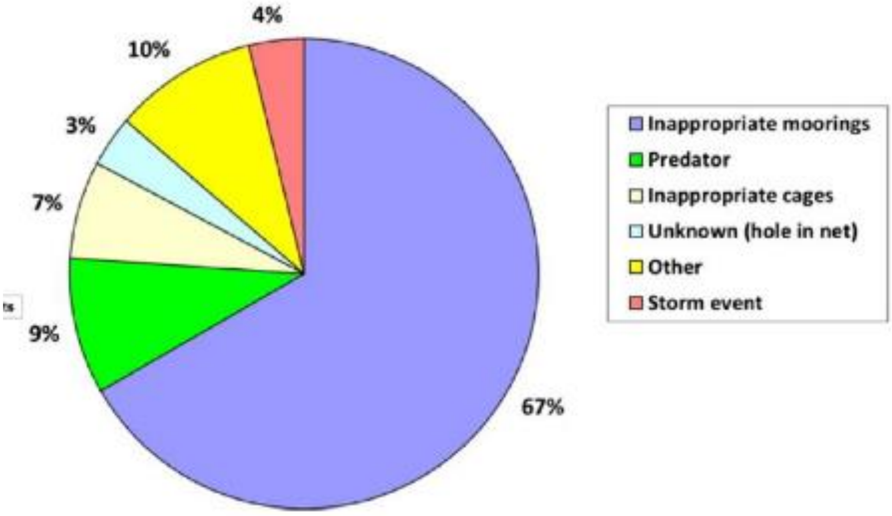


Figure 12. The most common causes of fish losses

The causes of fish escapes from farms are the rupture of the net from being bitten by predators, the material of the nets gets old and worn out, cracks during fouling, storms and high waves, poor installations and anchoring berths, human error, or fish transfer from cage.

Behavior changes of predatory species caused by new food sources

Farming in aquaculture involves large number of individuals that are food not only for humans but for other marine animals. The presence of food attracts predators and causes them to change their natural patterns of behavior and adapt to the exploitation of this new food source. In doing so, predators are doing damage. Smaller fish attract larger predators, such as tuna, dolphins, and sharks, which are often found near farms.

Mussel farming attracts gilthead sea bream, and it was detected that they began to gather around the cage for tuna farming as well, due to the available food - sardines and anchovies (T. Šegvić-Bubić et al.2017). Fish gathered around the cage clean the waste and recycle food scraps from the farm.

Gathering of individuals of the same species around cages to spawn

Individuals of the same species also gather around the cage. To be able to farm as large fish as possible, they are kept in cultivation for up to 3 years, gilthead bream and sea bass females of that age already become sexually mature and begin to produce eggs. These eggs are released into the environment and can be fertilized by wild individuals that are attracted to the spawn and are located outside the cage. In this way, genetic material can be transferred to wild populations, but the survival of larvae that reaches the natural environment is uncertain.

Figure 13. Gilthead breams near the cage, Source: Katavić, I. Šegvić-Bubić, T. Grubišić, L. Talijančić, I. Žužul.I., Predation on shellfish farms along the eastern Adriatic coast –recent experiences; Aquaculture Congress Vukovar 2016

Transfer of genetic material to wild populations

In addition to spawning, the genetic material of farmed species is spreads with escaped farmed organisms. Storms or predator attacks can cause the rupture of mesh and cages on installations. It has been established that escaped fish can survive in the natural environment, but it is easy to catch because it has not been taught to run away from people and fishing tools. Therefore, there is a possibility that the flock will be caught again and returned to the cage (Šegvić-Bubić et al. 2011, Šegvić-Bubić et al. 2016). On the other hand, cultivated individuals are the result of natural genome selection, so they are expected to have the same genes as the natural population. In the worst case, it takes time to re-establish the most environmentally adapted genome, and that is the one that is inherent in the natural population.

Introduction of new species

The indigenous species of oyster in the Adriatic Sea is the European flat oyster (*Ostrea edulis*). In the rest of Europe, when a mass mortality of flat oysters ocurred at the beginning of the last century, farming of less valued Japanese or Pacific oysters began (*Crassostrea gigas* or *Magallana gigas*, Thunberg, 1793). Pacific oysters have already begun to spread across natural habitats in the Adriatic as an invasive species. Since it is more resistant to ecological conditions, it grows faster and reproduce by external fertilization, it is a common occurrence that its juveniles are in large numbers caught on collectors and thus pushing away European oysters.

Introduction of invasive species when moving cultivated individuals from one area to another (no quarantine)

The species *Clavelina oblonga* (Herdman, 1880) was introduced to the Mediterranean a long time ago, but it was not until 2016 that it was first observed in the Adriatic. Since then, it has expanded to about 5 square kilometers of Piran Bay. This species most often inhabits new artificial structures in the sea because when finding a medium to attach it prefers surfaces that are completely free from other fouling. For now, it does not appear to have a negative impact on benthic communities, however it creates significant fouling on submerged structures in aquaculture. Mussel juvenile is a favorite surface on which larvae of *C. oblonga* species are attached. Fouling reduces the flow of sea water to shellfish which results in slowed growth of shellfish. The result is reduced aquaculture production and economic damage.

The appearance of the species *Clavelina oblonga* was first observed on a mussel farm near Kanegra in Istria, in the southern part of the Piran Bay. During the summer of 2016, this species completely covered mussel pergolas and caused large financial losses to growers. In 2017 and 2018, *C. oblonga* was also found in the northern part of the Piran Bay where it spread to neighboring mussel farms. Previous research suggests that the spread of *C. oblonga* has been caused by human activities.

Field research found that these ascidians formed dense colonies on pergolas while growing on mussels (*Mytilus galloprovincialis*). The colonies completely covered the pergolas and in places were 10 cm thick. Underwater photographs were taken and the causes were recorded for further research. Morphological and genetic analysis was performed to identify the species. This is the first genetic characterization of the population of *C. oblonga* in the eastern Mediterranean.

11.4 Impact on people

Toxins in shellfish

On the shellfish farms, species of the genus *Dinophysis* is most numerous in the northern Adriatic in Istria. In 2016, no illicit concentrations of ASP toxin (domoic acid) and PSP toxin (saxitoxin and its derivatives) were recorded in shellfish. Illegal concentrations of lipophilic DSP toxins were detected in only 4 samples in the northern Adriatic out of a total of 478 analyzed samples from that area (http://baltazar.izor.hr/azopub/bindex).

Shellfish are a particularly risky food category because they are filter feeder animals and therefore, accumulate various substances in their body, including bacteria, viruses, biotoxins, heavy metals, other toxic substances. In addition, their meat is rich in water, protein and unsaturated fats and very quickly begins to spoil after dying. Since shellfish digestive tract is not removed before consumption (exception are some types of scallops), digestive enzymes further accelerate the breakdown of shellfish meat and spoilage. However, since shellfish can survive a few days out of the water if kept cold and moist, this process can be somewhat delayed. An additional risk in shellfish consumation is that they are often eaten raw or after minimal heat treatment that fails to destroy the bacteria in them. Also, if shellfish are contaminated with biotoxins, heat treatment does not help. Namely, biotoxins are not degraded at high temperatures.

Biotoxins are produced by algae in phytoplankton and are toxic to humans. They are accumulating in the meat of shellfish due to their diet- filtration (Paralytic Shellfish Poison-PSP, Diarrhetic Shellfish Poison-DSP).

The presence of *E. coli* in shellfish and water is taken as an indicator of faecal contamination. With human and animal faeces, other types of bacteria (such as fecal coliforms) which live the intestine, can enter the farm waters. Shellfish meat can also be contaminated with several types of biotoxins.

12. MEASURES AND RECOMMENDATIONS FOR IMPLEMENTATION OF MEASURES IN WHITEFISH AND TUNA FARMING

Cage fish farming is a result of demand for fish products in which continuous supply and a certain level of quality are expected. In this way the supplies for cage fish farming are also transformed into new products, that equally adapt to the demand and supply laws.

Cage fish farming entails a sequence of interactions with the environment, which are a consequence of the physical presence of the farming site in the space and the cultivation of the fish in it. The fish farming as a production process results in absorption of elements for the environment, and emission of metabolic products into the sea environment. The metabolic process inside of the farming system is a natural process, which is due to the efficiency of the production intensified in both space and time.

Moreover, the farming is carried out via farming installations that make out the artificial ridge. Unlike the artificial ridges in which a complete succession of fouling communities is supported, measures that support renewal of succession are supported on farming installations

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In cage fish farming zones, by the Maritime Fishery Law (N.N. 62/17, 130/17, 14/19) fishing is forbidden within a 300 meters distance from the farming site mark, which makes the farming site a ‘no-take’ zone.

The composition of the stated facts leads to the conclusion that the farming sites presents a relatively small anthropogenized ecosystem. In terms of a precautionary approach, the emphasis was until now put on the negative or unwanted impacts of the cage fish farming on the environment. In the past period the focus was directed towards choosing the farming location and assessing the production capacities for the respective location. In that sense, acquiring location permit and the procedure of assessing the impacts on nature and the environment are a constituent component of farming.

The assessment procedure is reduced to assessing the most critical impact of the farming on the location itself, which is the impact of the faecal emission on the seafloor in the farming zone. Threshold values are difficult to set here, since the impacts parameters may be enlarged with respect to the water column. The limitation of the farming implies the enlargement of the farming site in order to have the same yearly production. For now, this threshold is set according to experiential parameters, which are determined by the relation of quantity of farmed fish and the seafloor for each respective bearing capacity category.

The current approach to impact assessment varies from location to location, meaning that the common denominator of cage fish farming sites, which significantly determined the farming capacity, is disregarded.

The common denominators of the caged fish farming sites are the following:

i. Farmed fish types
ii. Production volume
iii. Farming site surface
iv. Oceanographic and ecological properties of the farming site

Each producer wants to achieve the best result at the farming site. At the same time, that results is made up from the common denominators. The farmed fish are very demanding considering the environmental conditions, and the final result will significantly depend on it. In effect, the process of technological optimisation must take account of the synergies between the listed components, in the sense that the production capacity area and volume is determined by the quality of the environmental conditions in which it is generated. In short, by defining the farming surface and volume the production capacity of the location is already determined to a large extent.

Besides the environmental and the precautionary approach, the acceptability of farming is significantly determined by the ecosystem services provided. According to the classification for the ecosystem economy and biodiversity (TEEB), ecosystem services are made up from:

- Supply service
- Regulation service
- Ecosystem support service
- Cultural services

The identification of ecosystem services which are generated by the setting of the cage site should be a constituent part of the validation procedure which determined the acceptability of the location and of the intervention in the space.

12.1 Interaction with species in the environment

Farming sites attract other species of fish and other organisms that find refuge, feeding site or food inside of the farming zone. These organisms are attracted by the food decomposing during the feeding of the farmed fish or of the fouling communities which act as natural food resource. The presence of the fish-eating birds is a consequence of the aggregation of the surrounding ichthyofauna and of the farmed fish. The farming installations are also suitable for resting. For this reason, fish farms are identified as Fish Aggregation devices (FAD). These types of aggregation have desirable aspects that can be measured in ecosystem services, but also disservices, since aggregation provide recognized as making these organisms more vulnerable to predators (e.g., dolphins). The recognition of these new anthropogenic ecosystem is of crucial importance for the adoption of measures for implementation and management.

The services that the farm provides to the species in the environment are direct and indirect. The services provided by aquaculture for fishery species should be seen in the light of support for fishing and the conservation of fishery stocks.

- Direct Supply Services pertain to the farmed species and are self-explanatory. They have the significance recognized in the Common Fisheries Policy. Supply services which are related to the species in the environment are indirect. The fishing refuge created by the farming zone gives a known effect to the establishment of no-take zones.
- Utilization of food that decays during feeding can provide ecosystem **support service**, because in this way this „no-take“ zone provides a trophic basis for its functioning. Most species in aggregations around cages are not monophagous. In cage farms in the Mediterranean, the surrounding ichthyofauna is dominated by adult fish individuals (Fernandez-Jover, et al. 2008). About 160 species of fish have been recorded in fish farms in general, and in the Mediterranean the presence of 20 species is attributed to farming itself (Sanchez-Jerez et al. 2011). In two-year research in Spain, it was found that 66-89% of fish consume food intended for feeding farmed fish. In addition, organisms in fouling communities are a source of food for the organisms in the refuge. At the time of bird migration, breeding installations provide resting and temporary feeding for species in migratory migration.
- When evaluating **regulation services**, it is important to recognize the spatial determination and concession of maritime property, which significantly facilitate the definition of areas and measures that can be applied in the farming site. In Croatia, the legislator recognized this possibility and ensured by law the protection of producers from obstruction of production, but at the same time it also provided new no-take zones.
- **The cultural services** of fish farming have in general not yet been used as a development potential of aquaculture in Croatia. The reason is the overlapping of competencies and the simultaneous implementation of activities that are under the jurisdiction of several ministries. Mariculture strengthens people's connection with the marine environment. There is certainly the potential for employment of local residents, who thus retain a cultural identity that can be attributed to a particular geographical area. The aggregation of organisms around the farm

itself is not further valorized as an opportunity in terms of the cultural services provided by mariculture.

12.2 Recommendations for implementation

Instead of a targeted approach to the evaluation of certain parameters in the farm, which as a precautionary principle covers threats and weaknesses in cage fish farming, it is necessary to evaluate the opportunities and strengths provided by the establishment of a farming ecosystem in the area. The proclamation of the farming ecosystem is not without basis, because the concession on the maritime property for cage fish farming is given for several decades, which means that the establishment of a new habitat is expected and represents a relatively permanent state in the area. In order for such systems to be fully valued in environmental and socio-economic terms, it is necessary to extend the interest from a specific to a general management approach. In this sense, it is necessary to:

- Establish data collection (biotic and abiotic) on the ecosystem of the fish farm itself
- Recognize public or special interest in species that aggregate around the farm
- Create a legislative framework that allows the use of potential services provided by fish farms by establishing habitats for the species in the environment.

In addition to establishing a new habitat generated by setting up a cage fish farm, the farm is a location of increased flow of energy and matter, a place where farmed species dominate en masse. Such systems are suitable for the growth and development of pathogenic microorganisms and multicellular parasites. In accordance with the Law on Veterinary Medicine, health care measures for bred organisms are implemented on farms, which include good breeding practice, ensuring conditions for animal welfare and veterinary supervision and control. There are very rigorous measures in the system of supervision and control of transport and plantations of organisms from different production areas, but no control over the health status of organisms in the environment has been established, especially no control of possible parasites. Therefore, it is necessary to establish measures to monitor the presence of microorganisms and parasites in the species of organisms that aggregate in the area of the farm.

Investments in measures against bird attacks.

There are two types of physical barriers that prevent predation from birds:

- barriers that completely prevent birds from approaching the farming area
- systems that make feeding and predatory behaviour difficult for birds by partially covering the breeding area.

Complete coverage of the growing area is achieved by placing awnings, nets (polyethylene) or roofs that cover the growing area. In this way, the access of fish-eating birds to farmed fish becomes completely impossible. Such systems are extremely demanding and sometimes too expensive or impossible to set up. All structures should be long-lasting and strong enough to withstand the weight of several large birds. In the event that the barrier can be stretched and hung, it must not reach the surface of the water or the distance at which the bird can reach the fish in the water. Barriers must be visible to birds to avoid accidental injury or entanglement of birds in them.

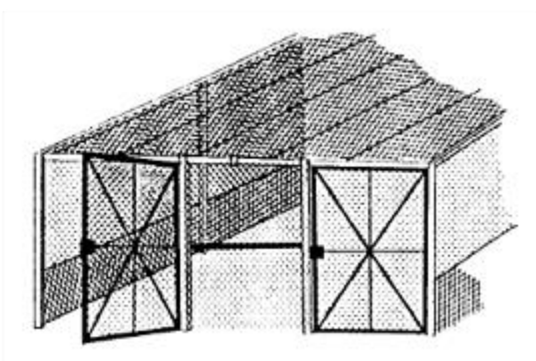
The barriers must be designed to allow pond maintenance, feeding, fishing and other operations or so that they can be removed as needed.

Only the barriers that completely prevent access to birds allow long-term control from all types of birds of prey.

Systems for interfering with the predatory behaviour of birds use wires, ropes, curtains, fences and other systems that prevent access to birds.

The wires should be of high strength, galvanized or stainless steel, arranged as a mesh or in one direction as parallel lines. The distance between the wire depends on the type of bird that is to be prevented from approaching the water surface. The strings are best used against predators that attack from the air such as sea swallows, gulls, cormorants and the ospreys. Pond birds can reach the pond by landing on the shore and walking to the water. They should be prevented by a fence surrounding the pond with electric fences or wires with a charge which must not be lethal to humans or birds

B



A

Figure 14. A) a network that partially covers the farm (Source: GettyImages); B) fully fenced pond (Gorenzel et al, 1994).

Bird scaring techniques

Equipment and techniques for scaring birds make it impossible for them to feed, nest or gather in a certain location. Frightening techniques are based on visual or audible stimuli that give birds a sign that the area is dangerous to stay in. The success of these methods depends on the number of devices used, the method and time of use, the place of application, and whether the birds have already adopted feeding techniques before setting up of the scare system. Scaring techniques work best in short periods of time (1-3 days) because birds quickly lose their initial fear. It is best to start scaring before the birds get used to feeding on the farm.

It is necessary to change the locations of the scaring devices often, especially the sound ones. Longer lasting results can be achieved by a combination of methods and frequent changes to the devices used:

- Devices that repel birds with noise or loud noises should emit these sounds at different intervals and be transmitted to different locations. Devices that replicate the voices of birds calling for help/announcing danger should be used as soon as the birds arrive at a particular location. Devices that emit the sound of falcons and owls at certain intervals or on a motion detector or automatic shutdown of the device at night so as not to disturb the surrounding population.
- The sound of gunshots or firecrackers
- Whistling rockets that can be fired into the air from special guns
- Gas cannons – automatically use an electronic mechanism to fire loud explosions of propane gas; after each shot, the device rotates to achieve a full 360-degree circular coverage. This is why the rifle fires in all directions. The rotation step can be adjusted as desired
- Sirens

Visual scaring methods include nocturnal scaring of birds and setting up scarecrows. Nocturnal scare methods are used to prevent nocturnal feeding, however, birds get used to them very quickly. These techniques are more successful when used in combination with other techniques. Scarecrows are models that look like imitations of people or bird-attacking predators. Inflatable scarecrows moving in the wind are placed in strategic places on the farm. They need to change position often. Performance increases if pyrotechnics are also together with them. Lights and lasers can also be used to scare birds in fish farms. Flashes, rotating reflectors, strobe lights confuse, frighten, temporarily blind and interfere with the activities of birds that feed at night. Lasers are mostly used at dusk or at night, and prevent birds from sleeping on surfaces. Autonomous Agrilaser chases birds even during the day.

Water cannons and sprinklers best repel seagulls. It is good to turn them on and off automatically because a sudden sound often chases birds (Svensson, 1976).

Bird repellent materials, in the form of gels and granules (repellents) are applied to the surfaces where the birds are expected to land. The gel is applied to the surface and irritates the skin on the feet of the birds to a sufficient extent that they begin to avoid landing on a particular surface. Repellents also work by smelling citronella or creating a sticky surface that repels birds.

Trained birds of prey or drones imitating birds of prey can be used to protect the farm from fish-eating birds.

To make fish less accessible to birds, all places where birds can rest or sleep should be eliminated. Besides that, fish habitats can also be improved by building shelters for them to hide from predators.

12.3 Interaction with catches of the same species in fisheries

In the Mediterranean area, cage farming is dominated by sea bream and sea bass. Tuna farming also occupies a significant place in Croatia. Recently, the cultivation of meagre has been mentioned more and more, while dentex and greater amberjack are still in the status of experimental production. Ecological tuna farming would not be the subject of an analysis of the interaction with the catch of the same species in fishing because their differentiation and marketing is clearly and narrowly determined by ICAT rules that are strictly applied in Croatia.

The interaction of farmed species with the catch of the same species in nature is manifested through two aspects:

- Market interaction
- Interaction in the environment

Market interaction is governed by market mechanisms and mechanisms provided by food regulations. Product traceability and declaration should provide information about the product, including its origin.

The interaction in the environment is not completely explained, but it is mainly focused on two main sources:

- the interaction that occurs due to the escape of farmed fish into the natural environment
- interaction due to possible spawning of farmed fish in the cage

Due to its biological characteristics, gilthead bream has the ability to penetrate the net weight of the cage and escape from the cage into the breeding environment. Such losses in production are known, but have never been precisely quantified. After the introduction of high molecular weight polyethylene into the yarn of the net weight, the strength of the net was significantly increased and the number of holes on the net of the cage was significantly reduced, especially the large holes that allow escape. In addition, accidents caused by severe weather conditions occasionally occur. Depending on the method of setting up breeding installations and their maintenance, these accidents can result in the loss or escape of fish from one or more cages. These are examples of unintentional restocking from mariculture. The consequences of the escape of farmed fish are:

- Occurrence of farmed fish in the catch of commercial and non-commercial fishermen
- Farmed fish are increasingly genetically narrowed to traits that are of interest to breeders, so the escape temporarily introduces a quantitative disproportion in the genetic diversity of a particular species in nature.
- With a large escape, there is a trophic disproportion in a certain habitat, which can have consequences for the growth and development of escaped fish, but also for potential prey in nature shares food with the natural population of the same species.
- In the case of escaped farmed tuna, it is not possible to unambiguously determine the difference between tuna that escaped from the tuna lives in the wider area of the farm.

The risks for fish escape from the cage correlate with the size of production. Namely, the growth of the production capacity of the farm is most often related to the increase of the unit breeding volume of the cage. This means that the assumptions for escape from a single cage give the potentially greater escape the larger the breeding volume of the cage. With the same depth of the mesh cage, the potential escape increases with the square of the cage radius increase.

In Zadar County, fishing and aquaculture are strategic economic activities. Over ten thousand tons of white fish are farmed in cage farming, where sea bream accounts for about 40% of production. From this it is clear that even a relatively small escape compared to the cultivated biomass can be significantly observed in the catch. Cage sea bream farming in the Mediterranean has been carried out for about thirty years, and there are protected populations of younger sea bream in lagoons that were once hunted for further breeding. Although there is no official estimate of sea bream biomass in the Adriatic, there is a significant presence of it in the sea and in the catch of commercial and non-commercial fishermen. Through the Interreg project Adri.SmartFish in Zadar County, the small-scale coastal fishing (SSF) sector was analysed. In the landing of SSF fishermen in Zadar County, the dominant species is sea bream, which represents 13.2% of the total catch in this category of commercial fishing. It is followed by octopus with a similar share, and then all the long species that are represented in the catch with 7% or less.

It is difficult to accurately valorise the impact of mariculture on SSF fishing, but the fact is that in other coastal counties, where cage farming is much smaller or non-existent, sea bream does not make up a significant part of catch in this category of commercial fishing.

The escape is unfavourable for the producer and there is no reasonable expectation that there will be no relative reduction in cage escape, but increased production on the other hand may make a relatively smaller escape result in an absolutely higher amount of escaped fish in the environment.

12.4 Measures and recommendations for implementation of measures

- From the point of view of the impact of the cultivation of a particular species on the same species in the natural population, precautionary measures require the establishment of administrative, technical and technological safety mechanisms. These mechanisms should reduce the escape of cultivated organisms to a level below the level of risk to natural populations.
- The level of risk is a quantitatively determined number of escaped organisms in relation to the size of the area in which the natural population is observed and the size of natural livestock.

The risk to the natural population therefore increases with the volume of cultivation of a particular species in an area, suggesting that in proportion to the increase in cultivation of a particular species, especially when it results from an increase in cage breeding volume, escape prevention measures should be increased.

12.5 Interaction with habitat

The interaction of the farm with the habitat in the classical sense separates the farming installations and the fish from the habitat on which the farm is located. In this sense, environmental interventions are carried out and the level of acceptable amount of annual production is determined.

Previous analysis of farming habitats indicate eutrophication of the sediment (footprint below the cages themselves) and the establishment of ofouling communities. Quantitative analysis of fouling communities at the cage fish farm in Zadar County were made through the Interreg project EcoSea. In developed fouling communities, mussels make up over 98% of the total biomass in the cage fish farm, in which another 18 species belonging to the macrobenthos infralittoral of the Adriatic Sea have been recorded. Estimates made through the project indicate the possibility of breeding up to 50 tons of mussels per 1500 tons of fish farming in large PHD semi-offshore cages. The inclusion of fouling biomass in the production program (polyculture) expands the ecosystem approach to the management of cage fish farms.

The analysis of biotic and abiotic relationships and the mechanisms that are placed at cage fish farming locations raises the question of the justification of the classical approach in aquaculture management.

Separating the farm from the natural habitat formally simplifies management, but splits the whole into components that are arbitrary and that are process-indivisible.

This study seeks to emphasize the importance of a holistic approach to the farm as a widely established ecosystem. Large farms or zones designated for farming are small polygons that need to be viewed as new micro-ecosystems. The formal and substantive establishment of the concept of **farming ecosystem** facilitates a comprehensive approach to farming management at the farm site.

In such a concept, farming management encompasses the care of all processes that take place in the farming ecosystem, and farming management recognizes a new desirable balance of the ecosystem in which the long-term sustainability of the activity should be ensured. Unlike the stationary approach of assessing the interactions of cultivation with habitat, which is now applied, the new approach includes the dynamics of processes and their monitoring through the seasons and technological phases of cultivation.

The challenges of approach are:

- establishing criteria for establishing the desired balance within the breeding ecosystem
- determination of the boundaries of the breeding ecosystem, which can be formal (concession boundaries) or substantive (area with characteristics of the isolated ecosystem)
- selection of the process to be monitored and selection of parameters (indicators) by which the processes will be monitored

In any case, it is necessary to investigate the processes and determine the indicators that would be continuously monitored in space and time (for example, continuous monitoring of dissolved oxygen at different measuring stations in the breeding zone). Digitization of data collection and data analysis enables dynamic adaptive management of the breeding ecosystem in a modern and comprehensive way.

13. MEASURES AND RECOMMENDATIONS FOR THE IMPLEMENTATION OF MEASURES IN SHELLFISH FARMING

Shellfish farming on the eastern Adriatic coast is much smaller than farming on the western Adriatic coast due to natural circumstances that create much smaller areas of ecologically suitable areas for farming. Unlike fish farming where food is entered into the farming system, shellfish farming is based on the use of the trophic status of the ecosystem that can produce enough food for economically successful shellfish farming. The management of shellfish farming therefore depends on the size and sensitivity of the farming area according to the establishment of cultivation.

Given that shellfish farming, like other forms of aquaculture, is an economic activity that produces food, and in this case food that has a positive balance in the use of protein, it is necessary to consider all services provided to the ecosystem by shellfish mariculture. Environmental services have been extensively described by Aloway et al. (2018) and Gentry et al. (2020).

By individual categories, the emphasis is on:

- **Supply service** – food production, production of raw materials, resources
- **Regulation service** – removal of carbon and nutrients from the system, coast protection
- **Ecosystem support service** – increasing the genetic diversity of species, creating new habitats for many species and providing food in those habitats
- **Cultural services** – contribution to the way of life in the coastal area and contribution to tourism

In order to fully evaluate shellfish farming in the Adriatic ecosystem, ie in numerous point ecosystems along the Adriatic coast, it is necessary to make a detailed assessment of ecosystem services that would be obtained by developing shellfish mariculture.

Shellfish farming represents the production of a high potential risk to human health, so a system of production areas has been established from which shellfish can be placed on the market in very specific and controlled conditions. To preserve the integrity of isolated farming areas and shellfish produced there, it is necessary to support the establishment of regional or even local centers for shellfish that are able to purify and ship shellfish produced in a particular geographical area.

In order to minimize microplastic pollution, the farm should replace plastic structures with metal or wood, and ropes and nets with biodegradable materials (cotton and coconut fibers). Given that, materials require a new cycle of change.

Live shellfish cannot be placed on the market unless they come from production areas or from shellfish re-laying areas. Pursuant to the Law on Official Controls Conducted in Accordance with Regulations on Food, Feed, Animal Health and Welfare (NN 81/2013 and 14/2014) and Regulation (EC) no. 854/2004, the competent authority must determine the location and boundaries of production areas and re-laying areas and draw up a plan for monitoring the quality of the sea and shellfish in those areas. The identification of production areas and re-laying areas is procedurally demanding and takes at least 12 months. Areas are classified based on the Ordinance on microbiological classification and procedure in the case of contamination of live shellfish (NN 118/2009) into three categories depending on the presence of *E. coli* in the sampled shellfish. The monitoring plan is implemented in shellfish production areas, in harvesting areas and in preliminary production areas. As part of the monitoring plan, sampling of seawater is performed to determine the qualitative and quantitative composition of the phytoplankton community (from December 1st to March 31st every two weeks, from April 1st to November 30th per week), sampling of shellfish meat for the determination of biotoxins (weekly), sampling of shellfish for the determination of microbiological quality (*E.coli*, monthly) and sampling of shellfish for the determination of heavy metals (arsenic, cadmium, mercury, lead) and benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene and chrysene (semi-annually, March and September).

Production zones are divided into 3 classes according to the number of coliform bacteria in the sample:

- Class A – less than 230 *E. coli* in 100 g of shellfish meat and interstitial fluid
- Class B – from 230 to 4600 *E. coli* in 100 g of shellfish meat and interstitial fluid
- Class C – more than 4600 *E. coli* in 100 g of shellfish meat and interstitial fluid

Class A shellfish may be placed directly on the market, Class B shellfish must be pre-treated in a purification center or in a re-laying area complying with Class A conditions. Class C shellfish may be placed on the market only after having been re-layed for an extended period to meet Class A standards.

When the official laboratory determines that a certain sample contains elevated values of any of these parameters from the production zone, it informs the competent office of veterinary inspection and then the inspector informs registered producers and collectors, responsible persons in approved treatment centers and dispatch centers. Thereafter, the veterinary inspector shall issue a decision ordering the shellfish purification in purification centers or re-laying areas with the case of elevated concentrations of E. coli. Only after three consecutive monthly samplings show correspondingly lower parameter values, the zone can be reclassified to the appropriate class.

The process of depuration i.e., purification of shellfish

Depuration/ purification or purification is a proces in which the gills that collect the food of the caught shellfish are cleaned using the clean sea water under controlled conditions. In this way, bacteria are removed from the digestive tract and a significant reduction in the presence of the virus is achieved and the most common pathogens for humans are eliminated. Purification should be carried out until the health of the shellfish is achieved, and usually lasts 48 hours. Several factors affect the efficiency of treatment: shellfish handling after fishing, the design and efficiency of the treatment system, the type and number of microorganisms present in the shellfish, and the condition in which the shellfish were delivered. Therefore, it is necessary to know what the conditions were on the farm. To cleanse the digestive tract at all, shellfish have to open their shells in purification vessels and start filtering seawater. In case the temperature or salinity does not correspond to those from the farm, shellfish can keep the shells closed for hours and during this time their purification does not actually take place, which prolongs the time needed to achieve microbiological correctness.

The purification center should have components that allow mechanical, biological and chemical filtration, control of temperature, salinity and the amount of oxygen, and it is desirable to have UV sterilization.

Food business operators must wash live shellfish of sludge and accumulated impurities with clean water before purification. The quantity of live shellfish that have to be purified must not exceed the capacity of the purification center. The thickness of the live shellfish deposits must not prevent the shell from opening during purification. Crustaceans, fish or other marine species must not be kept in the purification basin where live shellfish are being purified. Each package containing purified live shellfish and sent to the dispatch center must be marked with a label confirming that all shellfish have been purified (Regulation (EC) No 853/2004).

In addition to ensuring compliance with the microbiological criteria established in accordance with Regulation (EC) No 852/2004, food business operators must ensure that live shellfish placed on the market for human consumption meet the following standards: to have the organoleptic characteristics of fresh and vital shellfish and that, inter alia, their shell must not be dirty, they must respond adequately to shocks and they must have a normal quantity of interstitial fluid. They must not contain marine biotoxins in total quantities (measured in the whole body or individual parts that are eaten separately) that exceed certain limits. The dead are the shellfish that do not close the shell and remain open permanently.

13.1 Interaction with species in the environment

Shellfish farming in the Adriatic Sea is most often carried out with the technology of farming on floating parks. The installation of floating parks, as well as the installation of farming facilities for fish farming represents the establishment of new artificial reefs. Such structures attract other species. During the shellfish farming, new habitats are formed for numerous species that form overgrowth on farming installations and on cultivated organisms (macroalgae, gills, mollusks, mosses, mantles…). Mobile animals that find shelter on the farm are also aggregated here, as well as food, which are sometimes the organisms themselves. Then, however, it is often valued as damage to the farm. Shellfish farming generates the creation of new sediment which, in addition to pseudofeces, also contains numerous organisms, including the farmed species, which fall to the bottom during technological operations on the farm. The bottom in the shellfish farm area thus becomes a new detrital habitat for other organisms (Callier et al. 2018). Shellfish farms can also attract birds, marine mammals, and sea turtles. Such accumulations are often an indirect result of the accumulation of fish and long-lived organisms in the farm area.

Interaction with species in the environment may also have special cases that occur when shellfish are transferred from one production area to another. It is especially important to be careful when transporting between areas that are poorly connected by the movement of water masses. Then there is the possibility of transmission of organisms that survive in overgrowth, and for which it is not known what possible impact they may have on the new habitat, especially if they have not been previously recorded in that habitat. By approaching as a precaution, it is necessary to regulate the transfer of shellfish between production areas for which a direct connection of their water masses cannot be established.

Interaction with species in the environment also includes interaction with pathogenic organisms that can significantly reduce the production results of cultivation. In this sense, it is necessary to establish systematic monitoring of the health of shellfish in the wider zone of the establishment of a farming area for shellfish.

13.2 Interaction with natural shellfish habitat

Shellfish farming is most often initiated in areas where the habitats of natural populations of the same species or at least trophically identical species are known. It should not be forgotten that shellfish farming in the Adriatic Sea is still based on catching in the wild. That is why when exploiting shellfish from nature, there is a thin line that separates farming from fishing. In this sense, it is important to preserve the reproductive potential of the species that is exploited through farming and gathering. It is therefore crucial to identify the minimum required natural stocks of exploited species that will ensure sufficient reproduction required for its sustainable exploitation.

To preserve the productivity of shellfish production areas, it is necessary to:

- Systematic management of the use of natural capacities for shellfish farming should be considered holistically.
- Identify farms as new point ecosystems and new point habitats.
- Take a comprehensive look at the aquatorium in which the farming takes place and in which the ecosystem produces roes for the farming of the next generations.
- Establish zones of prohibition of shellfish collection from natural settlements in the wider area of the farm.

13.3 General measures for farming

Mariculture is the process of establishing the cultivation of organisms in the sea. Increasing the economy in cultivation often requires consolidation of production and its concentration in production zones. Placing an activity that uses natural resources in space implies quantitative and qualitative changes in the system in which it is carried out. One of the effects is a point change in the wider ecosystem that balances within the farming zone itself and between the farming zone and the wider environment. Cultivated organisms are regularly very demanding in terms of the quality of the farming environment, so farming itself is a constraint for their own growth in production intensity. To establish the stability of quality farming conditions, it is necessary to manage the farming in a way that controls all input parameters in terms of their impact on the sustainable stability of farming conditions. Therefore, in addition to the stationary criteria according to which the suitability of farming sites was determined, it is necessary to establish **adaptive and ecological management** of farming in development plans. This is particularly evident at the time of changing the basic environmental conditions that climate change brings. When we talk about aquaculture in open systems, we should keep in mind the risks posed by the establishment of other activities in the aquatorium that share with the farming of organisms.

In the previous chapters, the focus of the interaction between mariculture and the environment was in relation to the changes that farming itself introduces, to the ecosystem in which farming takes place. Mariculture, however, is also an economic activity of food production. When we talk about aquaculture in open systems, we should keep in mind the risks posed by the establishment of other activities in the aquatorium that are shared with the farming of organisms. **It is particularly important to ensure that the risk of disease and poisoning of cultivated organisms and/ or humans consuming the cultivated organisms is reduced.** In this sense, integrated management and spatial planning of space use should identify possible risks and interactions that will result in risks arising from the use of the same space. Risk reduction or its complete elimination can be established by obligations in future interventions that include the **regulation of wastewater and sewage treatment** that affects cultivation areas. **Measures** should also be introduced **to reduce the potential risks of maritime accidents or leaching of contaminated soil** (areas of high intensity of non-organic agricultural production or industrial areas with risks of soil contamination).

Case study - "offshore" aquaculture

The term "offshore" aquaculture means farming in areas of the sea characterized by severe oceanographic conditions, strong currents, waves and exposure to weather. In order for the construction of a farming site in such difficult conditions to be profitable, it must have certain advantages such as larger areas of farming sites that do not interfere with tourist or traffic facilities, distance from coastal pollution, reduced environmental impact due to higher currents and sea depths and similar. Offshore farming requires special technology, maintenance boats that can withstand harsher sea conditions, special anchorages, firmer equipment and similar. To reduce costs, offshore farming is often planned in combination with the construction of renewable energy plants, such as wind farms or wave power plants. Areas where wind turbine towers are located are exempt from maritime traffic for safety reasons and it makes sense to use the same area for aquaculture. In addition, wind turbine towers and foundations can be used as supports for growing structures. Abandoned oil or gas platforms can also be used for offshore farming. Once they are no longer used, the cost of dismantling and removing them is several million euros. As there is no fishing around the platforms due to safety conditions, they themselves turn into artificial reefs that abound in wildlife and become a kind of marine protected area.

To select a location for offshore farming, it is necessary to know the meteorological and oceanographic conditions, seabed characteristics, distance of the center for reception and processing of aquaculture products, maritime traffic routes, fishing areas and several other technical, social, political and environmental factors. The frequency of high waves has an impact on the availability of the farm and the number of days in which certain activities can be performed on the farm. The catch for shellfish is particularly sensitive. Market entry requires a certain continuity, which can be disrupted by frequent strong winds. If it is a seasonal phenomenon, this should be kept in mind when designing a shellfish farming strategy in a particular area.

The advantages of offshore cultivation are better water quality, less coliform bacteria and pollution, fewer parasites and diseases that infect shellfish, less fouling, less predators (gilthead bream). Sea currents bring more food to shellfish and their growth is faster, except when the flow rate exceeds a certain threshold and reduces the pressure difference between the inlet and outlet siphon of shellfish. High waves can cause shellfish losses, and in oysters shell damage and mortality.

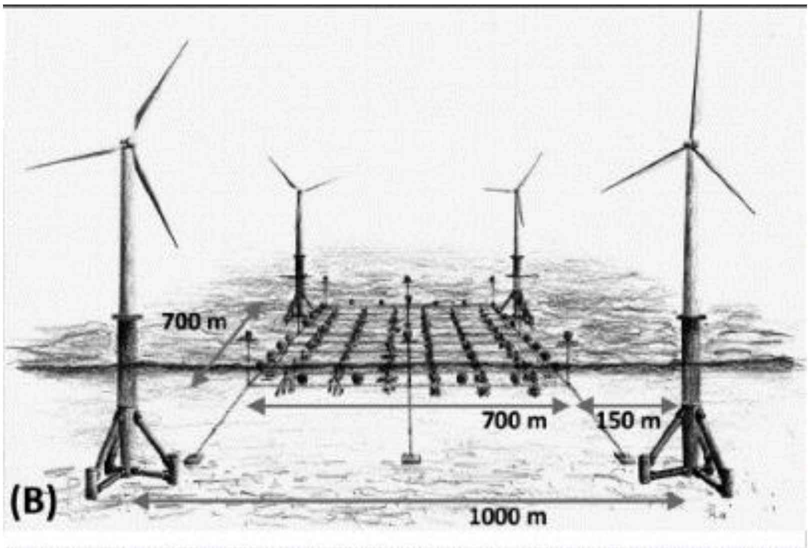


Figure 15. Conceptual design of offshore shellfish farming between wind turbine towers (Source: Buck et al.; 2012)

Case study - Construction of oyster reefs due to habitat restoration

In the US, there is the NOAA association (National Oceanic and Atmospheric Administration) which has an oyster reef restoration project (Oyster Reef Habitat). The project funded the construction of over 70 reefs in 15 U.S. states. Cultivated oysters are used as food, but are also planted in a way that creates habitats for other species, improves water quality by filtration and protects the coast from waves and storms. A project called Living Breakwaters (https://www.billionoysterproject.org/living-breakwaters) has started in Staten Island (New York), which aims to protect the coast from waves, create a marine habitat and a cleaner environment.

Figure 16. Construction of natural habitats

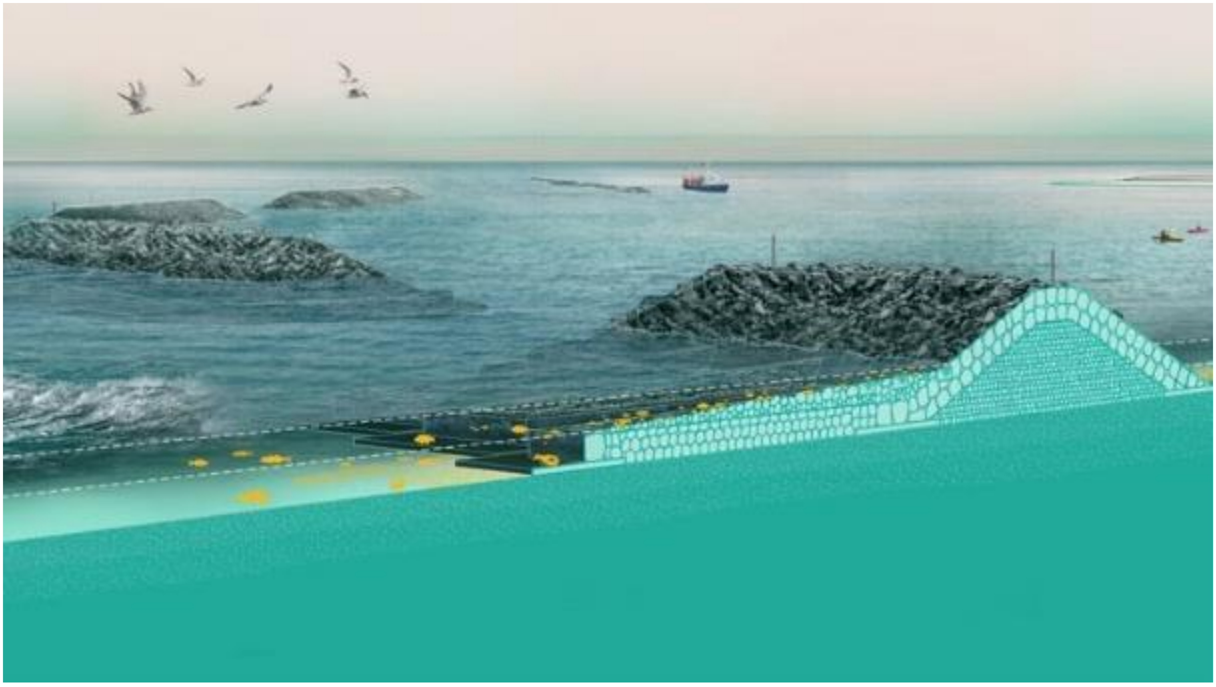


Figure 17. Construction of artificial habitats

This project is part of a larger "One Billion Oysters" project that aims to farm 1 billion oysters in the sea around New York. So far, they have created 14 reefs and cultivated 14 million oysters. Only one adult oyster can filter up to 200 liters of seawater per day. Oysters used to be much more numerous in the wild, but as people hunted them, their numbers were drastically reduced.

In some areas (Zadar County, Source: https://www.msp-platform.eu/story-1-croatia-aquaculture-and-tourism#overlay-context=story-2-united-kingdom-aquaculture-and-tourism), a negative attitude towards aquaculture was created due to the spread of unpleasant odors from the fish reception and processing facility. In addition, due to limited space on the coast, fish-loading trucks passed part of the promenade during the day when most tourists were present. A new strategy for the development of aquaculture in the county has been developed, with certain development zones.

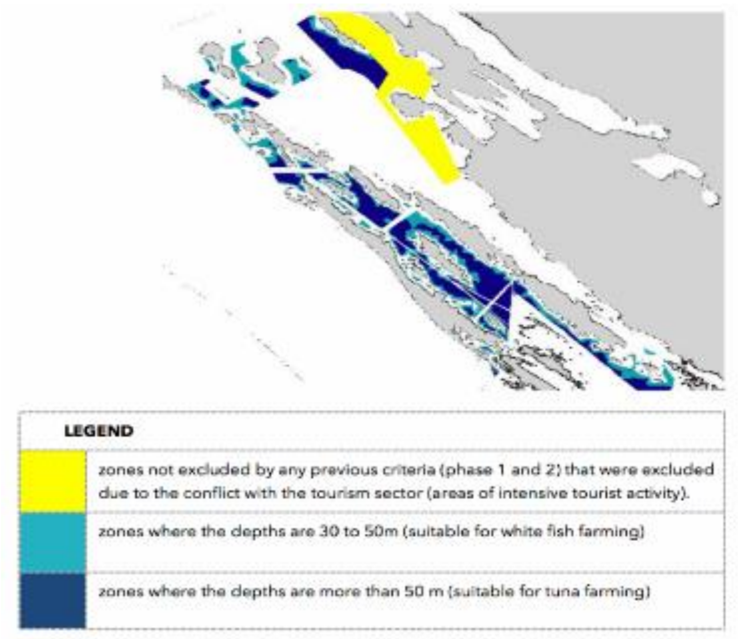


Figure 18. Aquaculture development zones in Zadar County

14. CONCLUSION

Demographic trends and the course of civilization have resulted in an increase in conflicts in the coastal belt. The Integrated Coastal Zone Management Program proposes zoning as the most acceptable approach to mitigate or avoid conflicts between traditional and potential users. The zoning or designation of mariculture areas must be in accordance with the Ordinance on the criteria for the suitability of parts of the maritime domain for fish farming and other marine organisms. Mariculture zone or area is a territorially demarcated area defined by the following content:

1. Preliminary or preparatory actions:

- Identification of locations suitable for cultivation
- Determination of zero condition at potential locations
- Determining the possible available coastline for the necessary coastal infrastructure
- Assessment of possible production in the zone according to the criteria of the law of minimum.

2. Mariculture control consisting of:

- Monitoring program which, according to the Law on Marine Fisheries, must be prescribed by the Minister
- Border measures of the situation in or outside farming location
- Corrective measures and mechanisms for their implementation.

3. Monitoring the adverse impact of other activities on mariculture

- Wastewater control in the zone
- Control of soil emissions in the zone (pesticides and fertilizers)
- Sanitary control of the sea.

This last point is especially important for shellfish farms.

Considering all the above, there are open topics that need to be discussed, and they can contribute to a significant reduction in the risk to mariculture itself as well as to the impact of mariculture on the environment.

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