Establishing the Suitability of the Agigea - Eforie Area for Designation as Allocated Zone for Aquaculture (AZA) and for Unlocking the Potentiality of Mariculture in Romania *(Victor Niță, Fabio Massa, Linda Fourdain, Magda-Ioana Nenciu)*	**"Cercetări Marine" Issue no. 50** **Pages 152 - 173**	**2020**

ESTABLISHING THE SUITABILITY OF THE AGIGEA - EFORIE AREA FOR DESIGNATION AS ALLOCATED ZONE FOR AQUACULTURE (AZA) AND FOR UNLOCKING THE POTENTIALITY OF MARICULTURE IN ROMANIA

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ABSTRACT

In the Black Sea, the development and expansion of marine aquaculture depends on the availability of space to develop this activity in a sustainable way, even more so in the case of the Romanian coast, characterized by hindering environmental conditions (very few sheltered areas, strong storms, variable salinity and temperature). Additionally, the extension and creation of new Natura 2000 sites was made by overlapping with pre-existing traditional economic activities, mainly fishing, but also other uses of the maritime space. Allocated zones for aquaculture (AZAs) are therefore considered as an essential tool towards the sustainable development of mariculture and they have a special role to play in maritime spatial planning in an area as limited and crowded by uses as the Romanian coast.

The level of interest of an area for developing aquaculture can be defined based on a Degree of Compatibility (DC). The DC allows the categorization of the study area into zones with the aim to define the suitability for the development of aquaculture activities. The analyzed parameters, the Suitability Index (SI) and the Weighting Factor (K) applied to each parameter considered will depend on the socio-economic context and on the specificities of the study area.

One of the areas proposed for developing aquaculture at the Romanian coast is located in Agigea - Eforie. The pre-selection of this zone was made taking into account a series of parameters to indicate its suitability for aquaculture, of which we mention the absence of conflicts with other uses of maritime space, the absence of major land-based sources of pollution in the vicinity, appropriate water depth, substrate suitable for anchoring aquaculture facilities, existence of storm protection structures (southern dam of the port of Constanța).

The identification of an AZA results from zoning processes through participatory spatial planning, through which administrative bodies (in Romania, the National Agency for Fisheries and Aquaculture - NAFA) legally establish that certain spatial areas in a region have priority for the development of aquaculture. This would be the case of the Agigea - Eforie

area at the Romanian Black Sea coast, which meets all the prerequisites for developing aquaculture without causing pressure on the environment and, at the same time, being socially accepted by all users of the maritime space.
Key-Words: mariculture, allocated zones for aquaculture (AZAs), parameters, Degree of Compatibility (DC), suitability, employment opportunity, marine spatial planning

AIMS AND BACKGROUND

Aquaculture is one the fastest growing food-producing sectors in the world and is the main source of fish for human consumption, its contribution to world fish production growing continually (FAO, 2018; FAO, 2020). In particular, although not in a homogeneous way, aquaculture in Mediterranean and Black Sea riparian countries is an emerging sector and it is an important activity for coastal communities by contributing to food security, enhancing economic development, and by providing employment opportunities (Massa et al., 2017). Aquaculture is considered an essential element for the agenda on the European Union on Blue Growth (EC, 2014; EC, 2017). Suitable planning locations for aquaculture need to take into account other activities in the areas concerned, as it has been considered by the "Strategic Guidelines for the Sustainable Development of EU Aquaculture" one of the prerequisites for long-term sustainable development of aquaculture itself (EC, 2013).

Environmental factors have a decisive influence on the growth and development of all marine organisms, including cultured finfish or shellfish, so they are essential in any approach to the farming of these species (Zaharia et al., 2017). The North-Western coast of the Black Sea is characterized by wide environmental factors' fluctuations (Nicolaev et al., 2019), thus being challenging for any mariculture pursuit (Niță et al., 2019). The culture of marine organisms in the Romanian coastal area is conditioned by creating marine equipment that can withstand the hydrometeorological conditions specific to the Black Sea (Niță & Nenciu, 2020a).

Moreover, aquaculture endeavors at sea are strongly conditioned by other uses of the maritime space. At the Romanian coast, the extension and creation of new Natura 2000 sites was made by overlapping with pre-existing traditional economic activities (Nicolaev et al., 2018). In this context, allocated zones for aquaculture (AZAs) are therefore considered as an essential tool towards the sustainable development of mariculture and they have a special role to play in maritime spatial planning in an area as limited and crowded by uses as the Romanian coast. In order to support this process, the General Fisheries Commission of the Mediterranean (GFCM) of the Food and Agriculture Organization of United Nations (FAO) adopted a specific resolution (Res. GFCM/36/2012/1) to provide guidelines to the countries on allocated zones for aquaculture (AZA) (GFCM, 2012). The implementation of AZA, as well as the coordination among the different authorities involved in aquaculture and planning has been identified among the priorities during the

“High-level Conference towards Enhanced Cooperation on Black Sea Fisheries and Aquaculture“, held in Bucharest, Romania, in 2016 (Srour et al., 2016).

This paper aims to provide useful elements to unlock the potentiality of sustainable marine aquaculture on Romania’s coast located in the Agigea - Eforie area through the pre-identification of an AZA, considering the different farming systems and the interaction of aquaculture activities with the environment, social and economic aspects.

In order to assess this interaction among uses, in the frame of the MARSPLAN-BS Project (Spînu et al., 2017) a detailed analysis was performed. The focus area was the Eforie - Agigea zone, where the only aquaculture farm at the Romanian coast (MARICULTURA Ltd.) used to operate. A potential overlapping of activities in the area is represented by capture fisheries and aquaculture and commercial and touristic navigation, for continuous and seasonal intervals, respectively (Spînu et al., 2017). Another significant use of the maritime space is represented by military operations. marine protected areas (MPAs) interact with all sorts of activities in the zone, respectively: coastal protection works/activities, tourism and navigation, aquaculture and fisheries. Sketch Match is a modern method of spatial planning, developed by the Government Service for the Management of Coastal and Maritime Areas in the Netherlands (DLG). The process involves the organization of workshops in which representatives from all sectors of interest in the area actively participate, highlighting all the significant aspects, which are then actually drawn on the location map. Subsequent processing is done in GIS format, by overlapping all identified activities/uses (Spînu et al., 2017). Thus, a workshop was organized in November 2017 using maps of the Agigea - Eforie area. Participants were asked to draw on these maps the activities/zones they consider important for economic development and spatial planning, as well as areas that are vulnerable in terms of biodiversity or socio-economically. Two working groups were created, one focused on spatial planning and economic development and the other on natural capital and biodiversity, the participants being distributed according to their profile and expertise. The Sketch Match analysis performed for the Agigea - Eforie area (Romania) confirmed that aquaculture is an activity with great potential for future development, but the need to harmonize overlapping with other uses of maritime space must be taken into account, so that the designation of an allocated zone for aquaculture is a desirable long-term approach (Nițǎ & Nenciu, 2020a).

An AZA is a maritime area where the development of aquaculture takes precedence over other uses and will therefore be dedicated primarily to aquaculture (Sanchez-Jerez et al., 2016; Macias et al., 2019; Fourdain et al., 2019; GFCM, 2019). The identification of an AZA results from the zoning

processes through participatory spatial planning, through which administrative bodies (in Romania, NAFA) legally establish that certain spatial areas in a region have priority for the development of aquaculture. This would be the case of the Agigea - Eforie area, which meets all the prerequisites for developing aquaculture with a minimal impact on the environment and, at the same time, being socially accepted by all users of the maritime space.

The objective of this paper is to assess the level of interest of this area for developing aquaculture activities (cages for finfish), based on the Degree of Compatibility (DC) (Macias et al., 2019), and focus also on shellfish farming, given the fact that the proposed polygon is located in one of the three areas designated as suitable for shellfish exploitation and culture at the Romanian coast, according to national legislation (Ministry of Environment & Ministry of Agriculture and Rural Development, 2015) implementing the EU Shellfish Waters Directive No. 97/923 (EC, 2006).

EXPERIMENTAL

The study area pre-selected for potential establishment as AZA at the Romanian coast (Agigea - Eforie) was based on expert knowledge of its suitability for aquaculture development. The square-shaped polygon covers 4 km x 4 km (coordinates 44.0453, 28.7003; 44.0812, 28.7030; 44.0827, 28.6527; 44.0471, 28.6512) (Fig. 1). The methodology used to delineate the most appropriate zone for aquaculture development was to assess the level of interest and to estimate the DC of the pre-selected area (Del Castillo y Rey & Macias, 2006; Fourdain, 2017; Macias et al., 2019). The DC allows the categorization of the study area with the aim to define the suitability for the development of aquaculture activities.

Whereas this was the first attempt to perfom a pre-AZA assessment in Romania and the pre-selected polygon for AZA implementation does not have homogeneous oceanographic and environmental characteristics, the study considered two scenarios to determine the compatibility of the area both for shellfish and finfish farming, taking into account the slightly different environmental requirements of these activities.

This categorization was carried out considering the parameters explained below (Table 1). Each parameter has ranges or conditions assigned. A Suitability Index (SI) was established for each range of parameter considered in the study based on the available data. The SI can take four different values according to the potential influence of the range considered: -100 (exclusion criteria), -1 (unwise characteristic), 0 (moderate) or 1 (optimum characteristic). The Weighting Factor (K) ranges from 1 to 10 and the value assigned is directly proportional to the reliability and the importance of each parameter (Del Castillo y Rey & Macias, 2006).

The parameters used to calculate the DC for the Agigea - Eforie area are summarized in Table 1. The ranges and conditions considered for each parameter, as well as the SI and K were assigned for finfish (Del Castillo y Rey & Macias, 2006; Macias et al., 2019) and shellfish (Marino et al, 2020) farming. Regarding shellfish farming, the pre-selection was based on the fact that the proposed polygon is located in one of the three areas designated as suitable for shellfish exploitation and culture at the Romanian coast (EC, 2006; Joint Ministerial Order, 2015), and following expert opinion and stakeholder consultation. This consultative approach aimed to meet socio-economic and environmental requirements for the sustainable development of aquaculture.

Table 1. Parameters and ranges used for calculating the Degree of Compatibility for AZA designation focused on finfish farming (modified from *Del Castillo y Rey & Macias, 2006, and Macias et al., 2019).*

PARAMETER	LEVEL OF INTEREST		WEIGHTING FACTOR (K)
	Ranges and conditions	SI	
Uses compatibility	Incompatible zone	-100	10
	Limited zone	0	
	Compatible zone	1	
Depth	< 20 m	-100	7
	(< 8; > 40) (*)	-1	
	20-50 m (10-30 m) (*)	1	
	>50 m (8-10 m; 30-40 m) (*)	0	
Medium swell	> 3 m	-1	4
	< 1 m (0 - 3 m) (*)	0	
	1 - 3 m (< 0.2 m) (*)	1	
Extreme swell (storm)	> 6 m	-1	4
	3-6 m	0	
	< 3 m	1	
Average speed of currents	< 5 cm/s (< 0.02 > 0.5 cm/s) (*)	-1	8
	5 - 15 cm/s (0.02-0.5 cm/s) (*)	0	
	15 - 60 cm/s (0.03-1 cm/s) (*)	1	
	> 60 cm/s	-1	
Water Quality Index (WQI)	WQI ≤ 3.33	-1	5
	3.33 < WQI ≤ 6.66	0	
	WQI > 6.66	1	
Bionomic (ecosystem value)	High	-1	6
	Medium	0	
	Low	1	
Seabed	Rock or mud	-1	1
	Rock and sand	0	
	Sand or gravel	1	
Dissolved Oxygen	< 5 mg/l (**)	-1	7
	5-7 mg/l (**)	0	
	> 7 mg/l (**)	1	

Temperature	< 5; > 28°C (**)	-1	7
	5-10; > 24-28°C (**)	0	
	10-24°C (**)	1	
Salinity	< 12; > 40‰ (**)	-1	6
	12-40‰ (**)	0	
Chlorophyll *a*	<0.5 µg/l (**)	-1	5
	> 0.5 < 10; > 20 < 50 µg/l (**)	0	
	10-20 µg/l (**)	1	

Notes:

(*) The level of interest for shellfish is indicated in blue text (Marino et al., 2020) and it was used for the determination of the physical area within the AZA suitable for shellfish farming.

(**) These data are according to Shellfish Waters Directive 2006/113/EC (EC, 2006)

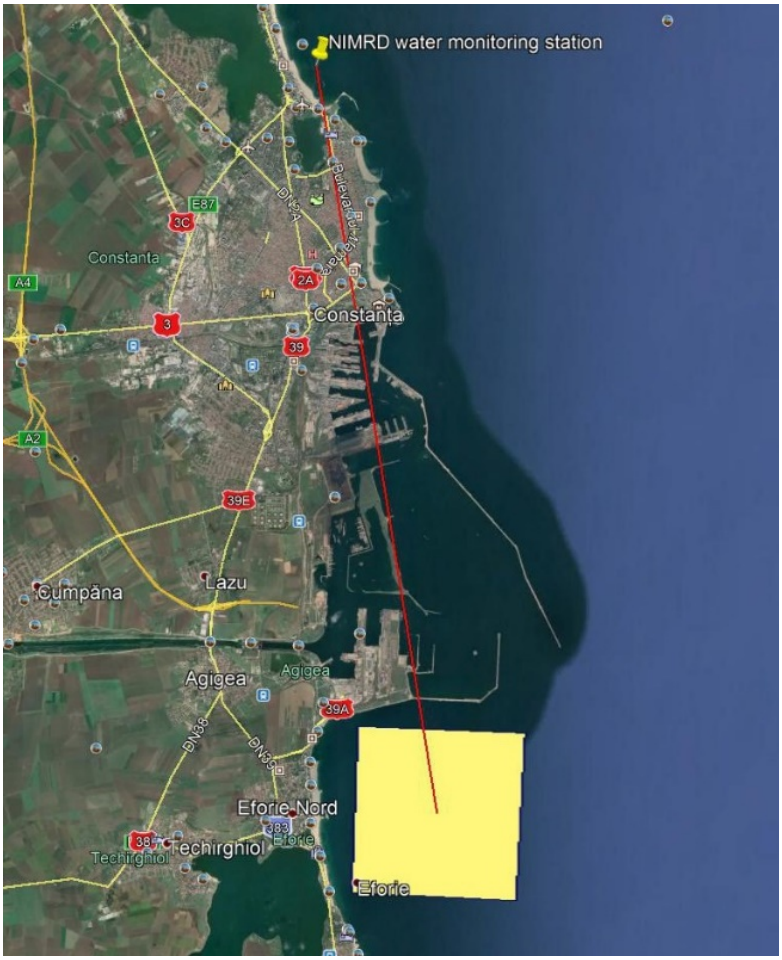

Fig. 1. The location of the pre-selected polygon (Agigea - Eforie area, Romania) in relation to NIMRD's monitoring station *(data source: Google Earth, 2020)*.

The **compatibility** of aquaculture with other uses of the maritime space in the Agigea - Eforie area was assessed as a follow-up of the spatial analysis and stakeholder consultation performed in the frame of the MARSPLAN BS Project (Spînu et al., 2017).

Water depth in the area was retrieved from the EMODnet Bathimetry portal (2020).

Regarding the **wave regime**, the **medium swell** in the proposed polygon was calculated from the iSWIM model (Integrated Service for Water Quality Monitoring in Mamaia Bay, 2020) developed by NIMRD. The **extreme swell** (during storms) was derived using a Significant Wave Height (SWH) equation (Niculescu, 2019).

The **average speed of currents** in the Agigea - Eforie area was estimated from the iSWIM model (iSWIM, 2020).

Estimation of WQI for finfish farming

The parameters used to estimate WQI were: dissolved oxygen (DO), temperature (T), salinity (S), total suspended solids (TSS), chlorophyll *a* (Chl *a*) and nitrites (NO_2^-) (Lazăr, 2020). The values (except for TSS) were measured from NIMRD's monitoring station in Mamaia, located 20 km north of the proposed AZA (Fig. 1), covering almost daily measurements for the period 2009-2019, thus having a high continuity degree. For TSS, the only values available were from samples collected from Eforie 20 m depth, during seasonal surveys at sea (Lazăr, 2020).

In order to calculate the WQI for the proposed area, the following equation was used (after Del Castillo y Rey & Macias, 2006):

$$\text{WQI} = \frac{K\ x\ 10 - f_1(O_2) - f_2(T) - f_3(S) - f_4(TSS) - f_5(Chl_a) - f_6(NO_2^-)}{K}$$

Where:

K = number of variables used for study

$f_1(O_2)$ = function for the variable Dissolved Oxygen

The ranges used to assign values for Dissolved Oxygen were:

10	if	iO_2 min. ≤ 3 mg/l
2.5 x (7 – O_2 min.)		3 mg/l ≤ O_2 min. ≤ 7 mg/l
0		O_2 min. ≥ 7 mg/l

The data used for calculation covers a period of 10 years, between 2009 and 2019, and the value considered represents the lowest dissolved oxygen in the area in the analyzed time series.

$f_2(T)$ = function for the variable Temperature

The ranges used to assign values for seawater temperature were:

10	if	T min. < 10°C
20 – T min.		10°C ≤ T min. ≤ 20°C
0		20°C < T min.

The data analyzed cover a period of 10 years, between 2009 and 2019. The value used for calculation represents the minimum seawater temperature recorded in the area during that time frame.

$f_3\,(S)$ = function for the variable Salinity

Whereas salinity is a rather constant parameter, only with seasonal oscillations (Macias et al., 2019), and mussels are an euryhaline species, the formula used for this variable was:

$$f_3\,(S) = \frac{\sigma\ X\ 10}{\bar{x}}$$

Where: σ = standard deviation of values of salinity for the period 2009 - 2019.

$\bar{x}$ = average salinity

$f_4\,(TSS)$ = function for the variable Total Suspended Solids (TSS)

For Total Suspended Solids (TSS), a natural logarithm of the maximum value for the period 2009 - 2019 was calculated:

$$f_4\,(TSS) = \text{Ln}\,(\text{TSS}_{\text{max.}})$$

$f_5\,(Chl_a)$ = function for the variable Chlorophyll *a*

The ranges used to assign values for chlorophyll *a* were:

10	if	$\text{Chl}_{a\ \text{max.}} \geq 15$ µg/l
$\frac{Chl_{a\ max.}}{1.5}$		$\text{Chl}_{a\ \text{max.}} < 15$ µg/l

As an estimate of phytoplankton biomass in the area, the maximum value for chlorophyll *a* (Vasiliu & Boicenco, 2009-2019) was used.

$f_6\,(NO_2{-})$ = function for the variable Nitrites (NO_2^-)

The ranges used to assign values for nitrites were:

10	if	$NO_2^-{}_{\text{max.}} \geq 10$ µM
$NO_2^-{}_{\text{max.}}$		$NO_2^-{}_{\text{max.}} < 10$ µM

The value used for nitrite function calculation represents the maximum concentration of nitrites recorded in the area during 2009 - 2019.

Quality estimation required for shellfish waters

The EU Shellfish Waters Directive (EC, 2006) was implemented in Romania based on national legislation consisting of technical methods regarding the water quality for mollusks (Romanian Government, 2006). NIMRD "Grigore Antipa" has implemented a monitoring system of coastal waters, sediments and mollusks according to the requirements of the EU Shellfish Waters Directive (EC, 2006). In 2015, by a Joint Ministerial Order (Ministry of Environment & Ministry of Agriculture and Rural Development, 2015), one of the four initially designated areas for exploitation and culture of shellfish at the Romanian coast was removed due to its closeness to the Danube outflow, with salinity values below the minimum recommended threshold by the above mentioned legislation (12‰).

Currently, at the Romanian coast, there are three designated areas suitable for shellfish exploitation and culture, the proposed AZA polygon being included in the southernmost zone (Agigea - Mangalia).

The parameters considered to assess the water quality for shellfish farming were: dissolved oxygen (DO), temperature (T), salinity (S) and chlorophyll *a* (Chl_a).

The **bionomic assessment** of the proposed AZA was performed by expert judgement, considering the overall ecosystem value of the Agigea - Eforie area, with regard to sediment type, associated biocoenoses and biodiversity in general.

The **seabed characteristics** of the Agigea - Eforie area were determined using maps of the substrate of the closest already mapped area, namely the Site of Community Importance (SCI) Submerged Beach from Eforie North - Eforie South, by extrapolation (Management Plan of the Eforie North - Eforie South Submerged Beach - ROSCI0197, 2016).

Degree of Compatibility estimation

Finally, in order to quantify the DC of the proposed AZA for each parameter considered in Table 1, the following formula was applied (Del Castillo y Rey & Macias, 2006):

$$DC = 100 \text{ x} \frac{\sum_i^n (K_i \ _X \ SI_i)}{\sum_i^n K_i}$$

Where:

DC = Degree of Compatibility

K = Weighting Factor applied to each parameter considered

SI = Suitability Index applied in the area according to the potential influence of each parameter

i = Parameter

n = Number of parameters

According to the DC estimation, the result could be classified and delineated according to the following table (Table 2):

Table 2. Degree of Compatibility for assigning an AZA
(after Del Castillo y Rey & Macias, 2006; Macias et al., 2019).

Value	Final Assessment	Explanation
-10.000 < DC < -30	Low DC	Areas unsuitable for aquaculture activities: administrative and/or environmental incompatibilities
-30 ≤ DC ≤ 30	Medium DC	Areas for aquaculture activities with particular regulations and/or restrictions, stemming from interactions with other uses, administrative competencies or characteristics of the environment, that will have to be taken into consideration for the establishment and management of AZAs
30 < DC < 100	High DC	Areas suitable for aquaculture activities: no interference with other uses and good environmental conditions;

RESULTS AND DISCUSSION

Uses compatibility = compatible zone

Analyzing all the activities in the area, corroborated with stakeholder consultation, it can be concluded that in the Agigea - Eforie North area there are no potential conflicts with other uses of the maritime space, the selected area for potential AZA designation not overlapping with maritime traffic routes, fishing areas, military areas or other types of activities. Also, no possible sources of contamination were identified nearby, the Constanța South Wastewater Treatment Plant discharging inside the Constanța Port (Niță & Nenciu, 2020b). Consequently, for this parameter a Suitability Index = 1 was assigned.

The uses of the maritime and coastal space in the Agigea - Eforie area are graphically represented on the map below (Fig. 2).

Depth

Based on the bathimetric map of the area (Fig. 3), the water depth in many parts of the proposed AZA is estimated to be less than 20 m, which results in a Suitability Index of -100 in the case of finfish and -1 for shellfish farming.

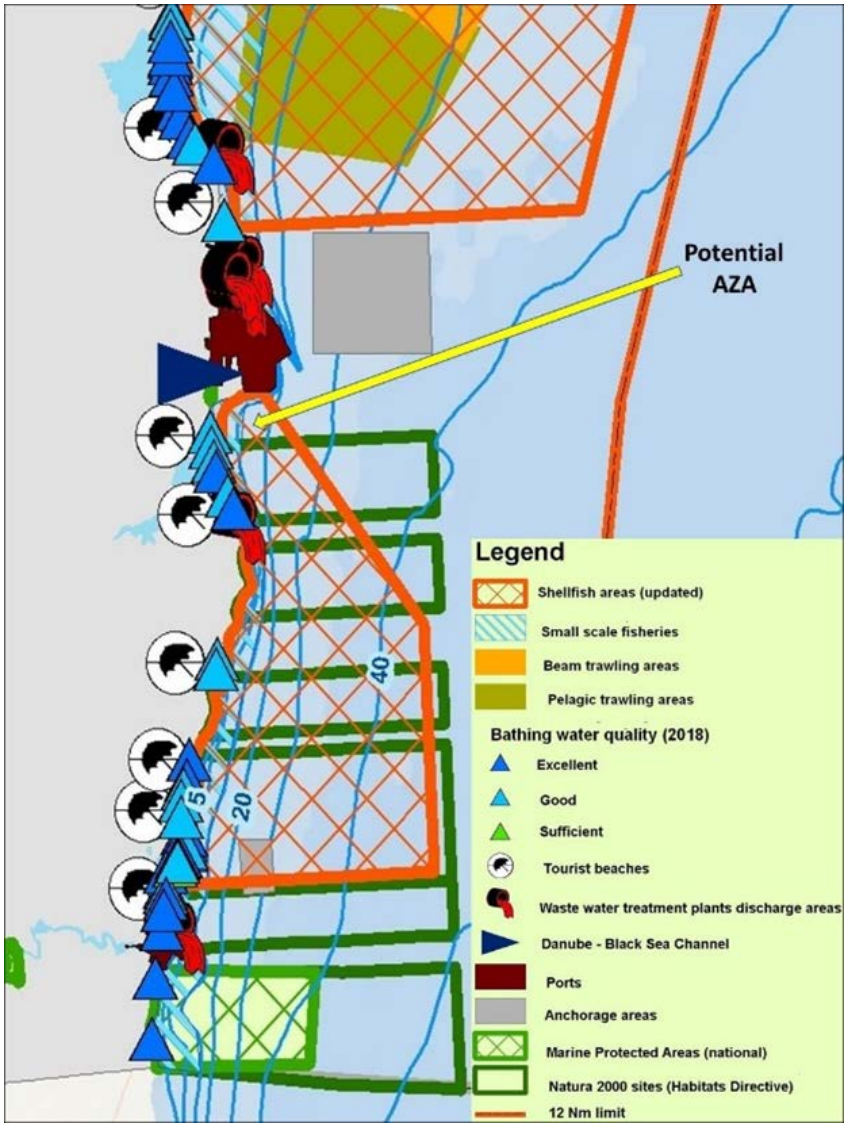

Fig. 2. Uses of the maritime and coastal space in the Agigea - Eforie area, Romania *(after Alina Spînu, in Niță & Nenciu, 2020b)*.

This could be considered a limitation for the finfish cage culture in terms of interaction with the environment. So, in this respect, a distinction needs to be done in the area in which aquaculture modules will be planned for the installation of cages. Water depth less than 20 meters should be avoided and, between 8 - 20 meters depth, the area should be considered only for the farming of shellfish (see Table 1).

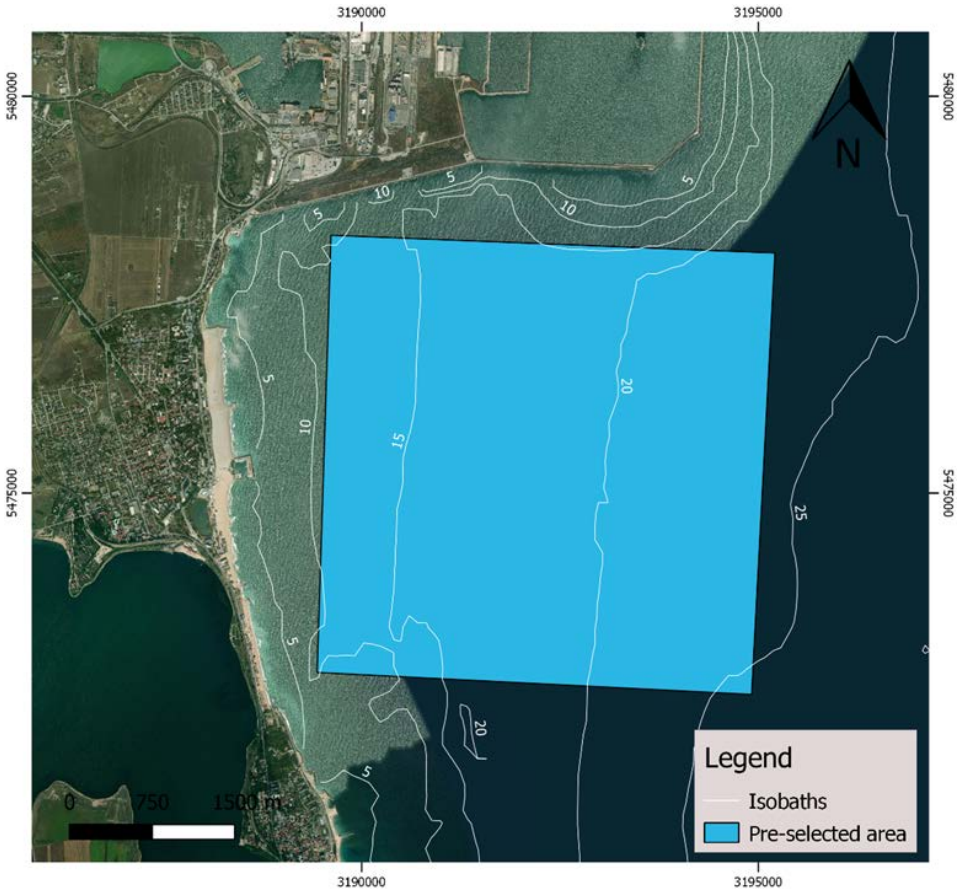

Fig. 3. Bathimeric map of the Agigea - Eforie area, Romania
(data source: EMODnet Bathimetry, 2020).

Medium swell

Regarding the wave regime, the average wave height derived from the iSWIM model is 1.16 m (Fig. 4), resulting in a Suitability Index of 1.

Extreme swell (storm)

The extreme swell during storms was calculated to maximum 5.23 m (Niculescu, 2019). Consequently, for this parameter the area scores a Suitability Index of 0.

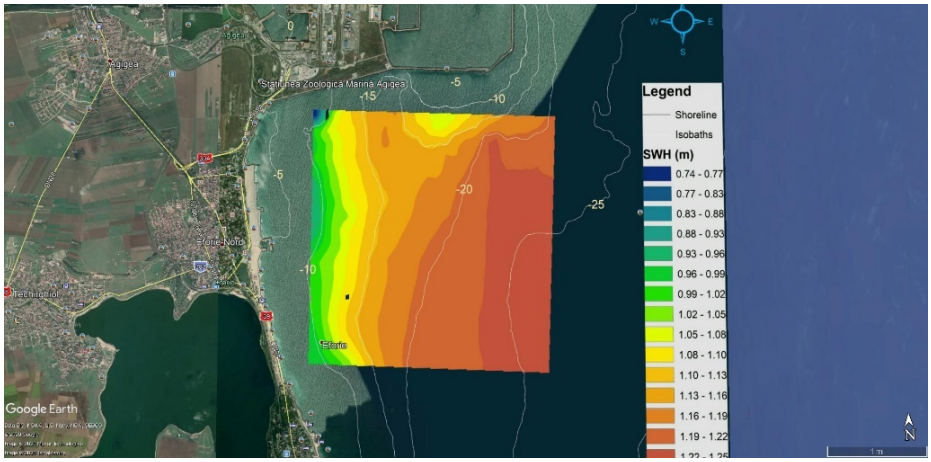

Fig. 4. Wave regime - medium swell (Significant Wave Height - SWH) in the Agigea - Eforie area, Romania *(data source: iSWIM, 2020)*.

Average speed of currents

Currents in the Agigea - Eforie area recorded an average speed estimated from the iSWIM model ranging between 5 - 15 cm/s (Fig. 5), thus the Suitability Index is 0.

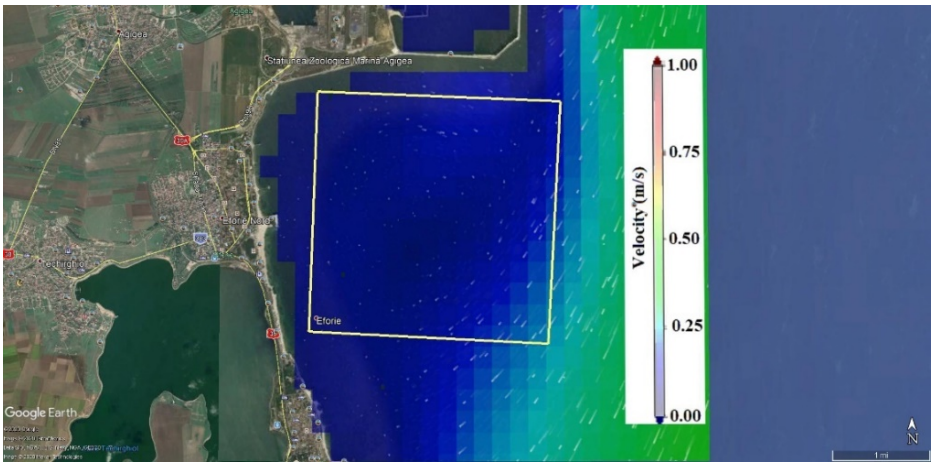

Fig. 5. Currents velocity in the Agigea - Eforie area, Romania *(data source: iSWIM, 2020)*.

Water Quality Index (WQI)

The parameters used to estimate WQI were: dissolved oxygen (DO), temperature (T), salinity (S), total suspended solids (TSS), chlorophyll *a* (Chl *a*) and nitrites (NO_2^-) (Del Castillo y Rey & Macias, 2006).

The minimum value of DO in the area was 4.67 mg/l, recorded in August 2018. Applying the equation, the value of $f_1(O_2)$ = 5.82.

Regarding seawater temperature, the minimum value in the area was -3°C, recorded in February 2012. As such, the value for $f_2\ (T)$ = 10.

For salinity, using the standard deviation of 2.29 PSU and the average of 15.45 PSU in the past 10 years of data records, the result for $f_3\ (S)$ = 1.48.

For Total Suspended Solids (TSS), the result of the natural logarithm of the maximum value (30.8 mg/l, recorded in July 2018) was 3.42.

As an estimate of phytoplankton biomass in the area, the maximum value for chlorophyll *a* was 58.47µg/l, recorded in March 2010, consequently $f_5\ (Chl_a)$ was 10.

For nitrites, the maximum value recorded in the area was 7.12 µM, measured in November 2019. This value was used in the equation as it was lower than 10 µM.

Ultimately, applying the WQI equation (Del Castillo y Rey & Macias, 2006), the result for the Agigea - Eforie area was 3.69, which results in a Suitability Index of 0 for this parameter.

$$\text{WQI} = \frac{6\ x\ 10 - 5.82 - \ 10 - \ 1.48 - \ 3.42 - \ 10 - \ 7.12}{6} = \ 3.69$$

Bionomic (ecosystem value)

Detailed data regarding the abundance of bivalves, as well as the number of species/area unit (biodiversity) in the proposed AZA are not available. As such, an accurate calculation as per Del Castillo y Rey & Macias (2006) could not be performed.

However, the authors indicate that the decisive aspects for a high ecosystem value are marine phanerogams and sea caves, which is not the case for the analyzed area, where they are absent. From the conservative value point of view, the Eforie area is the only place in Romania where there are significant populations of the psamobiont bivalves *Donacilla cornea* and *Donax trunculus* (Management Plan of the Eforie North - Eforie South Submerged Beach, 2016) (Fig. 6), but the operation of an aquaculture farm would not affect in any way these mid-littoral species. Consequently, by expert judgement, we assigned a Suitability Index of 1 for this parameter.

Whereas part of the proposed AZA overlaps ROSCI0197 Eforie North-Eforie South Submerged Beach, the seabed characteristics were assessed as sand and rock, corresponding to the Natura 2000 habitat types mapped according to the Management Plan of SCI, namely 1110 - Sandbanks which are slightly covered by sea water all the time, 1140 - Mudflats and sandflats not covered by seawater at low tide and 1170-Reefs (Fig. 7). For this parameter, the assigned Suitability Index used in calculations was 0.

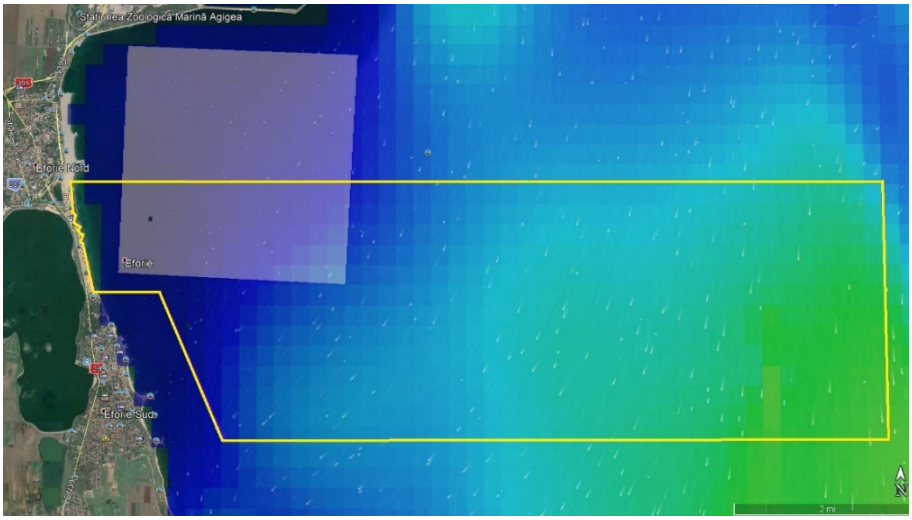

Fig. 6. Location of the proposed AZA (Agigea - Eforie) in relation to ROSCI0197 Eforie North - Eforie South Submerged Beach (yellow perimeter) and currents *(data source: natura2000.eea.europa.eu; iSWIM, 2020)*.

Seabed

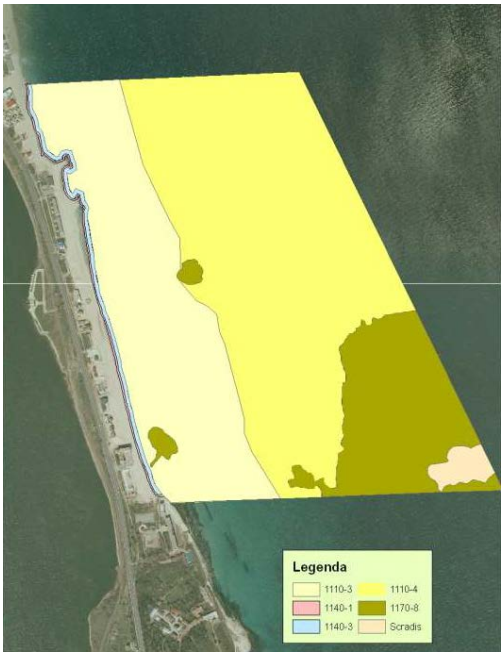

Fig. 7. Natura 2000 habitat types in ROSCI0197 Eforie North - Eforie South Submerged Beach *(source: Management Plan of the Eforie North - Eforie South Submerged Beach, 2016)*.

Degree of Compatibility

Finfish

The integration of the parameters (Table 1) during the evaluation criteria and multi-criteria analysis allowed the identification of 2 different zones for finfish farming within the pre-selected area studied (Fig. 8): an unsuitable area (-10 000 < DC < -30) and a suitable area (30 < DC < 100). Therefore, according to the DC estimated, the most suitable area for finfish farming is the one located in the eastern part, with a value of 65.85.

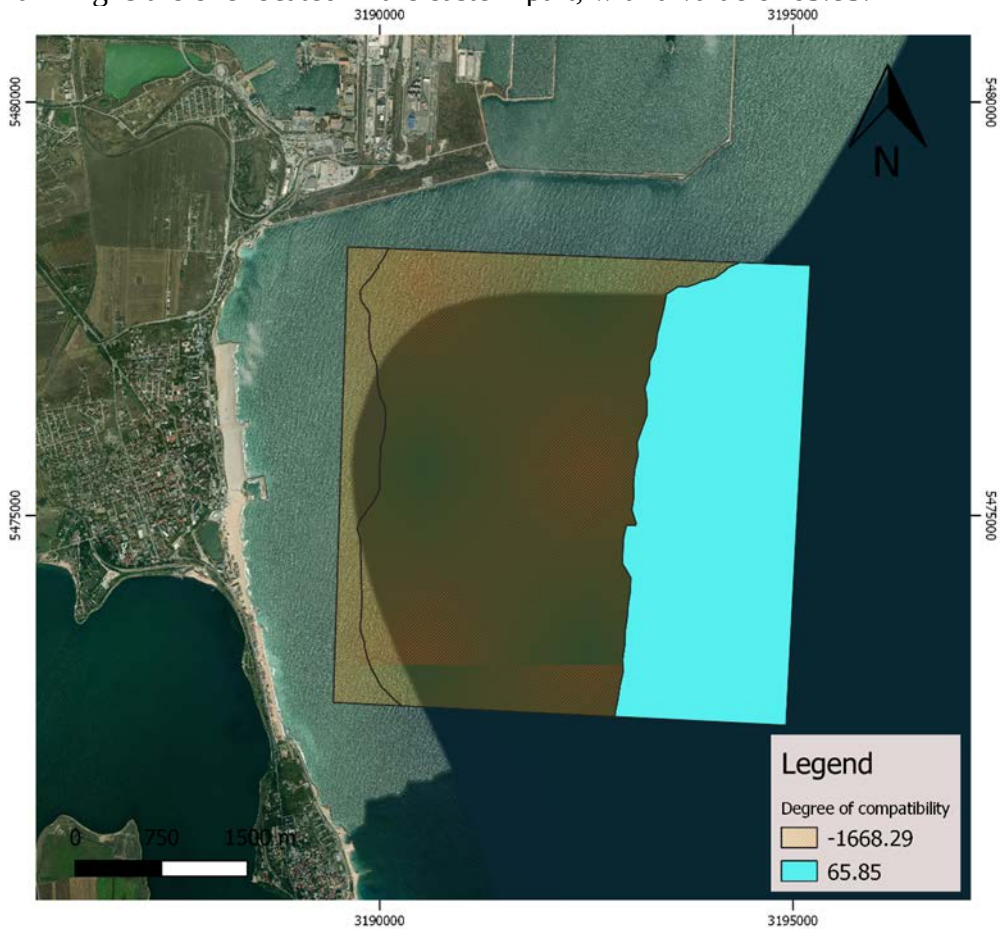

Fig. 8. Delineation of compatible zones for finfish farming in the Agigea-Eforie area (most suitable area in blue).

Shellfish

After obtaining the scores of each parameter's range and estimating the DC of the pre-selected area, the most suitable zone for shellfish was identified (Fig. 9). Thus, according to our results, shellfish farming should be developed in most part of the study area, which corresponds to a DC of 31.48. Due to the small depth of the water closer to the shore in the studied area, the

northwestern and the southwestern parts of the polygon, with a DC of 5.55, are considered areas for shellfish farming with limitations.

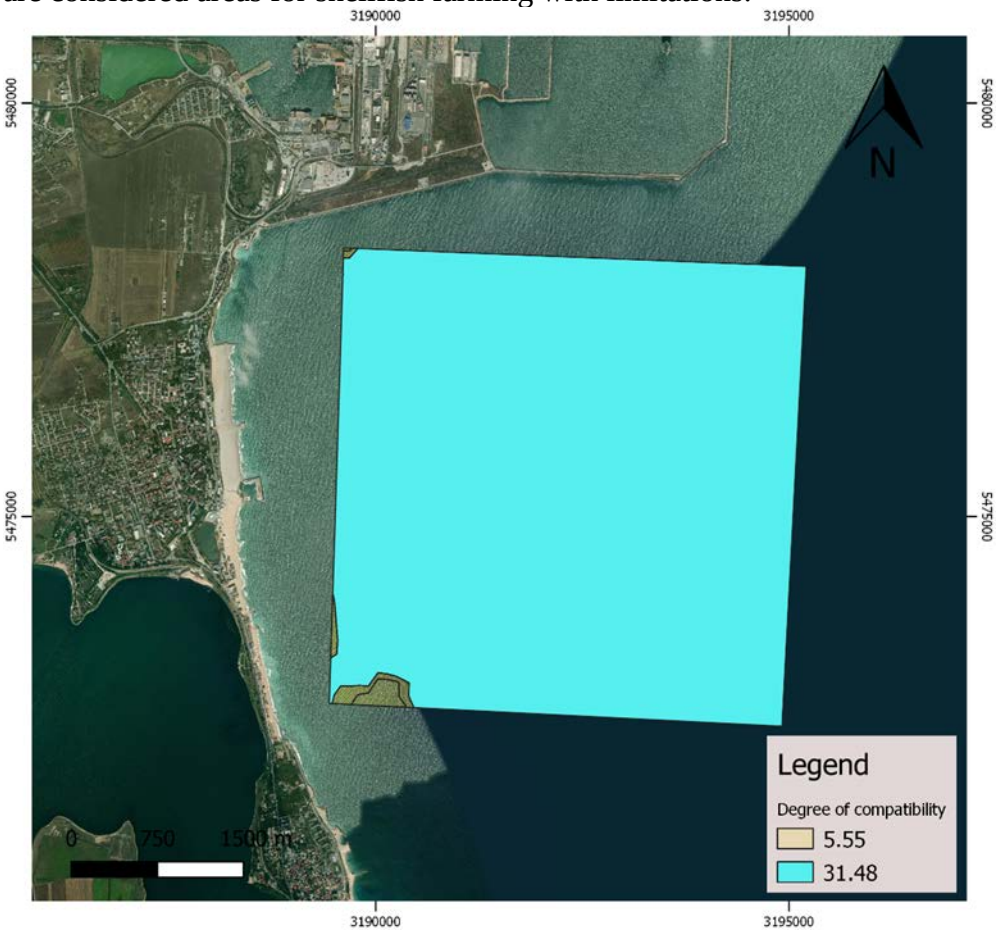

Fig. 9. Delineation of compatible zones for shellfish farming in the Agigea-Eforie area (most suitable area in blue).

CONCLUSIONS

Although the range of the DC changes within the pre-selected polygon, the results presented in this study allowed to identify the potential AZA at the Romanian coast, located in Agigea - Eforie, taking into account the available historical environmental data and scientific knowledge.

As such, the area is suitable for intensive finfish farming at sea at depths greater than 20 m (covering about one third of the pre-selected polygon) (Fig. 8), while shellfish farming could be developed within the whole area in Agigea - Eforie, with particular attention in the shallower zone (Fig. 9). For what concerns the farming of shellfish, further analysis will be necessary in order to define specificities of water quality and food safety.

For the concerned area, the main limitative factors that resulted in lower SI are all related to environmental constraints, of particular importance being seawater temperature and extreme swell. A negative temperature in winter could completely compromise the shellfish or finfish harvest; extreme storms also occurring in winter may negatively affect any shellfish long-line installation or fish cage, but the southern dam of the Constanta Port creates an artificial shelter. Thus, these two should be considered as the main risk factors. Water depth, currents, salinity, substrate type are not optimal, yet suitable enough to allow the construction of an operational aquaculture farm, for the anchorage of long-line installations or cages. The high content in chlorophyll a, on the other hand, is a confirmation of the abundance of food (phytoplankton biomass) for the cultured organisms (in case of shellfish farming).

Regarding the uses compatibility, corroborated with stakeholder consultation, it can be concluded that in the Agigea - Eforie North area there are no potential conflicts with other uses of the maritime space, the selected area for potential AZA designation not overlapping with maritime traffic routes, fishing areas, military areas or other types of activities. With reference to Marine Protected Areas, even though part of the proposed AZA overlaps ROSCI0197 Eforie North - Eforie South Submerged Beach, the potential influence of this activity on the protected area is negligible, whereas there are no sensitive species or habitats that could be affected by potential effluents from an aquaculture farm. Moreover, no possible sources of contamination were identified nearby, and possible interactions and synergies could also be considered in terms of conservation and contribution to the ecosystem provisions (Le Gouvello et al., 2017; Gentry et al., 2020).

Moreover, the implementation of Integrated Multitrophic Aquaculture (IMTA) could be considered in the Agigea - Eforie area. This activity considers the implementation of the cultivation of different species (e.g finfish, mollusks and algae) in proximity in a more sustainable way, taking into consideration the different trophic levels. IMTA can improve the sustainability of the aquaculture activity itself, while also improving its social acceptability (Chopin, 2013).

Overall, the analysis performed indicates that the Agigea - Eforie area has been pre-identified as suitable for aquaculture development. However, the area is not homogeneous and part of it could be more suitable for the farming of shellfish, while the deeper area for finfish.

The zoning process for the formal and official establishment of AZAs should follow a participatory approach, be transparent, coordinated by the responsible authority (NAFA) and carried out in cooperation with the different authorities involved in aquaculture licensing and leasing procedures and monitoring (Romanian National Sanitary-Veterinary and Food Safety Authority - NSVFSA, Romanian Waters National Administration etc.). Once

established, the AZA should be based on legal and regulatory provisions, and ultimately integrated into the national legislation.

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