Fostering the Development of Romanian Marine Aquaculture: Testing Feasible Species and Identifying Potential Allocated Zones for Finfish Cage Farming

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BOOSTING BIOMASS GAIN AND MEAT QUALITY OF RAINBOW TROUT REARED IN BLACK SEA WATER

CONTEXT

- In the Black Sea area, rainbow trout [*Oncorhynchus mykiss* (Walbaum, 1792)] aquaculture in floating cages dates back to early 1970s in Turkey and developed extensively in the 1990s.

- In the early 1980s, there were attempts by NIMRD to rear rainbow trout in marine water, but the main drawback that prevented the application of the technology was the absence of formulated high-quality feed for large scale cultivation, resulting in high operational costs.

- In the context of an increasing interest of economic operators to engage in sea cage farming at the Romanian coast, **our research aimed at testing the adaptation of rainbow trout to the Black Sea marine environment, determining its growth rate, establishing the optimal size of specimens for transfer to salt water, and increasing meat quality**.

MATERIALS & METHODS (1)

Fish collection and acclimation

- The experiment was performed for 7 months, between October and April. The *O. mykiss* individuals were transferred from a mountain trout farm located in the Prahova County and transported using a temperature-controlled van, maintaining water temperature at 10°C. Upon arrival to NIMRD's aquaculture laboratory, the fish were weighed and separated in two batches according to their size (Tank 1 - 30 large fish, mean biomass approximately 300 g; Tank 2 - 30 small fish, mean biomass 180 g), and placed in two fiberglass tanks.

- At the moment of transfer, the tanks were filled with freshwater, which was gradually replaced by seawater within 24 hours, reaching a salinity of 14 PSU and a temperature of 20°C.

MATERIALS & METHODS (2)

Feeding protocol

- During the experimental period, two types of feed were provided to the fish, both produced by Skretting, namely Focus Salmo 3P F (7 mm extruded floating pellets) for the large batch and Optiline 2P F (3 mm extruded floating pellets) for the small batch, at a calculated food ratio of 2% of the fish biomass.

- After 4 months of growth, both batches were fed with the astaxanthin-enriched Focus Salmo 3P F pellets, which resulted in the final pink colorization of the flesh.

MATERIALS & METHODS (3)

Calculation of growth parameters

- Weight and length measurements were made monthly.
- Feed Conversion Ratios (FCR), Specific Growth Rates (SGR%/day) and Fulton's Condition Factor (K) were determined for the two batches.

Meat quality analysis

- Upon completion of the experimental period, a comparative analysis of the proximate composition of the trout meat was performed: one sample reared in saltwater for seven months and one sample reared in the mountain trout farm, both in two replicates.

RESULTS & DISCUSSIONS (1)

Overall adaptation

- All specimens in both batches displayed normal swimming behaviour and began feeding immediately as pellets were administered. No mortalities were recorded during the experiment.

T, S, DO and pH were constantly monitored, showing no significant variations among the two experimental batches ($p \geq 0.05$).

Taking into account the differential solubility of oxygen, being much lower in seawater than in freshwater, the risk of **low DO levels** was avoided by constantly ensuring a sufficient water flow and additional aeration.

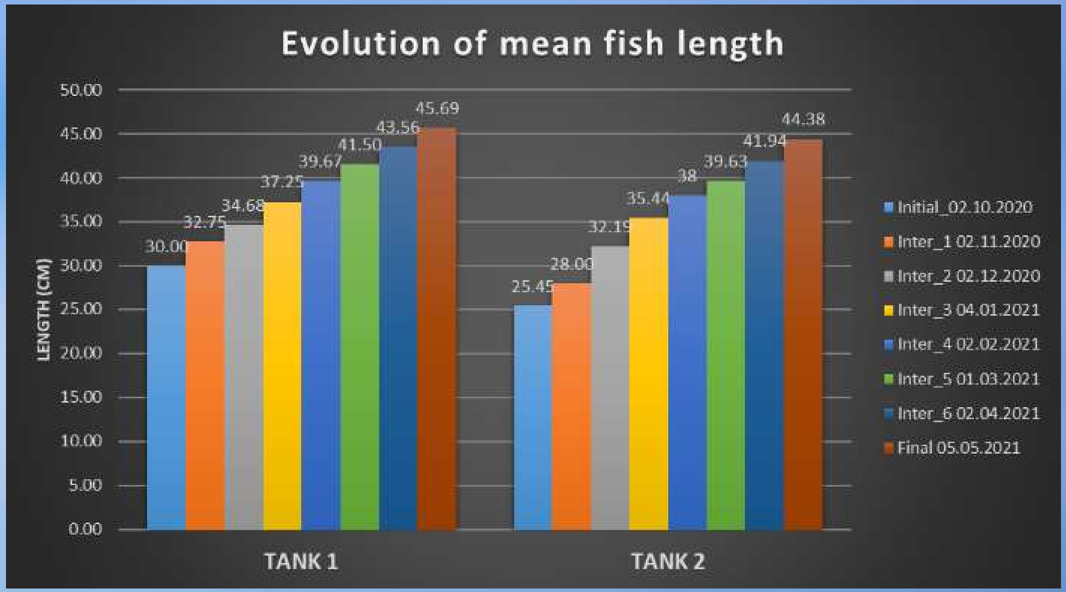
RESULTS & DISCUSSIONS (2)

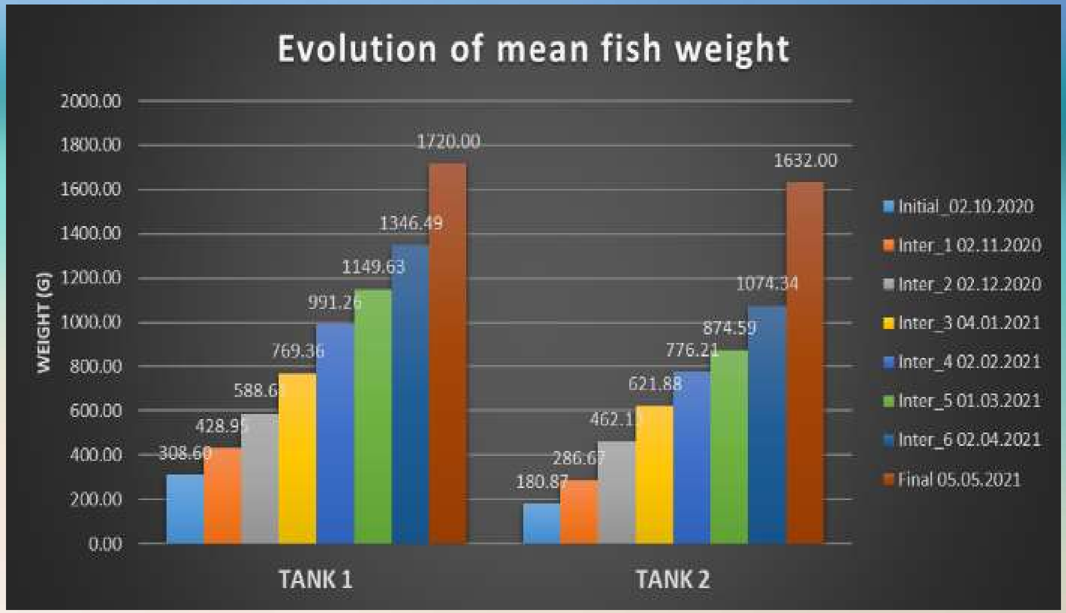
Growth and biomass gain

Mean values of growth parameters

Parameter	Tank 1 (large fish)	Tank 2 (small fish)	ANOVA
Initial length (cm)	**30**±1.87	**25.45**±1.70	$p < 0.05$
Final length (cm)	**45.69**±2.98	**44.38**±3.57	NS
Initial weight (g)	**308.60**±33.38	**180.87**±46.32	$p < 0.05$
Final weight (g)	**1720.00**±349.86	**1632.00**±427.05	$p < 0.05$
K	**1.48**±0.21	**1.41**±0.20	NS
FCR	**1.71**±0.11	**1.51**±0.29	$p < 0.05$
SGR (%/day)	**0.82**±0.20	**1.05**±0.40	$p < 0.05$

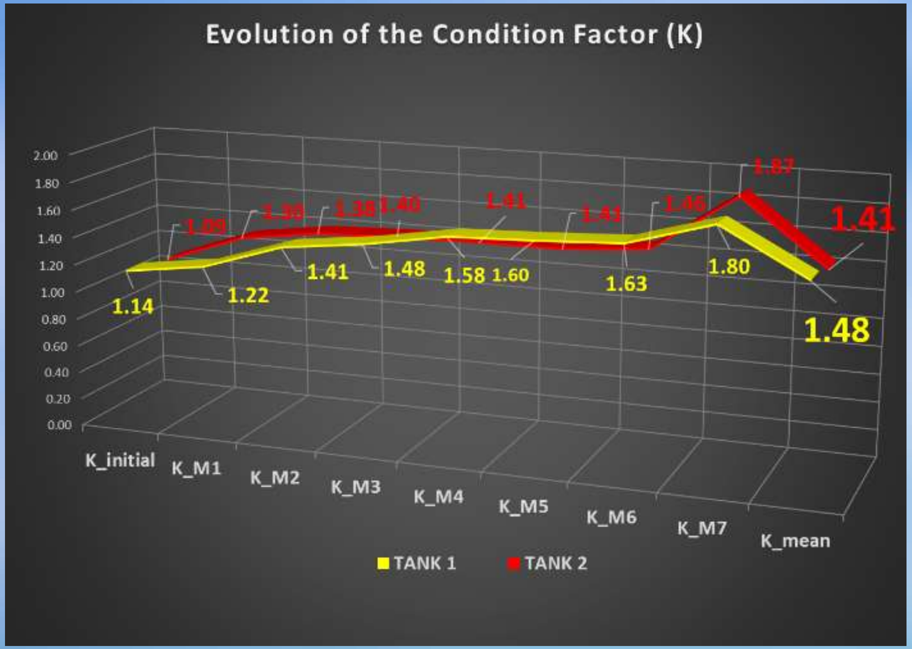
- There was a normal linear increase in both batches and the **final lengths were comparable (around 45 cm)**. However, the small fish batch (Tank 2) showed a more significant growth in length, from an initial mean length of 25.45 cm to 44.38 cm, while the fish with larger initial weight (Tank 1) grew from 30 cm to 45.69 cm.
- The **biomass gain was more extensive in fish with an initial smaller size** (Tank 2), which multiplied their weight 8 times from the beginning of the experiment, while larger fish (Tank 1) increased their weight 4.5 times.
- The **averaged total weight gain for the two batches was approximately 1,400 g/7 months of rearing in seawater** (total biomass gain Tank 1 = 1,420 g, total biomass gain Tank 2 = 1,452 g).



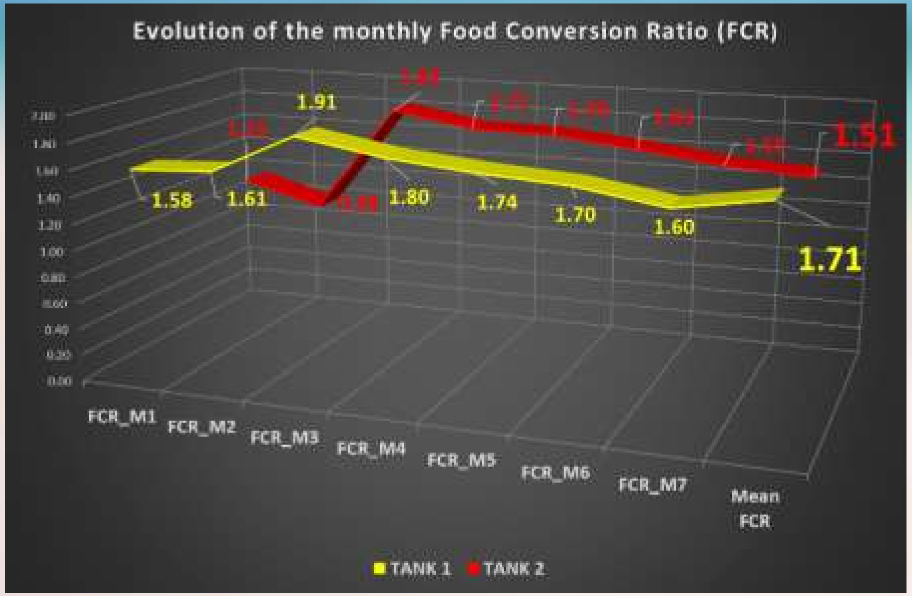


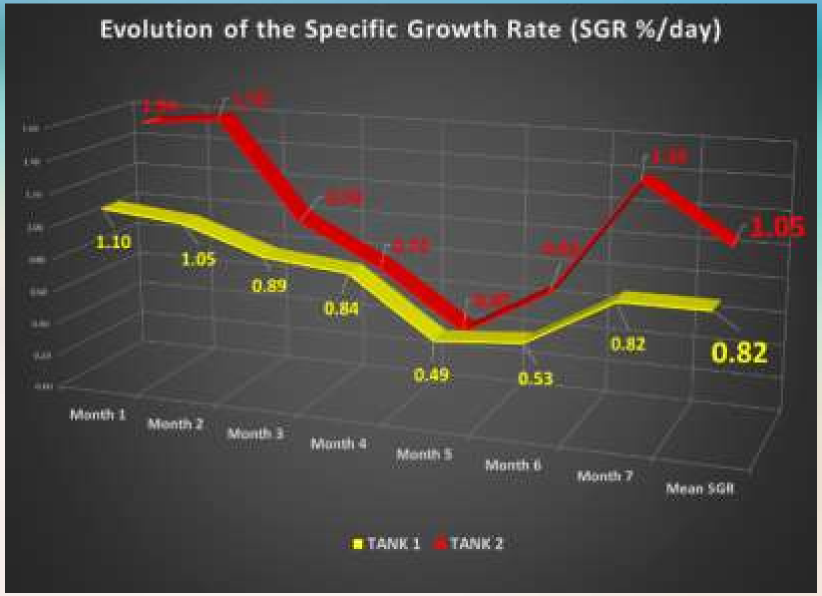
RESULTS & DISCUSSIONS (3)

Growth parameters



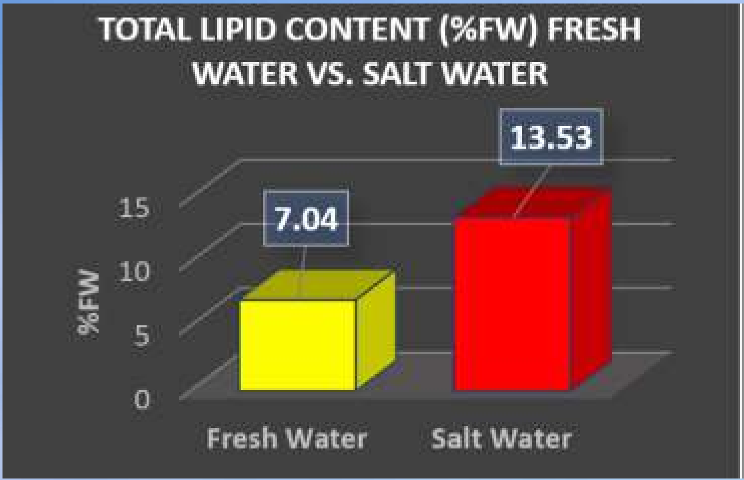
- **Fulton's Condition Factor (K)** for the two batches recorded mean values of 1.48 (Tank 1, large fish) and 1.42 (Tank 2, small fish), respectively, thus indicating a **good to excellent condition of the specimens.**
- The **FCR** in the two experimental tanks recorded mean values of 1.71 in Tank 1 (large fish) and 1.51 in Tank 2 (smaller fish), **indicating a good efficiency of the feed provided**. Smaller fish proved to be more efficient in converting the extruded pellets that were offered as feed. **Marine water culture of the species improves food conversion efficiency**.

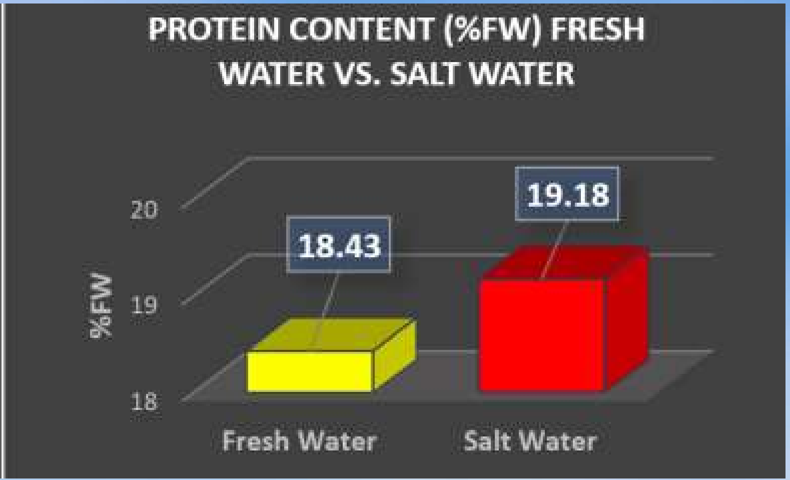




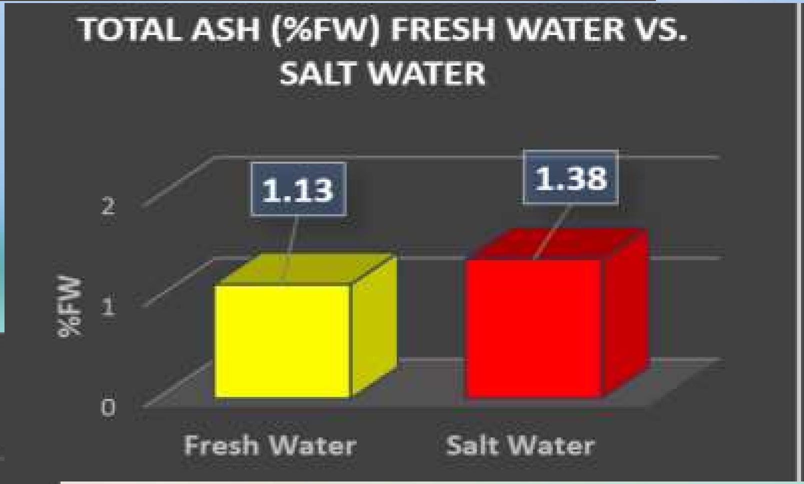
- Regarding the **Specific Growth Rates - SGR (%/day),** fish in Tank 2 (small) recorded a higher value (1.05) than larger fish in Tank 1 (namely, 0.82). T**he maximum daily growth increments were observed at the beginning of trial, when the fish were relatively small.**

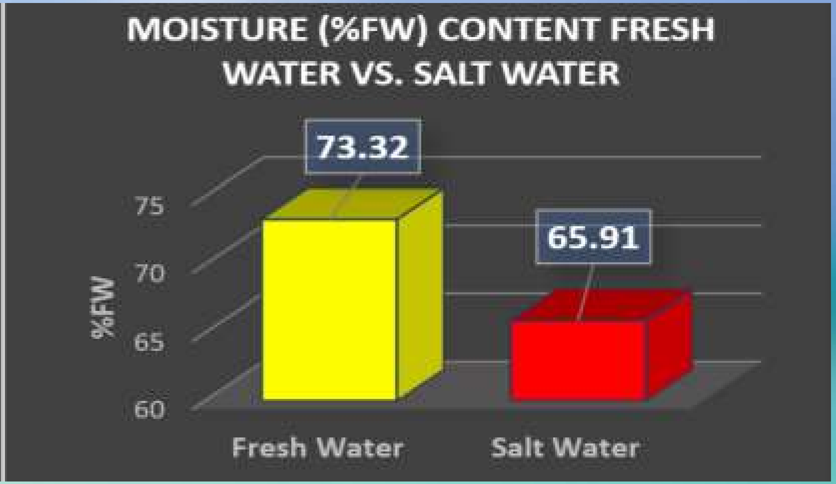
RESULTS & DISCUSSIONS (4)

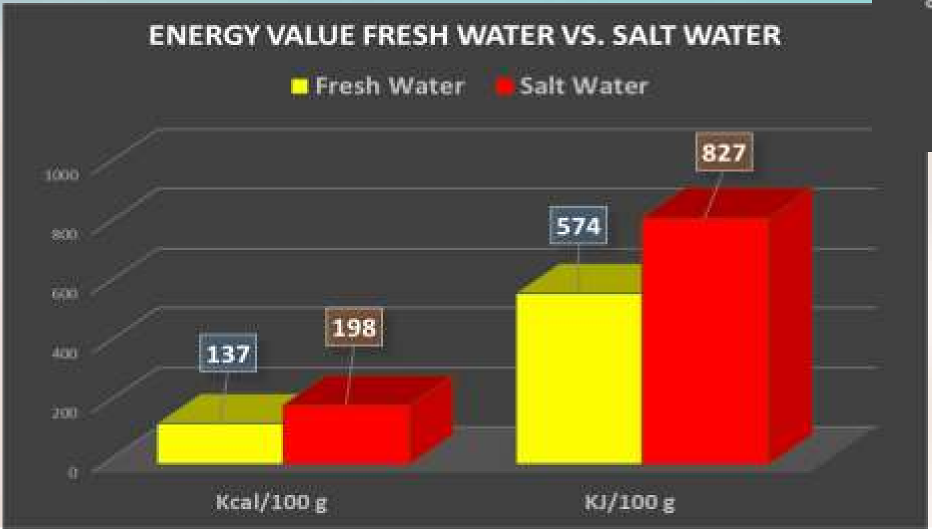




Meat composition of freshwater reared vs. saltwater reared rainbow trout







RESULTS & DISCUSSIONS (5)

- One of the most important quality parameters of salmonid fish is their **flesh color.** As such, the feed provided to the two batches was represented by astaxanthin-enriched (75 mg/kg) extruded pellets, with a protein content of 41% and a lipid content of 24%.

- The administration of this high-quality feed resulted in the **final pink colorization of the meat**, much more appealing to potential consumers compared to specimens cultured exclusively in the mountain farm.

MOVING FORWARD TOWARDS AZA DESIGNATION

- The settlement of the Black Sea waters concession legislation finally opened the way for the first finfish cage farming endeavor at the Romanian coast.

Nenciu, M.; Niță, V.; Nicolae, C.; Akbulut, B. Boosting Biomass Gain and Meat Quality of Rainbow Trout *Oncorhynchus mykiss* (Walbaum, 1792)-An Approach for Fostering Romanian Aquaculture. *AgroLife Sci. J.* 2022, 11, 145-156

- In this context, the NIMRD (through the ADC) has sealed a collaboration protocol to provide scientific consultancy for the economic operator who intends to set-up the first **marine cage farms for rainbow trout in Romanian Black Sea waters**, in the Mangalia area. There are prospects of development in the northern area, too.

SCIENTIFIC CASE STUDY FOR FINFISH CAGE FARMING AZA DESIGNATION - MANGALIA (RO)

Objectives and needs of aquaculture sector in the study area

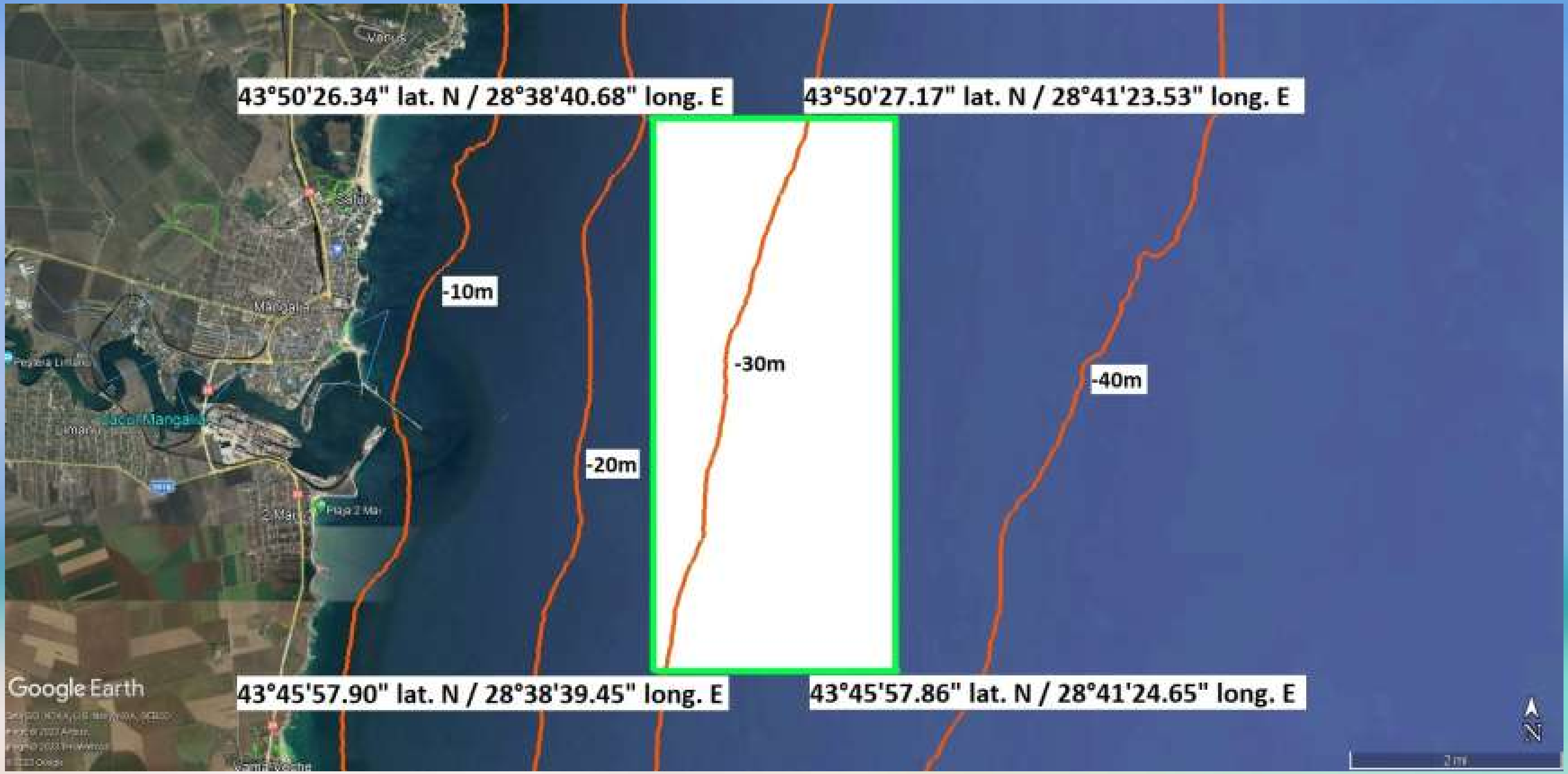
- In Romania, an initial step towards potential AZA identification was performed by investigating the Agigea-Eforie area, considering different farming systems and the interaction of aquaculture activities with the environment, social, and economic aspects, and assessing the level of interest of this area for developing mariculture activities based on the Degree of Compatibility (DC). The results of this first study indicated the excellent suitability of the area for performing shellfish aquaculture*.

- Further, the objective of the present research was to analyze, by applying and adapting a well-documented and internationally endorsed methodology, the level of interest and the Degree of Compatibility (DC) of the first area suitable for practicing finfish farming in offshore floating cages in order to foster the development of the sector in Romania and, by extension, the north-western Black Sea region.

- The rationale for this novel research pursuit is the desire to unlock the potentiality of Black Sea aquaculture by providing scientific support to the competent authorities for the settlement of legislation and governance issues.

*Niță, V.; Massa, F.; Fourdain, L.; Nenciu, M. 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. *Cercet. Mar.* 2020, 50, 152–173. https://doi.org/10.55268/CM.2020.50.152

SITE SELECTION



The southern positioning of the site guarantees a lower variability of environmental parameters and less influence from the Danube.

The selection of the study area (Mangalia) was based on pre-selected criteria assessing its suitability for aquaculture development (no conflicts of uses, no major contamination sources, sufficient water depth, proper substrate), as well as on the interest of economic operators, who expressed their willingness to invest in this field of activity, and of policy makers, who considered the area for designation as the first AZA for finfish farming at the Romanian coast.

METHODOLOGY APPLIED - DEGREE OF COMPATIBILITY (GFCM & Macias et al.)

The methodology used was to assess the level of interest and estimate the **Degree of Compatibility (DC)** of the pre-selected area according to **Macias et al., 2019 & Del Castillo y Rey & Macias, 2006** using 8 parameters:

1. Uses compatibility - was assessed as a follow-up to the analysis of all uses documented in the EMODnet Human Activities database, the National Maritime Spatial Plan Draft and the MARSPLAN: BS-II project database.
2. Depth - was retrieved from the EMODnet Bathimetry portal.
3. Medium swell and **4. Extreme swell (storm)** - annual mean values for wave height and maximum wave height provided by CMEMS, reprocessed by the Black Sea Waves system based on the WAM spectral wave model (2011–2021).
5. Average speed of currents - retrieved from CMEMS, the Black Sea physical reanalysis system, based on the NEMO general circulation model.
6. Water Quality Index (WQI) - dissolved oxygen (DO), temperature (T), salinity (S), total suspended solids (TSS), chlorophyll a (Chl a), and nitrites (NO_2^-) - NIMRD survey data 2012-2021.
7. Bionomic (ecosystem value) - expert judgement, considering the overall ecosystem value of the Mangalia area with regard to sediment type, associated biocoenoses, sensitive habitats, and biodiversity in general, referring to the management plans of the relevant marine protected areas in the vicinity.
8. Seabed - data from EUSeaMap 2021 (EMODNet Seabed Habitats).

Ranges and weighing factors were assigned and the DC formula applied:

$$\mathbf{DC} = 100 \times \frac{\sum_i^n [\![(K]\!]_i \times SI_i)}{\sum_i^n K_i}$$

RESULTS (1)

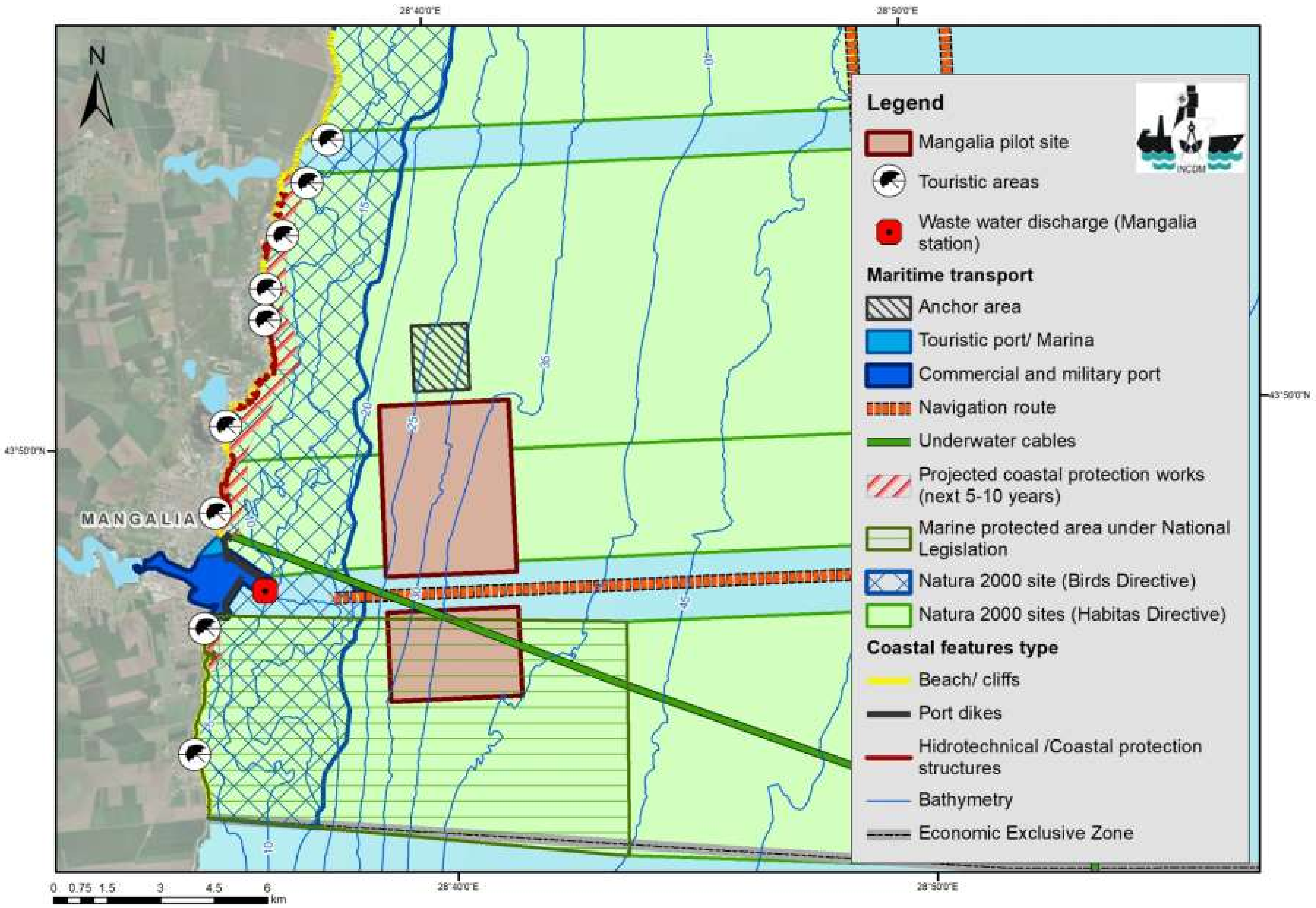
1. Uses Compatibility

No major potential conflicts with other uses of the maritime space (just navigation route corridor of the Mangalia Port).

Mangalia AZA can be divided into 2 sub-areas: a northern zone suitable for large-scale farming installations and a southern zone appropriate for small-scale/family farming operations.

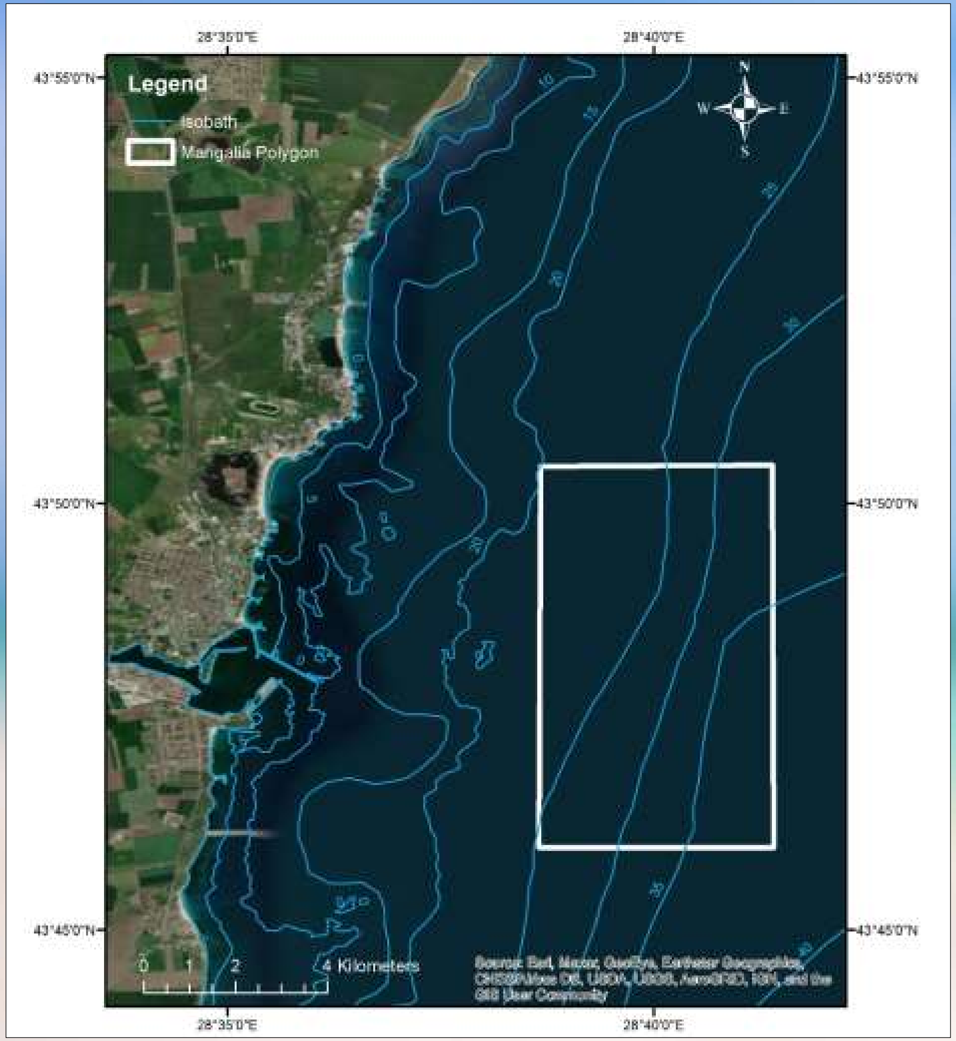
No possible sources of contamination.

Suitability Index = 1



RESULTS (2)

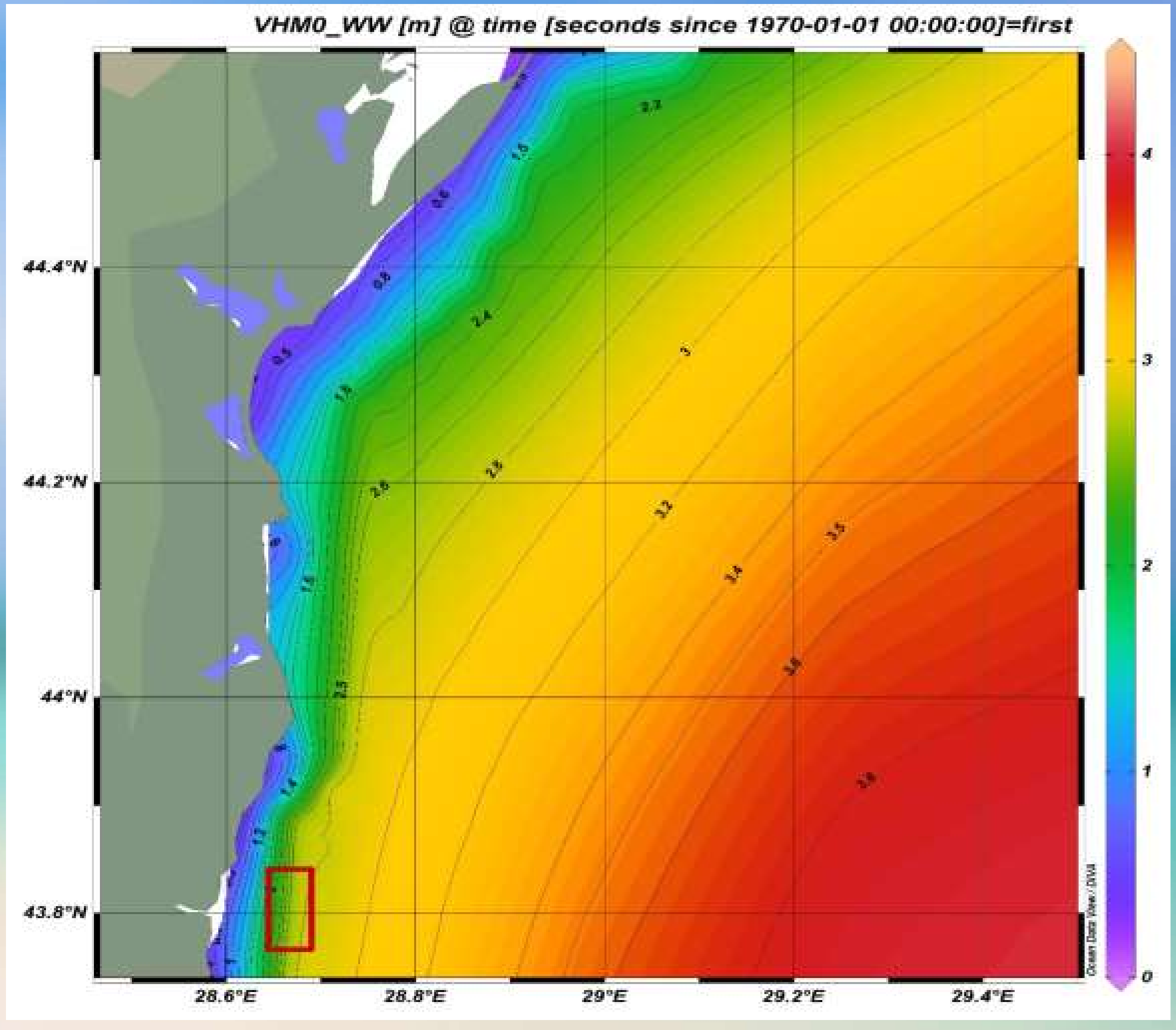
2. Depth



Average water depth = 33 m

Suitability Index = 1

3. Medium Swell

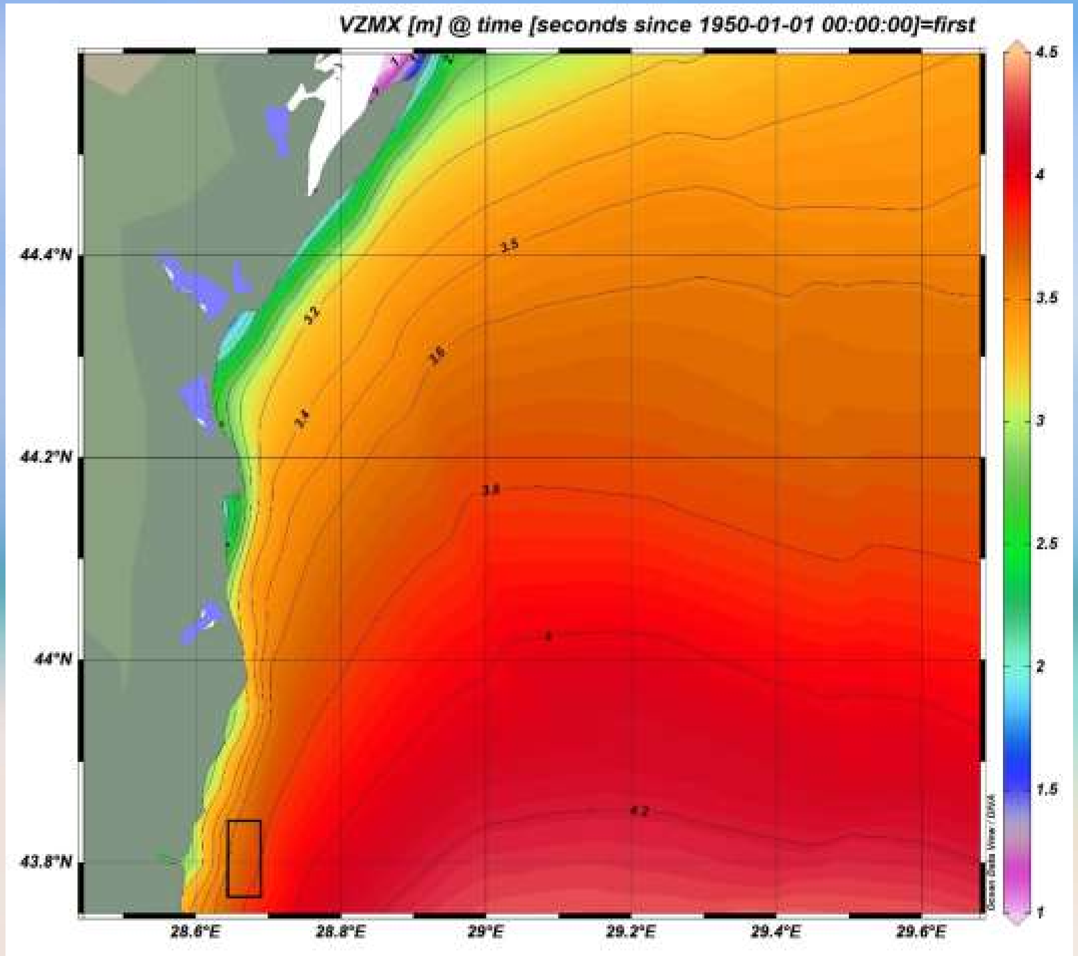


Medium swell (wind waves) = 1.5–2.8 m

Suitability Index = 1

RESULTS (3)

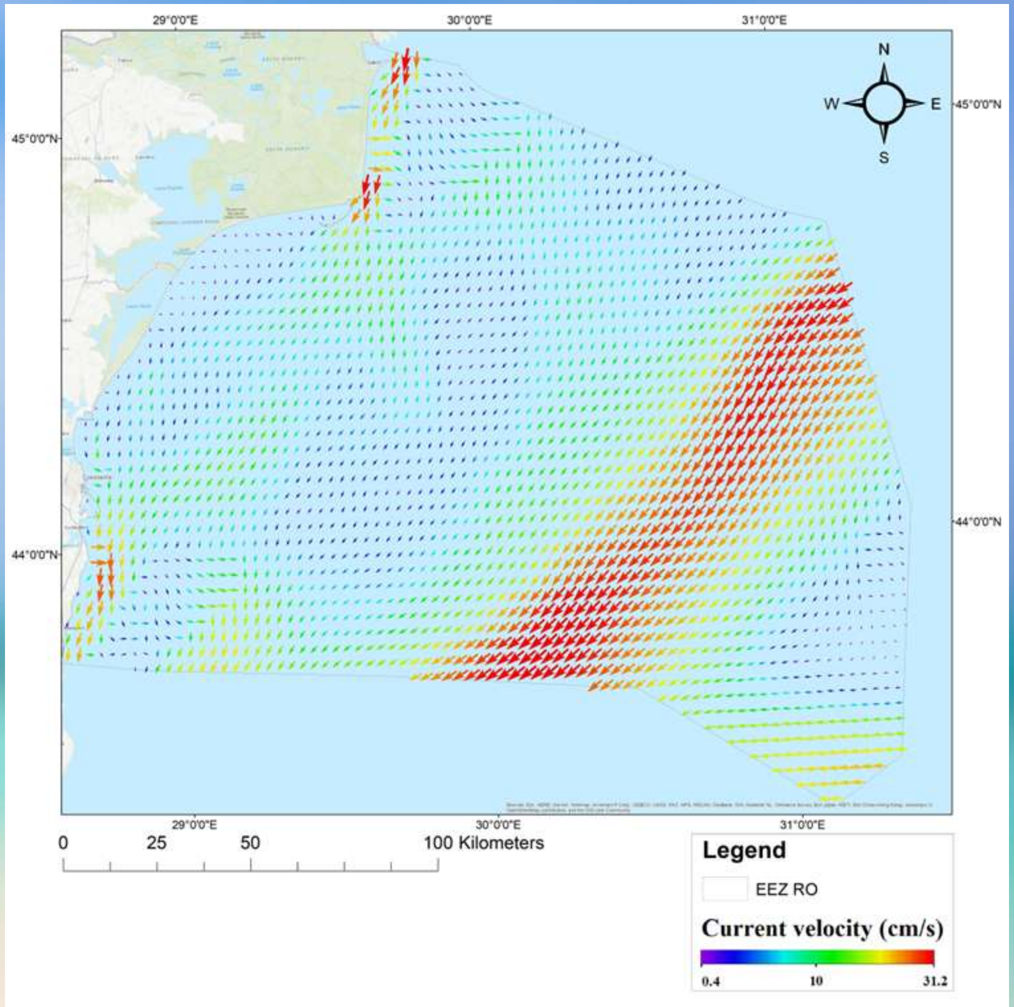
4. Extreme swell (storm)



Maximum wave height = 3.5–4 m

Suitability Index = 0

5. Currents



Mean values of the intensity of surface currents = 10–20 cm/s

Suitability Index = 1

RESULTS (4)

6. Water Quality Index (WQI) (2012-2021)

Minimum value of DO = 7.7 mg/l $\boldsymbol{f_1(DO)}$ **= 0**

Minimum value of seawater temperature = 7.42 °C $\boldsymbol{f_2(T)}$ **= 10**

Salinity (standard deviation 2.47‰ and average15.60‰) $\boldsymbol{f_3(S)}$ **= 1.58**

Total Suspended Solids (TSS) -natural logarithm of the maximum value (25.20 mg/l) $\boldsymbol{f_4(TSS)} =$ **3.22**

Maximum value for chlorophyll *a* = 55.94 µg/l $\boldsymbol{f_5(Chl_a)}$ **= 10**

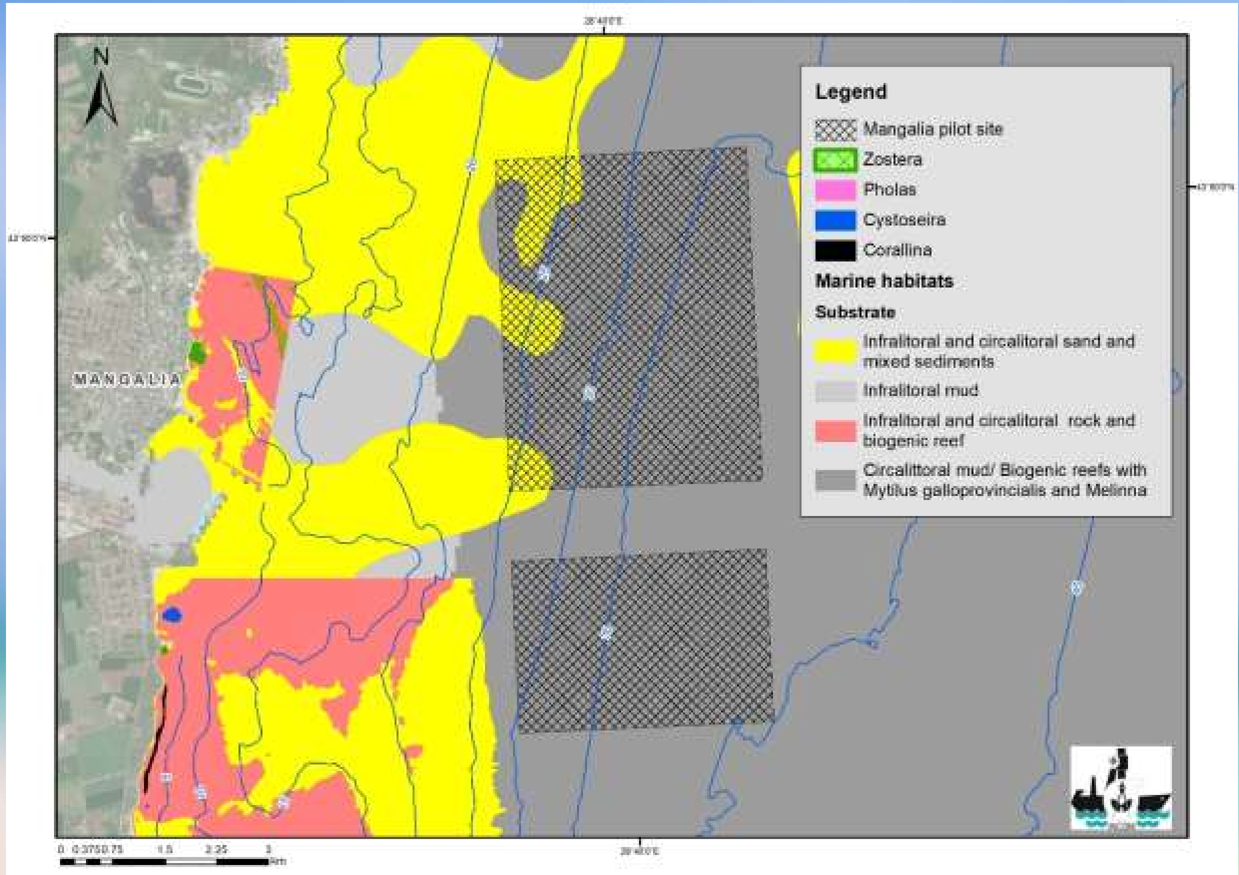
Maximum value of nitrites = 20.44 µM $\boldsymbol{f_6(NO_2-)}$ **= 10**

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

Applying the **WQI equation**, the result for the Mangalia area was **4.2**, which results in a **Suitability Index = 0** for this parameter.
Thus, the water quality in the Mangalia area is appropriate for supporting finfish aquaculture activities.

RESULTs (5)

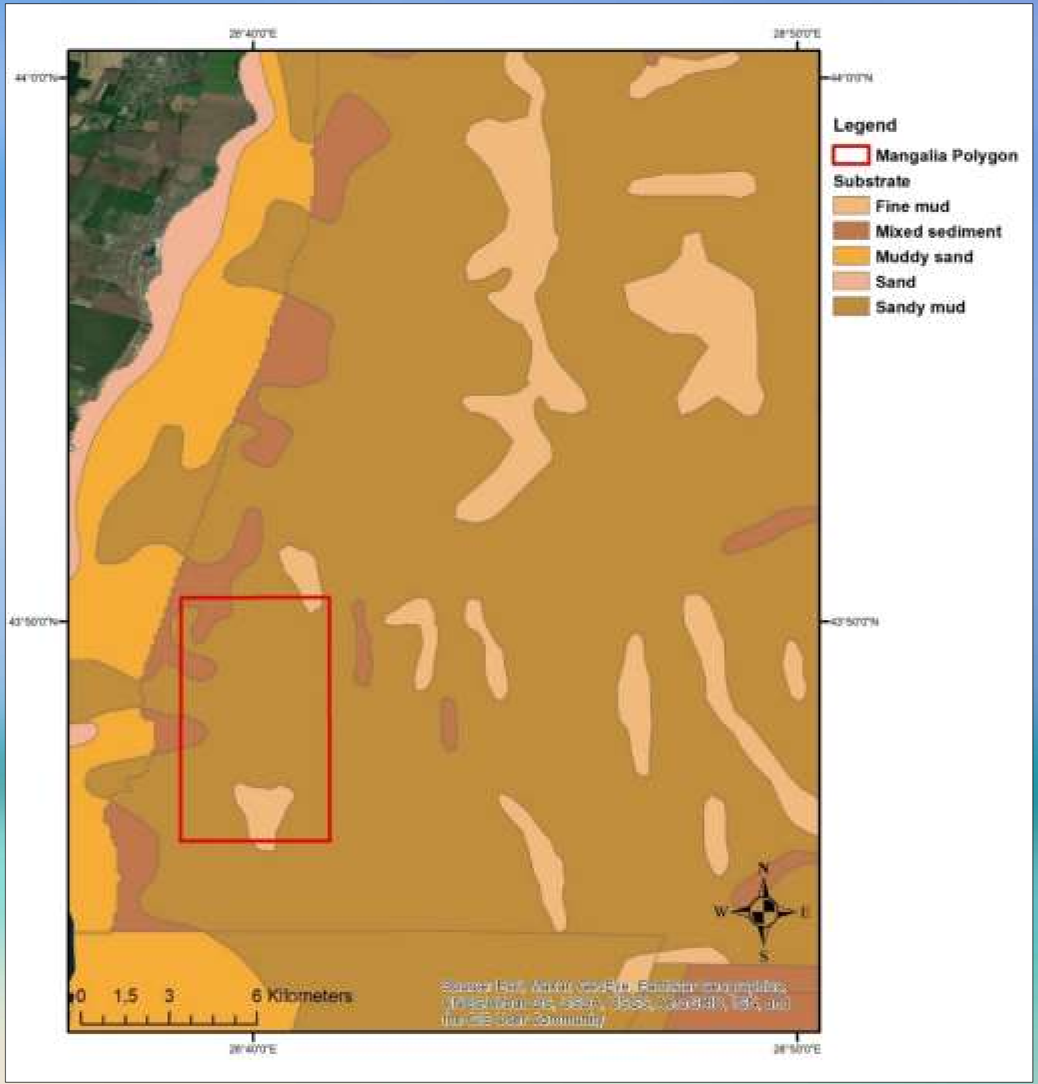
7. Bionomic (ecosystem value)



Despite the fact that the proposed Mangalia AZA overlaps with two Natura 2000 MPAs, there is no foreseen conflict with nature conservation, as no sensitive and/or essential habitats and species are located within the polygon.

Suitability Index = 1

8. Seabed



The seabed structure in the Mangalia area is appropriate for mooring/anchoring cage farming facilities (muddy sand, sand, mixed).

Suitability Index = 1

RESULTS (6)

Degree of Compatibility of the Mangalia AZA*

Parameter	Value	SI	K
1. Uses compatibility	Compatible zone	1	10
2. Depth	33 m	1	7
3. Medium swell	1.5–2.8 m	1	4
4. Extreme swell (storm)	3.5–4 m	0	4
5. Average speed of currents	10–20 cm/s	1	8
6. Water Quality Index (WQI)	4.2	0	5
7. Bionomic (ecosystem) value	Low	1	6
8. Seabed	Sandy silt (85%)	1	1
Degree of Compatibility (DC)			**80**

The result (30 < 80 < 100) (high DC) clearly indicates the Mangalia area as suitable for finfish aquaculture activities: there is no major interference with other uses of the maritime space, no conflicts with nature conservation, and the environmental conditions are appropriate for fish culture in floating cages.

Integration into the Legislative Framework

The final step of this research endeavour would be the establishment of the Mangalia AZA for finfish farming by integration into the Romanian legislative system.

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

*Nenciu, M.; Niță, V.; Lazăr, L.; Spînu, A.; Vlăsceanu-Mateescu, E. Fostering the Development of Western Black Sea Aquaculture: A Scientific Case Study for Finfish Cage Farming Allocated Zone Designation. *Fishes* 2023, 8, 104. https://doi.org/10.3390/fishes8020104

CONCLUSIONS & RECOMMENDATIONS

- The rainbow rout seawater rearing experiment proved to be a success: the weight gain and meat quality encourage aquaculture endeavors in this direction.

- Spatial allocation for farm placing is essential, thus an AZA identification was performed, in the context of legislation settlement and economic operators' interest.

- Applying an adapted methodology for AZA designation at the Romanian coast, eight parameters [compatibility, water depth, medium swell, extreme swell-storm, average speed of currents, Water Quality Index (WQI), bionomic (ecosystem) value, seabed] were included in the calculation.

- All in all, the results obtained for the Mangalia area (DC = 80) are optimal for establishing it as the first AZA for finfish farming in the Romanian Black Sea, as well as encouraging good examples to be showcased at the regional level.

- The novel data provided by this study can be the building block for Romanian authorities to settle the governance gap that has so far impeded the development of marine aquaculture in Romania.

ACKNOWLEDGEMENTS

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THANK YOU FOR YOUR ATTENTION!

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