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Research of marine protected habitats in EEZ and determination of the necessary conservation status in Latvia
LIFE19 NAT/LV/000973 LIFE REEF

A.4 Assessment of the effectiveness impact of the MPA network

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INTRODUCTION

MPAs are recognized as a powerful tool to sustain the viability of marine biodiversity. They.have become a key component of conservation and fisheries management and are recognised as a primary management approach in attempts to alleviate anthropogenic pressures and ensure sustainable use of marine resources.

In Latvian marine waters the designation of MPAs started only in 2006. Initially territories were designated for protection of wintering and migratory waterbirds, therefore comparatively large territories were assigned for protection in the Gulf of Riga and on open coast of the Baltic Sea. Further research of habitats revealed presence of stony reefs (protected habitat 1170). Stony reefs are the most prominent and ecologically significant habitat types in the Eastern part of the Baltic Sea, hot-spots of biodiversity hosting invertebrates, fishes, birds and plants. The most typical specie here is mussel *Mytilus trossulus*, accompanied by other macrofauna, e.g. bivalves, bryozoa, crustaceans and benthic fish. In the euphotic zone reefs are hosting also the diverse macroalgae community. However the research of deep water habitats in EEZ zone was delayed till 2020, when LIFE REEF (2020-2025) project started mapping of 4116 km2 of elevated banks in EEZ. Results of mapping in EEZ revealed at least 630km2 of stony reef habitats (1170). Aphotic stony reefs showed rich coverage of macrofauna till 58m depth with dominant species *Mytillus edulis* and accompanying species of macroinvertebrates, mysids, shrimp and fish. Higher species diversity has been found in shallowest banks at depths between 18 and 30 metres.

Increasingly, MPAs are viewed as networks of managed areas with the goal to achieve 'ecologically coherent' MPAs where a network provides protection of a range of features, e.g. habitats, species, and ecological processes, more efficiently than unconnected, individual MPAs. To date, an often implicit assumption is that populations within selected MPAs will persist through local recruitment, survival, and reproduction. The validity of this assumption critically depends on the relative scales of MPA size and dispersal distance of target species. A crucial question is whether individual MPAs or networks of MPAs are biologically functional, i.e. whether they have the capacity to sustainably protect target populations. About 70% of marine macro-invertebrates and many demersal fish and macro-algae disperse during early life as planktonic larvae. Most sedentary marine macro-organisms therefore form partially open local populations, which has fundamental consequences for the design of MPAs. The sustainability of protected populations requires either: (1) that MPAs are large enough to allow significant self-seeding for persistence; or (2) that MPAs are inter-connected through dispersal or connected to unprotected populations leading to network persistence.

The assessment of the Baltic Sea MPA network with respect to ecological coherence showed that individual MPAs are generally too small for persistence based only on local recruitment. However, the overall connectivity among the MPAs and with surrounding unprotected areas seem satisfactory with respect to a positive effect on the whole metapopulation. Latvian MPAs on the open coast of the Baltic Sea are all to small for retention of local recruits. However, the previous study of physical water transport of larvae or other propagules didn't included the species analysis nor presence/absence of necessary substrates for species of interest. The maps of Jonsson et al, 2020 allows to speculate that addition of sufficiently large MPAs on Latvian coast of open Baltic would greatly enhance the connectivity of Baltic Sea MPAs, especially their extension in EEZ as they might close the gap over Gothland basin.

In this report we present two independent studies 1) regarding mathematical modeling of connectivitu of LIFE REEF territories to coastal habitats, and 2) analysis of effectiveness of existing Latvian MPAs using METT tool.

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Report: Ecological connectivity between Latvian Baltic Sea rock shoals and the shore. Assessment of ecological connectivity between the MPA in Latvia.

Introduction

Physical data characterising 3 pilot areas are provided in Section 1.

Longshore sediment transport along the Baltic Sea coast of Latvia had been characterised in Section 2.

Ecological connectivity between the shoals – LIFE REEF pilot areas and current MPA in Latvia had been assessed analysing the modeled surface current drift patterns in the Baltic Sea in Latvia and provided in Sections 3 and 4.

Two numerical experiments had been done:

1. Section 3– analysis of the ecological connectivity from 3 LIFE REEF pilot areas towards the Baltic Sea shore coastline paying attention to connectivity to coastal parishes (5x5 km source resolution in the numerical experiment used). Results of the experiment also included in the conference proceedings [3], Supplementary material 1.
2. Section 4 - ecological connectivity of 2 LIFE REEF pilot areas – Papes kalva and Alku shoal with MPAs along the Baltic Sea shore coastline in Latvia (2x2 km source resolution used), the results of the analysis pays attention to the coastal segments of the current MPA – Nida-Perkone, Akmensrags, Irbe Strait. 2 local scale properties mentioned by (*Roberts KE, Cook CN, Beher J, Treml EA. Assessing the current state of ecological connectivity in a large marine protected area system. Conserv Biol. 2021 Apr;35(2):699- 710. doi: 10.1111/cobi.13580. Epub 2020 Sep 5. PMID: 32623761; PMCID: PMC8048790*)- *rescue potential* of a site, which is the degree to which the patch can be rescued by surrounding upstream source habitat patches and *source strength*, or the capacity of a site to act as a larval source to other habitat patches has been analysed in the section. These properties are provided also for current MPA system of Baltic Sea shore in Latvia – Nida-Perkone, Akmensrags and Irbe Strait. Special attention had been paid to 1) the rescue potential of the current MPAs system from upstream source in Klaipeda-Ventspilio plynaukste; 2) Latvian MPAs and Papes kalva and Alku shoal's role in providing the larval source to MPAs outside Latvia.

Results of the experiments illustrate that ecological connection between the current MPAs does not take place each year in 11 year period analysed. Similarily the ecological connection between 3 pilot areas and the current MPAs is

1. Physical characteristics of 3 LIFE REEF pilot areas

General information

Defined marine pilot areas of LIFE REEF project are located in the Excluzive economical zone of Latvia, Figure 1.

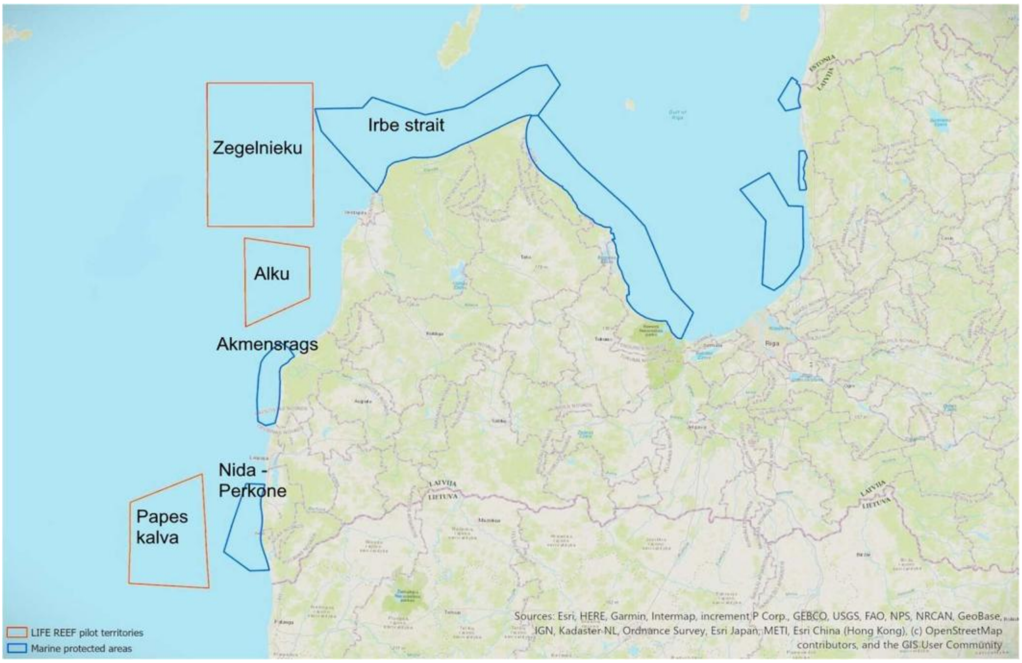


Fig. 1. Study pilot areas – rock shoals in EEZ of Latvia Zegelnieku, Alku, Papes kalva (red), MPAs - blue.

There are 3 marine protected areas in the Baltic Sea in Latvia: Nida – Perkone 36694.5217 ha, Akmensrags 25828.614 ha and Irbes strait 172242.3614 ha, Fig. 1.

3 pilot areas more distant from the coast had been investigated in LIFE REEF. Valuable habitat had been found there. Mussel in its larvae stage is spread by currents. Connection between the mussel generations on a whole Baltic Sea scale, had been presented previously by *[1] J. Larsson, E.E. Lind, H. Corell, M. Grahn, K. Smolarz, M. Lönn, Regional genetic differentiation in the blue mussel from the Baltic Sea area.* The results of the study present the number of mussel generations necessary to spread among distant locations along the coast of the Baltic Sea. It approximate the shortest distance between the mussels species from Sweden and Poland and the Baltic Sea coast in Latvia as 6-8 mussel generations distant. The study does not provide the ecological connectivity between the mussel reefs in Klaipeda Ventspils plynaukste in Lithuania, Latvian coast and the reefs of the Estonian mussel reefs in Saaremaa and Hiumaa islands.

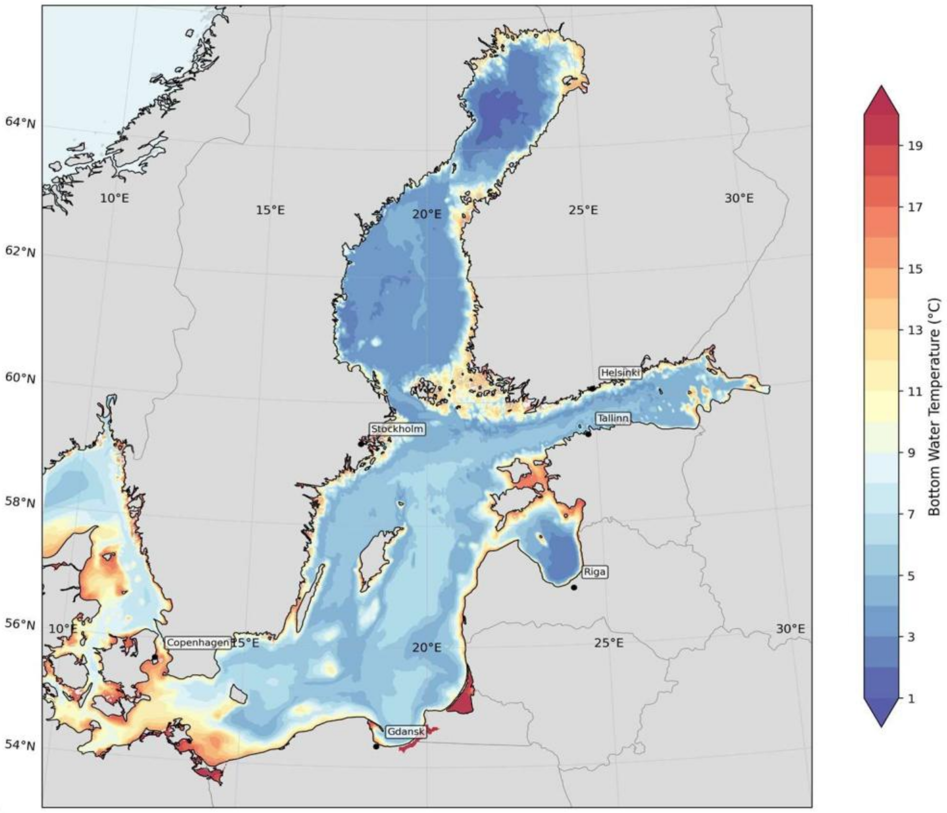
This study is looking on existing connection pattern between LIFE REEF and existing MPA locally paying more attention to potential sources and sinks in Latvia, Lithuania and Estonia. Oceanographic model results archive of the region for 2008-2018 had been used. Benefitial current directions and magnitudes right after the spawning period can lead to mussel habitat spreading to other suitable substrates. It may also provide ability for regeneration. The analysis had been done that allows estimating ecological connectivity among LIFE REEF pilot areas and Latvian Baltic sea shoreline segments. The statistics of surface migration patterns originating in June from LIFE REEF pilot areas towards sea shoreline segments had been reported for 2008- 2018.

Physical conditions in the defined pilot areas

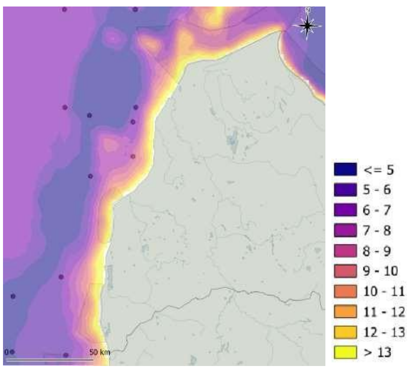
Degree day and temperature variability and seasonality characterized for random location in each of the pilot areas, Table 1.

Table 1. Monthly average sea bottom temperature (columns 1-9) and degree days since 1st of March (columns 10- 18) according to CMEMS oceanographic model data in randomly selected sites in LIFE REEF pilot areas, March – October 2022-2024.

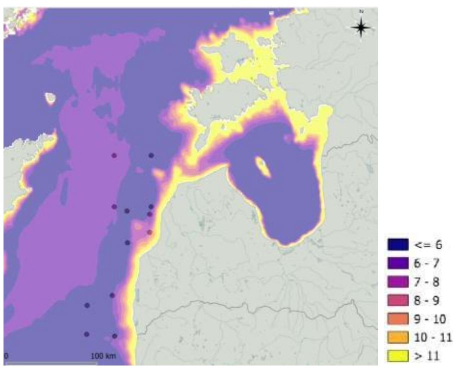
Parametrs	**Mēneša vidējā temperatūra izvēlētā teriorijas punktā pie grunts**									**Grāddienu, GDD novērtējums kopš 1. marta**								
Teritorija	*Papes kalva*			*Alku sēklis*			*Zēģelnieku sēkļi*			*Papes kalva*			*Alku sēklis*			*Zēģelnieku sēkļi*		
Gads	**2022**	**2023**	**2024**	**2022**	**2023**	**2024**	**2022**	**2023**	**2024**	**2022**	**2023**	**2024**	**2022**	**2023**	**2024**	**2022**	**2023**	**2024**
Marts	4,1	2,8	3,4	3,9	2,7	3,1	3,6	2,9	3,3	126	88	105	120	85	96	112	89	101
Aprīlis	4,3	3,7	3,8	4,1	3,5	3,8	4,0	3,3	3,8	255	198	220	244	190	209	232	189	216
Maijs	4,9	3,8	4,2	6,2	5,5	5,4	5,4	4,5	4,4	408	315	351	435	360	378	401	329	352
Jūnijs	6,1	3,6	4,8	11,9	6,5	11,6	7,7	4,5	6,8	592	424	496	792	556	724	631	462	555
Jūlijs	8,4	6,8	8,8	13,7	15,7	17,3	6,6	11,7	11,3	843	629	759	1203	1026	1244	829	814	893
Augusts	8,9	17,8	12,8	18,7	18,3	18,4	8,4	16,1	12,0	1120	1181	1155	1782	1595	1813	1090	1314	1266
Septembris	7,9	16,9	9,5	13,0	17,7	18,0	7,3	16,1	12,2	1358	1686	1441	2172	2127	2354	1310	1798	1633
Oktobris	12,4	14,1	13,1	13,0	13,9	14,3	11,3	13,7	13,6	1742	2122	1846	2575	2559	2797	1659	2224	2054



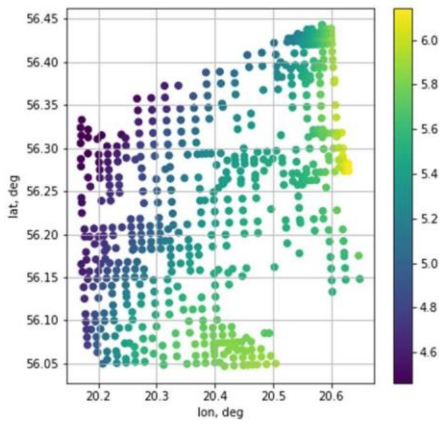
a)



b)



c)



d)

Fig. 2. Mean bottom temperature in the Baltic Sea in June in 2010-2024, CMEMS oceanographic model data, different spatial and temperature scales (b, c) and bottom temperature in in situ observed points (d) in C°.

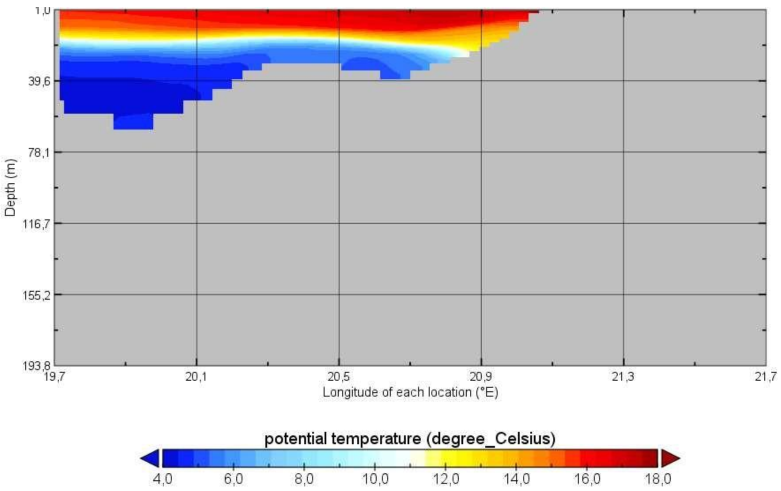


Fig. 3. Potential temperature profile in Papes kalva, lat = 56.0916 N, CMEMS oceanographic model data. June 2024.

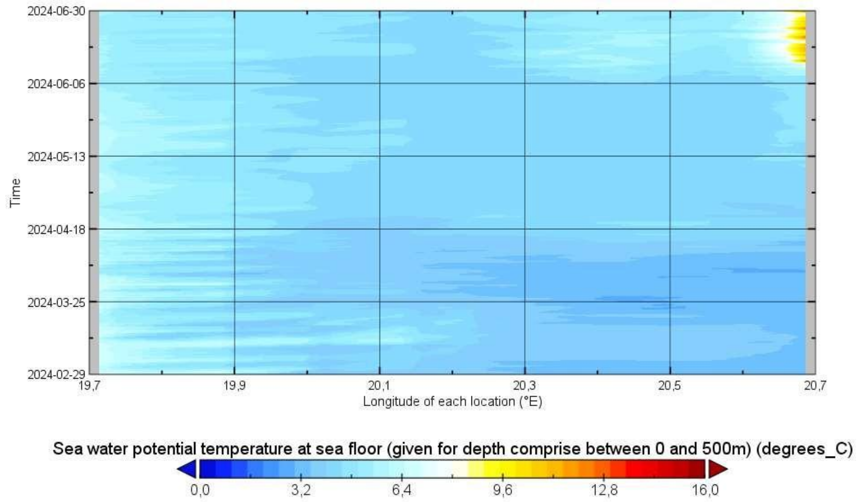


Fig. 4. Bottom temperature in Papes kalva (lat=56.0916 N) in March – June 2024, CMEMS oceanographic model data.

Fig. 5. Daily variability of bottom temperature in selected site in Papes kalva in March – June 2024.

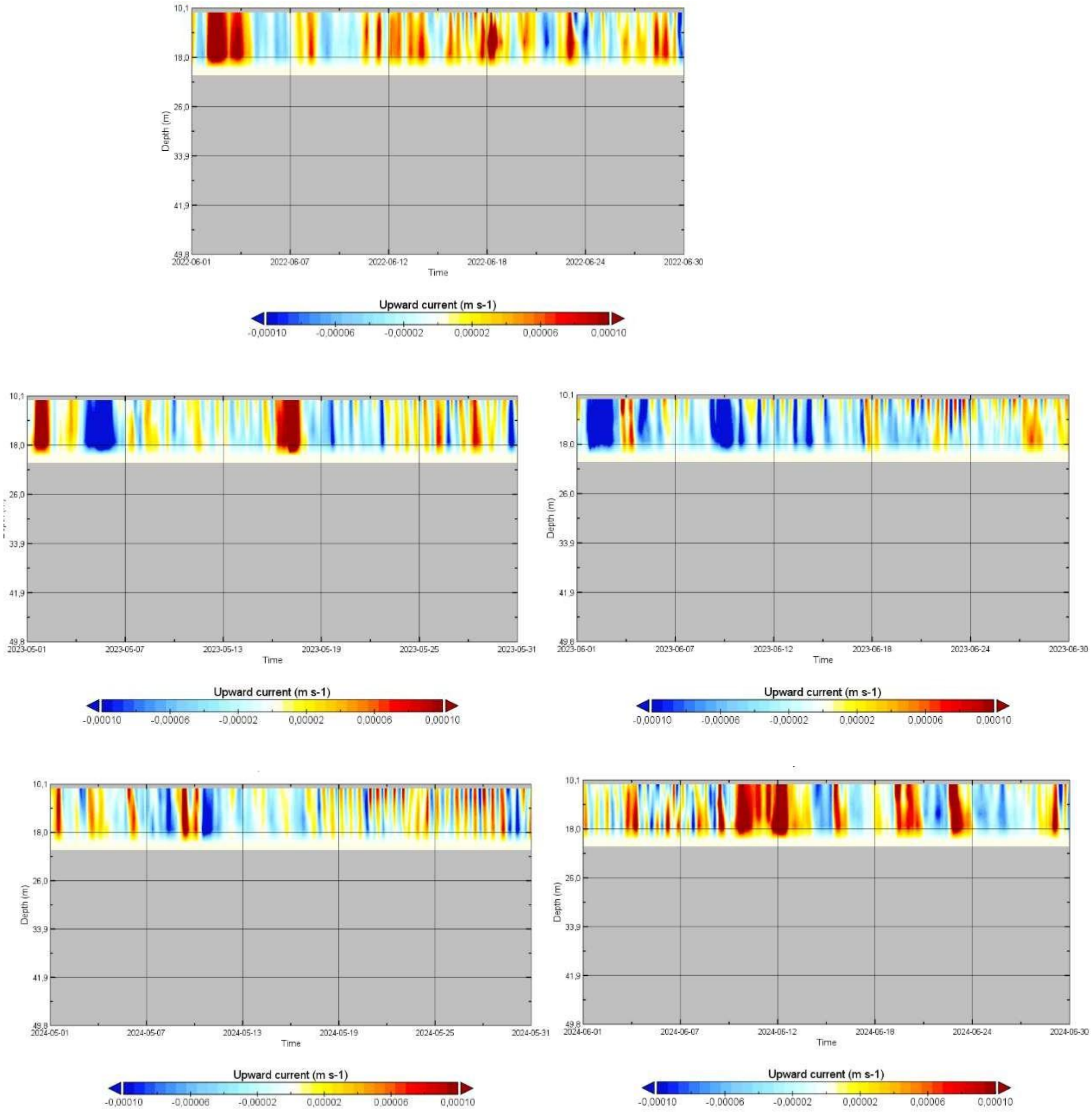


Fig. 6. Upward (vertical) velocity variability in Alku shoal (lat=57.1249 N, lon=21.0139 E), May – June, 2022 – 2024, CMEMS oceanographic model data.

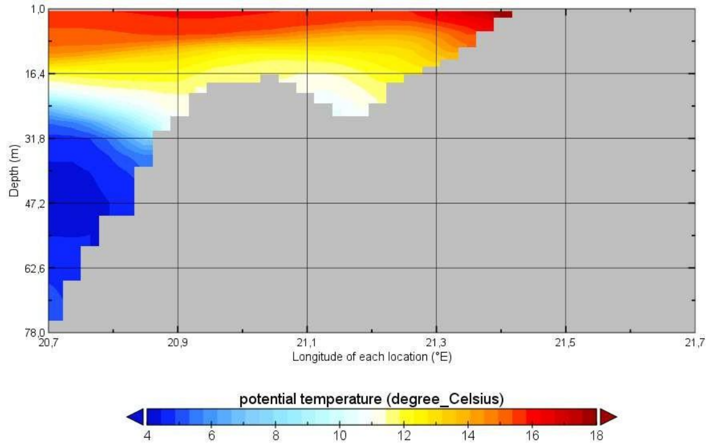
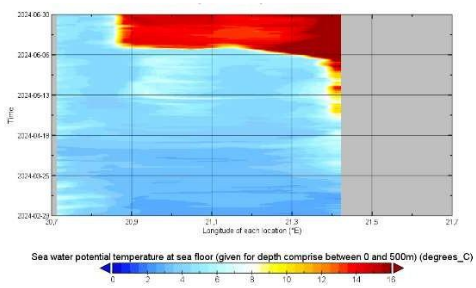
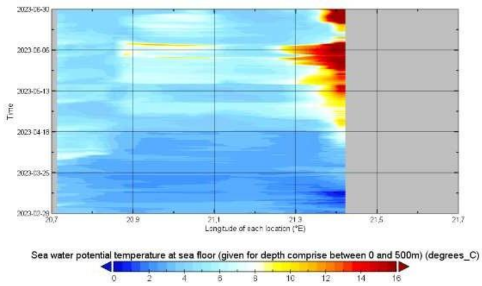


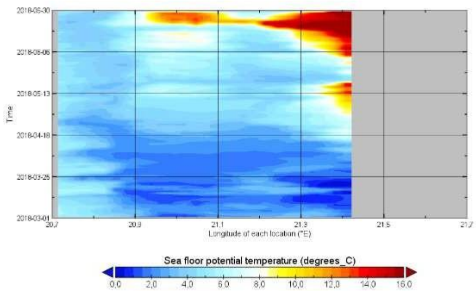
Fig. 7. Potential temperature profile in Alku shoal, lat = 57.1249 N, CMEMS oceanographic model data. June 2024.



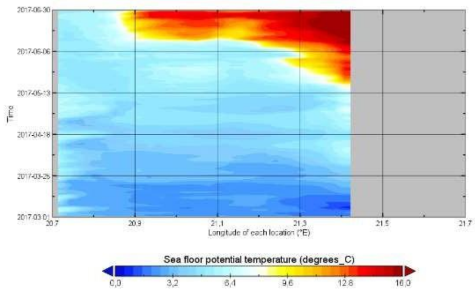
2024



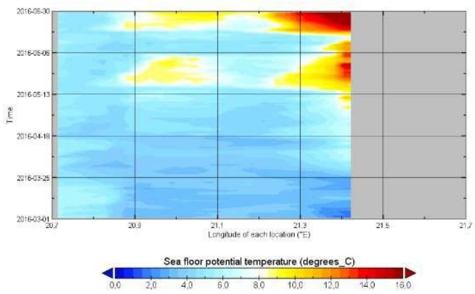
2023



2018



2017



2016

Fig. 8. Bottom temperature in Alku shoal (57.1249 N) in March – June, CMEMS oceanographic model data.

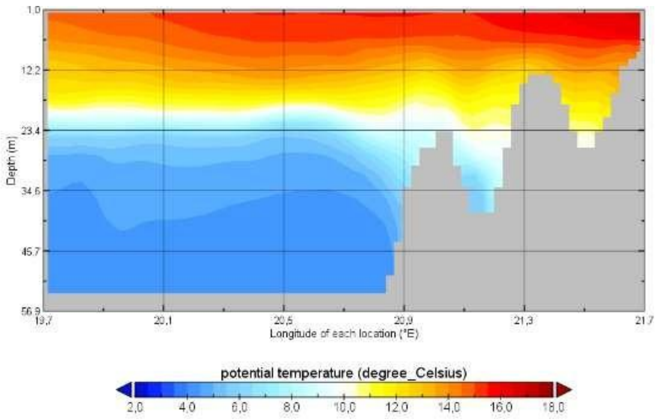


Fig. 9. Potential temperature profile in Zegelnieku shoal (data deeper than 50 m not included), lat = 57.6749 N, CMEMS oceanographic model data. June 2024.

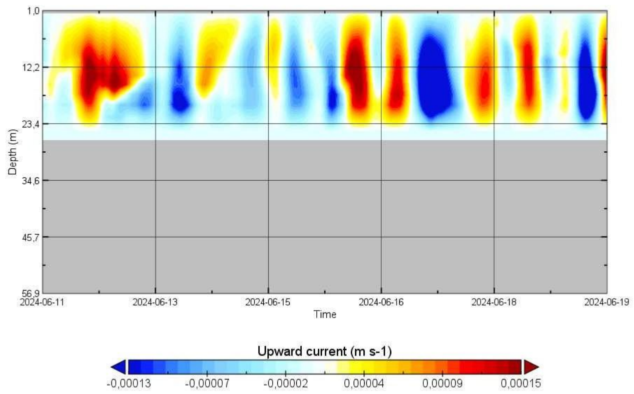


Fig. 10. Upward (vertical) velocity variability in Zegelnieku shoal at lon=20.9306 E, lat=57,6196 N.

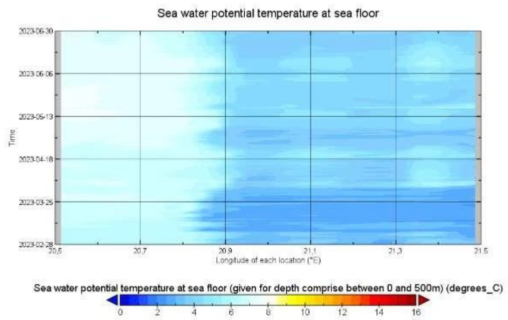


Fig. 11. Bottom temperature in Zegelnieku shoal (lat=57.7749 N) in March – June 2023, CMEMS oceanographic model data.

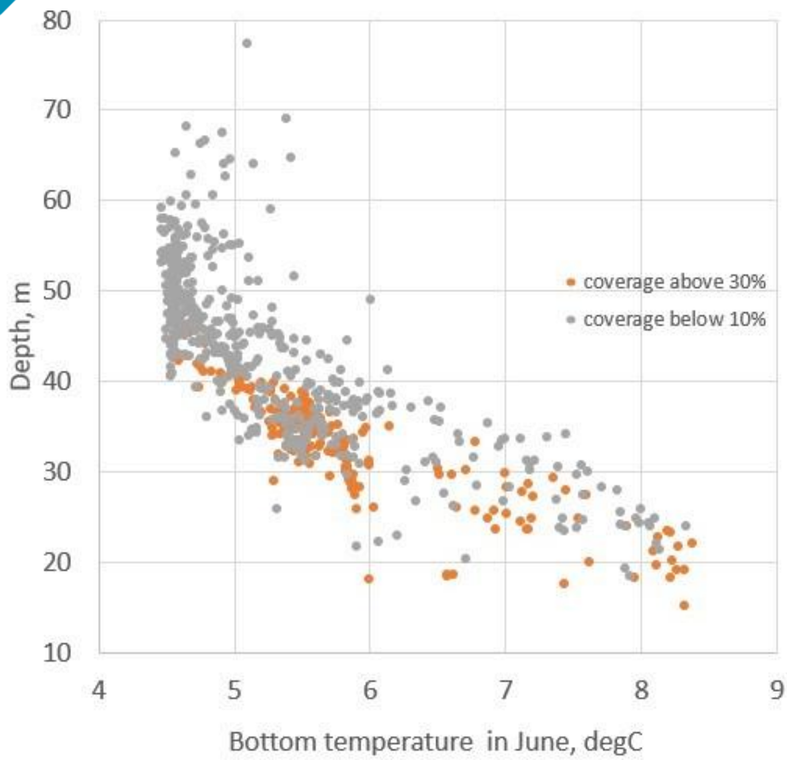


Fig. 12. Modeled sea bottom temperature in June versus depth. Observation sites with low and high mussel coverage during LIFE REEF campaign had been outlined.

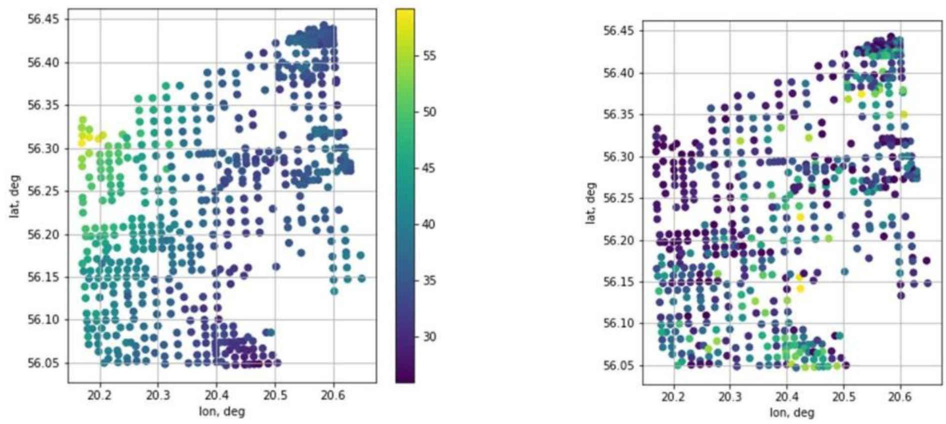


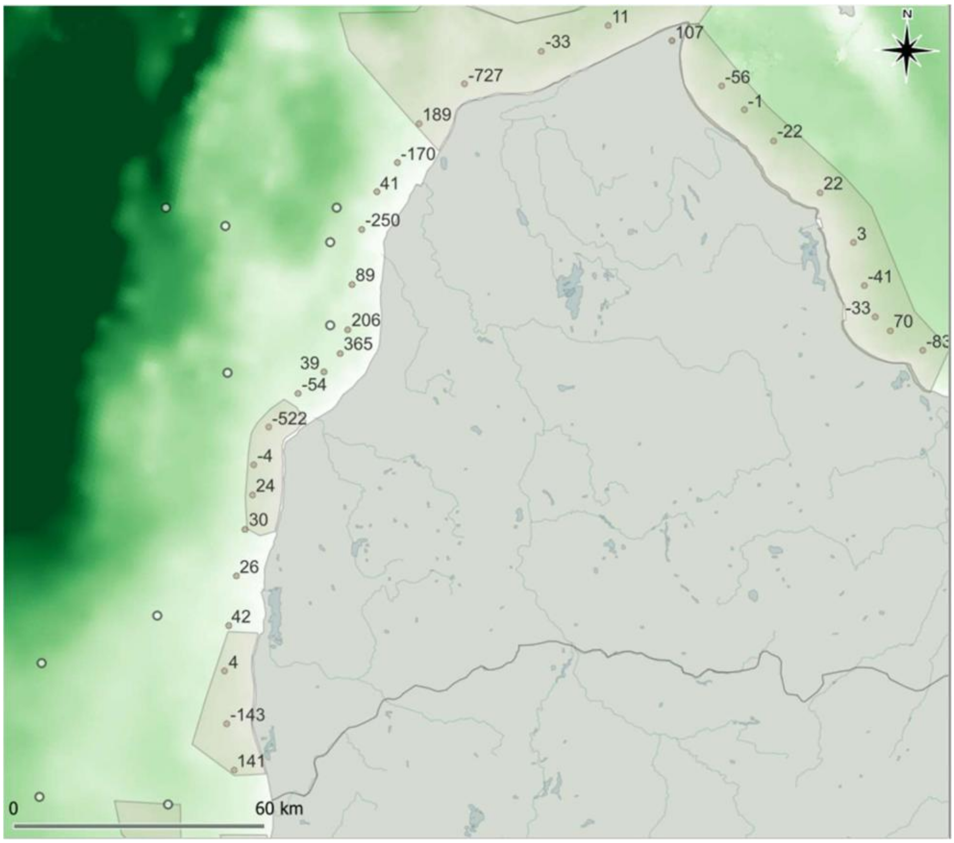
Fig. 13. In situ depth (left) and M. trossulus coverage in LIFE REEF observation campaigns (right) in Papes kalva.

2. Longshore sediment transport along the Baltic Sea coast of Latvia

Table 2. Balance of the modeled climatic longshore sediment transport per year and in June in the coastal segment

Name	Yearly balance (gain - positive), thousand m3	Balance in June (gain – positive), thousand m3
Nida-Pape	320	7
Pape-Jūrmalciems	-1097	-28
Jūrmalciems-Bernāti	-825	-22
Bernāti-Liepāja S	1342	30
Liepāja S-Liepāja N	-1487	-42
Liepāja N-Saraiķi	304	8
Saraiķi-Ziemupe	852	21
Ziemupe-Akmensrags	-129	-3
Akmensrags-Pāvilosta W	-757	-9
Pāvilosta W-E	60	0
Pāvilosta E-Labrags	-133	-5
Labrags-Jūrkalne	168	0
Jūrkalne-Sārnate	1309	28
Sārnate-Užava	-284	-8
Užava-Vārve	-1575	-33
Vārve-Ventspils	228	6
Ventspils S-N	336	11
Ventspils N-Ovīši	161	1
Ovīši-Lūžņa	681	18
Lūžņa-Sikrags	-55	-3
Sikrags-Saunags	69	1

Table 2 shows that the highest sediment gains can be expected in Bernati-Liepaja S; Saraiki-Ziemupe; Jurkalne-Sarnate; Ovisi-Luzna. The sediment loss is characteristic to Pape-Jurmalciems, Liepaja S-Liepaja N; Akmensrags-Pavilosta; Uzava-Varve. Components of the sediment balance in positive and negative direction are given in fig. X and y. Sediment balance in June is less than 5% of the yearly balance in all segments. The sign (gain or loss) is the same in June and yearly balance for all of the segments.



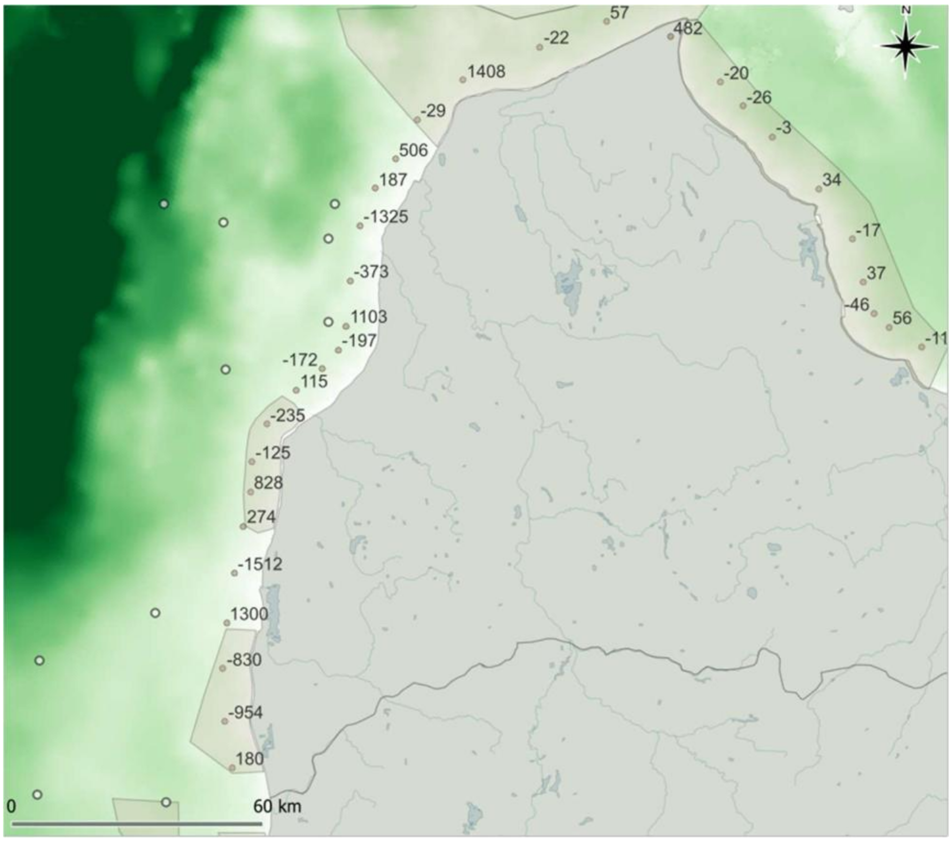


Fig. 14. Balance of the sediment transport component arising from the longshore sediment transport in negative direction (top); positive direction (bottom).

3. Results

Latvian Baltic sea rock shoals located in exclusive economic zone of the Baltic Sea in Latvia host the specially protected habitats of European Union importance, Stony reefs in the sea (1170). It's geomorphology and habitat forming species have been currently mapped in detail during in situ expeditions within LIFE REEF project 2020-2025. Rock bottoms with mussel mytilus trossulus has been discovered widely in the project pilot areas.

The marine protected areas should include the recently discovered biotopes in the exclusive economic zone of the Baltic Sea in Latvia. Its role and ecological connectivity with the currently protected marine territories need to be understood.

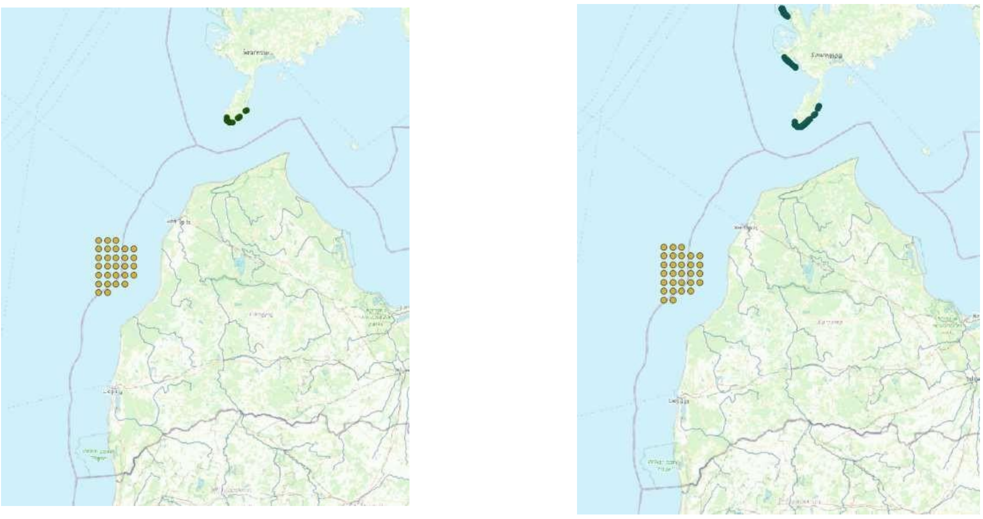
Proposed method addressed the research question on ecological connectivity based on modelling the veliger pathways towards the coast in June – passive drift by surface currents as also proposed by [1]. Archive data of processed surface currents 2008-2018 in FIMAR system provided by University of Latvia to Armed forces of Latvia has been implemented in the study. Implemented data originate from DMI oceanographic model.

Migration pathways originating from the rock shoals are followed for the next 40 days in the current experiment.

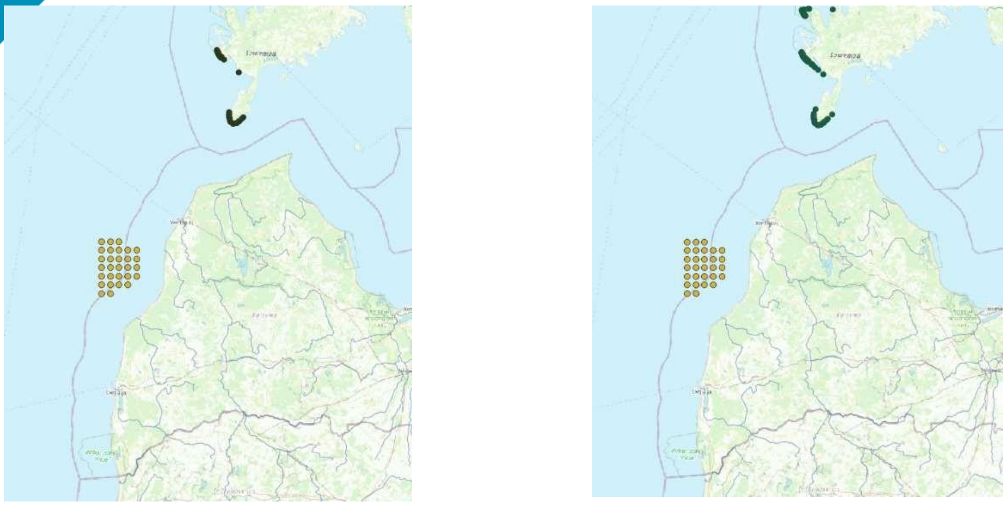
The method is based on tracking the surface currents during June – when migration of blue mussel in veliger state occurs in the Baltic Sea.

Since wild mussel beds propogate during relatively warmer summer month – understanding of current directions could be important to predict sources and sinks of the larvae pool of the wild mussel in the region. It is expected that wild mussel beds in Sweden – Gotland and Kalmar islands as the Gulf of Gdansk are too distant localities to impact the availability of veliger pool in Latvian exclusive economic zone under ordinary conditions. It is expected that Lithuanian protected marine Klaipeda-Ventspils bank could be expected to be important source as well as the mussels in west and north of Estonian Saaremaa island.

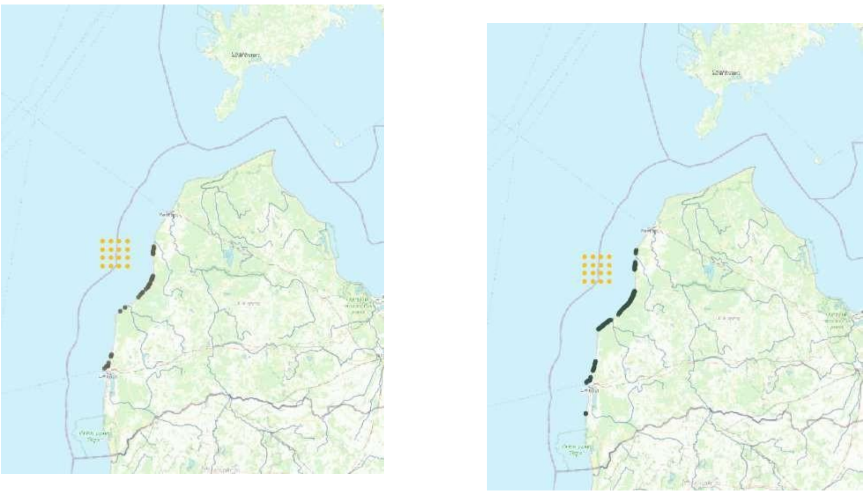
Annual variability of the connectivity between the Alku shoal and the coast along the surface layer had been examined for several years among 2008-2018. 40 days and 80 days long drift pathway analysis had been implemented. Daily sources had been initialized in June on the regular grid shown in fig. 24.



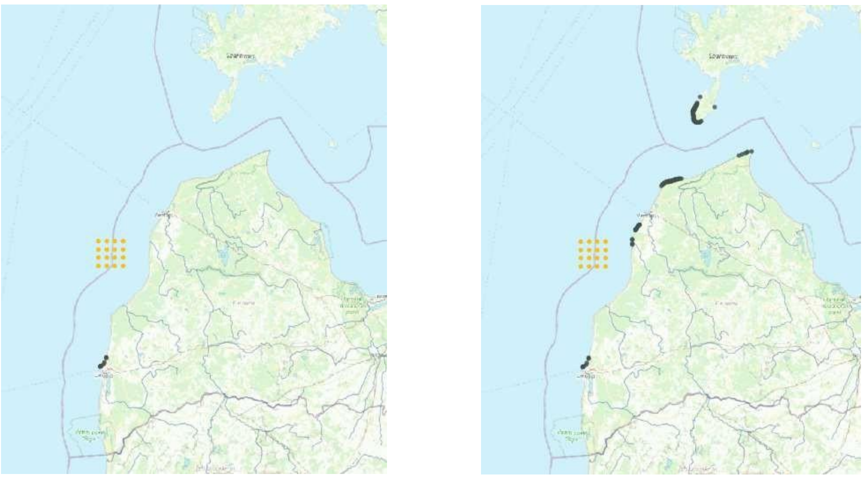
(a) 2011



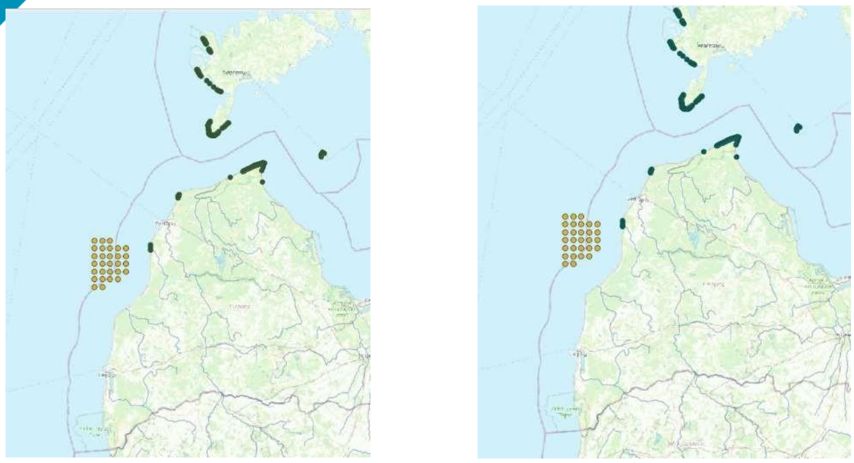
(b) 2012



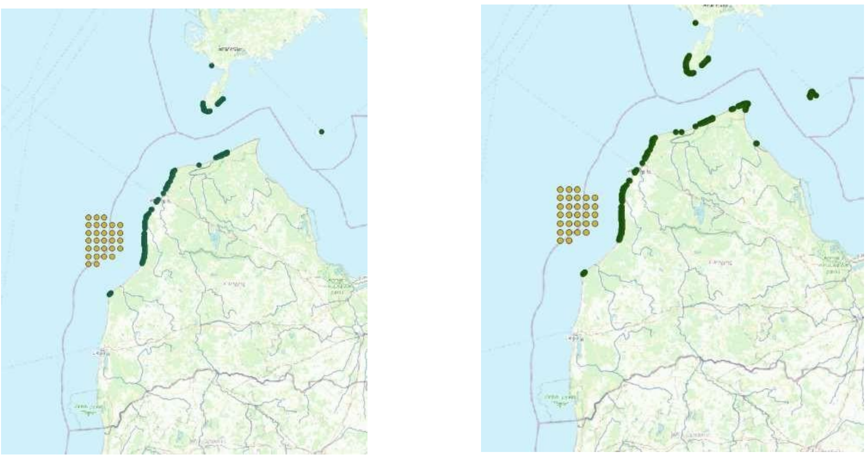
(c) 2013



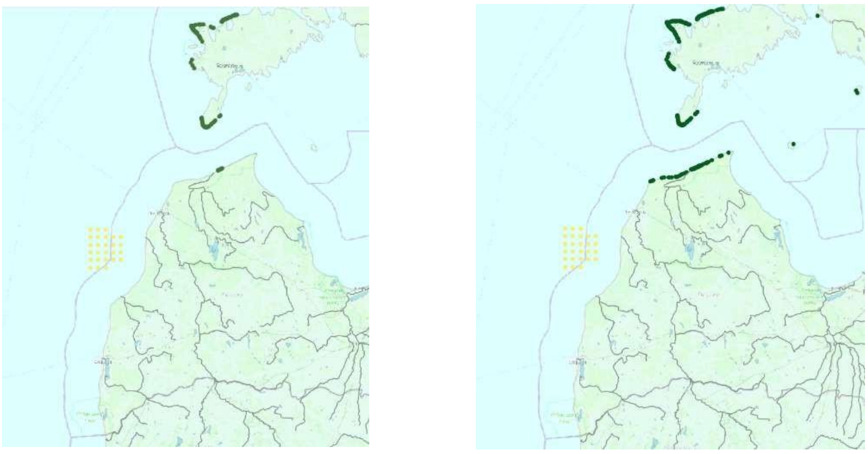
(d) 2014



(e) 2015



(f) 2016



(g) 2017

(h) 2018

Fig. 15. Annual variability of drift pathway endpoints reaching the shore in 40 days (left) and 80 days (right). Daily initalization had been done on the surface grid in Alku shoal in June.

Fig. 15 illustrate that currents can transport the drifting elements both – northward and southward along the coast.

Table 3. Drift pathway character for each source towards each coastline segment

Coastline	days, %			Source median in time of origin			Median migration length in days		
	Papes kalva	*Alku*	*Zegelnieku*	*Papes kalva*	*Alku*	*Zegelnieku*	*Papes kalva*	*Alku*	*Zegelnieku*
LT/LV - Bernati	13	-	-	June 7th	-	-	31	-	-
Skede - Ventspils parish S.	20	9	3	June 13 th	June 16 th	June 6th	23	11	24
Jurkalne parish	4	2	3	June 14th	June 12th	June 22nd	27	38	36
Uzava parish	20	14	4	June 14th	June 14th	June 8th	23	14	31
Varve parish	3	6	2	June 15th	June 20th	June 24th	20	35	31
Targale parish S. - Luzna	-	9	10	-	June 19th	June 21st	-	18	27

Table illustrate that Skede- Ventspils parish S. and Uzava parish coastline had the most frequent connection with Papes kalva – it both had received modeled larvae migration originating from 20% of total released days in Junes 2008-2018. The most frequent connection for Alku shoal had been found towards Uzava shoreline where 14% of total released days in Junes 2008-2018 had been reached. Zegelnieku shoal showed the most frequent connection with Targale parish S.- Luzna *coastline* - 10% of total released days in Junes 2008-2018 had been reached there. LT/LV – Bernati coastline had been connected with Papes kalva only. Pathway analysis show the median source being 7th June. The median source for Zegelnieku shoal connection towards Targale parish S. – Luzna coastline has been detected 21st of June. Median migration length in days has been the shortest for migration from Alku shoal towards Skede- Ventspils parish S. and Uzava parish – 11 and 14 days respectively, acording to the study.

4. Ecological connectivity between Papes kalva, Alku shoals and present MPAs (higher resolution 2x2 km sources and coastal segments of MPAs only included in the assessment)

Additional numerical experiment had been done. Daily sources on 2x2 km grid in June had been released. Its passive drift by the modeled surface current had been examined for 40 days, similarily to the experiment presented in section 4 and [Cepite-Frisfelde et. al.]. Coastal segments of the present MPAs that are reached by at least 1% of released sources in each of the years had been outlined in Tables 13-17. The method is close to the one used by [1]. It pays attention to migration received in MPAs only and assumes migration received elsewhere – in areas that have not been protected areas – lost.

Results show Papes kalva contribute as larvae source the most frequently to Akmensrags. Alku shoal contribute as larvae source the most frequently to Irbe Strait MPA (in case Latvian MPAs are considered), but it seems playing important role for Esonian and Finnish coastal areas.

Table 4. Nida Perkone ecological connectivity to current MPA in the region in 2008-2018

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Estonian MPAs											
Irbes Strait								■	■	■	
Akmensrags								■	■	■	■
Nida Perkone	■	■	■	■	■	■	■	■	■	■	■
Lithuanian coastal MPAs							■	■	■		■

33% of released source reaches the coastal segments in 40 days. 38% of those reach the coast of Nida Perkone; 11%- Akmensrags coast; 2%- Irbe Strait coast; 4%- Lithuanian coast.

Table 5. Akmensrags ecological connectivity to current MPA in the region in 2008-2018

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Estonian MPAs								■		■	
Irbe Strait								■	■	■	
Akmensrags	■	■	■	■	■	■	■	■	■	■	■
Nida Perkone							■		■		
Lithuanian coastal MPAs									■		

52% of released source reaches the coastal segments in 40 days. 36% of those reach the coast of Akmensrags; 1%- Irbe Strait; 1%- Nida Perkone; 1%- Lithuanian coast; 2%- Estonian coast.

Table 6. Klaipeda – Ventspils pl. ecological connectivity to current MPA in the region in 2008- 2018

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Estonian and/or Finish coast			■	■	■		■			■	
Irbe Strait					■		■			■	
Akmensrags	■						■	■	■	■	
Nida Perkone	■						■	■	■	■	
Lithuanian coastal MPAs								■			

24% of released source reaches the coastal segments in 40 days. 23% of those reach the coast of Akmensrags; 4%- Irbe Strait; 6%- Nida Perkone; 1%- Lithuanian coast; 13%- Estonian and Finnish coast.

Table 7. Papes kalva ecological connectivity to current MPA in the region and coastal areas abroad in 2008-2018

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Estonian coast										■	
Irbes Strait								■			
Akmensrags								■	■	■	
Nida Perkone								■	■		
Lithuanian coastal MPAs								■			

14% of released source reaches the coastal segments in 40 days. 20% of those reach the coast of Akmensrags; 2%- Irbe Strait; 11%- Nida Perkone; 5%- Lithuanian coast; 5%- Estonian coast.

Table 8. Alku shoal ecological connectivity to current MPA in the region and coastal areas abroad in 2008-2018

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Estonian and/or Finnish coast	■		■	■	■	■	■	■	■	■	■
Irbes Strait			■				■	■	■	■	■
Akmensrags						■					■
Nida Perkone											■
Lithuanian coastal MPAs											■

32% of released source reaches the coastal segments in 40 days. 1% of those reach the coast of Akmensrags; 2%- Irbe Strait; <1%- Nida Perkone; 1%- Lithuanian coast; 31%- Estonian and Finnish coast.

References

[1] Roberts KE, Cook CN, Beher J, Treml EA. Assessing the current state of ecological connectivity in a large marine protected area system. Conserv Biol. 2021 Apr;35(2):699-710. doi: 10.1111/cobi.13580. Epub 2020 Sep 5. PMID: 32623761; PMCID: PMC8048790.

Report: Efectiveness of Latvian MPA network

This report presents a METT-4 assessment of site-level management effectiveness across the Latvian MPA network, carried out within the LIFE REEF project to inform the national MPA revision and support an ecological-coherence review. In this study, we apply the Management Effectiveness Tracking Tool (METT-4) to evaluate site-level performance across the Latvian EEZ and to illustrate how METT-derived indicators can be used to inform an ecological-coherence assessment based on HELCOM criteria (representativity, replication, adequacy, and connectivity). Translating METT-4 outputs into concise indices allows us to identify where weak governance or limited capacity reduces the "effective protection" offered by the network, even where spatial design appears adequate on paper.

The METT is a globally recognized, questionnaire-based instrument designed to assess protected area management by scoring planning, inputs, processes, outputs, and outcomes (Stolton *et al*., 2019; Leverington *et al*., 2010). Its structured format makes it a cost-effective way to produce comparable qualitative and quantitative assessments across sites and over time (Stolton et al., 2021). While METT has been extensively applied in terrestrial and some marine contexts, its use in the Baltic Sea remains limited (Coad *et al*., 2015). Nevertheless, previous studies highlight METT's utility in identifying MPA management strengths and weaknesses (Chen *et al.*, 2023).

The evolution of METT over the years has led to the development of additional indicators and guidelines, making the process more user-friendly and fostering better management strategies. For instance, the METT developers have compiled lessons learned from various implementations, which can serve as a valuable resource for new users (Stolton *et al.*, 2019). These insights can help practitioners avoid common pitfalls and adopt best practices in their assessments, ultimately leading to more effective management of protected areas (Stolton *et al.*, 2019; Leverington *et al.*, 2010). Furthermore, integrating METT data into broader conservation planning frameworks can enhance the overall impact of management practices by ensuring they are grounded in empirical evidence (Coad *et al.*, 2015).

Here we report METT-4 results for the national network, summarize key management gaps (planning, enforcement, monitoring, finance, and stakeholder engagement), and present simple, reproducible indices that translate METT-4 scores into management priorities. We then discuss how these indices can be combined with spatial and ecological information to assess the network's functional coherence and to prioritise management investments where they will most improve effective protection.

RESULTS

METT-4 questions overall cover and provide measurements across 38 indicators, which are set within 6 elements: context, planning, inputs, process, outputs, and outcomes (for the full list of questions and scoring, see Table 1 in Annex 1). The answers to the appropriate questions were grouped to provide assesment across 7 indices: management plan quality, enforcement, monitoring of conservation features, staff capacity, financing, stakeholder engagement, and operational implementation.

1) Management plan quality

Questions used: Q2, Q7 (+7a–c), Q8, Q9.

Q2 - Is management undertaken to achieve the objectives of the protected area?
Q7 - Is there a management plan or equivalent and is it being implemented?
Q7a - The management planning process allows adequate and equal opportunities for stakeholders to influence management.
Q7b - There is an established schedule and process for periodic review and updating of the management plan.
Q7c - The results of monitoring, research and evaluation are routinely incorporated into management planning.
Q8 - Is there a regular work plan and is it being implemented?
Q9 - Do you have enough information to manage the area?

Score summary:

- Q2 (objectives): **2 / 3**.
- Q7 (management plan exists and implementation): **3 / 3**.
- 7a–c (participation, review, monitoring in plan): **1 / 3**.
- Q8 (regular work plan): **0 / 3**.
- Q9 (sufficient information/resource inventory): **2 / 3**.

Interpretation: A formal management plan exists on paper, but has not yet been implemented, and stakeholders had input during planning. However, the plan lacks operationalisation - there is no annual/regular workplan and several objectives may be unrealistic without secured funding. Information (surveys) is moderate but not comprehensive.

2) Enforcement

Questions used: Q15, Q16 (and Q3, Q15 reinforced).

Q15 - Are equipment and facilities sufficient for management needs? Q16 - Can staff (i.e., those with responsibility for managing the site) enforce protected area legislation and regulation? Q3 - Are appropriate regulations/controls in place to manage use and activities in accordance with the management objectives of the protected area?

Score summary:

- Q15 (equipment and facilities): **0 / 3**.
- Q16 (capacity to enforce law/regulation): **0 / 3**.
- Q3 (regulations/controls): **1 / 3**.

Interpretation: Enforcement capacity is effectively absent - equipment/facilities are absent, and legal enforcement capability is scored zero. Some regulations exist on paper, but the authority or means to implement/enforce them are weak. This is a critical implementation gap: without enforcement, protective rules have a low practical effect.

3) Monitoring of conservation features

Questions used: Q20, Q35, Q37, Q38 plus Q9, Q19.

Q20 - Are management activities regularly monitored, evaluated and adapted? Q35 - What is the condition of the important natural values of the protected area as compared to when it was first designated? Q37 - Has the status of key indicator species changed over the last 5 years? Q38 - Has the status of habitats changed over the last 5 years? Q9 - Do you have enough information to manage the area? Q19 - Is there a programme of management-orientated survey and research work?

Score summary:

- Q19 (programme of management-oriented surveys/research): **3 / 3**.
- Q20 (monitoring and adaptive management): **1 / 3**.
- Q35 (condition of natural values since designation): **1 / 3**.

- Q37 (status of indicator species change last 5 years): **0 / 3**.
- Q38 (status of habitats change last 5 years): **0 / 3**.
- Q9 (information sufficiency): **2 / 3**.

Interpretation: There is a program of surveys and research (Q19 = 3). However, the research has not yet been fully translated into regular monitoring and adaptive management. The status of key species and habitats is mostly trending negatively, and invasive/alien species (*Dreissena polymorph*a, *Amphibalanus improvisus*, and *Cardilophora caspia*) are spreading.

4) Staff capacity

Questions used: Q10, Q11, Q18 (plus Q15 and Q14 as supporting).

Q10 - Are there enough people to manage the protected area? Q11 - Do the people involved in managing the protected area have the necessary knowledge and skills? Q18 - Do protected area staff have safe working conditions and does management prioritise safety? Q15 - Are equipment and facilities sufficient for management needs? Q14 - Is the budget managed to ensure effective administration of the protected area?

Score summary:

- Q10 (enough people): **0 / 3**.
- Q11 (knowledge and skills): **0 / 0** (not assessed/recorded).
- Q18 (staff safety/priority): **0 / 0**.
- Q15 (equipment): **0**, Q14 (budget management): **0**.

Interpretation: Staff capacity is essentially absent: no dedicated people, no training/skills recorded, and no equipment. This is a major operational bottleneck - without staff (or without responsible employees from other institutions), you cannot reliably implement workplans, monitoring, or enforcement.

5) Financing

Questions used: Q12–Q14 (and Q15, Q28/29 supporting).

Q12 - Is the current budget sufficient? Q13 - Is the budget secure? Q14 - Is the budget managed to ensure effective administration of the protected area? Q15 - Are equipment and facilities sufficient for management needs? Q28 - If fees (i.e., entry fees or fines) are applied, do they help protect area management? Q29 - Are visitor facilities and services adequate?

Score summary:

- Q12 (current budget sufficiency): **0 / 3**.
- Q13 (budget security): **0 / 3**.
- Q14 (budget managed): **0 / 0**.
- Q15 (equipment) **0**; Q28/29 (fees/facilities) **0**.

Interpretation: There is no dedicated or secure funding recorded for management - the METT scores for finance are zero. This explains many downstream problems (no staff, no equipment, no work plans implemented).

6) Stakeholder engagement

Questions used: Q7a, Q30, Q31, Q26, Q27, Q25.

Q7a - The management planning process allows adequate and equal opportunities for stakeholders to influence management. Q30 - Are Indigenous people involved in management decisions? Q31 - Do local communities living in or near the protected area have input to management decisions? Q26 - Is there co-operation with neighbouring land/sea State and commercial users? Q27 - Do commercial tour operators contribute to protected area management? Q25 - Is there a planned education programme linked to the management needs?

Score summary:

- Q7a (planning participation): **1 / 1**.
- Q30 (Indigenous involvement): **0 / 3** (although many coastal families in Latvia have sustained traditional fishing livelihoods over generations, they are not recognized as "indigenous people" in the official or legal sense).

- Q31 (local community input): **3 / 3**.
- Q26 (cooperation with neighbours/users): **0 / 3**. Q27 (tour operators): **0**. Q25 (education): **0**.

Interpretation: Good local stakeholder input and participatory planning are present. However, broader stakeholder engagement (tourism, commercial operators, and formal outreach) is largely absent.

7) Operational implementation

Questions used: Q7, Q8, Q17, Q16, Q21, Q15 (+ Q10/Q11 supportive).

Q7 - Is there a management plan or equivalent and is it being implemented? Q8 - Is there a regular work plan and is it being implemented? Q17 - Are systems (e.g. patrols, permits, intelligence gathering etc) in place to control access/resource use in the protected area? Q16 - Can staff (i.e. those with responsibility for managing the site) enforce protected area legislation and regulation? Q21 - Is active resource management being undertaken? Q15 - Are equipment and facilities sufficient for management needs? Q10 - Are there enough people to manage the protected area? Q11 - Do the people involved in managing the protected area have the necessary knowledge and skills?

- Q8 (work plan): **0 / 3**.
- Q17 (systems to control access): **0 / 3**.
- Q16 (enforcement capacity): **0**.
- Q21 (active resource management): **1 / 3**.
- Q15 equipment: **0**.
- Q10/11 staff: **0**.

Interpretation: The MPA network has plan-level readiness but lacks the operational systems (work plan, staffing, enforcement, equipment) needed to turn policy into practice. Some project-based and ad-hoc actions exist, but are insufficient for full implementation.

The results of these seven indices reflect site-specific management conditions and highlight particular strengths and weaknesses within the Latvian MPA network. To provide a broader overview, the scores were further aggregated according to the five core METT-4 management elements - *planning, inputs, process, outputs,* and *outcomes.* The following graphs (Figure 1 and 2) present these element scores, offering a concise visual summary of overall management performance and indicating which components of site management require the most improvement.

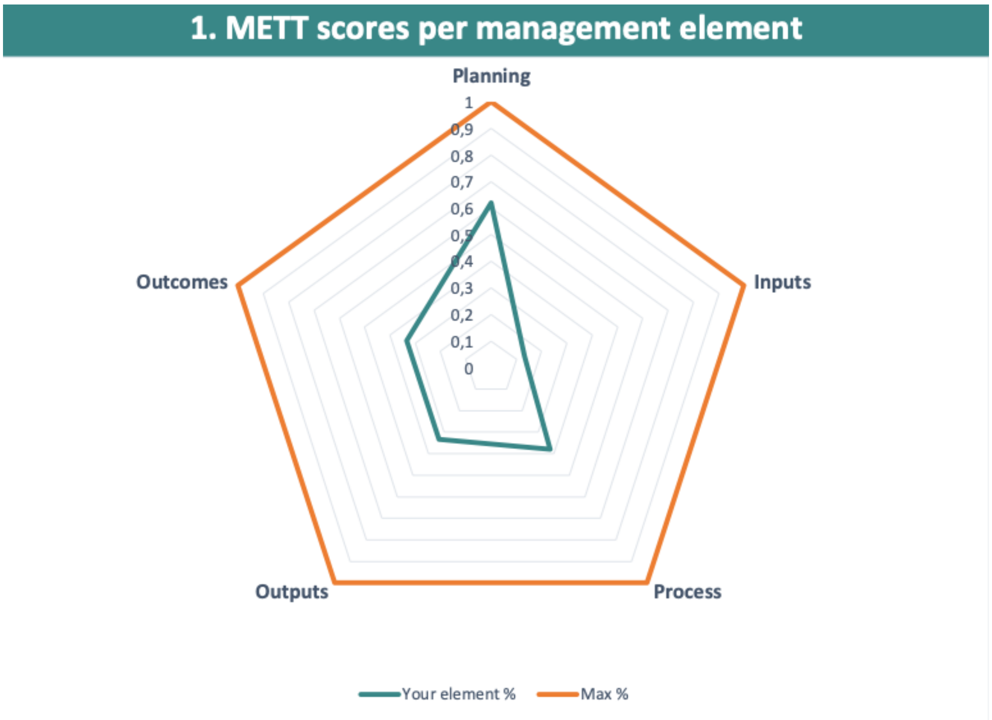


Figure 1 MET-4 scores in percent per management element

This graph (Figure 1) illustrates the percentage of the maximum possible score obtained for each of the five METT-4 elements - *planning, inputs, process, outputs,* and *outcomes.* The highest values were recorded for *planning* and *process,* indicating that management objectives and basic administrative procedures are largely in place. In contrast, *inputs* (reflecting staff, funding, and equipment) and *outputs* (reflecting the level of implemented activities) received the lowest scores, revealing significant limitations in operational capacity and delivery of management actions.

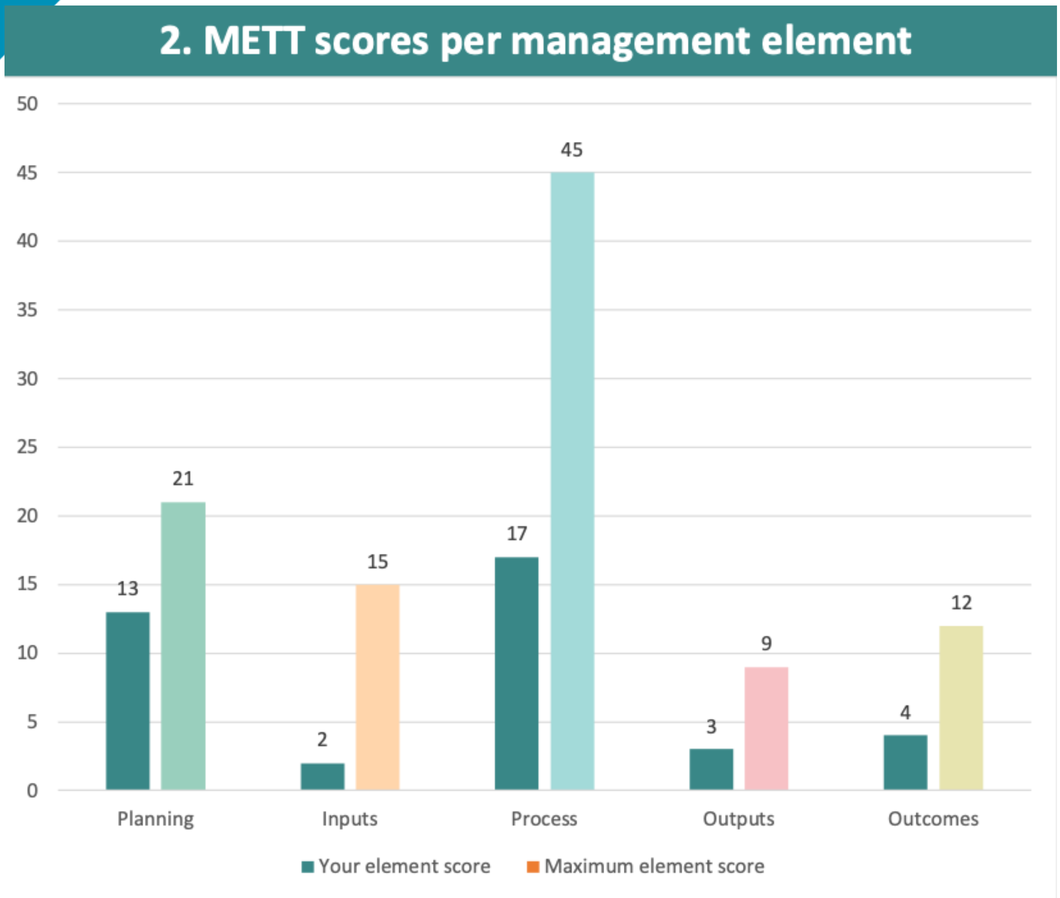


Figure 2 METT-4 scores per management element

The second figure (Figure 2) demonstrates these same results as absolute scores, allowing direct comparison between components with differing numbers of questions. This graph shows that *planning* performs best, achieving the largest share of its potential score, followed by *process,* which reaches moderate levels. *Inputs, outputs, and outcomes* remain well below half of their possible maximum values, confirming that resource constraints and limited implementation capacity are the main factors reducing overall management effectiveness.

Valsts reģionālās attīstības aģentūra
Dabas aizsardzības pārvalde
BIOR
LATVIJAS HIDROEKOLOĢIJAS INSTITŪTS

Threats

The METT-4“ Threats” panel summarises current pressures on the Latvian MPA network by combining assessments of *extent* (how much of the site is affected) and *severity* (how strongly the pressure impacts the values) for standard threat categories. Higher scores indicate pressures that are more widespread and/or more damaging to the key species and habitats within the MPA territories. The treats, as well as their extent and severity, for the most part, are the same across the network.

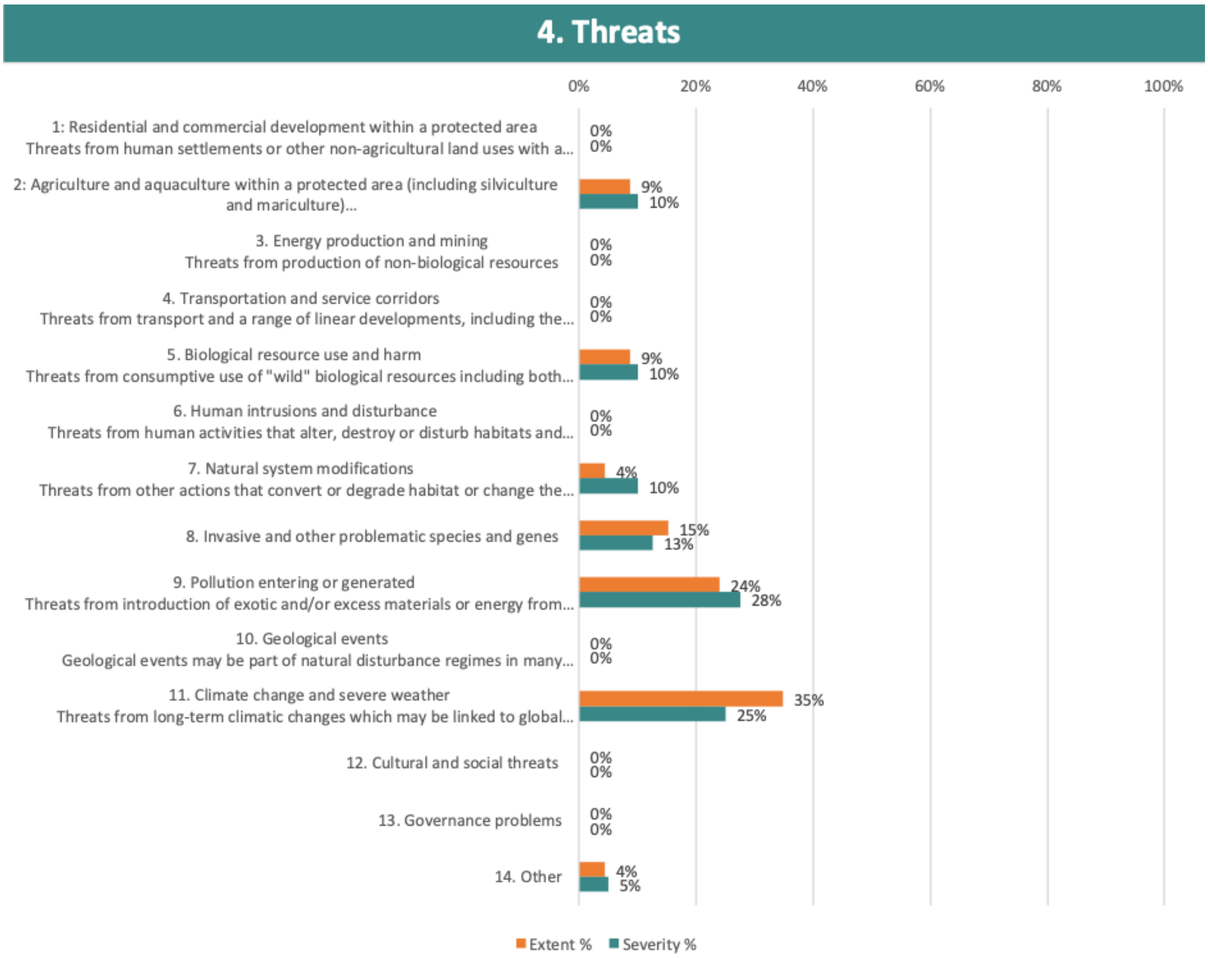


Figure 3 Threats and their extent and severity across the Latvian MPA network

Figure 3 identifies several medium to high-scoring threats (pollution/eutrophication, biological resource use, invasive/alien species, and climate change impacts) and a set of secondary pressures (coastal development, recreation, as well as potential aquaculture facilities planned within the MPA “Rīgas līča Vidzemes piekraste” territory). These scores, therefore, indicate where management attention and mitigations are most urgently required.

Figures 4 and 5 show the percentage of the levels of threat extent and severity accordingly.

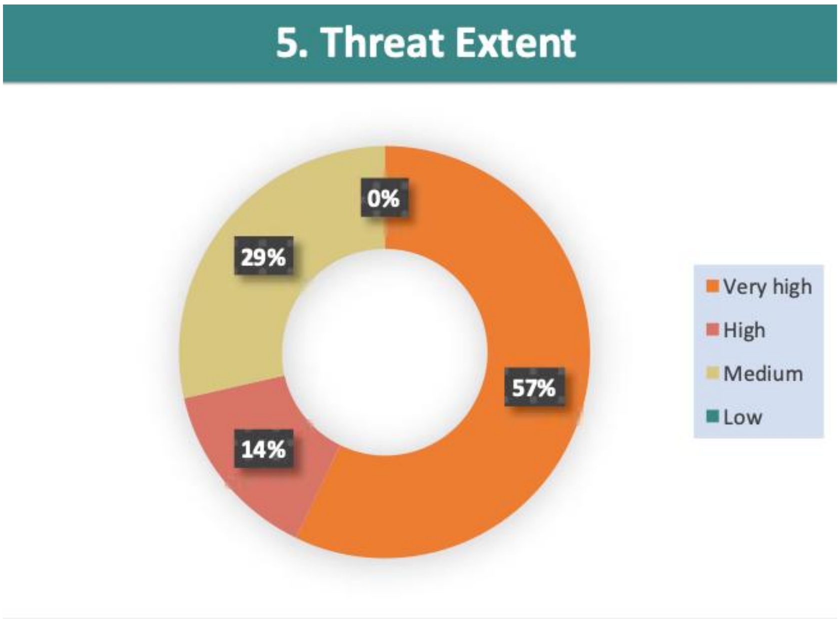


Figure 4 Extent of the threats

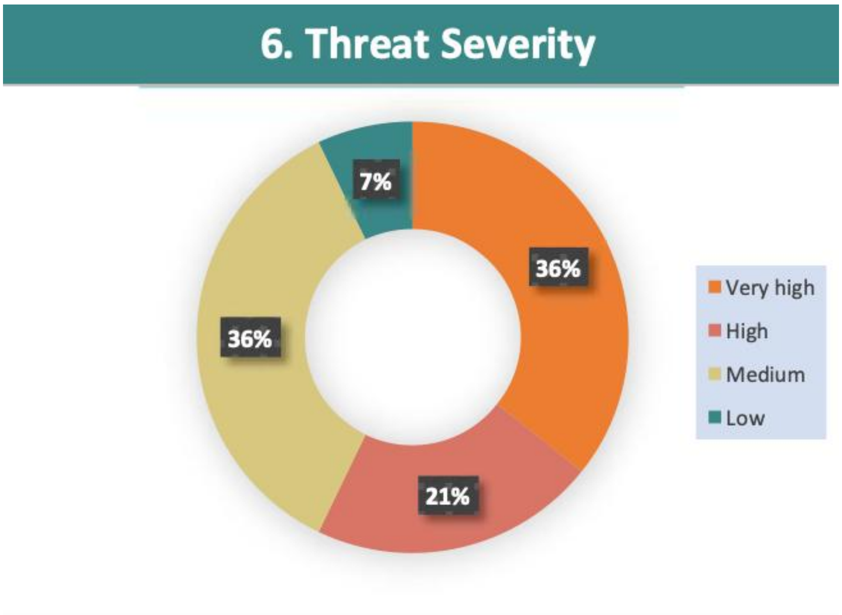


Figure 5 Severity of the threats

Eutrophication and marine pollution

The eutrophication and general water-quality pollution are ranked among the highest-scoring threats in both extent and severity for the Latvian MPA network, indicating these pressures are widespread and have substantial impacts. In the majority of the coastal areas, a significant decline in perennial macroalgae (notably *Fucus* spp.), and concurrently opportunistic/filter-feeding species (e.g., *Dreissena*, *Amphibalanus*) are reported as increasing. The evidence points to eutrophication and related water-quality issues as a major, ongoing driver of change. The diffuse land-based sources (runoff, riverine nutrient inputs) and coastal point sources are the likely origins, and the management responses to control these diffuse sources are currently limited according to the METT outputs. The river basin management plans identify and describe mitigation measures, but they currently don't have a legally binding status unless approved by the Cabinet of Ministers. To reduce nutrient loads from point sources, it is necessary to enhance the efficiency of wastewater treatment plants.

Biological resource use (fishing and gear impacts)

Consumptive uses (fishing, incidental bycatch, and related gear impacts) are highlighted as a significant local pressure. A prolonged overfishing of fish species of commercial interest has led to a dramatic decline of some of these fish stocks. Additionally, coastal fishing, which often occurs on herring spawning habitats (perennial macroalgae), disturbs them mechanically, removing fish biomass and affecting the food chains of coastal habitats. Even though static gear, used for small-scale coastal fishing, has a much lower impact compared to contact fishing gear (such as trawling), the ability of epifauna to resist impacts from static gears varies between species, and the degree of impact depends on the intensity of fishing and its duration. The damage could be caused during the setting of nets and their associated ground lines and anchors, and by their movement over the bottom during rough weather and during recovery (Fennell *et al.*, 2021; Tyler-Walters & Arnold, 2008). When assessing the impacts, the recovery rate (potential) of different benhic species must be taken into consideration, as slow-growing non-colonial organisms need a significant amount of time to recover from the damage (Fennell *et al.*, 2021). In short, biological resource use pressure is important and insufficiently controlled at present.

Aquaculture within the protected area

Since 2024, two aquaculture areas have been proposed in the Gulf of Riga, located within the territory of the marine protected area "Rīgas līča Kurzemes piekraste", which is also included in the European Union's Natura 2000 network of specially protected areas. The sizes of the areas "Roja" and "Mērsrags" are 3,69 and 1,97 km2 accordingly (Cabinet Order No. 664). It is planned to grow the rainbow trout (*Oncorhynchus mykiis*). Near Roja, in the first year, it is planned to install an anchored fish sea cage network. Starting next year, the number of cages will be increased to 10 anchored cages with a total area of 368,9 ha. Similarly, near Mērsrags during the first year it is planned to install one cage and increase the number the following year to 10, but with a total area of 196,4 ha. As it is stated in the initial environmental impact assessments (No. AP24SI0076 for the area "Roja", and No. AP24SI0077 for the area "Mērsrags"). The company applications indicate that in each of the territories, in open cages, it is planned to obtain up to 5000 t (in total in both territories up to 10000 t) of trout per year, using up to 4000 t (in total in both territories 8000 t) of feed. For every 10000 t of trout, at least 400-600 t of nitrogen and 50-100 t of phosphorus emissions per year must be taken into account, according to the literature. However, according to preliminary calculations done by the Latvian Institute of Aquatic Ecology, to breed up to 10000 t of trout per year in both territories, approximately 100000 t of feed is required, which significantly exceeds the amounts indicated in the application (in total, in both territories, 8000 t of feed). With such amounts of feed used, nitrogen and phosphorus emissions will increase significantly, which, according to the Institute, will reach at least 400 - 600 t of nitrogen and 50 -100 t of phosphorus per year. If the loads (nitrogen, phosphorus, and organic matter) are not eliminated, reduced, or compensated, then significant negative effects are expected. According to the initial environmental impact assessments, the key concerns are local nutrient enrichment and benthic deposition (uneaten feed and faeces), increased sedimentation and benthic organic loading beneath cages, disease/parasite transfer and escape risk to wild stocks, chemical inputs, and increased vessel traffic. And according to the assessment by the Scientific Institute of Food Safety, Animal Health and Environment "BIOR", the planned activities may contribute to an increase in eutrophication in the Gulf of Riga, which may have a significant impact on the environment and fish resources. All in all, these stressors interact with the existing threats already highlighted by METT-4. Severity, therefore, ranges from moderate to high depending on distance to sensitive habitats, hydrodynamics, and stocking density.

Additionally, the current state of the marine environment doesn't meet good marine environmental status in terms of total nitrogen and phosphorus. The HELCOM Baltic Sea Action Plan intends a 15% reduction in nitrogen and 25% in phosphorus loads, and it should be noted that, unlike nitrogen, phosphorus loads don't show a decreasing trend. Therefore, it can be concluded that the planned action will have a significant impact on the environmental status of the Baltic Sea, as in a situation where measures must be implemented to improve the environmental status of the Baltic Sea, the planned action will create additional pollution loads (HELCOM, 2021).

As indicated in the initial environmental impact assessments (AP24SI0076, AP24SI0077), an environmental impact assessment procedure has been started for both of these planned aquaculture activities, which is currently still undergoing.

Invasive and opportunistic species

The assessment shows invasive/opportunistic taxa as a substantial and rising pressure. A variety of alien/invasive species are found, introduced mainly via shipping (especially ballast waters), and also through aquaculture. The most important species is the round goby (*Neogobius melanostomus*), which has no significant natural enemies, and its development is limited only by the availability of food and fishing pressure. As a result of the feeding pressure of this species (it feeds on mussels), the stony reef habitats are significantly degraded. However, in recent years, the fishing of the round goby has led to a significant decrease in the round goby population. This has resulted in a partial recovery of the population of blue mussels (*Mytilus trossulus*).

Also, *Dreissena polymorpha* and *Amphibalanus improvisus* are increasing in abundance and spatial coverage. These species have the capacity to alter benthic community structure (competition, smothering, and changed sediment dynamics) and to aggravate the declines in native habitat-formers.

Generally speaking, invasive and alien species can outcompete and displace native species, alter the food webs, change nutrient cycling, and cause other negative impacts on the ecosystem. However, there is a need to research their impact on ecosystems, habitats, native species, and the best methods for their control.

Climate change and severe weather

Climate-related pressures are recognised in the METT as an emerging threat (changing temperature, storminess, and salinity regimes), and the assessment indicates only limited active adaptation measures. Although climate is not currently the single largest immediate driver, it interacts with local pressures promoting shifts in species composition, accelerating eutrophication and hypoxia, and increasing the vulnerability of habitats that are already degraded by pollution, extractive use, and invasive species. These interacting effects mean that climate impacts will increasingly determine whether management actions succeed in preserving key habitat functions, unless adaptation is built into the work plan.

A clear, measured signal of climate-linked change in the Gulf of Riga is water browning and light limitation. Long-term monitoring shows a decline in median summer Secchi depth from 2.81 m to 2.30 m, while Forel–Ule colour indices shifted toward browner tones (from roughly 10–12 to 11–13) when comparing the periods 1998–2007 and 2008–2018 (Aigars *et al.*, 2024). This reduction of the photic zone directly shrinks the habitat available to benthic macroalgae such as *Fucus vesiculosus*, reduces in situ macrophyte productivity, and limits food availability for higher trophic levels (as a result of the loss of ecological functionality of stony reefs) (Viitasalo & Bonsdorff, 2022). Experimental field data from the northern Baltic further indicate that elevated humic substances (the driver of browning) degrade the fatty-acid quality of seston and zooplankton, thereby diminishing the nutritional value of planktonic food for bivalves and fish larvae - a pathway that links primary-production changes to recruitment success and ultimately to fish and bird foraging conditions (Bandara *et al.*, 2022).

Hydrological changes linked to climate also matter. Less frequent inflows of oxygen-rich North Sea water mean that deep basins receive fewer ventilating events. This creates bottom-water oxygen deficits that reduce the area of suitable habitat for benthic fauna and demersal fish. Increased average precipitation and river discharge cause a suite of knock-on effects: more frequent coastal storm surges, lower salinity in nearshore zones (negatively affecting the size and physiology of the keystone species), enhanced sediment delivery and sedimentation that can smother shallow benthic communities, and a shift in benthic community composition toward opportunistic green algae in many coastal areas. The combination of lower salinity, higher sedimentation, and reduced light is particularly damaging to perennial macroalgae and mussels that underpin stony reef functionality (Viitasalo & Bonsdorff, 2022; Takolander *et al.*, 2017).

Temperature extremes and a longer, stronger summer stratification period compound these problems. Warmer surface waters and extended stratification lower dissolved oxygen in bottom layers, increase metabolic stress, and accelerate eutrophication by lengthening phytoplankton growing seasons. Warmer conditions also favour the spread and establishment of alien and opportunistic species (which we already record as increasing), while creating physiological stress for certain native taxa (Takolander *et al.*, 2017). In short, temperature extremes increase both bottom-up and top-down instability in the system.

Ocean acidification adds further, species-specific pressure. Although Baltic Sea organisms experience naturally large pH variability and some planktonic taxa appear relatively robust to moderate pH declines, recent experiments show that sensitivity depends on the magnitude and frequency of extremes. Projected declines in annual pH minimum may exceed tolerance thresholds for some calcifying and larval stages. Experiments indicate that *Macoma balthica* shows difficulties under acidified conditions, and bivalve larvae (including mussels) incur higher mortality and slower development. While adult blue mussels can be comparatively tolerant, larval vulnerability is of particular concern for population replenishment (Viitasalo & Bonsdorff, 2022; Gustafsson & Winder, 2024; AirClim, 2021). For macrophytes, elevated dissolved inorganic carbon can slightly increase photosynthetic potential, but these benefits are typically outweighed by concurrent stressors (warming, salinity declines). Perennial algae communities (e.g., *Fucus vesiculosus*) may lose competitive fitness relative to other functional groups under combined warming, browning, and acidification scenarios. Changes at lower trophic levels (phytoplankton and zooplankton composition and fatty-acid quality) and reduced recruitment of key fish species. These shifts translate into impacts on higher-level consumers like seals and seabirds (Pajusalu *et al.*, 2024; Gustafsson & Winder, 2022).

Coastal development and infrastructure

Although large-scale residential/industrial development isn't reported as the top immediate driver, pressures from coastal development and associated shoreline modification (runoff, altered sediment dynamics) are noted among the threat categories and can exacerbate water-quality and habitat impacts.

Governance and cross-cutting (policy, enforcement, capacity shortfalls)

Even though it doesn't fall exactly under the METT-4 *Governance problems* subcriteria (namely, *Conflicting policies across sectors* and, *Confusion about goverment roles and resposibilities*) it is important to mention that the METT overall also identifies governance-related issues (low staff, no secure funding, little enforcement capacity, and no consistent operational work plan) as cross-cutting pressures that reduce the ability to address the biophysical threats above. In other words, many high-scoring threats (pollution, biological use, invasive/alien species) are made worse by the governing institution's limited ability to monitor, prevent, or respond. Strengthening enforcement, monitoring, and financing will directly reduce the effective severity of the listed threats.

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