Possible impact of offshore wind park on temperate reef ecosystem – EIA study, Baltic Sea

Georg Martin, Kristjan Herkül

Estonian Marine Institute, University of Tartu

Ørsted

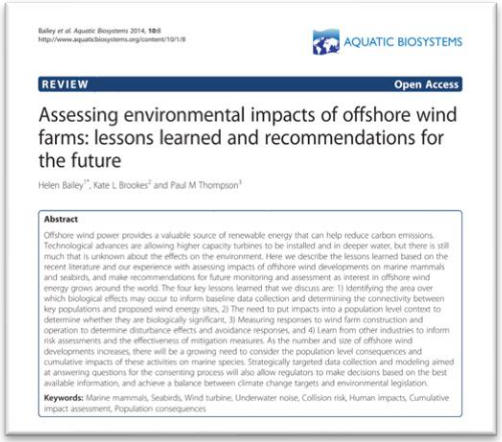
The world’s biggest offshore wind farm, Hornsea 2

When fully operational, Hornsea 2’s 165 8 MW Siemens Gamesa wind turbines will be capable of generating 1.32 GW of clean electricity – taking the title of ‘world’s largest operating offshore wind farm’ from its sibling project Hornsea 1. Together, the two projects will be capable of providing enough power for well over 2.3 million homes.

Once Hornsea 2 is completed, power will be transferred from the 165 wind turbines via 373 km of array cables to the OSS and RCS, reaching the national grid via 390 km of offshore and 40 km of onshore export cables which terminate at the onshore substation in Killingholme.

Rotor diameter 167 m

https://orsted.com/en/media/newsroom/news/2021/12/20211220460511



Bailey *et al. Aquatic Biosystems* 2014, **10**:8
http://www.aquaticbiosystems.org/content/10/1/8

AQUATIC BIOSYSTEMS

REVIEW Open Access

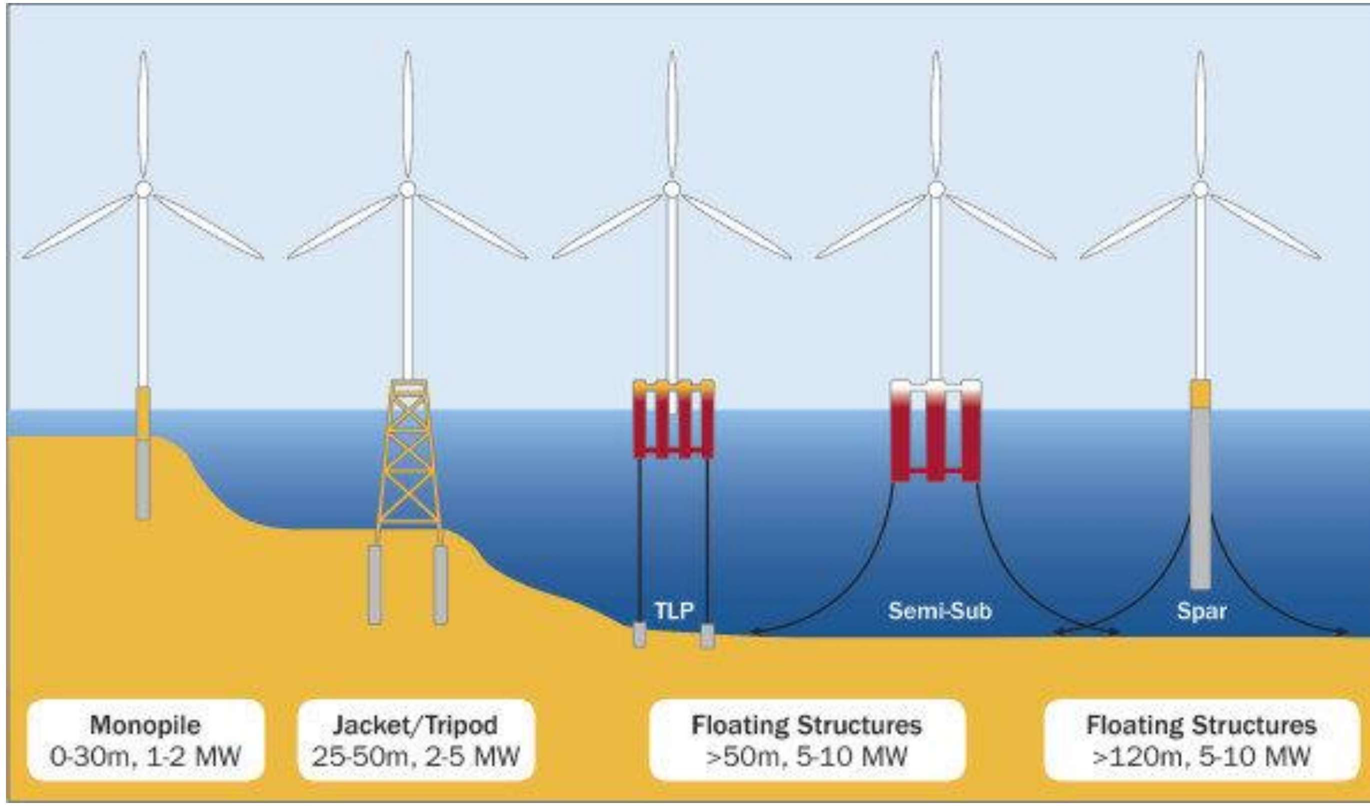
Assessing environmental impacts of offshore wind farms: lessons learned and recommendations for the future

Helen Bailey[1*], Kate L Brookes[2] and Paul M Thompson[3]

Abstract

Offshore wind power provides a valuable source of renewable energy that can help reduce carbon emissions. Technological advances are allowing higher capacity turbines to be installed and in deeper water, but there is still much that is unknown about the effects on the environment. Here we describe the lessons learned based on the recent literature and our experience with assessing impacts of offshore wind developments on marine mammals and seabirds, and make recommendations for future monitoring and assessment as interest in offshore wind energy grows around the world. The four key lessons learned that we discuss are: 1) Identifying the area over which biological effects may occur to inform baseline data collection and determining the connectivity between key populations and proposed wind energy sites, 2) The need to put impacts into a population level context to determine whether they are biologically significant, 3) Measuring responses to wind farm construction and operation to determine disturbance effects and avoidance responses, and 4) Learn from other industries to inform risk assessments and the effectiveness of mitigation measures. As the number and size of offshore wind developments increases, there will be a growing need to consider the population level consequences and cumulative impacts of these activities on marine species. Strategically targeted data collection and modeling aimed at answering questions for the consenting process will also allow regulators to make decisions based on the best available information, and achieve a balance between climate change targets and environmental legislation.

Keywords: Marine mammals, Seabirds, Wind turbine, Underwater noise, Collision risk, Human impacts, Cumulative impact assessment, Population consequences



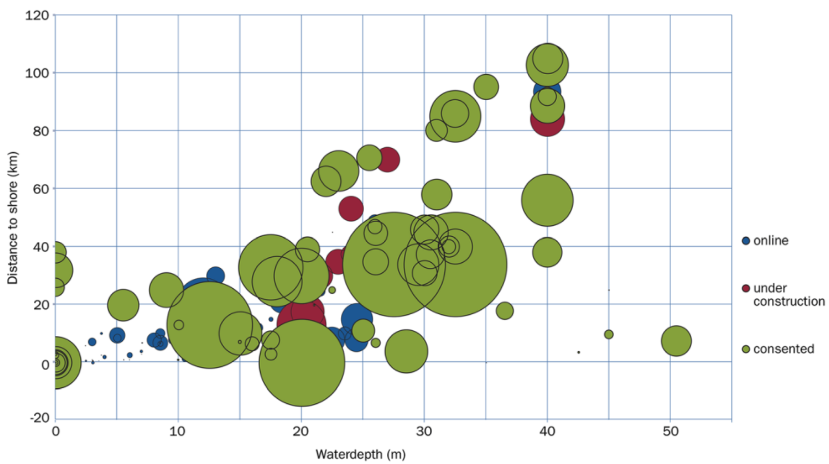


Figure 1 Average water depth and distance to shore of offshore wind farms (reproduced from ref. 3, source EWEA). Operational (online), under construction and consented wind farms in Europe up to the end of 2013 are occurring at increasing water depths and distances from shore. The circle size represents the total power capacity of the wind farm.

Bailey *et al. Aquatic Biosystems* 2014, **10**:8
http://www.aquaticbiosystems.org/content/10/1/8

ICES Journal of
Marine Science

ICES CIEM International Council for the Exploration of the Sea / Conseil International pour l'Exploration de la Mer

ICES Journal of Marine Science (2019), doi:10.1093/icesjms/fsz018

Review Article

Benthic effects of offshore renewables: identification of knowledge gaps and urgently needed research

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[9]Normandie Univ, UNICAEN, Laboratoire Morphodynamique Continentale et Côtière, CNRS, UMR 6143 M2C, 24 Rue des Tilleuls, Caen 14000, France
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Dannheim, J., Bergström, L., Birchenough, S. N. R., Brzana, R., Boon, A. R., Coolen, J. W. P., Dauvin, J.-C., De Mesel, I., Derweduwen, J., Gill, A. B., Hutchison, Z. L., Jackson, A. C., Janas, U., Martin, G., Raoux, A., Reubens, J., Rostin, L., Vanaverbeke, J., Wilding, T. A., Wilhelmsson, D., and Degraer, S. Benthic effects of offshore renewables: identification of knowledge gaps and urgently needed research. – ICES Journal of Marine Science,doi:10.1093/icesjms/fsz018.

Received 1 November 2018; revised 17 January 2019; accepted 20 January 2019.

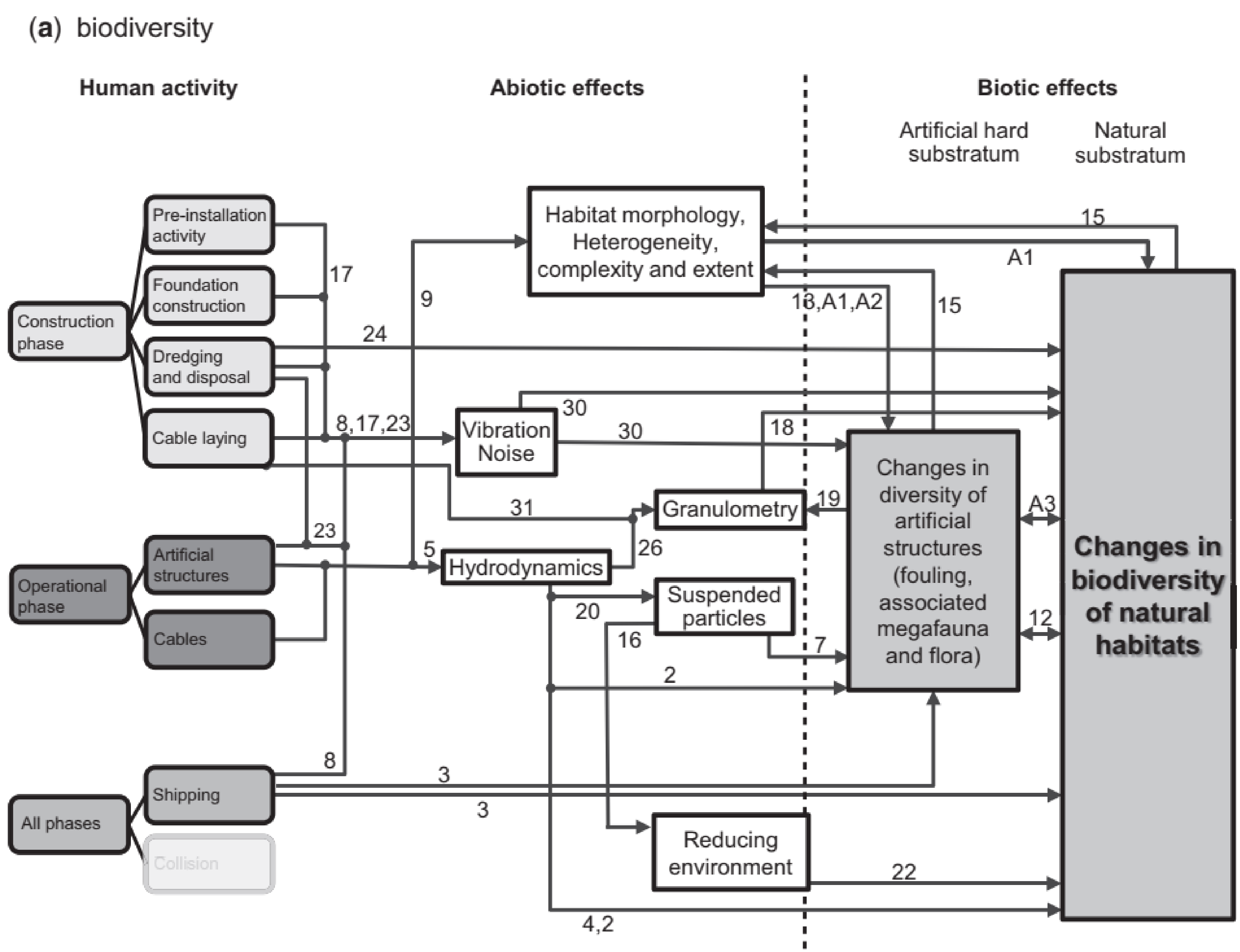
As the EU's commitment to renewable energy is projected to grow to 20% of energy generation by 2020, the use of marine renewable energy from wind, wave and tidal resources is increasing. This literature review (233 studies) (i) summarizes knowledge on how marine renewable energy devices affect benthic environments, (ii) explains how these effects could alter ecosystem processes that support major ecosystem services and (iii) provides an approach to determine urgent research needs. Conceptual diagrams were set up to structure hypothesized

Table 1. Criteria for assessing the probability of impact on marine life from pressures associated with offshore renewable energy devices.

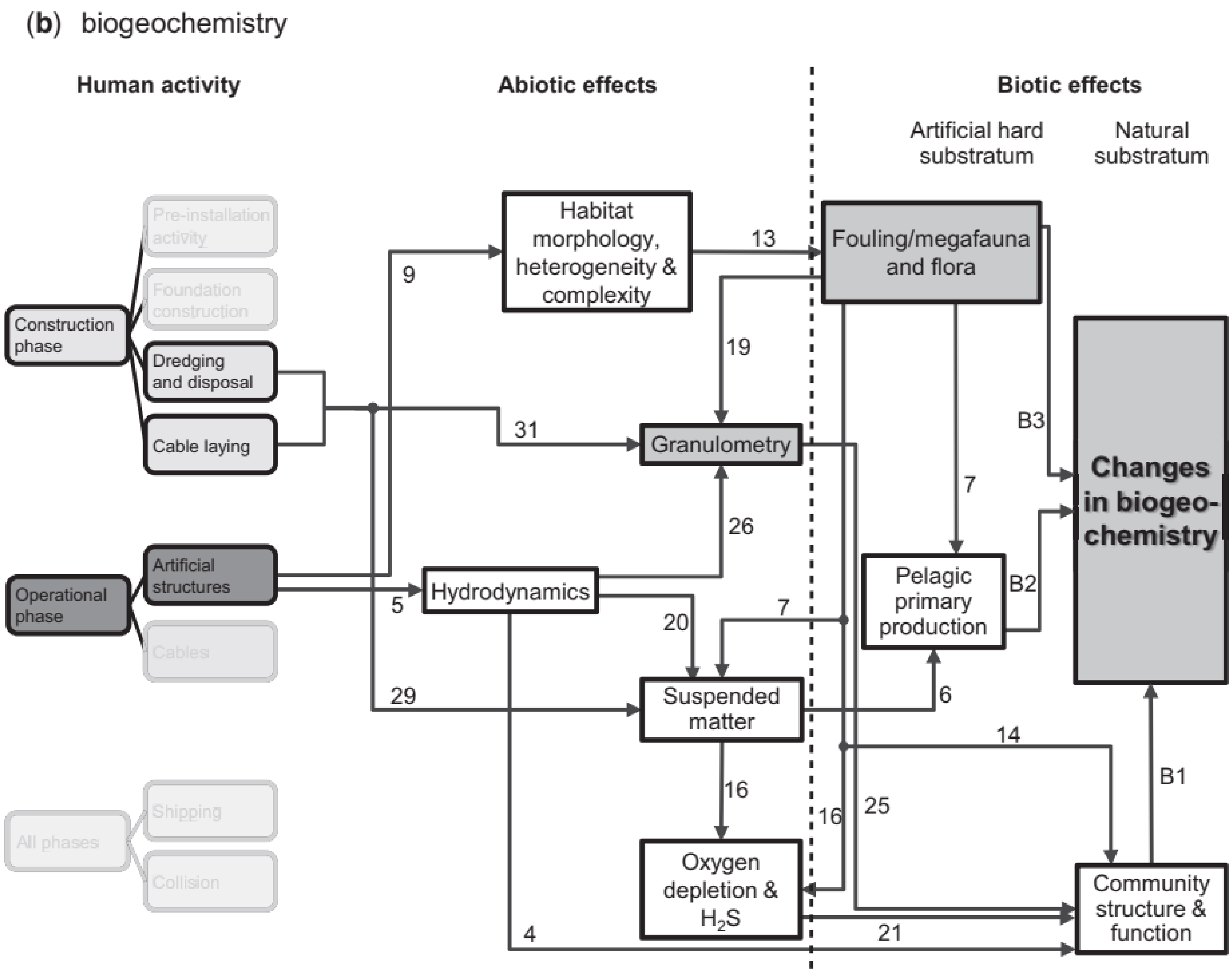
Criteria	Score			
Following (Bergström *et al.*, 2014)				
	1 (low)	**2 (moderate)**	**3 (high)**	
Spatial scale	<100 m	<1 000 m	>1 000 m	
Temporal scale	<2 years (mainly construction effect)	<30 years (operation effect)	>30 years, beyond MRED life time (permanent)	
Sensitivity = quality of impact, extent of change	Minor or no effects on abiotic and biotic processes	Effects on abiotic and biotic processes, no cascading effects	Effects on abiotic and biotic processes, cascading effects	
Consistency	Applicable to specific biotope/ecosystem components/effect size	Applicable to numerous biotopes/ecosystem components/effect size	Applicable to all biotopes/ ecosystem components/ effect size	
Following the evidence ranking of MarLIN (www.marlin.ac.uk/evidenceranking.php)				
	1 (very low)	**2 (low)**	**3 (moderate)**	**4 (high)**
Confidence	Information by "informed judgement" where very little or no information is present at all on the species	Information has been derived from sources that only cover comparable studies or effects or from a general understanding of the cause–effect relationship. No information is present regarding the specific cause–effect relationship.	Information has been derived from sources that consider comparable effects of a particular cause–effect relationship (e.g. such as artificial reef studies)	Information has been derived from sources that specifically deal with the cause–effect relationship of MREDs. Experimental or field work has been done to investigate the specific cause–effect relationship.

Each hypothesized cause-effect relationship (see supplementary material in ANNEX S2) was scored separately (1–3) for the effect size in space, time and magnitude (sensitivity), as well as consistency of the effect following (Bergström *et al.*, 2014). Confidence was scored (1–4) following the evidence ranking of Marlin.

Dannheim et al 2019



Dannheim et al 2019



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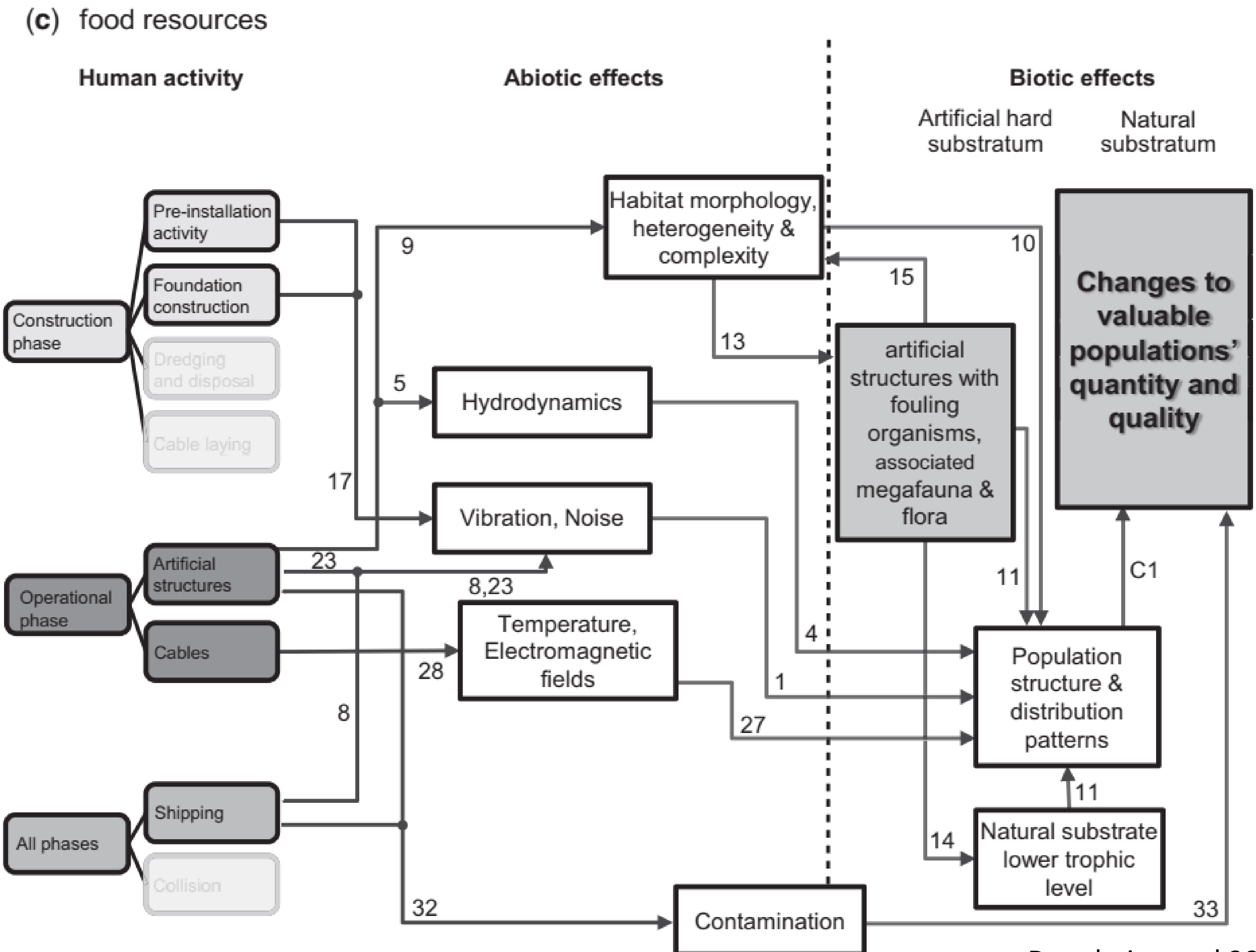

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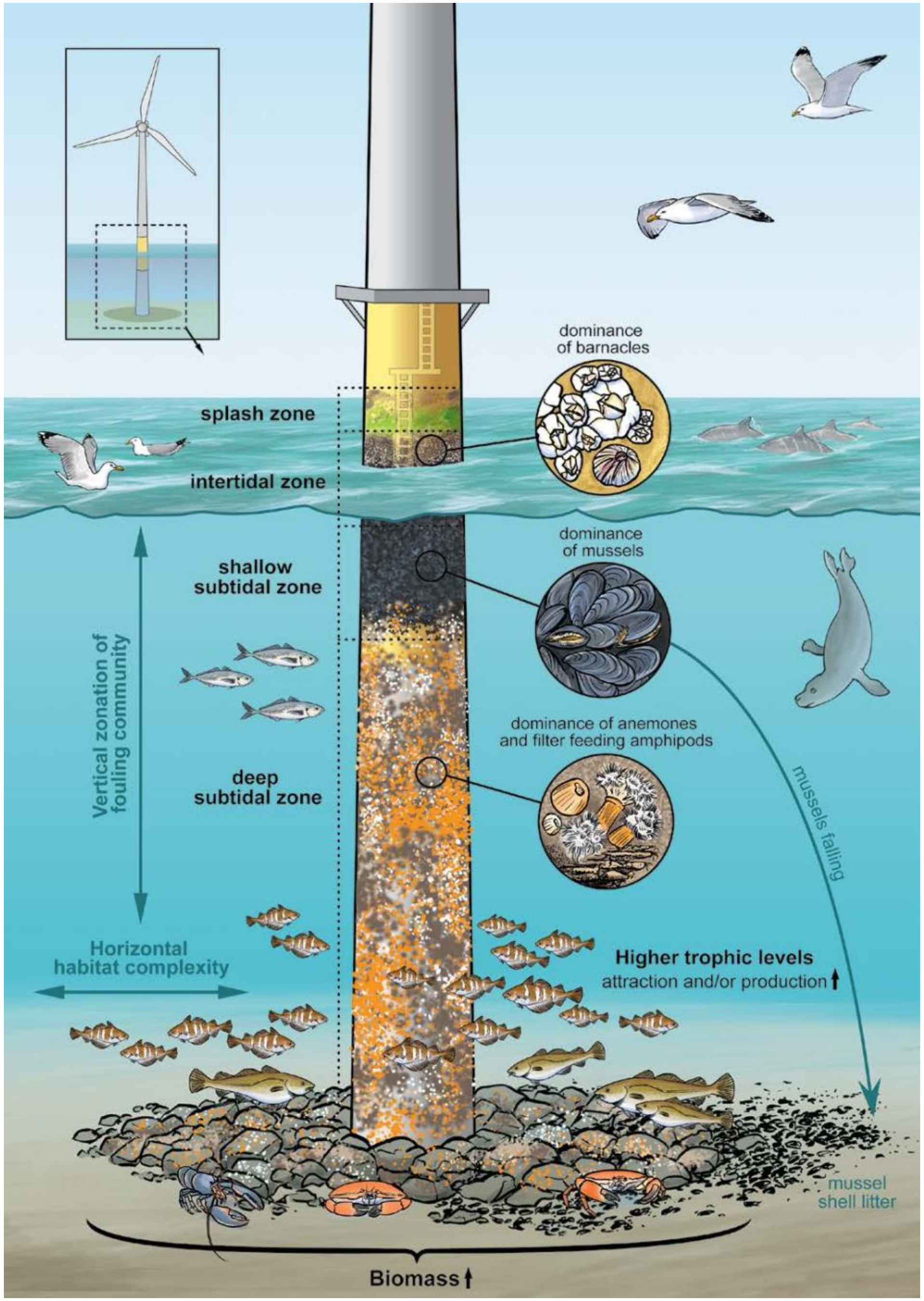

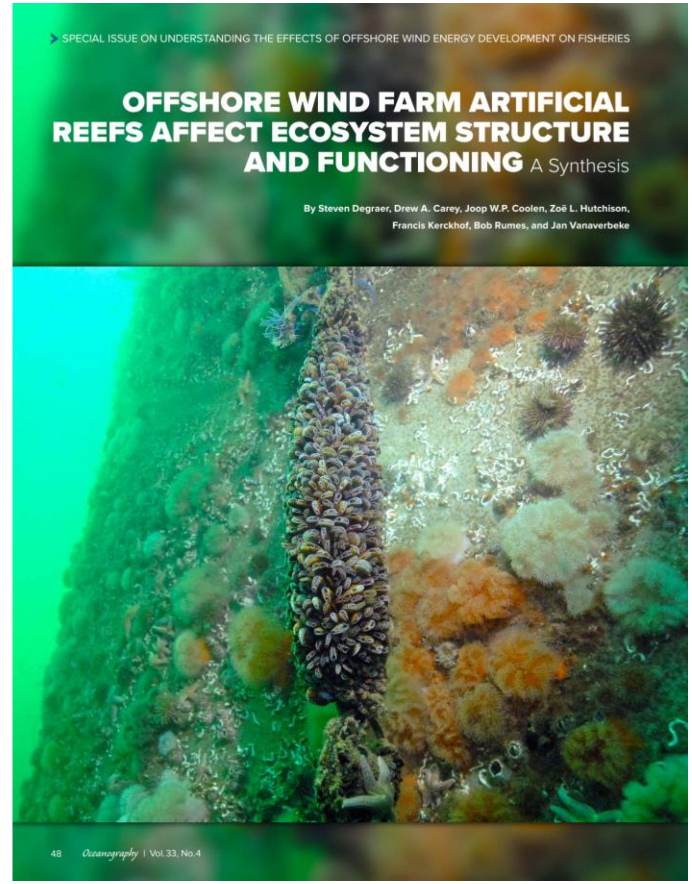
SPECIAL ISSUE ON UNDERSTANDING THE EFFECTS OF OFFSHORE WIND ENERGY DEVELOPMENT ON FISHERIES

OFFSHORE WIND FARM ARTIFICIAL REEFS AFFECT ECOSYSTEM STRUCTURE AND FUNCTIONING A Synthesis

By Steven Degraer, Drew A. Carey, Joop W.P. Coolen, Zoë L. Hutchison, Francis Kerckhof, Bob Rumes, and Jan Vanaverbeke

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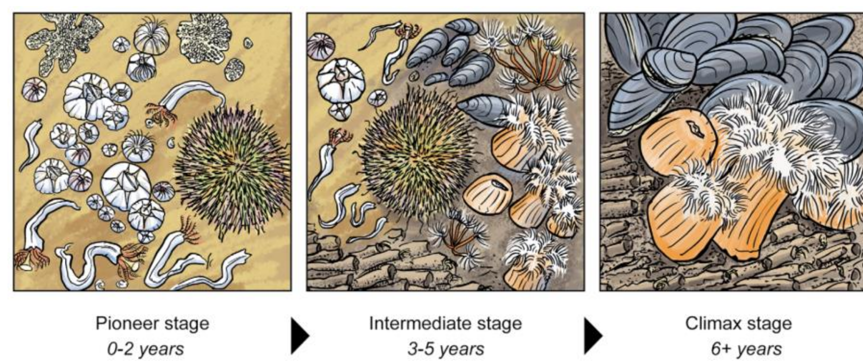

Degraer et al 2020

The multi-use in wind farm projects: more conflicts or a win-win opportunity?

Denis Lacroix* and Sylvain Pioch**

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** Egis eau, 78 allée John Napier, 34000 Montpellier / Géographie côtière. Université de Montpellier 3. Route de Mende 34000 Montpellier. France

Received

Abstract
The pressures on the use of the seashore are steadily rising, not only in developed countries but worldwide. Anthropogenic activity has long impacted the marine continental shelf down to a depth of approximately -200 m. New activities are now affecting this coastal space such as renewable energies, recreational uses and aquaculture in addition to the traditional ones of navigation or fishing. This evolution raises new sources of conflict amongst users which can require state involvement in order to manage the different stakeholders and pressure groups.

However, the coastal space still offers a large potential for development for two reasons. Firstly, the physical three dimensional potential of this space enables the whole water column to be used, principally to increase the fishing productivity as in Japan. Secondly, innovative synergies can be created between socio-technical and ecological uses, (a "fourth dimension") such as the eco-design of wind turbine foundations in order to create fish habitat or sea grass settlement.

This new vision in "4D" for the design and the management of coastal infrastructure can potentially reduce the risk of conflict as different uses of the coastal space would not necessarily exclude one another. Indeed, several forms of synergy could be developed such as fisheries with aquaculture or biological sustainability with social acceptability. Until now, limited attempts at such an approach have been done. We suggest this is likely due to the absence of a common eco-engineering vision and the lack of experience amongst biologists and engineers in the co-construction of projects. This eco-engineering, or "green" vision, also takes into account the complexity and resilience of the ecosystem in the long term, if underwater engineered infrastructures are also "eco"-designed to increase ecological gain This new conception, for development within the coastal area, provides for an increased bio-oriented complexity to engineered structure and therefore a better resistance of the ecosystem in the long term to anthropogenic pressures and a reduction in multi-user conflicts.

Key-words : Integrated coastal zone management, marine continental shelf management, ecological engineering, off-shore wind farm, aquaculture, artificial habitat, eco-design, green infrastructure.

Estonian marine area

Total area: 36 500 km^2

Territorial sea: 25 200 km^2

Mean depth: 30 m

EEZ: 11 300 km^2

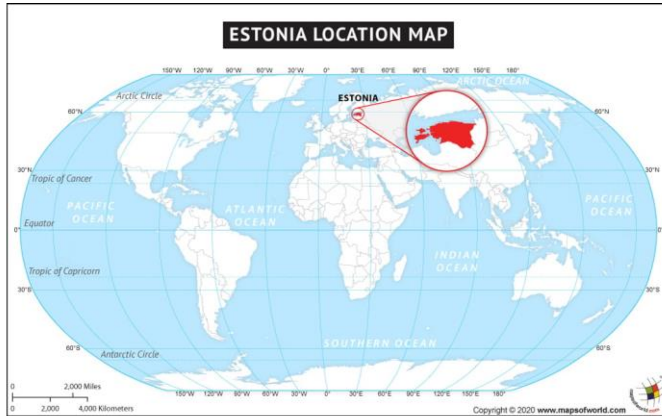
Mean depth: 80 m

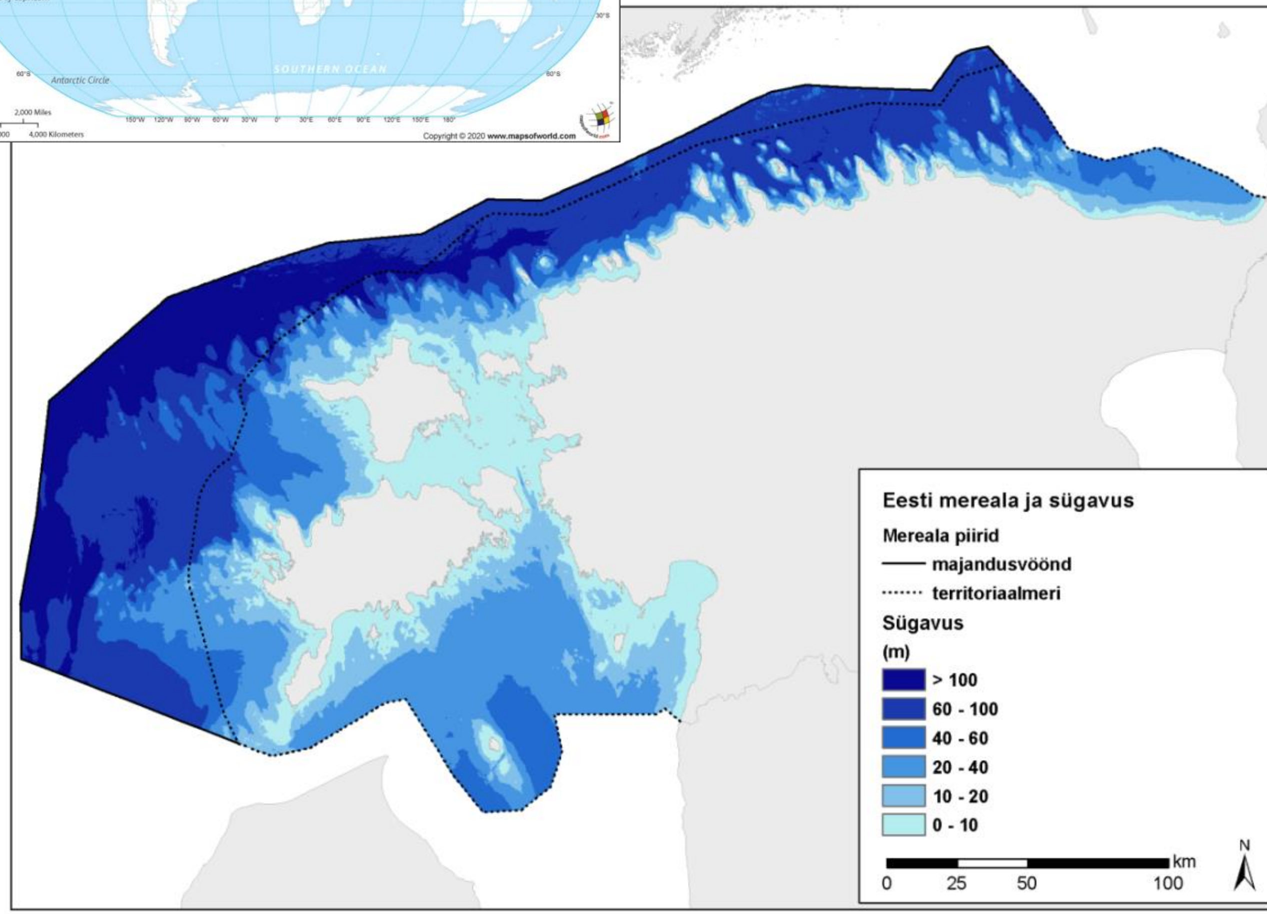
Shoreline: 4015 km

Max depth: 138 m

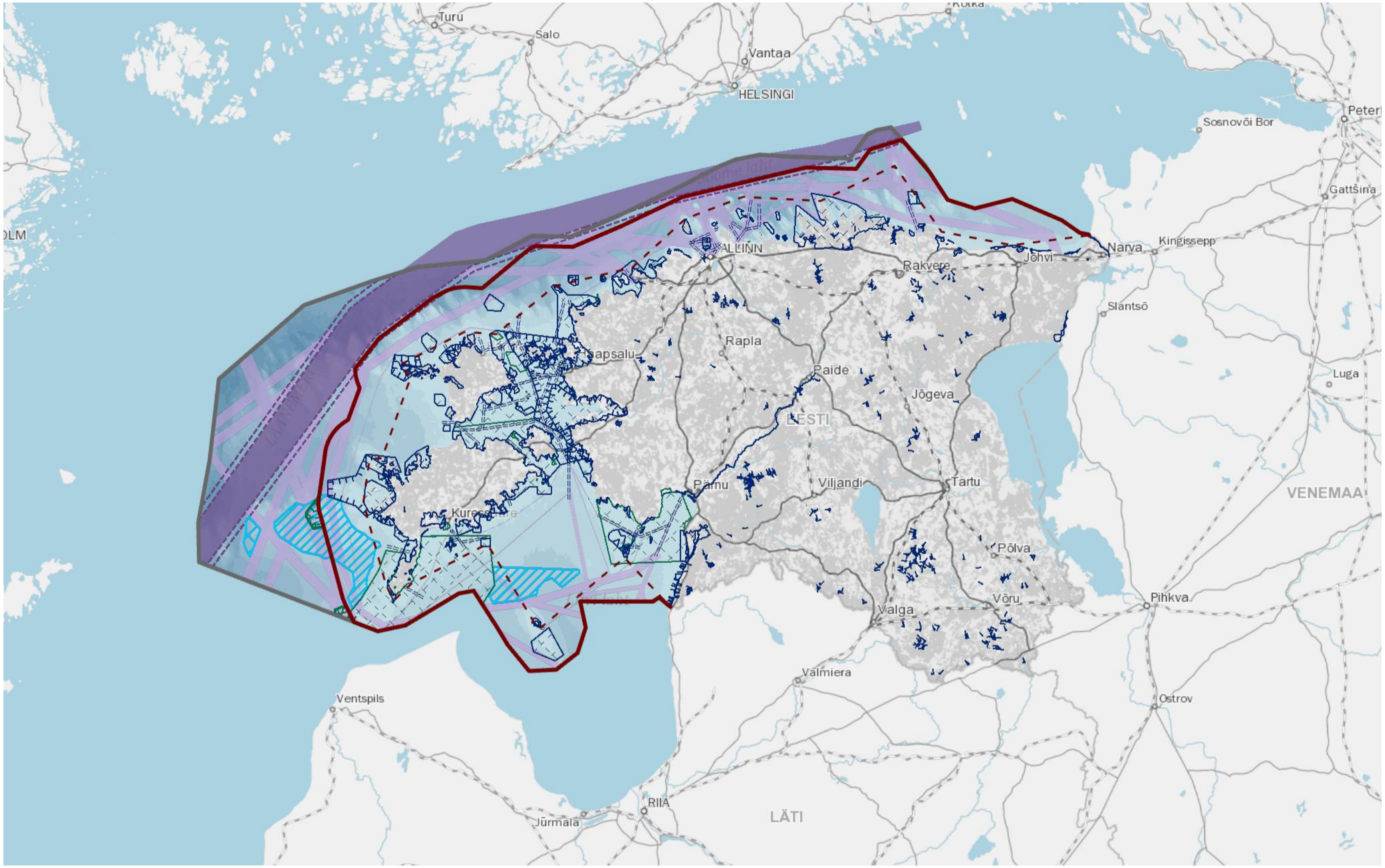
Islands: 2222

Salinity gradient: 0-7



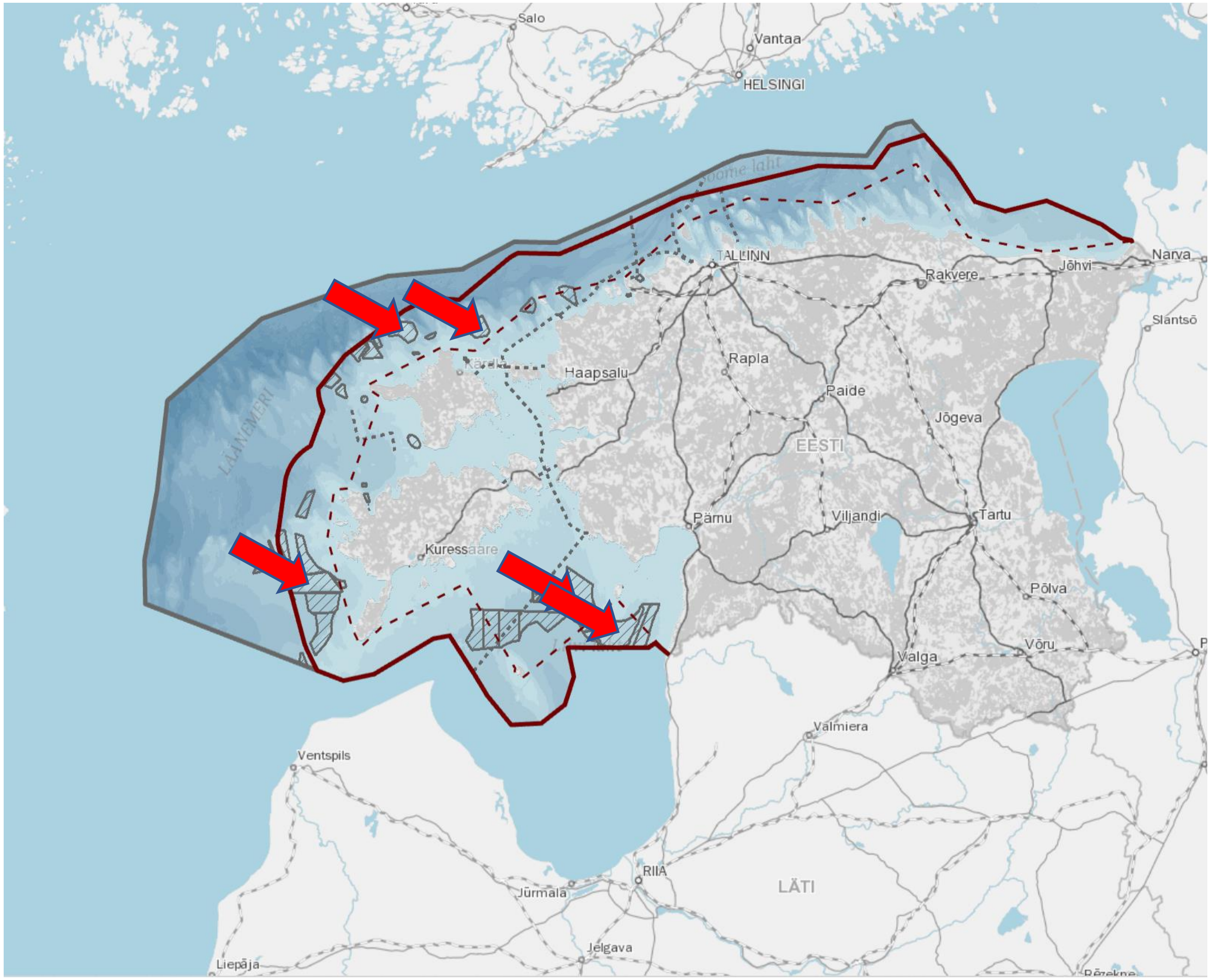


Estonian MSP established in 2022

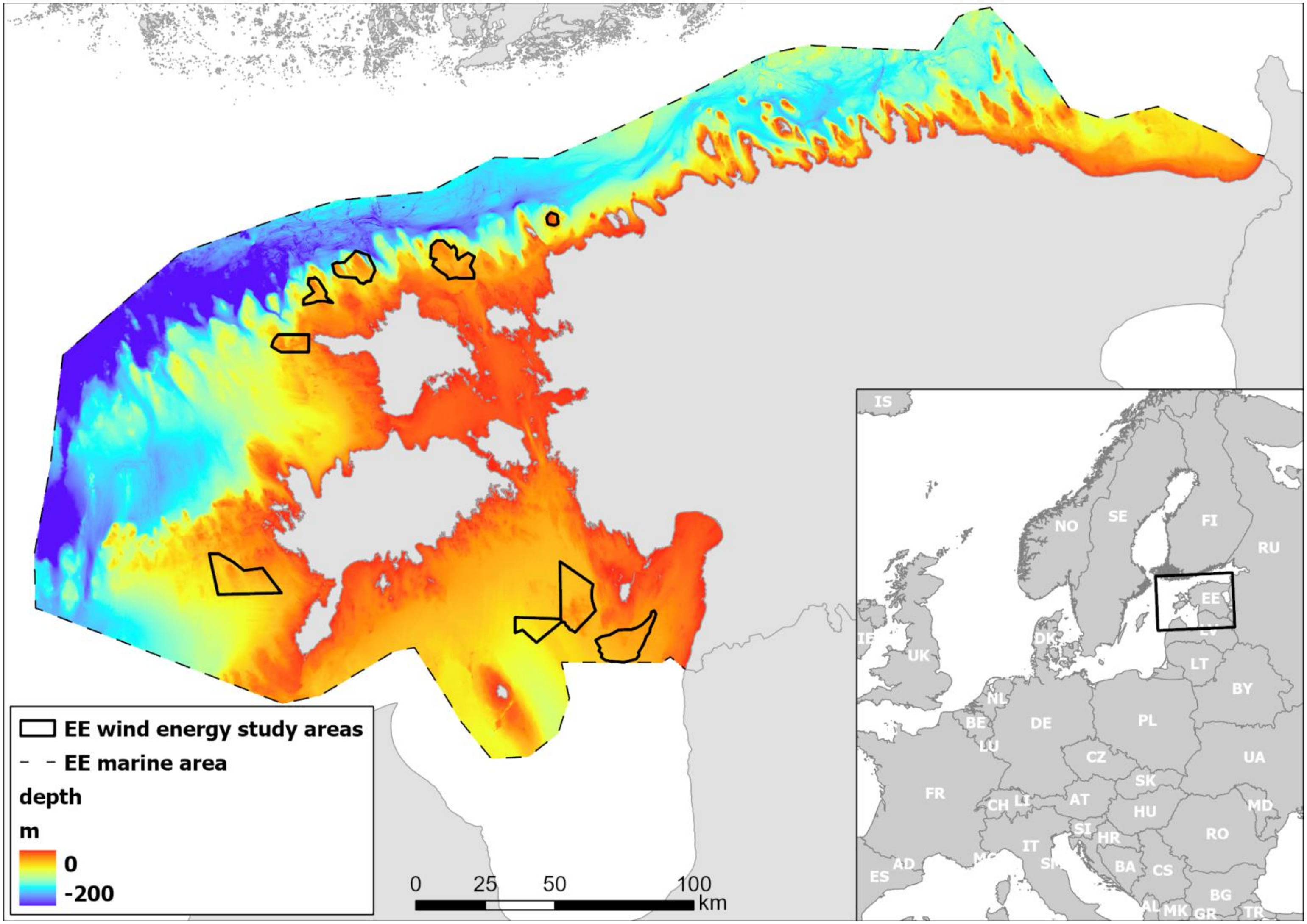


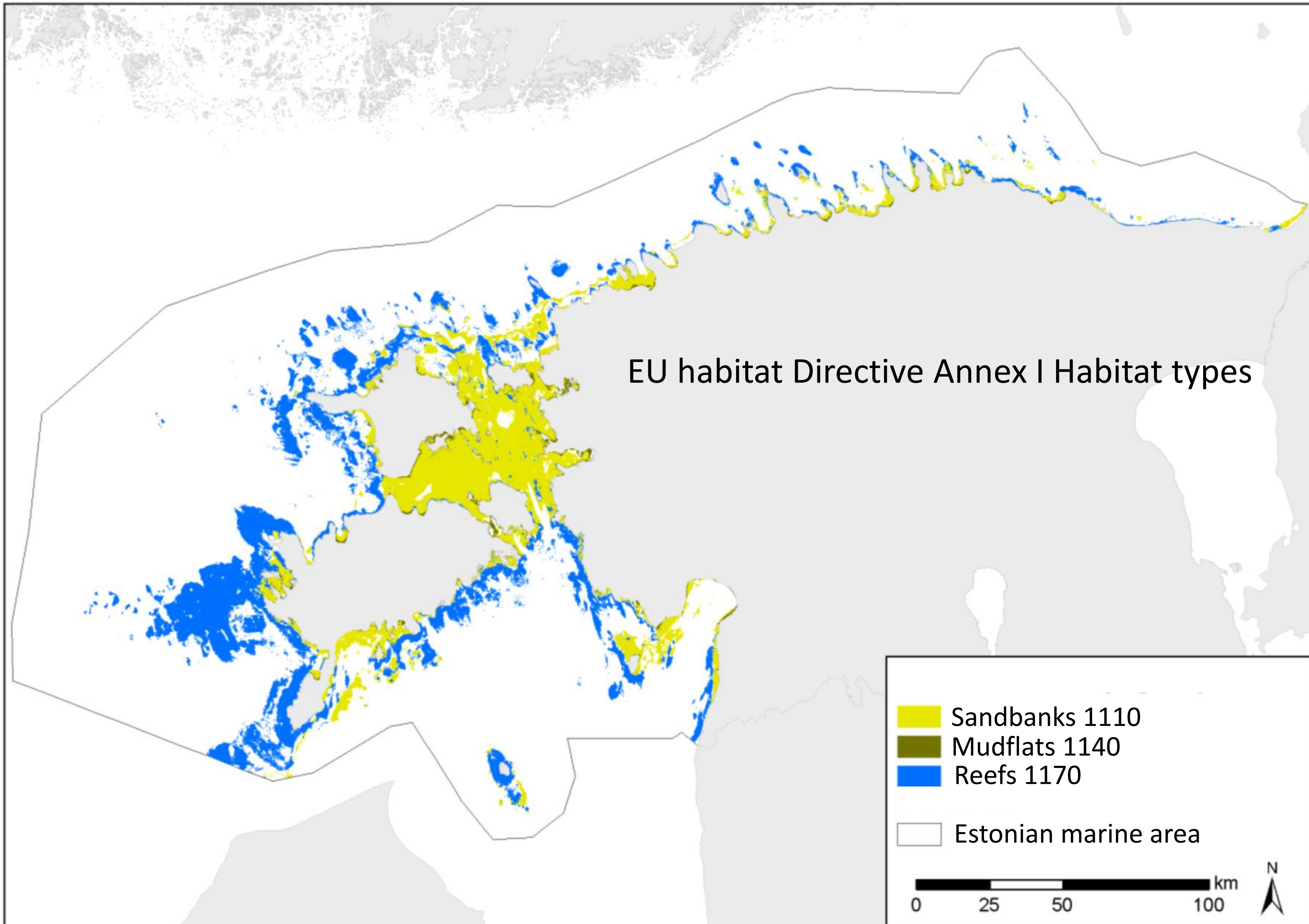
https://mereala.hendrikson.ee/kaardirakendus.html

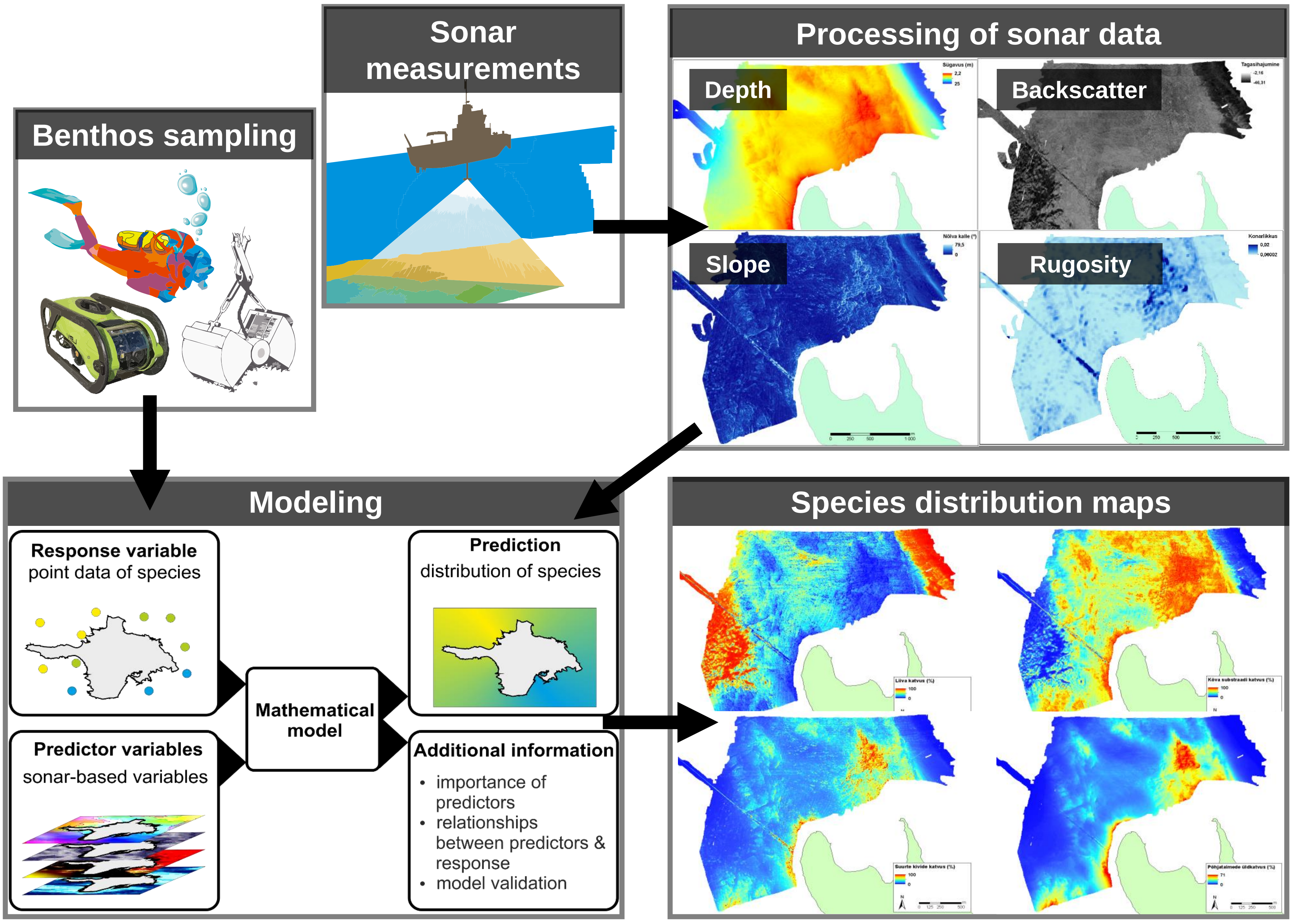
Applications for building permits by Dec 2021



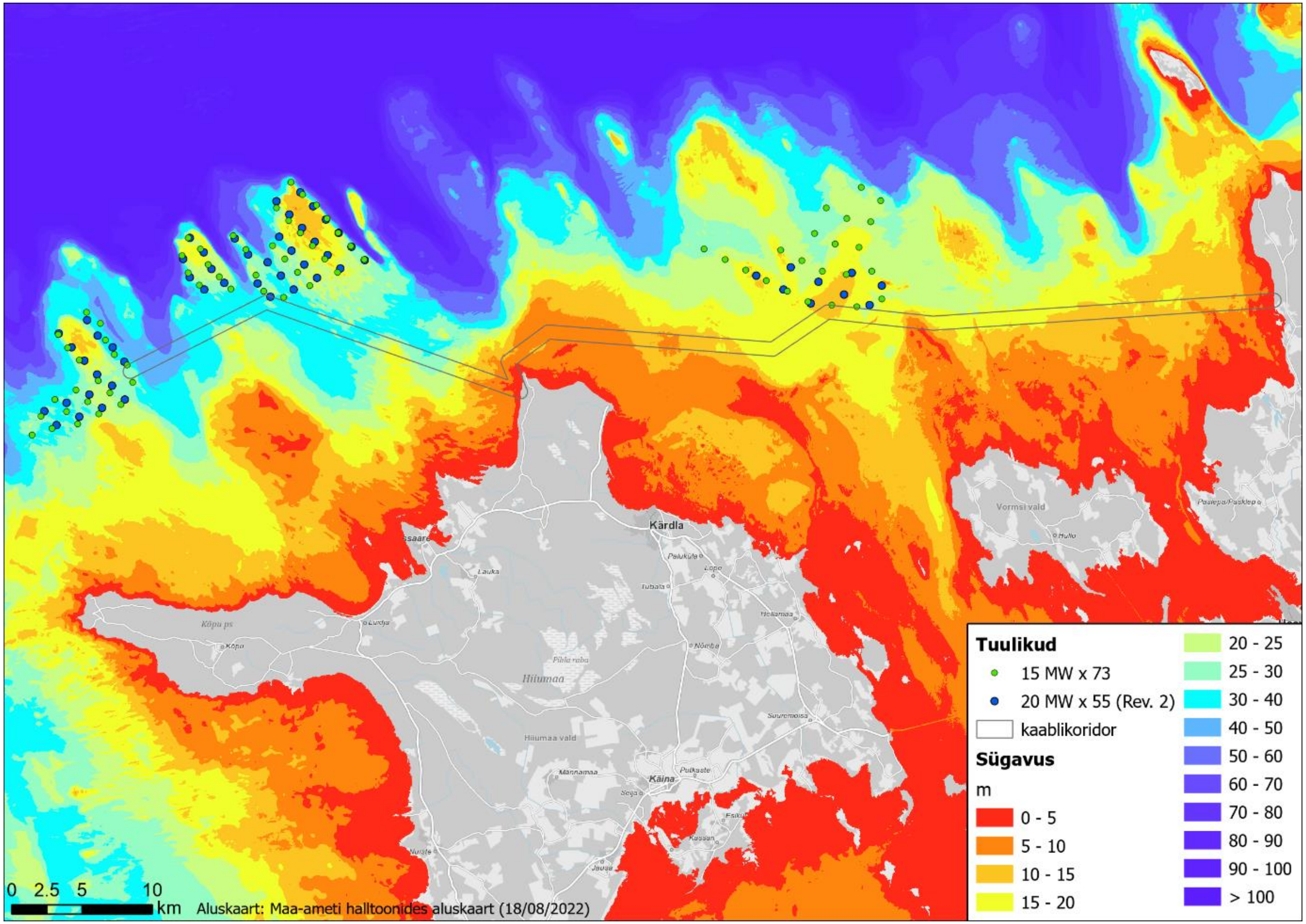
Locations of OWP currently under investigation in Estonian marine area



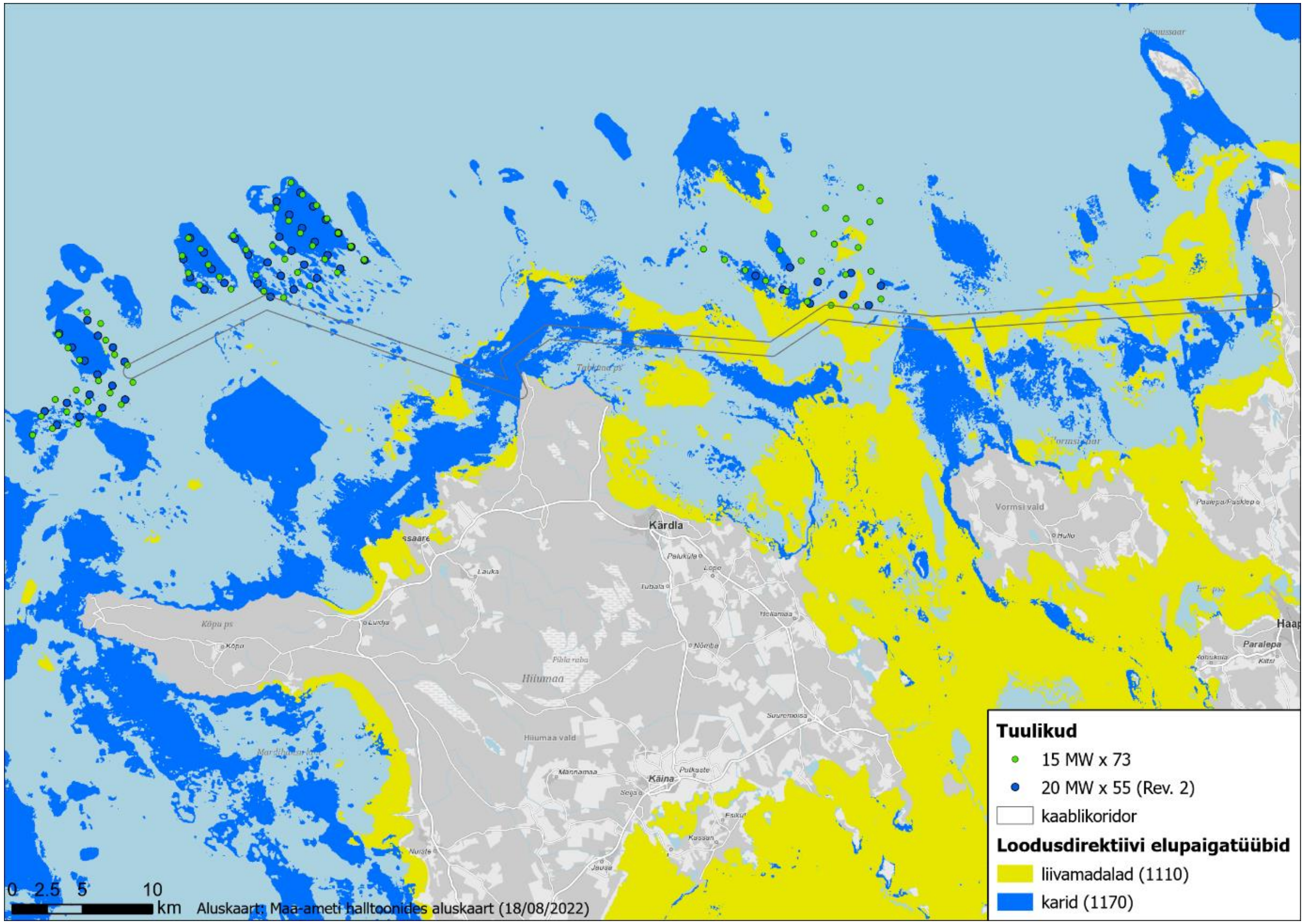

EU habitat Directive Annex I Habitat types
Sandbanks 1110
Mudflats 1140
Reefs 1170
Estonian marine area
km
0
25
50
100
N


Sonar measurements
Processing of sonar data
Depth
Backscatter
Slope
Rugosity
Benthos sampling
Modeling
Response variable
point data of species
Predictor variables
sonar-based variables
Mathematical model
Prediction
distribution of species
Additional information
importance of predictors
relationships between predictors & response
model validation
Species distribution maps

Example – Hiiumaa OWP alternatives



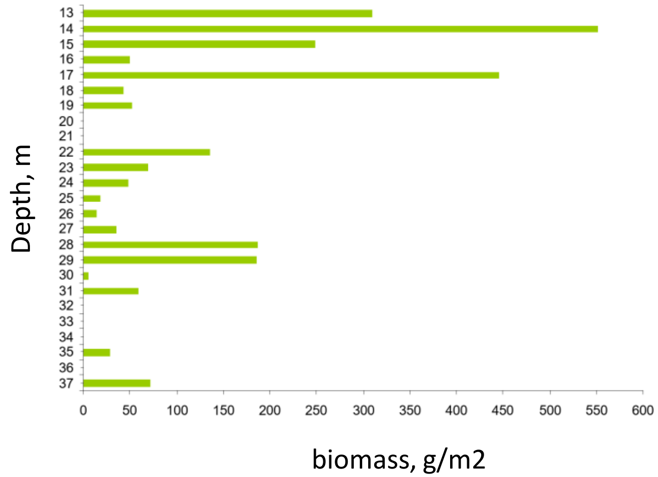
Example – Hiiumaa OWP alternatives – assessment of habitat loss/disturbance

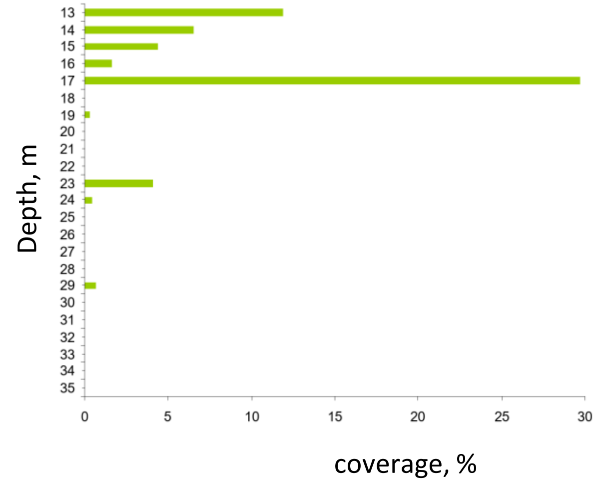


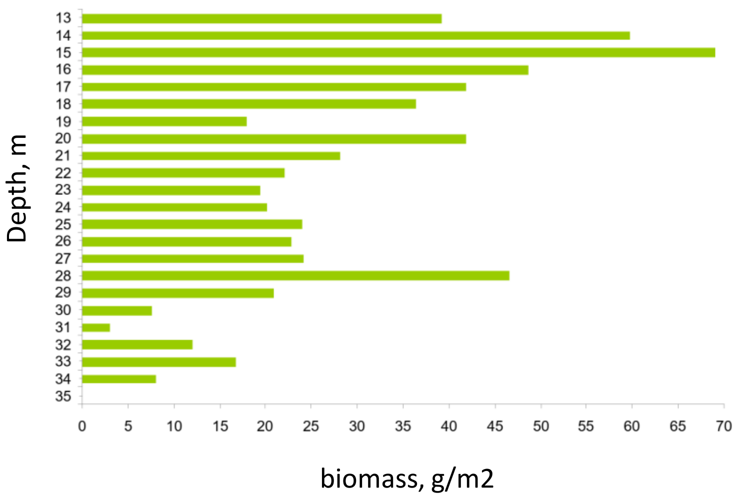
Habitat	Code	Name	15MW loss	15MW disturbance	20MW loss	20MW disturbance
Natura	1110	Sandbanks	0.20	1.82	0.29	1.67
Natura	1170	Reefs	5.91	46.61	8.05	48.38

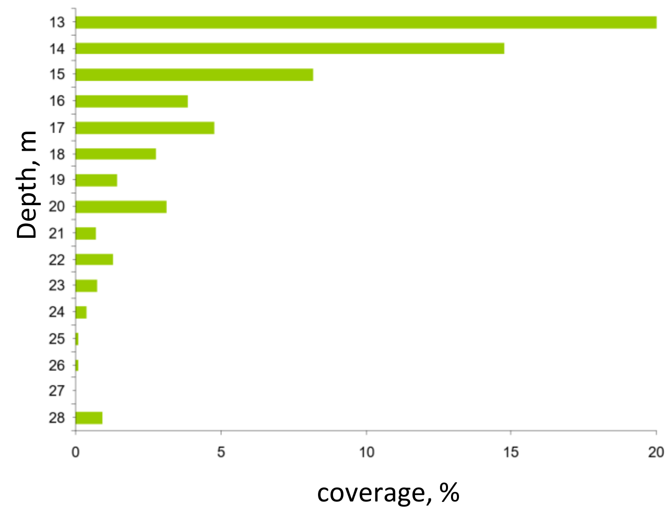
Invertebrates

Macrovegetation



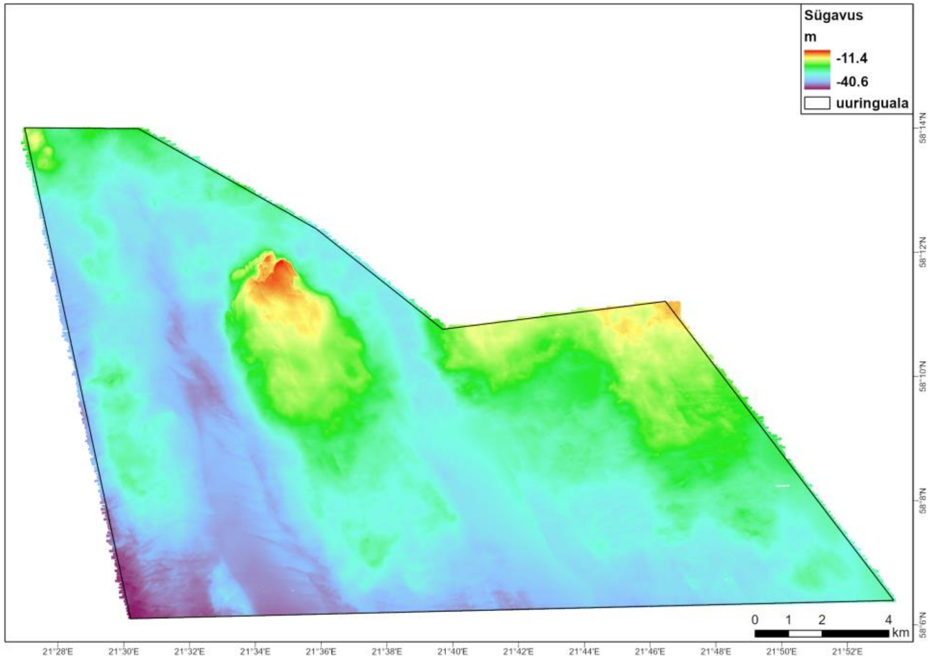


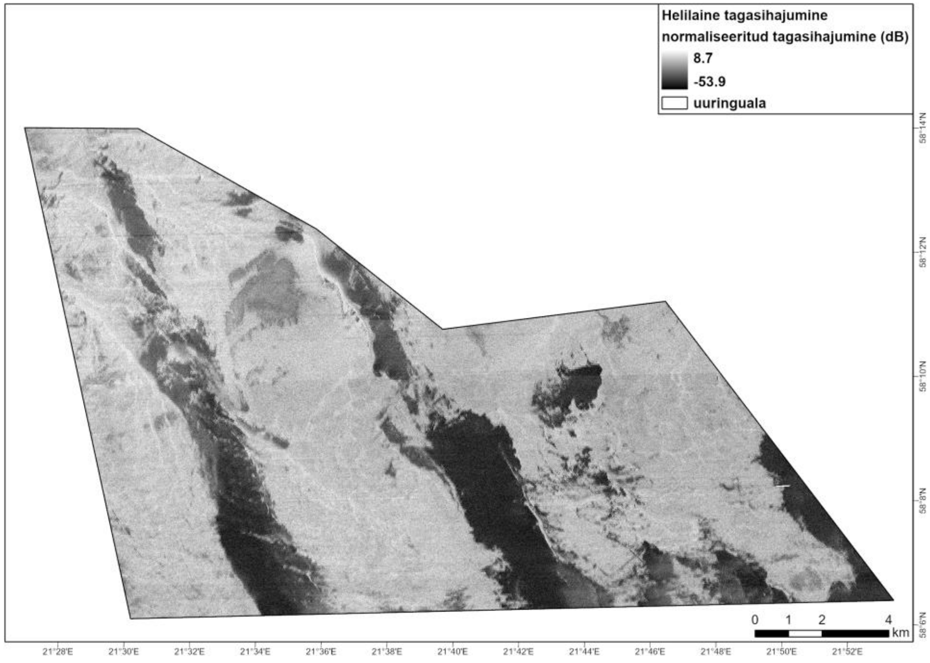




Alternative	Mean depth, m	Surface area of underwater foundation, m2	New animal biomass, kg	New plant biomass, kg
15MW	24,40	36913	25473	6368
20MW	23,75	42455	22147	5536

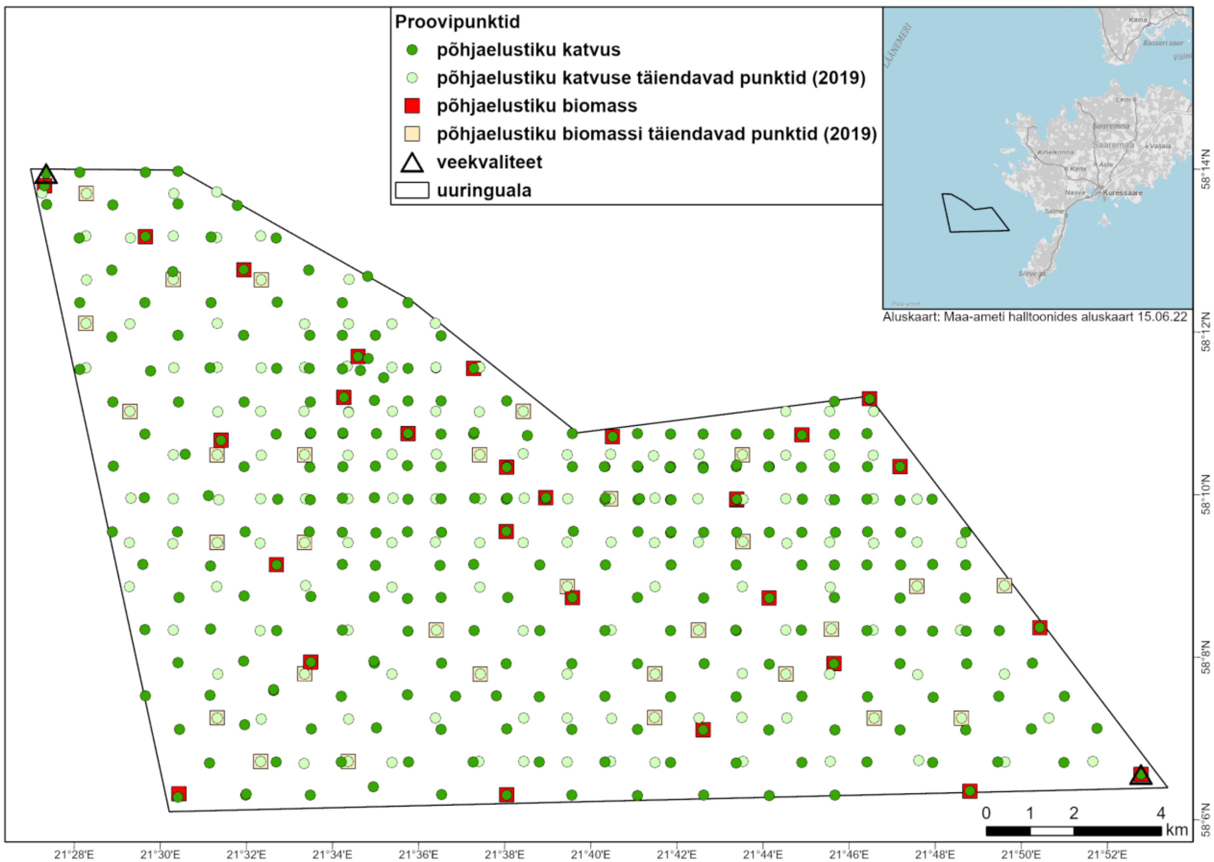
Example: SaareWindEnergy survey area – multibeam survey





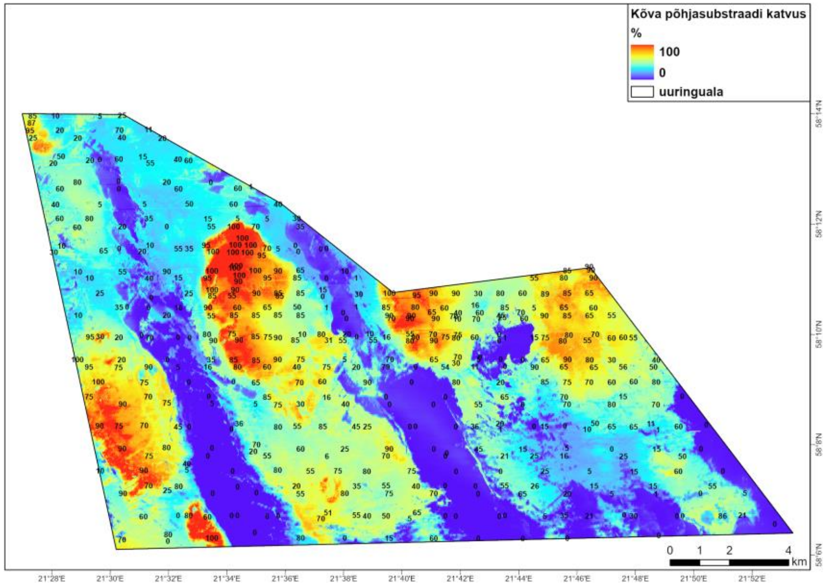
Bathymetric model and backscatter data of the area. Data from VBW WEIGT GMBH

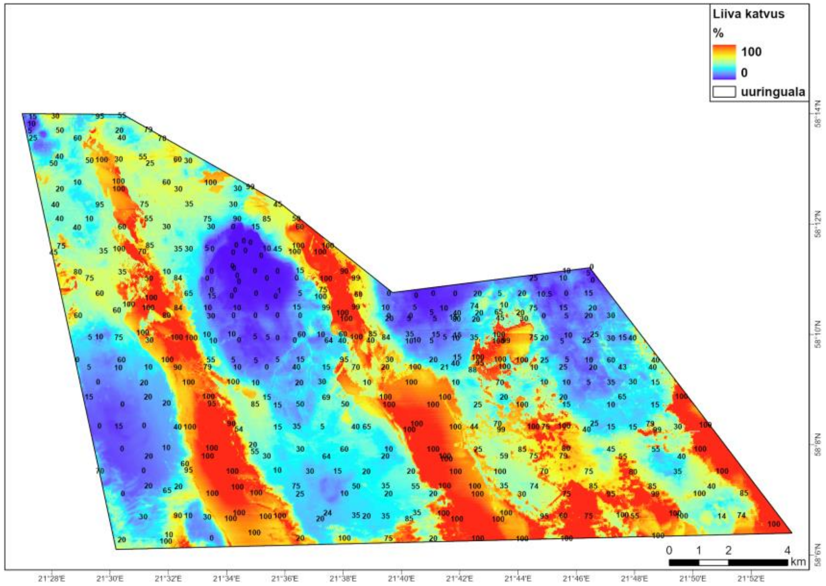
SaareWindEnergy survey area



Sampling dates	25.07. – 15.09.2021
UWV sampling	284 stations
Quantitative sampling	42 samples from 30 locations
Additional data used for modelling (2019)	161 video, 31 biomass

- Coverage of hard substrate and sand. Raster – model. Data points – actual measurements





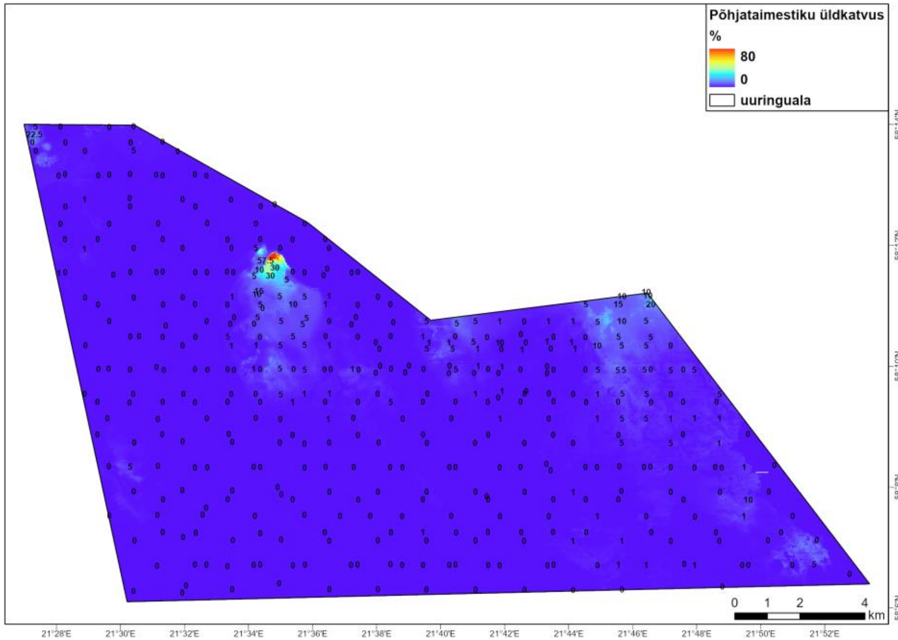
Benthic biodiversity – SaareWindEnergy survey area

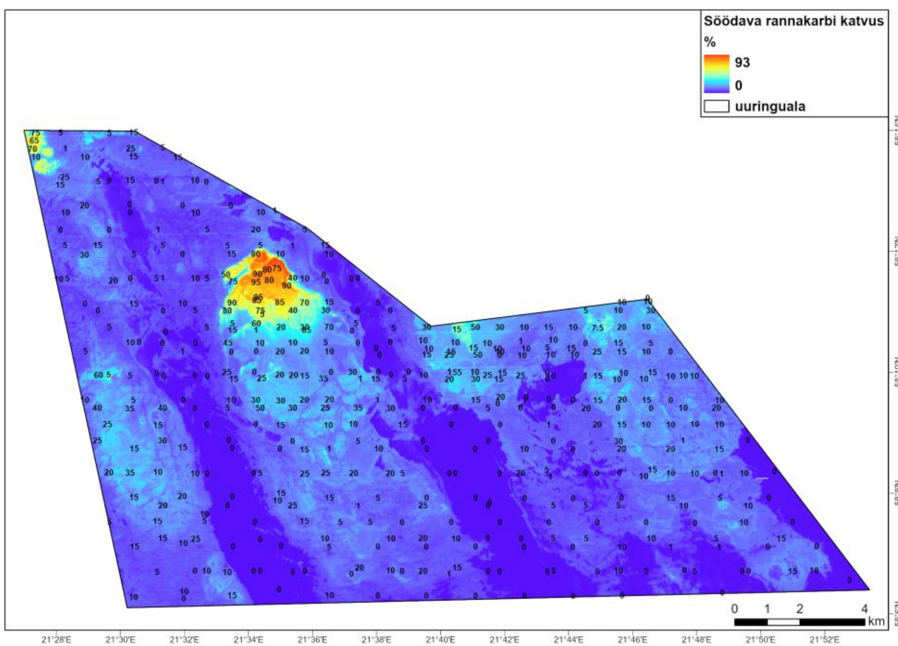
Video survey

Videovaatlus/takson	esinemine (%)	sügavus, miinimum (m)	sügavus, maksimum (m)	katvus, keskmine (%)	katvus, maksimum (%)
taimestik					
Battersia arctica	31	12.9	34.9	3.6	20
Coccotylus truncatus	0.4	16.2	16.2	5	5
Furcellaria lumbricalis	2.1	12.9	16.2	7.2	15
Rhodomela confervoides	0.4	12.9	12.9	0.5	0.5
Vertebrata fucoides	10.9	12.9	27	7.1	50
loomastik					
Amphibalanus improvisus	2.8	12.9	24.7	8.1	20
Hydrozoa	21.1	16.9	40.5	6.1	15
Mytilus trossulus	66.9	12.9	40.5	18.4	95

Quantitative sampling

Biomass/takson	esinemine (%)	sügavus, miinimum (m)	sügavus, maksimum (m)	biomass, keskmine (g/m²)	biomass, maksimum (g/m²)
taimestik					
Battersia arctica	26.7	12.9	25.4	0.2237	0.5567
Ceramium tenuicorne	13.3	12.9	16.9	0.1848	0.4525
Coccotylus truncatus	10	12.9	16.2	2.1492	6.0592
Cyanobacteria	3.3	18.1	18.1	0.0442	0.0442
Furcellaria lumbricalis	6.7	12.9	16.2	1.485	2.7975
Pylaiella/Ectocarpus	13.3	12.9	17.5	2.8815	11.4317
Rhodochorton purpureum	3.3	16.9	16.9	0.0008	0.0008
Rhodomela confervoides	23.3	12.9	27.5	2.0458	6.18
Vertebrata fucoides	30	12.9	27.5	2.184	11.6817
loomastik					
Amphibalanus improvisus	26.7	12.9	27.5	9.8596	16.485
Bylgides sarsi	26.7	12.9	31.4	0.0314	0.0731
Calliopius laeviusculus	3.3	16	16	0.0033	0.0033
Cerastoderma glaucum	6.7	16	25.5	17.3939	34.787
Chironomidae	20	12.9	18.1	0.0122	0.0442
Corophium volutator	13.3	12.9	18.1	0.0396	0.0958
Cyanophthalma obscura	10	16	17.4	0.0039	0.0075
Ecrobia ventrosa	23.3	12.9	36	0.6065	1.2556
Einhornia crustulenta	26.7	12.9	30.1		
Gammarus oceanicus	13.3	12.9	27.5	0.0808	0.1625
Gammarus salinus	20	12.9	18.1	0.2043	0.4533
Gammarus zaddachi	6.7	12.9	17.4	0.0642	0.0875
Gammarus spp., juv.	20	12.9	18.1	0.1275	0.3817
Halacaridae	13.3	16	18.1	0.0071	0.0108
Halicryptus spinulosus	6.7	31.2	31.4	0.0172	0.0258
Hediste diversicolor	20	12.9	18.1	0.069	0.1633
Idotea balthica	10	16	17.4	0.0097	0.0133
Idotea chelipes	3.3	17.4	17.4	0.0117	0.0117
Jaera albifrons	26.7	12.9	30.1	0.0437	0.0742
Laomedea flexuosa	30	12.9	33.3	0.0554	0.2525
Macoma balthica	76.7	12.9	39.9	16.6863	59.8603
Manayunkia aestuarina	13.3	12.9	18.1	0.0042	0.0075
Marenzelleria neglecta	13.3	25.4	39.9	0.029	0.043
Mya arenaria	13.3	17.4	31.4	0.0704	0.0925
Mytilus trossulus	46.7	12.9	35.8	254.1478	784.2583
Oligochaeta	36.7	12.9	39.9	0.0133	0.0301
Ostracoda	3.3	31.4	31.4	0.0301	0.0301
Palaemon elegans	3.3	16.2	16.2	0.0408	0.0408
Peringia ulvae	46.7	12.9	31.4	0.2851	0.86
Piscicola geometra	6.7	12.9	16.2	0.0067	0.0083
Platyhelminthes	3.3	17.4	17.4	0.0025	0.0025
Potamopyrgus antipodarum	3.3	18.1	18.1	0.0392	0.0392
Praunus inermis	13.3	16	17.4	0.0058	0.0183
Pygospio elegans	50	16	39.9	0.7412	7.1036
Saduria entomon	3.3	36	36	0.8858	0.8858
Theodoxus fluviatilis	13.3	12.9	18.1	0.8208	2.2583


Põhjataimestiku üldkatvus
%
80
0
uuringuala
0 1 2 4
km
21°28'E
21°30'E
21°32'E
21°34'E
21°36'E
21°38'E
21°40'E
21°42'E
21°44'E
21°46'E
21°48'E
21°50'E
21°52'E
58°14'N
58°12'N
58°10'N
58°8'N
58°6'N


Söödava rannakarbi katvus
%
93
0
uuringuala
0 1 2 4
km
21°28'E
21°30'E
21°32'E
21°34'E
21°36'E
21°38'E
21°40'E
21°42'E
21°44'E
21°46'E
21°48'E
21°50'E
21°52'E
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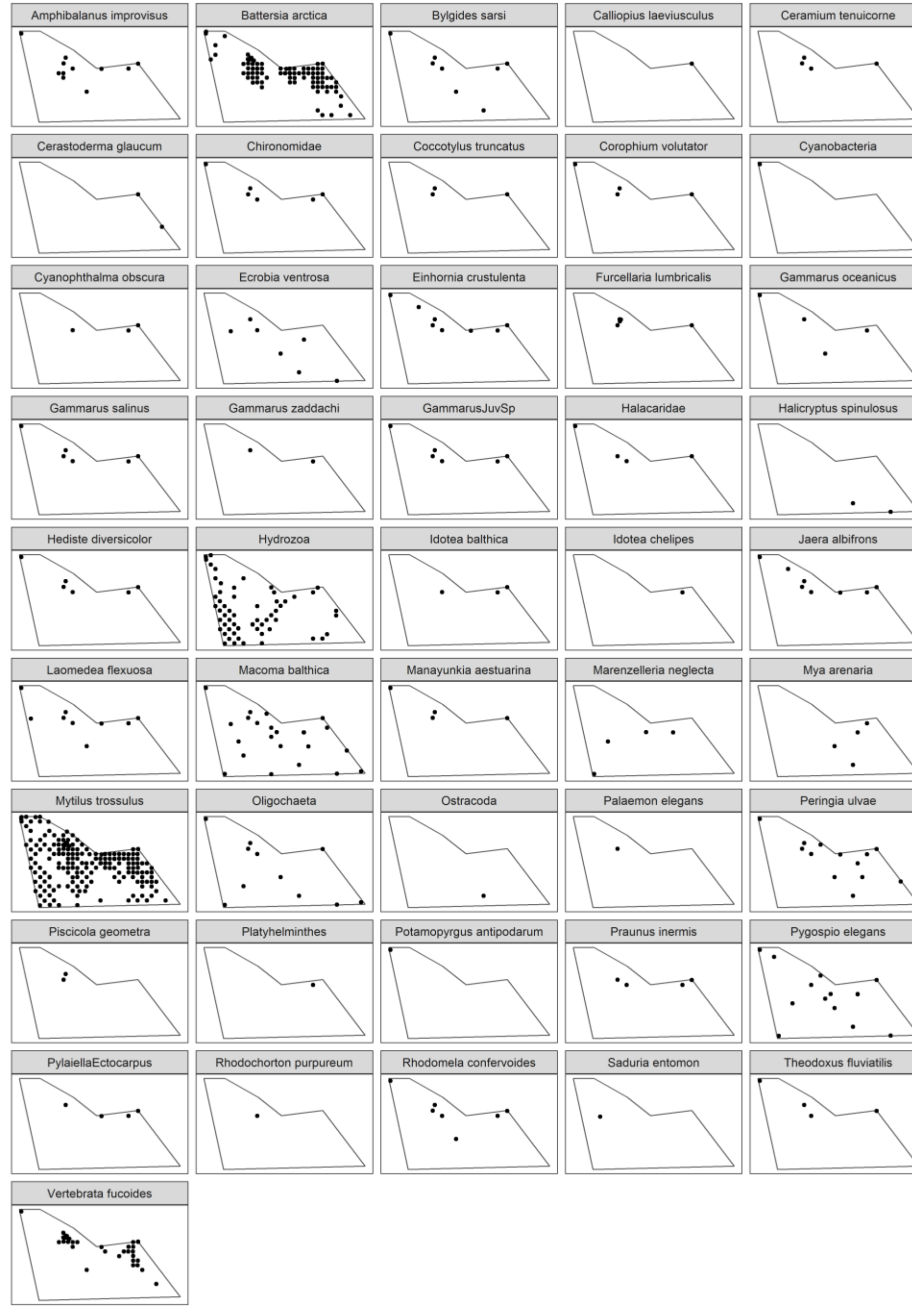
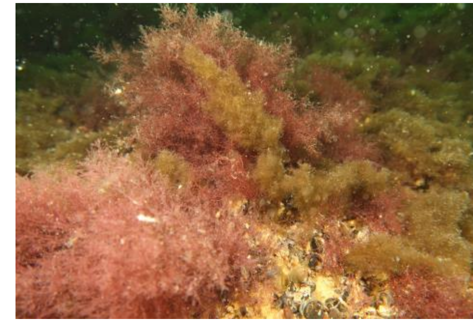
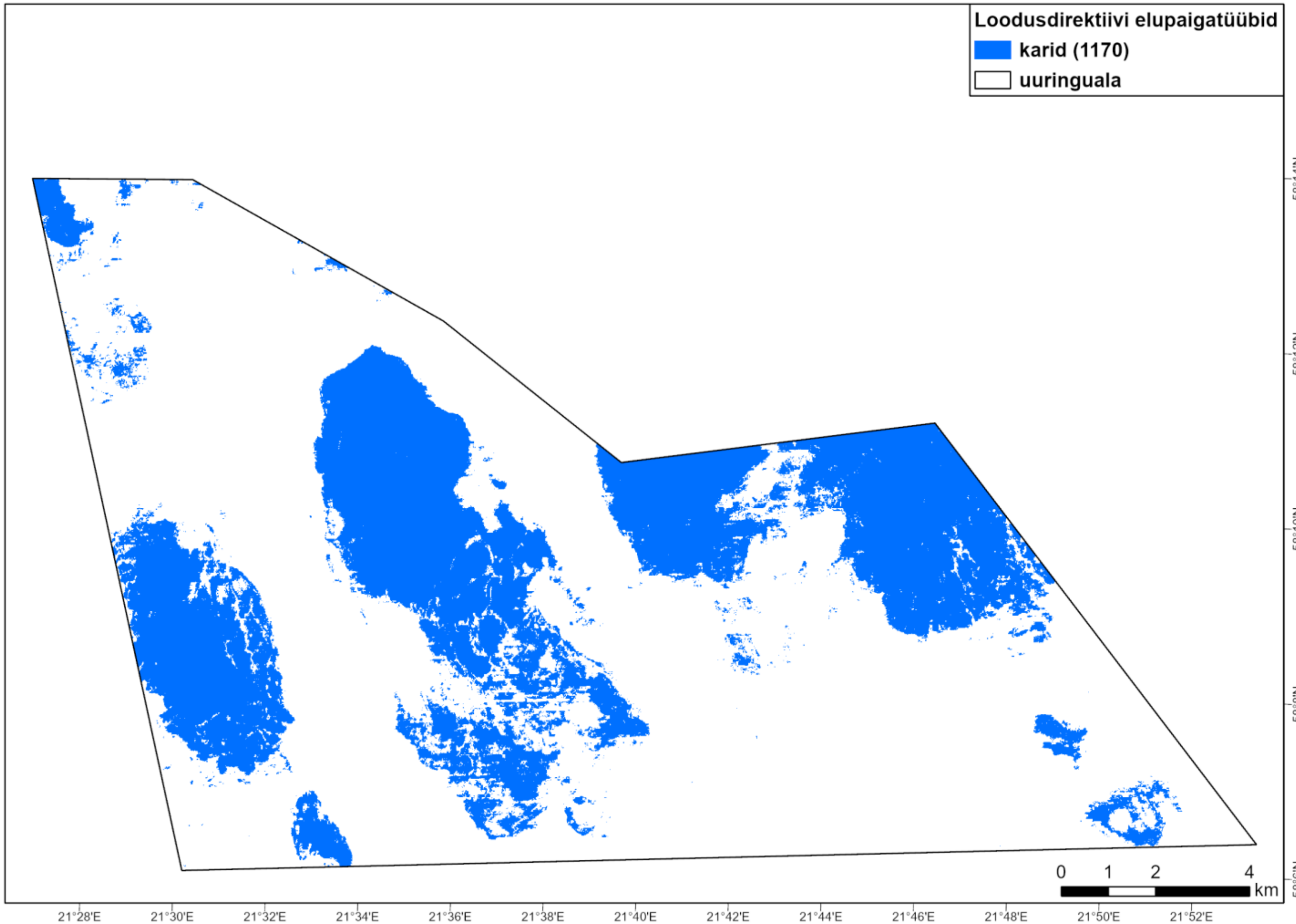
58°12'N
58°10'N
58°8'N
58°6'N


Amphibalanus improvisus
Battersia arctica
Bylgides sarsi
Calliopius laeviusculus
Ceramium tenuicorne
Cerastoderma glaucum
Chironomidae
Coccotylus truncatus
Corophium volutator
Cyanobacteria
Cyanophthalma obscura
Ecrobia ventrosa
Einhornia crustulenta
Furcellaria lumbricalis
Gammarus oceanicus
Gammarus salinus
Gammarus zaddachi
GammarusJuvSp
Halacaridae
Halicryptus spinulosus
Hediste diversicolor
Hydrozoa
Idotea balthica
Idotea chelipes
Jaera albifrons
Laomedea flexuosa
Macoma balthica
Manayunkia aestuarina
Marenzelleria neglecta
Mya arenaria
Mytilus trossulus
Oligochaeta
Ostracoda
Palaemon elegans
Peringia ulvae
Piscicola geometra
Platyhelminthes
Potamopyrgus antipodarum
Praunus inermis
Pygospio elegans
PylaiellaEctocarpus
Rhodochorton purpureum
Rhodomela confervoides
Saduria entomon
Theodoxus fluviatilis
Vertebrata fucoides

Habitats





Distribution of HD habitat type 1170 “Reefs”

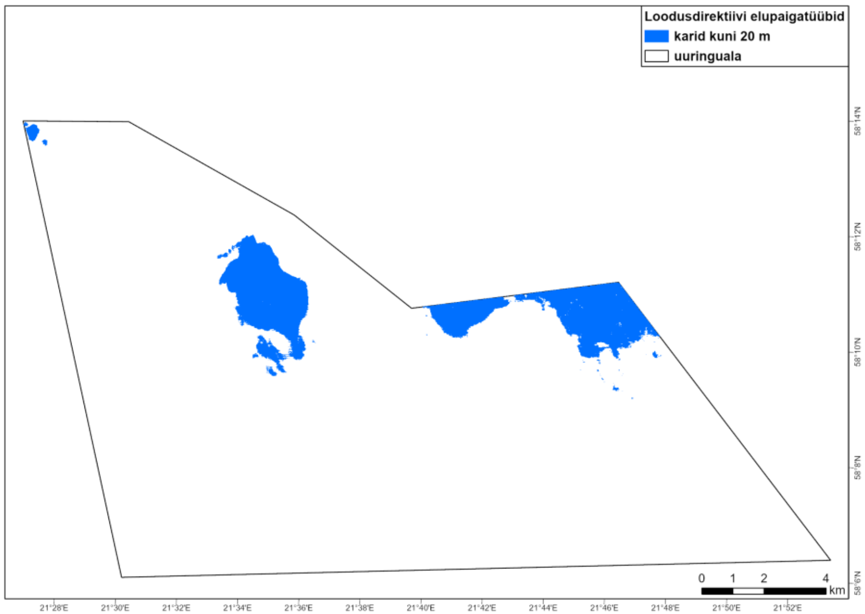
Assessment of “loss” and “disturbance”

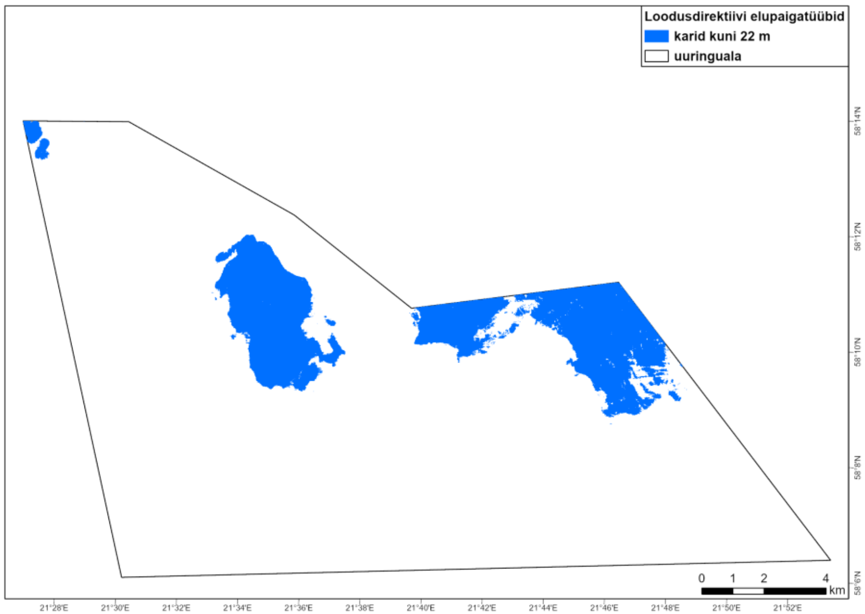
Area of the study area	223,8 km2
Mean depth	28,5 m
Foundation	Radius = 5 m, diametre = 10 m
Disturbance zone around the foundation	50 m
Number of foundations	100
Area covered by one foundation	78,5 m2
Area covered by all foundations	7853,982 m2 = 0,0078 km2 = 0,0035% of the study area
Distrurbance area from one foundation	9424,778 m2
Disturbance area of all foundations	0,942 km2 = 0,42% of the study area

Area of „reef“ habitat in study area	64,2 km2
Area of „reef“ habitat lost	0,002247 km2
Area of habitat disturbed	0,26964 km2

Total surface area of new substrate	0,08954 km2 = 0,04 % of study area
Total surface area vs existing hard substrate	0,1 %

Prioritisation (according to value to BD)





14.1 km2 = 21% of ”reef” = 6.3% from whole area

25.8 km2 = 40.2% of ”reef” = 11.5% from the whole area

Some conclusions

- Despite high complexity of possible impacts of renewable energy installations to the marine environment we lack knowledge and possibilities to assess full range of possible impacts during EIA procedure.
- Concentrating on the loss and disturbance of main features describing structure and function might cover most of the possible impacts.
- Both high quality baseline information together with well designed construction and operational phase monitoring programme will help to gather evidence for future EIA projects.

Thank you for your attention!

Photo – Vilsandi area, West-Estonian Archipelago, August 2021, made by Kaire Kaljurand