Policy Brief

No 3/5

from projects BONUS FUMARI and BONUS SEAM

Novel methods advancing Baltic Sea environmental monitoring

The impacts of human activities on the Baltic Sea are extensive and require monitoring to assess its state. Despite a long tradition and regional coordination, the current Baltic Sea monitoring system still displays gaps, which could be filled by novel methods.

The potential of novel methods regarding monitoring and assessment required by MSFD

Novel methods can achieve higher temporal and spatial resolution with higher cost efficiency[1] when compared to traditional monitoring methods. Furthermore, they can be used to monitor pressures acting on the ecosystem, which are not assessed enough so far. To address gaps in Baltic Sea monitoring[2,3] , and to meet current and future societal and policy demands, BONUS FUMARI and BONUS SEAM explored a wide range of novel methods1[4,5], and assessed their costs and applicability. The focus was on the overall suitability of the methods and their ability to fill in the monitoring gaps of the 11 descriptors (D1-D11) of good environmental status (GES) of the Marine Strategy Framework Directive (MSFD. The holistic ecosystem assessment of the Baltic Sea uses elev-

Aerial drones ready for deployment on the deck of the research vessel Aranda.

Photo: Ilkka Lastumäki

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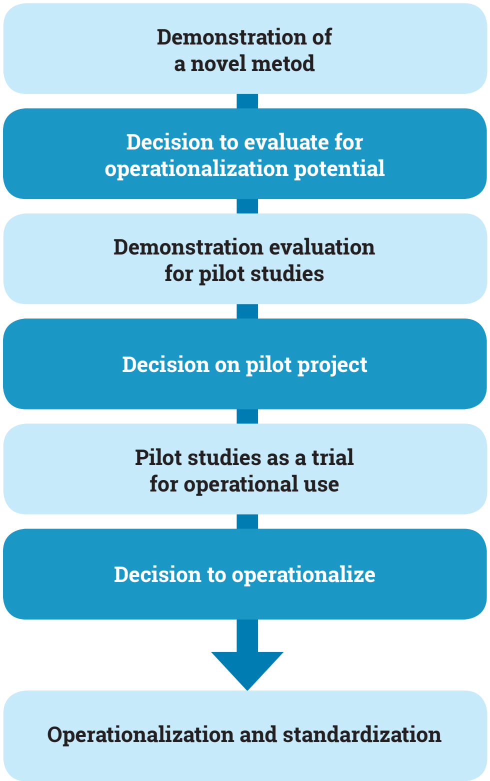
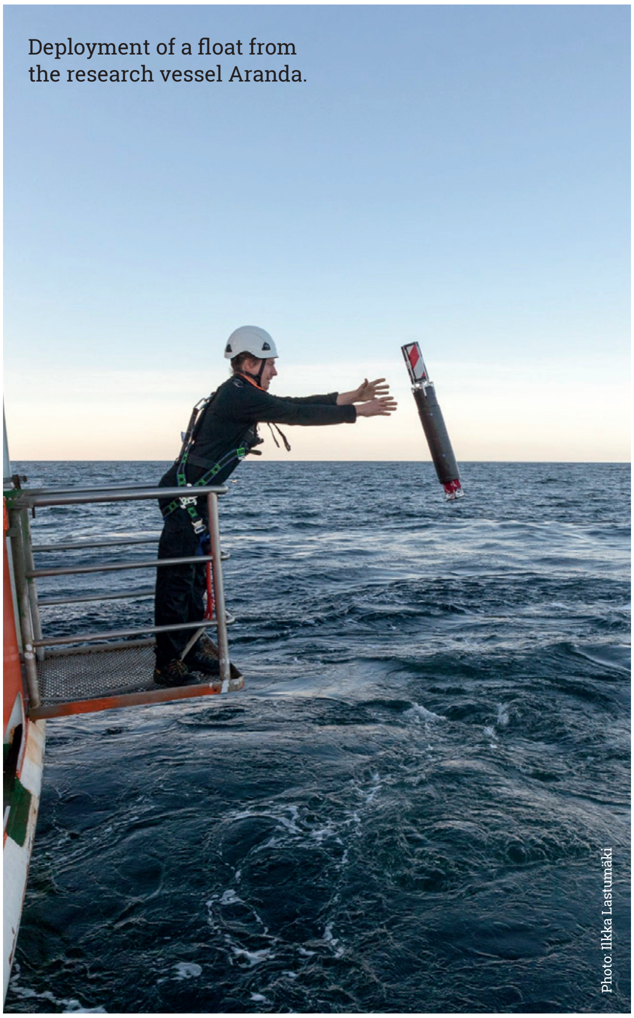


Figure 1. Simplified path from innovation to adoption and operational implementation of novel monitoring methods.



Deployment of a float from the research vessel Aranda.

en descriptors (D1-D11) to evaluate if good environmental status is achieved or maintained. This requires for example that, biological diversity is maintained, nonindigenous species do not adversely alter the ecosystem, the exploitation of fish stocks is within safe biological limits, and that the food web structure should show natural abundances and diversity (D1-D4). Novel molecular methods are promising and could advance monitoring to meet these demands. Moreover, modern technological development, underwater image recognition as well as remote sensing can support shipborne monitoring by significantly increasing the spatial and temporal coverage. Significant contributions are expected from ferry-box systems, using flow-through systems for counting, pigment/species identification and size/structure determinations.

A healthy Baltic means that human-induced eutrophication is minimized, and sea-floor integrity is maintained (D5, D6). For habitat surveillance, new physical and chemical sensor techniques for oxygen and nutrients have been developed. Remote sensing by satellites as well as in situ acoustic and optic measurements for phytoplankton/chlorophyll-a, habitat types and macrophytes can deliver new information. The permanent alteration of hydrographical conditions (D7) is increasing because of climate change and ocean acidification. Increases in atmospheric carbon dioxide are converted into more carbonic acid in the marine environment. Marine acidification can be monitored by novel autonomous devices, sensor packages and spectrophotometric measurements of pH. Such sensors can be attached either to drifters, buoys, fixed platforms or put onto ships. Combining these measurements with satellite observations, other monitoring data and models can produce better forecasts and improve the reanalysis of past changes.

The large variety of chemical compounds introduced in the marine environment requires clear strategic approaches to assess the risk of these contaminants (D8) to the ecosystem and human health (D9). The use of novel and relatively cheap passive sampling techniques is useful as it accounts for the bio-accumulative potential of substances. Further, for surveillance of acute oil spills, coastal radar stations could support current surveillance activities. Both marine litter (D10), including plastics in the marine environment, and underwater noise (D11) have caught a lot of attention recently. The use of autonomous platforms and automated identification methods can contribute to the monitoring of these pressures and their impact on the Baltic Sea.

Implementation steps and availability of novel methods

Recent technological achievements enable miniaturized sensors, carriers and vehicles with improved power management. These developments help to significantly support current monitoring, making measurements more precise and increasing the extent of observations over both temporal and spatial scales. In addition, advanced data visualization could help to better identify deviations from a good environmental status and the origin or cause of the threat, leading to quicker use of adequate abatement measures.

The path from an innovation to a novel method that is implemented in international monitoring requires several steps (Figure 1). Additional effort and costs during the test and transition phase are needed to assure the reliability or the benefits of the highly improved information output and/or the cost-efficiency of a novel method. International validation and standardization of novel methods, as well as demonstrated backward transferability or production of superior data are therefore central steps in the uptake of any novel methods into routine Baltic Sea monitoring.

A frequent deficiency of novel methods is the lack of validated data on measurement accuracy, cost-efficiency and internationally agreed standardized protocols. However, there are platforms and methods that are already applied in parts of the Baltic Sea for other purposes, but which are not yet fully integrated into the national MSFD compliant monitoring programs. Examples of these are ferryboxes, used for operational oceanography and carbon system monitoring (ICOS), ARGO floats and fixed profilers applied in the Gotland Deep, the Gulf of Finland, and the Gulf of Riga, as well as gliders. All these platforms can be used for monitoring of pelagic habitats and can improve the assessment of environmental status regarding, e.g., eutrophication.

Assessing the suitability of novel methods for Baltic monitoring

A range of novel methods has been developed that open new possibilities for monitoring and closing some of the identified gaps. We identified these methods by reviewing scientific literature and outcomes from recent projects, including BONUS projects as well as through key expert inputs. In the BONUS FUMARI project, both investment and monitoring costs of these novel methods were evaluated. For determining the applicability of a novel method in future Baltic monitoring, we assessed the evaluation criteria: reliability (as the failure safety of the method itself and the precision of acquired data), environmental impact (as beneficial or harming to the organismic/physical environment), added value (as the benefit for the monitoring, like an increased data re-

Cost rating and applicability of novel methods

Step in monitoring	Method	Main improvement for the monitoring	Overall costs	Applicability
Field sampling/ surveying	Manta Trawl	Sampling of (water surface) microplastics (D10)	low	high
	Encapsulated Filtration Device	Sampling of (water column) microplastics (D10)	low	very high
	Sediment Corer	Sampling of (sedimented) microplastics (D10)	low	very high
	Argo Float	Increased spatio-temporal resolution (D5, 7, 11)	low	high
	Ferrybox	Increased spatio-temporal resolution (D4, 5, 7)	moderate	very high
	Profiling Buoy	Increased temporal resolution (D1, 5, 7)	moderate	very high
	Bottom-mounted Profiler	Increased temporal resolution (D1, 5, 7)	moderate	very high
	Passive Samplers: Chemcatcher and POCIS	Increased spatio-temporal resolution of already monitored and novel contaminants (D8-9)	moderate	very high
	Artificial Substrates: ARMS and ASU	Increased temporal resolution (D1, 2, 5, 6) and enhanced monitoring of benthic organisms	low	high
	Citizen Observations	Increased spatio-temporal resolution (D2, 5, 7, 10) and increased environmental awareness of citizens	very low	very high
	Earth Observation	Increased spatio-temporal resolution and Baltic wide coverage (D1, 5, 7, 10)	low	very high
Sample analysis	HydroFIA®pH	Increased spatio-temporal resolution (D1, 5, 7)	low	very high
	(e)DNA Metabarcoding	Increased precision (spatial coverage) of data (D1, 5, 7), makes novel indicator species accessible, non-invasive	low	high
	Stable Isotope Analysis	Enhanced data acquisition (D5) and monitoring of food webs	low	very high

Table 1: Rating of costs and applicability of novel methods. Costs include investment and monitoring costs while applicability comprises reliability, environmental impact, added value, limitations and required expertise. The rating for overall cost vary from 'moderate', 'low' to 'very low' and the rating for applicability vary from 'high' to 'very high. The most cost-efficient methods/platforms have the lowest costs and highest applicability.

solution or monitoring for new indicators), limitations (disadvantages/shortcomings) and required expertise (the level of expertise needed to conduct the measurements) by assigning scores ranging from 'very low' to 'very high' (Table 1). Overall cost and applicability rating were done by averaging the grades for the single ratings. Monitoring costs were given higher weight than investment costs to emphasize annual running costs over one-time (initial) investments. Our analysis identified fourteen promising methods with moderate to high affordability and high applicability. Eight methods could not achieve such a positive rating but are still recommendable for specific monitoring tasks or are believed to be very promising when further developed.

Recommendations for novel methods inclusion into the Baltic Sea monitoring program.

Novel methods to be included in future monitoring of the Baltic Sea should:

1. directly address a current gap in Baltic monitoring or improve the performance regarding current monitoring;
2. produce comparable or more cost-efficient or novel and superior data;
3. be based on developed guidelines and international standards;
4. be internationally agreed upon (e.g., through HELCOM)
5. have moderate cost and high applicability and gradually be phased into the existing monitoring program.

Priority should be given to the novel methods able to fill in obvious gaps in monitoring of microlitter and underwater noise, as well as to new methods for plankton and probably also biodiversity/NIS monitoring. Further inclusion of autonomous platforms into the monitoring and assessment system for pelagic environment and eutrophication is encouraged, considering their sustained use in other observational programs.

1. Hyvärinen et al. 2020. Are we actually assessing the cost-efficiency of marine monitoring methods? – A systematic mapping of literature. Submitted manuscript.
2. BONUS FUMARI Deliverable 1.1. Gaps in the current monitoring and data management of the Baltic Sea (Kahlert et al., 2019)
3. BONUS SEAM Deliverable 2.1. Holistic synthesis of reviews and analysis of current Baltic Sea monitoring and assessment (Emmerson et al., 2019)
4. Mack et al 2020. A synthesis of novel marine monitoring methods with the potential to enhance the status assessment of the Baltic Sea. Submitted manuscript.
5. BONUS SEAM Deliverable 3.1. Technical review report on novel and cost-effective monitoring technologies and their potential applicability in Baltic Sea monitoring and assessment (Kuss et al., 2020)

THIS POLICY BRIEF summarises a syntheses on gaps and challenges in the current Baltic Sea monitoring system, conducted in the projects BONUS FUMARI and BONUS SEAM. The general aim of these projects is to develop recommendations to improve the monitoring of the Baltic Sea. Our series of five policy briefs provide comprehensive evidence based perspectives on current and improved future monitoring and aim to support monitoring of the Baltic Sea ecosystem and its ecosystem services.

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