PROPOSAL FOR A REGIONAL BALTIC BIOFOULING MANAGEMENT ROADMAP

Table of Contents

Preamble[1]

There is a clear international commitment to minimizing the risk of transfer and spread of invasive aquatic species and harmful aquatic organisms and pathogens by maritime traffic, which has been demonstrated e.g. in adopting the *International Convention for the Control and Management of Ships' Ballast Water and Sediments* (IMO BWMC) in 2004. The Convention entered into force in September 2017. Nevertheless, the other main shipping-related vector, biofouling, responsible for between 56-69 % of the established coastal and estuarine non-indigenous species (NIS) globally[2] is only addressed by the non-mandatory IMO *Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species* (Resolution MEPC.207(62)) (IMO Biofouling Guidelines), or in case of leisure boats less than 24 meters in length, *Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft* (MEPC.1/Circ.792) (IMO Biofouling Guidance). The IMO Biofouling Guidelines are currently under review[3]. The review was considered by the IMO-Sub-Committee on Pollution Prevention and Response (PPR) during its 7th session in 2020 (PPR 7), where a correspondence group was established to further assess the effectiveness of the Guidelines, review them[4], and report to PPR 8 in 2021.

IMO has requested its Member States "to take urgent action in applying these Guidelines, including the dissemination thereof to the shipping industry and other interested parties, taking these Guidelines into account when adopting measures to minimize the risk of introducing invasive aquatic species via biofouling, reporting to the MEPC on any experience gained in their implementation" and to bring the Guidance to the attention of all parties concerned.

In addition to the IMO Biofouling Guidelines and Guidance, which focus on preventing the transfer of invasive aquatic species, the *International Convention on the Control of Harmful Antifouling Systems on Ships, 2001* (IMO AFS Convention, 2001) needs to be considered to include a holistic approach regarding biofouling management. The Convention, which prohibits the use of harmful organotin compounds in antifouling paints used on ships and establishes a mechanism to prevent the potential future use of other harmful substances in antifouling systems, was adopted in 2001 and entered into force in 2008. An amendment to the Convention to prohibit globally the use of antifouling systems (AFS) containing cybutryne is expected to be finalised and adopted by MEPC 75.

From the environmental point of view, there is an imbalance between the strictly controlled ballast water management and the varying interpretation of the regulatory framework for the biofouling management since the introduction of invasive aquatic species are equally harmful, irrespectively of the introduction pathway.

Goal

There is an urgent need to develop a regionally harmonized biofouling management strategy for the Baltic Sea Region (BSR) that is consistent throughout the region and based on a holistic approach, considering introduction and spread of invasive species, use and release of biocides, climate impact of biofouling due to increased vessel fuel consumption, waste management of hull cleaning as well as economic aspects.

Biofouling is a concern worldwide and thus, demanding a globally consistent approach to its management. Therefore, this Biofouling Management Roadmap is aligned with and based on the IMO Guidelines and Guidance but explicitly addressing the specific conditions of the Baltic Sea Region (BSR) and aspects relevant for its implementation in the region. Thus, the Roadmap may therefore be seen as an important contribution

---

[1] Please note that this proposal is an output of the COMPLETE project.

[2] Galil, B.S., McKenzie, C., Bailey, S., Campbell, M., Davidson, I., Drake, L.., Hewitt, C., Occhipinti-Ambrogi, A. & Piola, R. 2019: [ICES Viewpoint background document: Evaluating and mitigating introduction of marine non-native species via vessel biofouling]. ICES Ad Hoc Report 2019.

[3] MEPC.1/Circ.811

[4] PPR 7/22 Para 7.12

to the work currently going on within IMO on the issues regarding biofouling, i.e. the revision of the IMO Guidelines for commercial ships

In the Roadmap, special attention has been given to further formalizing and concretizing the aspects covered by the IMO Biofouling Guidelines, which are only mentioned, but without any detailed information for their practical implementation (e.g. “in-water cleaning”). In particular, this Roadmap provides a state of knowledge on the biofouling management measures based on experience gained not only in projects but also through national regulations. Furthermore, the Roadmap contains three guidance documents that are addressing needs of relevant stakeholders:

- Guide on best practices of biofouling management in the Baltic Sea (Annex 1);
- Biofouling assessment protocol for leisure boats and marinas (Annex 2); and
- Recommendations for mitigating potential risks related to biofouling of leisure boats (Annex 3).

These guidance documents together with a prototype for a decision support tool to plan a tailored sustainable biofouling management strategy provide a basis for a holistic approach in the Baltic Sea in relation to biofouling. For the next step, the implementation of the Roadmap, but before contents of the Roadmap are translated into official HELCOM documentation, input will be sought from the COMPLETE PLUS project, in close connection to relevant stakeholders and considering the challenges and management efforts that may arise in terms of implementation and enforcement.

Biofouling management measures

The Roadmap follows the structure of the IMO Biofouling Guidelines. The intention is that the Roadmap, its associated guidance documents (Annexes 1-3) and the decision support tool should be taken up and implemented to improve biofouling management in the Baltic Sea.

1. Biofouling Management Plan (BFMP) and Record Book (BFRB)

1.1. Documentation for commercial ships

In order to keep the ship constantly as free from biofouling as possible, the development of a ship-specific biofouling management plan (BFMP) is key. A BFMP, specific for each ship, is a description of the ship’s biofouling management strategy. Biofouling management comprises the choice of a suitable antifouling system (AFS), maintenance and control practices, and, if needed, integrated cleaning activities. The more tailored these aspects are, the more effective are the results of the overall management[2]. The documentation of biofouling management activities is as relevant as the development of the management plan because it enables the ship-owner to assess periodically whether the planned activities are really appropriate and practical for reaching the intended efficiency of biofouling management. If this is not the case, the management plan can be adapted accordingly. Furthermore, it may serve as evidence for antifouling measures already taken and planned.

The outcome of a questionnaire developed in the frame of the COMPLETE showed that most of the commercial vessels already have a BFMP (60 %) but in most cases, this plan is too generic to enable effective biofouling management. Challenges in this context are the current need for flexibility regarding trade routes and geographic areas where the ships operate, slow-steaming, as well as extended idle periods. Changes in the operational profile should be taken into account when developing a BFMP, e.g. by updating the plan. This might be easier to facilitate for ships, which consistently operate within the Baltic Sea or between other marine regions and the Baltic Sea. Some countries and regions (Australia, New Zealand, and California) implemented regulations, which require the submission of BFMPs to national authorities prior to arrival. The BFMP should be consistent with the IMO Biofouling Guidelines. It includes a description of the biofouling management practices, maintenance plan and AFS used for hull and niche areas. Management practices are described in the BFMP and completed actions are documented in the Biofouling Record Book (BFRB). The effectivity of biofouling management increases with the synchronization of the ship’s performance and operation, with the respective biofouling management. Therefore, it is recommended to assess the effectivity of the BFMP by performance monitoring and in-water inspections (IWI), especially when travel routes change and speed or idle periods differ from the considerations made during the development of the original plan. In this context, precise keeping of the BFRB is essential, because this is the only possibility to check the efficiency of the management retrospectively (Annex 1, Section 3.1).

1.2 Documentation for leisure boats

For leisure boats, development of a BFMP and keeping a BFRB is not common practice. Studies undertaken in the frame of the German Ministry of Transport Network of Experts project on NIS in biofouling of leisure boats showed that the highest rates of biofouling occurred on boats whose owners had no information about the applied AFS[5]. These results demonstrate that by planning biofouling management and keeping a biofouling record book also the leisure boat sector could significantly contribute to minimizing the spread of invasive species as well as the input of biocides. A first step to improve biofouling management of leisure boats is the recommendation to keep information about the actual AFS (specification, age, and condition) on board. To cover and comprise the majority of leisure boats in the BSR it is recommended to prepare this information already for boats larger than 8 m (IMO Biofouling Guidance relates to leisure boats larger than 24 m). In addition, receipts or documentation of cleaning actions including cleaning before overland transport should be included in the logbook, which has to be present on each boat sailing coastal waters, as appropriate surrogate to the BFRB. Another advantage of the BFRB is the ability to track the history of the AFS when buying a used boat. According to the above mentioned project, this information is lacking quite often and leads to uncertainties in applying an appropriate AFS (Annex 1, Section 4.1).

2. Antifouling system (AFS) installation and maintenance

When choosing an effective, environmentally sustainable, and appropriate AFS for ships and boats operating in the Baltic Sea, the type of ship or boat, its activity level and operational profile, as well as the physical, chemical and biological conditions of the Baltic Sea should be considered. The characteristics of the Baltic Sea regarding decreasing fouling pressure with decreasing salinity from South/West to North/East and adjacent freshwater areas offer a wide range of effective, biosecurity, and environmentally sustainable AFS for both sectors: commercial shipping and leisure boating.

2.1. Choice of AFS for commercial shipping

As a basic requirement, all commercial vessels entering and leaving the Baltic Sea, and those operating in the Baltic Sea, must select an AFS compliant with the IMO AFS Convention, 2001.

It is recommended that vessels operating exclusively in the Baltic Sea use AFS with moderate biocide content (max. 20 % of copper) and moderate leaching rate ($\leq$ 10 µg/cm^2/day). According to the recommendations of manufacturers, these are appropriate for moderate climate and moderate fouling pressure. The latter has been proven for the Baltic Sea within several research projects.[6] [7]

The choice of AFS is, however, dependent on the operational profile of the vessel, taking into account the activity level, service speed, and trading areas. Vessels with high activity level and average speed faster than

---

[5] https://www.bsh.de/DE/THEMEN/Forschung_und_Entwicklung/Aktuelle-Projekte/BMVI-Expertennetzwerk-TF2/_Anlagen/Downloads/Hull_Fouling.pdf;jsessionid=B7CA233F6262E4573B2F4874C0C37C15.live11291?__blob=publicationFile&v=2

[6] Lindgren, J.F., Ytreberg, E., Holmqvist, A., Dahlström, M., Dahl, P., Berglin, M., Wrange, A.L. & Dahlström, M. 2018: Copper release rate needed to inhibit fouling on the west coast of Sweden and control of copper release using zinc oxide. Biofouling 34(4): 453-463.

[7] Watermann, B. & Dahlström, M. 2018: BONUS CHANGE: Recommendations towards regulations for a sustainable antifouling practice in the Baltic Sea.

10 knots may use antifouling paints with low biocide release rates, biocide-free hard coatings in combination with in-water cleaning, or biocide-free foul release coatings.

Another important aspect to take into account is the ship's operation under varying weather conditions. If operating year-round, even in drifting ice conditions, hard coatings in combination with cleaning are appropriate to use while fouling release coatings are not robust enough for use during wintertime at ice conditions.

For ice-free areas and seasons, foul-release coatings are a viable non-biocidal alternative to the above mentioned conventional biocidal antifouling coatings for the use in the Baltic Sea. These coatings rely on surface properties to mechanically preventing fouling, preferably by extruding non-persistent oils, degradable waxes, or polyethylene glycols to its surface, thus reducing both settlement and adhesion strength of biofouling. Present results[8] show that a non-biocidal foul-release coating can be more effective than a self-polishing copper antifouling coating, even under idle conditions. In the COMPLETE project, coated panels were deployed near the Port of Gothenburg, in an area of relatively high salinity and high fouling pressure (North Kattegat Sea, in the Outer Baltic). Visual inspections were carried out monthly and by the end of a yearlong period, the foul-release coating had, on average, approx. half the level of biofouling (US Navy fouling rating scale) compared with a conventional copper antifouling coating. This study was performed in an area with high biofouling pressure compared with Central and Inner Baltic and panels deployed in flow speeds lower than achieved on a ship hull.

In the Baltic Sea, ferries operating year-round in the Baltic Proper use anticorrosive coatings without antifouling paints as top layer, because antifouling paints are too soft to withstand the abrasion caused by drifting ice in wintertime. Ferries with pure anticorrosive paints have to be cleaned in-water by divers during the fouling season from April to October up to bi-weekly or even weekly to maintain a clean hull.

A further option for ships trading constantly between the Baltic Proper and adjacent freshwater areas like Lake Saimaa may be to use biocide-free self-polishing coatings (SPCs) which are available for a range of operational profiles. An additional option is the weekly or biweekly grooming of suitable antifouling paints or hard coatings as a proactive fouling prevention strategy. Several diving companies offer in-water cleaning with tools connected to capture, filtration and waste management systems (BSH Biofouling Management Database and interactive map).

In combination with effective and fast responding on-board performance systems, reactive cleaning in the biofilm stage is yet another option.

2.2. Choice of AFS for leisure boats

For the selection of an appropriate AFS for leisure boats, the location of the berth is the main criterion as the fouling pressure varies significantly within the Baltic Sea. Other aspects to consider are the operational profile of the boat and the visited areas together with their respective fouling pressures.

Currently, copper (Cu) is the most widely used active substance in antifouling paints, and application of an inappropriate AFS (too low or too high content and release of Cu) may result in unnecessary accumulation of biofouling or unnecessary release of biocides into the marine environment.

The Baltic Sea is characterized by decreasing salinity from west to east. Along with this salinity gradient, the fouling pressure decreases.[9] Hard-shelled calcareous macrofouling can develop in the western and southern

[8] Oliveira, D.R. & Granhag, L. 2020: Ship hull in-water cleaning and its effects on fouling-control coatings. Biofouling 36(3): 332-350.

[9] Wrange, A.L., Barboza, F.R., Ferreira, J., Eriksson-Wiklund, A.K., Ytreberg, E., Jonsson, P.R., Watermann, B. & Dahlström, M. 2020: Monitoring biofouling as a management tool for reducing toxic antifouling practices in the Baltic Sea. J. Environ. Manag. 264: 110447.

Baltic Sea, whereas in the central, northern, and eastern parts, fouling is merely composed of soft fouling more typical for freshwater, with lower presence or missing of hard fouling organisms.[10] Taking into account these circumstances, some Baltic Sea countries (Denmark, Finland and Sweden) have adopted legislative restrictions, which only allow the use of AFS with high biocide content in the western Baltic. AFS with low biocide load should be used in the central and eastern parts and only biocide-free products in the freshwater areas.[11]

Based on numerous test panels coated with different antifouling products exposed around the Baltic Sea (during the research projects CHANGE and COMPLETE), a gradual scheme for the choice of the appropriate AFS is proposed:

- In the **Western and Southern Baltic Sea**, information on the local fouling pressure as basis for the selection of AFS should be gathered according to the results of Wrange *et al*. 2020.
- From the **Kattegat to the Central Baltic Sea**, AFS are effective with Cu release rate of 5 µg/cm^2/day. In biofouling hot spot areas (see 3.2.3), the efficacy can be enhanced by zinc oxide.
- In the **eastern part of the Baltic Sea (east coast of Sweden)**, AFS with release rate of 2 µg/cm^2/day shall be effective.
- In the **eastern and northern part of the Baltic Sea and adjacent freshwater areas**, biocide-free coatings[12] in combination with cleaning effectively prevent fouling. Suitable coatings include silicone-based foul release coatings and epoxy-silicone hybrids as hard, abrasion resistant coatings.

This information is also included in the interactive map.

3. In-water cleaning (IWC) and maintenance

In-water cleaning (IWC) of leisure boats and commercial ships is an essential part of biofouling management. However, it may pose a risk to the environment depending on the nature of biofouling (e.g. microfouling or macrofouling, occurrence of non-indigenous species), the type of AFS applied (e.g. biocides and paint flakes) and the methods applied for IWC (e.g. high-pressure waterjet or brushes with or without collecting container or filtering). Based on the results of a COMPLETE questionnaire with 483 and 68 participants representing leisure boat owners and commercial shipping companies operating in the Baltic Sea respectively, 10 % of the boat and 72 % of the ship owners stated to perform IWC. Of the respondents representing leisure boats, 33 % knew that removed material is collected and disposed in waste containers. The remaining participants disposed the material in water (19 %), used other facilities (21 %) or did not know anything about the whereabouts of removed material (27 %). These results demonstrate that there is a need for a regionally harmonized approach in order to minimize the risk of species introduction and pollution by biocides and polymers from AFS caused by IWC.

3.1. Regulation of biofouling management practices in Baltic Sea States

With the implementation of the EU Water Framework Directive, the chemical status of the water bodies must not be deteriorated. The EU Marine Strategy Framework Directive (MSFD, in relation to D2) and Invasive Alien Species Regulation[13] (IAS Regulation) aim at minimizing non-indigenous (MSFD) or invasive (IAS) species introduction and spread. Therefore, the procedure of IWC, coming along with a certain environmental risk for the Baltic Sea, should be approved by responsible authorities. In the BSR, granting of permissions for IWC

---

[10] Lagerström, M., Ytreberg, E., Wiklund, A.K. & Granhag, L. 2020: Antifouling paints leach copper in excess – study of metal release rates and efficacy along a salinity gradient. Preprint, 1-22.

[11] Kymenvaara, S., Tegnér Anker, H., Baaner, L., Ekroos, A., Gipperth, L. & Seppälä, J. 2017: Regulating Antifouling Paints for Leisure Boats - A Patchwork of Rules Across Three Baltic Sea Countries. Nordic Environmental Law Journal 1: 7-32.

[12] List of biocide-free AFS

[13] Regulation (EU) 1143/2014 on invasive alien species (the IAS Regulation) https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32014R1143&from=EN

is in the responsibility of national or even local administrations, depending on the country. National environmental protection agencies, municipalities, or port authorities are the competent authorities. At this point, no common understanding of the regulation of IWC and no common basis for the granting of permissions exists. In addition, there is a lack of information on IWC technologies, facilities, and procedures. The BSH Biofouling Management Database aims at providing information on the status and opportunities for IWC in the BSR. With this database, it is possible to gain information on ports and marinas and their respective requirements for IWC. In addition, companies providing IWC with capture and filtration of biofouling waste are listed.

Nevertheless, the issue of the IWC in the Baltic Sea region requires further coordinated efforts among the relevant authorities (e.g. Maritime Authorities, Environmental Agencies, Port Authorities, Water Authorities) with the aim of harmonisation at national and later, regional level. This is crucial to ensure consistent conditions and regulations for IWC, transparency for stakeholders, and an environmentally sound implementation of IWC in the Baltic Sea Region.

3.2 Assessing the risk of species introduction and spread by biofouling

Biofouling of commercial vessels and leisure boats acting as vectors for NIS is a well-known fact[14]. Nevertheless, quantity and quality (species composition) of biofouling arriving in the Baltic Sea is largely unknown. In the COMPLETE project, the potential for biofouling has been quantified to improve the knowledge base for the removal and handling of biofouling material, and thus, to decrease the risk of introduction and spread of NIS.

Quantification of biofouling potential is highly relevant for biofouling waste handling issues (collection, proper handling, and treatment) and possible synergies with e.g. already existing ballast water and sediment reception facilities and treatment procedures in ports.

3.2.1 Biofouling potential of commercial shipping

Biofouling accumulates on ship hulls over time and space continually, posing a potential risk to all ports visited by the ship. Ports are recipient areas for new species by providing opportunities to establishment and their further spread by attaching to other ships. Due to huge underwater surface area of commercial ships, which can transfer living organisms, it is important to estimate the biofouling potential in the BSR by the combination of science-based methods and port data.

Aiming at indicating the potential surface area for transmitting NIS from outside and inside the BSR, the biofouling potential of commercial shipping was assessed within the COMPLETE project by using the Wetted Surface Area (WSA) method.[15] Analyses were carried out via evaluation of WSA for the year 2018 as biofouling habitat flux into the Baltic Sea from all BSR countries except Russia. The estimates were based upon the number and WSA of incoming ships, their respective bioregion, and vessel type. WSA calculations were carried out based on vessel type, the total length, average moulded draft, breadth, and hull coefficients[16], the number of vessels arriving during a particular time period, and geographic location. The WSA estimation results are given in square kilometres of surface that can be potentially biofouled. Such information can be used by stakeholders and authorities for designing biofouling management strategies in

---

[14] Ojaveer, H., Galil, B.S., Carlton, J.T., Alleway, H.,Goulletquer, P., Lehtiniemi, M.,Marchini, A., Miller, W., Occhipinti-Ambrogi, A., Peharda, M., Ruiz, G.M., Williams, S.L., Zaiko, A. 2018: Historical baselines in marine bioinvasions: Implications for policy and management. PLoS ONE 13 (8)

[15] Miller, A.W., Davidson, I.C., Minton, M.S., Steves, B., Moser, C.S., Drake, L.A. & Ruiz, G.M. 2018: Evaluation of wetted surface area of commercial ships as biofouling habitat flux to the United States. Biological Invasions 20: 1977-1990.

[16] Van Maanen, J.D. & Van Oossanen, P. 1988: Resistance. In: Lewis, E.V. (ed.): Principles of naval architecture, volume II. The Society of Naval Architects and Engineers, Jersey City, pp 1-93.

relation to NIS introduction risk. Furthermore, the data might be highly relevant for the waste management of hull cleaning services in the BSR.

The number of ships entering the Baltic Sea ports in 2018 was above 155,000, of which 82 % came from other Baltic Sea ports. The highest total number of port visits was recorded in Sweden (over 46, 000) and the lowest in Germany. Moreover, Swedish ports also registered the highest values of visits from outside of the Baltic Sea, with the highest number of donor ports (624) and bioregions visited before entering the Baltic Sea. German ports had the lowest number of ports visited before entering BSR (14), since the largest German port (Hamburg) is not situated in the Baltic Sea.

The total biofouling potential of commercial ships entering the Baltic Sea was estimated to be over 656 km^2 of underwater hull surface in 2018. The highest biofouling flux was observed in Swedish and Finnish ports with 31 % and 28 % of the total WSA, respectively, and the lowest in Latvia (4.5%), Lithuania (3.7%) and Germany (0.6%). The highest ratio of WSA flux between ships entering the ports from inside the BSR to those coming from outside was noted in Estonia (9:1), Finland, Denmark, and Germany (5:1), whereas the lowest ratio was observed in Latvia and Lithuania (2:1). Generally, cargo and Ro-Ro[17] ships dominated, both in the number of vessels entering the ports and in the WSA flux from outside and inside of the BSR.

3.2.2 Biofouling potential of leisure boats

Leisure boats may act, to a large degree, as a vector of secondary spread of NIS between adjacent harbours, marinas and other coastal regions. Marinas play a similar role as ports, acting as recipient areas for new species, which can be introduced there and spread further to other regions by fouled leisure boats. It is important to know the potential of leisure boats to be fouled by living organisms as well as boat owners' behaviour regarding sailing and maintenance of their boats.

Within the COMPLETE project, the biofouling potential of leisure boats was assessed using a fuzzy logic model[18]. Analyses were carried out based on the results of questionnaires, answered by boat users, concerning vessel type, antifouling painting frequency, hull cleaning frequency, frequency of taking the boat out of the water and mooring time. The goal was to indicate high and low risk profiles of boats and boat owners and their habits during the boating season. This can be especially important for stakeholders and authorities as it gives an insight into boat owners' activities, which may increase or decrease the biofouling potential. It can be also used to identify specific behaviours on which more attention should be paid in biofouling management, e.g. hull cleaning frequency, mooring time, or maintenance of the AFS.

According to the fuzzy 'boater' model, low-risk derives e.g. from application or renewal of the AFS at least once a year, taking the boat out of water few times in the season for hull cleaning, and use of the boat not less than weekly. The high-risk derives e.g. from application or renewal of AFS every 4-5 years, cleaning of the boat less than once a year, and leaving it in the water, or remove it only at the end of the season.

The model allows to define biofouling risk (potential) for a defined vessel type, boat user habits and craft maintenance from very low to very high. The biofouling potential was modelled for German, Finnish, Polish, Russian, Swedish, and Dutch boats/boaters operating in the BSR, as there were no respondents to the questionnaire from Estonia, Latvia, or Lithuania. In the majority of cases (54 %), the biofouling potential was at medium level. High biofouling potential was noted in 36 % of the crafts, very high risk in 4 % and low risk to biofouling in 6 %. Germany, Finland, and Poland were countries with the largest contribution to the study, from which Germany had the lowest percentage (20 %) of boats with high and very high (1.5 %) biofouling potential. Even though in Finland the high potential of boats' fouling was noted for more than half of the

[17] Roll-in/Roll-out

[18] Ferrario, J., Marchini, A., Borrelli, P., Berzolari, F.G. & Occhipinti-Ambrogi, A. 2016: A fuzzy 'boater' model to detect fouling and spreading risk of non-indigenous species by recreational boats. Journal of Environmental Management 182(1): 198-207.

crafts (57 %), the very high potential of biofouling was very low (3 %). On the other hand, although Polish leisure crafts were represented by lower percentage of high biofouling potential than in Finland, very high biofouling potential was noted in over 16% crafts and there were no boats with low or very low biofouling potential.

3.2.3. Mapping of the risky areas for introduction and spreading of NIS by commercial shipping and leisure boating

Vessels visiting BSR ports transfer a potentially large amount of organisms attached to the hull surfaces thereby increasing the risk of introduction of new species, not only in the ports but also in all surrounding waters. Areas with maricultures also act as recipients of new species, which can escape or be accidentally released during transportation or cultivation. However, not only locations where introductions take place are exposed to invasion. All areas located close, which offer favourable settlement surfaces for NIS are prone to this process, ranging from quays and piers in ports as well as in marinas to offshore hard surfaces of drilling units or wind farms. Sensitive areas, e.g. marine protected areas (MPAs), but also industrial seawater discharge sites or nuclear power plant sites where water is warmer than nearby, are especially vulnerable to invasion.

The information on the geographical location of ports, marinas, mariculture, and other areas offering favourable substrates for settlement, and areas easy to invade and sensitive were analysed. Within the COMPLETE project, the location of these facilities as well as natural dispersal processes were considered and visualized on a heat map (https://complete.ug.edu.pl/en/chmen/), where the risk of each component/hazard was weighted to account for their relative importance. The map of the risky areas for arrival and spread of NIS has been constructed to give basic environmental knowledge and support for biofouling management issues like e.g. identification of areas where the risk from IWC is low. This visualization describes the potential suitability of areas for NIS establishment, which can be especially important for stakeholders and authorities giving an insight into natural conditions and diversity of human activities in specific geographic localizations. It can be also used to mark risky areas in which operating crafts require more attention regarding biofouling management e.g. actions preventing disseminating of NIS to other BSR or choice and maintenance of AFS.

The map developed in the COMPLETE project allows ranking the risk for arrival and spread of NIS in the BSR from very low to very high. According to the map, hot spots representing areas with very high risk are located mainly on the coast of the Finland e.g. Archipelago Sea, northern part of Gulf of Finland, eastern part of Bothnian Bay as well as Danish islands, e.g. the northern part of Lolland, the western part of Zealand, the western part of Fiona and Horsens Fjord in Jutland. Such high risk in these localities can be related to proximity of ports, mariculture, wind farms or marine protected areas. However, there were also areas with high risk identified at the coast of Finland, Sweden, Denmark, Germany, Poland and Lithuania. Medium risk can be assigned to many coasts, and islands of BSR countries. Whereas most of coastal areas of Estonia, Latvia, Lithuania, and Kaliningrad was noted to have low to very low risk for arrival and spreading of NIS in BSR.

There is an initiative to develop a fouling atlas of the Baltic Sea including consideration of NIS. For the German Baltic Sea coast, a fouling map is already available[19].

3.2.4. Biofouling assessment protocol for leisure boats and marinas

A protocol has been developed within the COMPLETE project to identify the potential risk of NIS transfer by leisure boats and trailers in the BSR (Annex 2). The sampling methods have been tested in Finland, Germany, Latvia, and Poland, being the final protocol developed according to the field-testing experiences. The protocol consists of the following sub tasks: 1. Questionnaire, 2. Sampling in marinas and 3. Post season examination of fouling levels of leisure craft.

---

[19] https://www.umweltbundesamt.de/bewuchsatlas-was-ist-bewuchs

The questionnaire for leisure boaters addresses such questions as the movement of leisure boats in the Baltic Sea region, anti-fouling method of choice, the use of trailer, cleaning procedures etc. It could be answered online or printed on paper. With help of the questionnaire, background information on the potential risk of transferring NIS by leisure boats and trailers via biofouling was collected.

Sampling in marinas by settlement plates and scraping samples addressed the question to what extent marinas represent a source of NIS to be further spread in the Baltic Sea via biofouling of leisure boats. The settlement plates were deployed to each subarea in the beginning of the boating season and scraping samples were taken during the season from structures present in the marinas. The plates were removed gradually after different periods of exposure (Annex 2). The organisms on the plates and scraping samples were identified.

The examination of biofouling on vessels was performed after the boating season to gather information on species and communities attached on the vessels. This was done by estimating the fouling levels, photographing the fouled surfaces, and sampling biofouling communities on the hull and niche areas of the boats (for details see Annex2.). Ideally, the post-season examination was conducted on leisure boats from marinas where settlement plates were deployed to allow comparison between the two studies. In addition, in optimal cases, vessel owners answered the questionnaire and the results were connected to the samples and photographs taken from the vessel. Due to difficulties in contacting the boat owners, this was not always possible.

3.3. Recommendations for mitigating environmental risks of in-water cleaning (IWC)

3.3.1 Commercial ships

As mentioned above, in addition to coating systems, in-water maintenance is often needed to keep biofouling on hulls to an acceptable level, preferably as microfouling (individuals up to 1 mm in size) rather than macrofouling (individuals larger than 1 mm in size). For commercial ships, biocide-free paint and cleaning can be the selected management option (see 2.1) or cleaning can be necessary if the biocidal paint is shown less efficient than expected according to planned maintenance and dry-docking period.

For IWC there is need to capture the waste to avoid pollution from both, biological material, chemicals and polymers (heavy metals and paint matrix). The size for filtration should be selected to capture viable stages of fouling organisms as well as the commonly found size of paint particles. Further, the waste should be handled on land considering the risk of invasive species introduction and pollution with toxic substances.

In-water maintenance of commercial ships includes in-water cleaning of hull, propeller surfaces and accessible niches relying on deployment of divers and ROVs (Remotely Operated Vehicles), typically using brush systems or water jet cleaning methods[8]. In-water maintenance may follow a reactive approach, in which cleaning events are triggered by a detectable increase in fuel consumption, or follow a *proactive* approach, in which cleanings are scheduled beforehand. Ideally, proactive cleaning is conducted before macrofouling has settled, as to reduce generation of large amounts of biological waste, increase the risk of spread of invasive species and damage of AFS. This also enables the use of gentler cleaning methods. The approach of frequent and gentle cleaning is commonly referred to in the literature as “hull grooming”.

During the COMPLETE project, to optimize cleaning schemes[20], bi-monthly and monthly cleanings with water jet system, was performed on panels deployed in the Port of Gothenburg. The port is situated in the Outer Baltic (Northern Kattegat), an area with salinity around 20 PSU and high fouling pressure. Results indicate that bi-monthly cleanings, using minimal forces adjusted to the adhesion strength of biofouling, keep an average fouling level equivalent to a light slime, i.e. a biofilm with visible underlying paint surface, on both biocidal antifouling and biocide-free foul-release coatings. Also, cleaning with minimal levels of shear and normal force did not result in any detectable damage or wear to a conventional biocide antifouling coating, meaning no measurable increase in emissions of copper to the marine environment. Still, it should be noted that other studies have pointed to significant increases in biocide release associated with cleanings, where admittedly higher forces were used.[20] [21] Thus, depending on the cleaning device and selected cleaning settings (e.g. brush material or waterjet pressure), as well as the level of biofouling to be removed, cleaning on biocidal coatings may result in significantly increased emission of biocides to the marine environment.

Regarding cleaning on inert hard coatings, e.g. ice-breaker abrasion-resistant coatings without any fouling-prevention properties, cleanings should be scheduled as tightly in time as practical, ideally targeting early stages of fouling and taking into consideration seasonality of fouling and vessel activity, i.e. vessel speed profile, travelling routes and duration of idling periods. For example, results by Oliveira and Granhag (2020)[8] (Fig. 3a and Fig. 4a-b) show that an unprotected vessel, i.e. using an inert coating, would require a cleaning frequency higher than monthly in order to avoid macrofouling during a 1-month idle period in the summer season, whereas less frequent cleaning would be required during the winter months. These results represent the worst-case scenario for the BSR, having been obtained in the outer Baltic Sea (the northern Kattegat) where salinity and fouling pressure are higher compared with the central and inner Baltic. Additionally, it should be noted that vessels entering the Baltic Sea need to be further considered, as these vessels pose a different scenario for management using IWC. Vessels operating both outside and within the Baltic may have been exposed to significantly higher fouling pressure outside the Baltic and are also expected to use Cu-containing SPC coatings.

3.3.2. Leisure boats

The guidance "Recommendations for mitigating potential risks related to biofouling of leisure boats" (Annex 3) provides biofouling management recommendations for recreational boaters to help minimize the risk of transferring NIS from biofouling as well as niche areas in the Baltic Sea. The guidance aims to share information of such practices that reduce the biofouling on recreational vessels and boat trailers, which contributes to reducing the potential of NIS spreading in new habitats. The management recommendations provided in the document, act as a precaution in preventing the NIS spreading in the Baltic Sea region. The recommendations can be used by marinas as well as boating associations to spread information throughout the leisure boat sector.

The boat owner should inspect the rate of biofouling growth regularly and clean the boat and/or trailer when necessary. It is however understood that there is a balance between the management efforts and a corresponding lower risk of transferring non-indigenous species. Leisure boats have significant differences in risk profiles. It is therefore important that the risk profile for leisure boats is differentiated prior to establishing the level of management efforts that is required for each boat.

The boat owner should estimate the necessity of cleaning regularly. Cleaning is recommended to be performed on all the submerged surfaces such as the hull, niche areas and movable structures. Whether the hull cleaning is performed on land or in water, the removed material should be treated as waste and not be allowed to enter the water. A hull cleaning machine or hand-held tool should not be used if the vessel was painted with antifouling paints containing biocides. After the trailer has been in contact with the water or marine environment, it should be inspected thoroughly for biofouling or other organisms present. The trailer should be cleaned of all biofouling before transporting it to another water system.

3.4. Conclusion: Guidance on best practices regarding in-water cleaning (IWC)

As no AFS can totally avoid biofouling, proactive or reactive IWC is a commonly applied component of biofouling management of ships and boats. If cleaning is not performed in an environmentally sustainable manner, it might pose risks to the Baltic Sea environment by release of antifouling paint particles, biocides,

---

[20] Tribou, M., & Swain, G. 2017: The effects of grooming on a copper ablative coating: a six year study. Biofouling 33(6): 494-504.

[21] Earley, P. J. *et al*. 2014: Life cycle contributions of copper from vessel painting and maintenance activities. Biofouling 30(1): 51-68.

polymeric backbone, and invasive species[22 23 24]. Nevertheless, the majority of cleaning is performed on biocidal antifouling paints, which are present on about 95 % of commercial ships and leisure boats[25 26]. Biocidal antifouling paints are not designed for cleaning. They are too soft, and cleaning might remove, along with the attached fouling organisms, in the range of 20-30 µm of the upper paint layers. During cleaning, immediately paint particles and dissolved along with undissolved biocides are released into the water. In addition, this has multiple additional implications:

- Reduction of the service life of the AFS and thereby, the docking interval.
- The impact of cleaning tools depends on the amount, composition, and adherence of the fouling. The heavier the fouling is, the higher the effort necessary to remove it. If AFS is completely removed or damaged, these hull areas are prone to new settlements.
- Macrofouling communities contain propagules of algae and barnacles and are hard to capture 100 %. Viable spores and larvae might invade ports and coastal areas[27 28 29].

3.4.1. Best Practice IWC for commercial shipping

In order to perform IWC in a sustainable manner, best practice is cleaning on abrasion resistant, non-biocidal hard coatings in combination with capture and filtration of the biological material and subsequent waste treatment and disposal. Information on coatings most suitable for cleaning is provided in Annex 1.

If IWC is performed on biocidal antifouling paints, the following aspects should be considered:

- Pre- and post-cleaning inspections.
- To avoid damage of the AFS, a reference area on the hull should be selected to test the cleaning tools with respect to efficacy, collection and measurement of undissolved paint particles and dissolved/undissolved biocides.
- More extensively developed fouling should be cleaned in dry dock.
- Capture of the removed fouling organisms should be mandatory and treatment by filtration shall use mesh sizes of at least 10 µm.
- Reliable and validated reports on cleaning test on reference areas including measurement results of accredited laboratories as well as pre- and post-inspections of the hull and niches shall be submitted to the operator.[8]

In Annex 1, the best available IWC techniques (BAT) are listed, which are available through cleaning companies in the Baltic Sea. These techniques include capture of the removed fouling and removed paint particles and filtration.

---

[22] Bighiu, M.A., Eriksson-Wiklund, A.K. & Eklund, B. 2017: Biofouling of leisure boats as a source of metal pollution. Environ. Sci. Pollut. Res. 24: 997-1006.

[23] Martin, D.M., Bergman, K., Harju, A.A., Koroschetz, B., Salminen, E., Solér, C. & Ziegler, F. 2018: Understanding antifouling practices and consumption patterns. In: Strand, H., Solér, C. & Dahlström, M. (eds.): Changing leisure boat antifouling practices in the Baltic Sea, pp. 74-86.

[24] Martin, D.M., Harju, A.A., Salminen, E. & Koroschetz, B. 2019: More Than One Way to Float Your Boat: Product Use and Sustainability Impacts. J. Macromark. 39(1): 71-87.

[25] Yebra, D.M., Kiil, S. & Dam-Johansen, K. 2004: Antifouling technology - Past, present and future steps towards efficient and environmentally friendly antifouling coatings. Prog. Org. Coatings 50: 75–104.

[26] INTERTANKO 2016: Guide to Modern Antifouling Systems and Biofouling Management. London, 20 pp.

[27] Woods, C.M.C., Floerl, O. & Jones, L. 2012: Biosecurity risks associated with in-water and shore-based marine vessel hull cleaning operations. Mar. Pollut. Bull. 64: 1392-1401.

[28] IMO 2019: Hull scrapings and marine coatings as a source of microplastics. London, 33 pp.

[29] Scianni C. & Georgiades, E. 2019: Vessel In-Water Cleaning or Treatment: Identification of Environmental Risks and Science Needs for Evidence-Based Decision Making. Front. Mar. Sci. 6: 467.

3.4.2. Best Practice IWC for leisure boating

In biofilm waste from boat hulls coated with biocidal antifouling paints, a content of up to 28 g copper/kg dw and 171 g zinc/kg dw has been documented.[22] Apart of this, leisure boats may harbour rich macrofouling communities, in case they are not used regularly and/or antifouling fails. To minimize environmental risks like the spread of invasive species and release of biocides and polymer flakes by IWC, the following recommendations should be considered.

IWC of leisure boats should be performed with brushes in a gentle manner and be accompanied by capture of fouling by e.g. underwater floating foils. A crucial aspect is the type of coating on which cleaning may be conducted. The best practice is cleaning on abrasion resistant, non-biocidal hard coatings, which releases no biocides during the cleaning and where the abrasion of paint flakes is minimal.[30] In tests of particle wear from paint with soft and hard matrix, a smaller volume of particles was seen to be removed from paint with a hard matrix.[31] The size of particles removed varied for different paint types with smaller fragments released from the hard paint type, which also gave smaller size of aggregates that were formed after water movement.

The frequency of IWC needed on leisure boats is dependent on the fouling pressure, and with the aim to avoid hard fouling, cleanings ultimately should match the time period when hard fouling organisms like barnacles and mussels are in their larval phase. The number of settling events, where invertebrate larvae change from the planktonic larval stage to the sessile form, increase with increasing salinity.

Around the Swedish and Finnish coast, ca. 20 stationary cleaning stations are in service during the fouling season. For motorboats, rough, floating foils fixed at berth are available on the market. Each time leaving and arriving, the foil will clean the hull.

3.5. Interactive map of hull cleaning service providers

An interactive map of good practices hull cleaning services and applied technologies (https://balticcomplete.com/maps) has been produced, covering the entire BSR. It combines technical and visual solutions in a convenient and understandable manner for easy processing of the placed information - location of in-water cleaning services for commercial shipping and leisure boats as well as contact information of organizations, used technology and methods of filtration and collection. It focuses primarily on hull cleaning service providers and these services' seekers.

4. Dissemination of information

4.1. Level of knowledge of and compliance with the IMO Guidelines among ship-owners

Based on the results of the COMPLETE questionnaire with 68 participants, representing commercial ships operating in the Baltic Sea, the level of knowledge of the IMO Biofouling Guidelines is high. 94 % of the respondents are aware of the Guidelines, 66 % follow the Guidelines, and 28 % do not follow. Merely 7 % of the participants have difficulties in implementing the Guidelines and state the required bureaucracy as the reason. Ship-owners should be kept informed about the biofouling-related ecological (e.g. spread of non-indigenous species) and economical risks (e.g. increased fuel consumption, reduced speed resulting in longer voyages, increased dry-docking costs) and innovations regarding IWC or AFS. The BSH Biofouling Management Database) provides an overview on:

- AFS that may be used in Baltic Sea countries
- IWC opportunities and their requirements in ports and marinas, and
- Companies which perform IWC with capture and filtration of biofouling waste

---

[30] Watermann, B. & Eklund, B. 2019: Can the input of biocides and polymeric substances from antifouling paints into the sea be reduced by the use of non-toxic hard coatings? Mar. Pollut. Bull. 144: 146-151.

[31] Stragnefeldt, F. 2018: Slitage av båtbottenfärger från skrovrengöring. Kandidatuppsats miljövetenskap, Institutionen för biologi och miljövetenskap, Göteborgs Universitet.

4.2. Level of knowledge of and compliance with the IMO Guidance among boat owners

Another COMPLETE questionnaire with 483 participants addressing boat owners shows a very low level of knowledge of the IMO Guidance. Only 10 % of the boat owners are familiar and comply with the IMO Guidance, 5 % do not follow and the remaining 85 % are unfamiliar with the IMO Guidance. These results show a clear difference between commercial and recreational shipping regarding the knowledge and implementation of the IMO Guidelines and Guidance, respectively. Through a targeted public relation, information on the subject of non-indigenous species and biocides combined with references to existing recommendations, guidelines for the prevention of biofouling accumulation and the COMPLETE Database can be spread with multimedia tools such as short video clips. These can be distributed quickly and in a targeted manner via the known channels. Additionally, an official antifouling officer should be trained in every club and marina. He would receive regular courses on the topics of antifouling systems, cleaning, legal issues, NIS, etc.

5. Implementing the Roadmap: Tools and case studies for the practical implementation of sustainable biofouling management in the Baltic Sea Region

Within the COMPLETE project, a prototype for a decision support tool to plan a tailored sustainable biofouling management strategy has been developed. In addition, practical cooperation and case studies were performed in co-operation with stakeholders. As follow-up of the COMPLETE project, COMPLETE PLUS aims at further elaborating the practical implementation of this Roadmap, which will be concretized in close connection to the respective stakeholders within COMPLETE PLUS.

5.1. Tool for planning a sustainable biofouling management strategy

In shipping companies, biofouling management is typically understood at a relatively general level, and the management strategies are based mainly on earlier experiences and various “rules of thumb”. Improved information is needed to facilitate the biofouling management, allowing the evaluation and comparison of the cost-effectiveness of alternative strategies. The optimal solution is case-specific and should be considered in the light of several aspects, including the risk of new NIS introductions, the release of eco-toxicological compounds from biocidal coatings, as well as the impact of biofouling on the fuel consumption and CO_2 emissions of the ships. Further, all these aspects depend on such factors as the ship design, operating profile, and maintenance of the ship, and are accompanied with uncertainty arising from divergent sources.

In the COMPLETE project, a first version of a decision analysis tool has been developed to support sustainable biofouling management in the Baltic Sea (Figure 1). The stakeholders, such as ship-owners and authorities, can apply the tool to compare different biofouling management options and methods case-specifically. In addition, the tool can increase their systemic understanding on the complex issue and help to recognize the most relevant factors and their interdependencies.

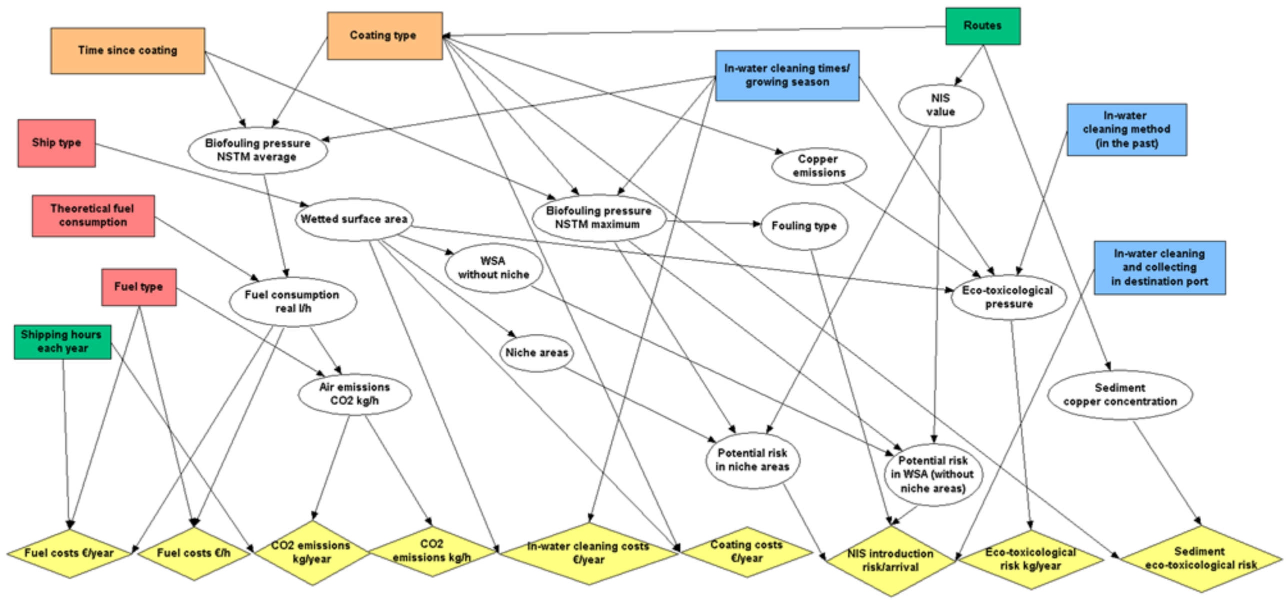

Figure 1. Graphical representation of the decision support tool for biofouling management. The model consists of decision (green, red, orange, and blue rectangles), random (white ovals) and utility (yellow diamonds) variables and their conditional dependencies (arrows).

The tool allows comparisons of a) **NIS introduction risk**, b) **eco-toxicological risk** due to biocidal AFS, c) **CO_2 emissions** resulting from fuel consumption, as well as d) **costs** related to fuel consumption, IWC, and coating, given different ship types, their operational profiles and the alternative biofouling management strategies. Preliminary results show that, generally speaking, optimal biofouling management strategy is based on a biocide-free coating and regular IWC, where filtering devices are used to collect the removed organic material. This strategy seems to result in very low eco-toxicological impact and NIS risk. In addition, savings in the fuel costs, due to the lower friction, promote the cost-effectiveness of the strategy from the economic perspective as well.

However, the best biocidal-free coating type depends on the operational profile of the ship. In the southern Baltic Sea, where ice-free conditions occur year-around, foul-release coatings is an optimal choice, whereas in the areas with more regular ice-cover, hard and ice-tolerable coating is more suitable. In addition, the optimal IWC interval varies, being dependent on the operational profile, as well as the coating type.

Although the tool can support the implementation of sustainable biofouling management in the Baltic Sea, harmonized implementation within the whole BSR is needed to minimize the application of ecologically harmful strategies, such as the use of overdosed biocidal AFS or IWC without collecting the debris or on biocidal AFS. In the future, the decision support tool will be developed further in co-operation with stakeholders, to receive active and constructive feedback concerning the structure, function, and results of the tool. The involvement of the knowledge of end-users in the development work will ensure that the tool will meet their needs and be suited to its purpose of supporting informed decision-making. The participatory development is also expected to increase the stakeholders' willingness to commit to the information and recommendations provided by the tool. In the future, when more data and knowledge is compiled, the tool can easily be updated.

5.2 Case study: Impact of biofouling on ship operation and maintenance for its mitigation

In the COMPLETE project, studies were conducted to clarify impact of biofouling on ship operation and maintenance in practice. Information has been gathered by on-board measurements and interviewing the crew and other staff of the maritime sector. Biofouling has been widely identified as a problem that requires appropriate actions.

Biofouling of immersed hull structures of a ship increases the hydrodynamic drag. The increase in friction can reach more than 50 % if the hull is coated with antifouling paint, which is running out of service life or coated exclusively with an anticorrosive paint and thus, heavily fouled. Therefore, almost all ship-owners have introduced at least a simple biofouling management strategy. As already mentioned above, in the BSR, ice conditions set special requirements for immersed hull coatings. Consequently, many effective anti-fouling or foul-release coatings cannot be applied. As a result, hard coatings are widely used, but especially during the summer season, immersed hulls treated by this type of coatings must be cleaned regularly to prevent increasing biofouling.

On immersed hulls without AFS, biofouling grows rapidly in underwater hull structures especially directly below the seawater surface where lot of sunlight is available, and temperature of the water is warmer compared with deeper areas. Interviews performed with engineering crew and cleaner-divers within the COMPLETE project revealed that during early summer, the fastest growth of predominantly algae occurs in the depth range of 0-3 m. In late summer, depth range increases to 0-5 m, varying according to annual water temperature and available sunlight. Deeper parts of the hull attract barnacles, mussels, and ascidians. Thus, the growth of biofouling leads to significant differences of biofouling levels and characteristics between parts of the hull, which is essential to recognize in planning of cleaning strategies. The flat bottom of the ship usually stays cleaner and cleaning operations can therefore be concentrated mainly on the fouled areas of the ship. However, based on experience gathered by questionnaire and interviews, on some shipping routes the flat bottom can also gather organisms faster than other areas.

As already mentioned above in 1.1, the best results are obtained if the biofouling management strategy is adjusted on a basis of vessel-by-vessel and route-by-route. Especially idle periods in ports increase the level of biofouling rapidly and sometimes even the position of the ship at berth in relation to the sun is reflected in the abundance of biofouling by side.

To clarify the effect of biofouling on ship fuel consumption and emissions, several on-board emission measurement sessions and voyage data collection were conducted during the summers of 2018 and 2019. Emission measurements were carried out following the standards accepted by the IMO[32]. Voyage data was collected from the ships' control systems. Position data was obtained by the automatic identification system (AIS), and weather data was delivered by the coastal weather stations of Finnish, Swedish and Estonian meteorological institutes. Ship-owners delivered voyage-specific data such as load conditions.

The ships participating in the study operated on regular routes, facilitating the comparison of separate voyages and achievement of reliable results. The analysis of the results was carried out by a tree-augmented naïve Bayes method, which is a suitable and reliable method for the analysis of big data problems. The results show that hydrodynamic drag increases a few percent (2-4 %) during a one-month period in the summer season when the growth of biofouling is strong. Effects of a similar scale have been reported in literature. A change in this order of magnitude is likely to result in a linear increase in demanded amount of fuel.

In terms of emissions, as the fuel consumption increases due to increased drag, also the carbon dioxide (CO_2) emissions increase quite linearly, but the composition of exhaust emissions practically does not change due to such a small increase in the needed thrust power. However, increasing engine load often increases the amount of nitrogen oxide (NO_X) emissions and other emission components as well, but their formation is a more complex and engine-specific process and does not follow straightforward the general loading curves.

6. Conclusion

There is an urgent need to implement environmentally sustainable, regionally harmonized biofouling management measures in order to minimize introduction and spread of non-indigenous, potentially invasive species, input of hazardous substances from AFS, and air emissions. The practical recommendations and tools

---

[32] CEN/TS 17021:2017; SFS-EN 14792; SFS-EN 15058; ISO 12039; SFS-EN 14789

presented in this Roadmap concretize all aspects mentioned in the IMO Biofouling Guidelines and may therefore serve, in co-operation with the relevant stakeholders of both the commercial shipping and leisure boating sectors in the BSR, as basis for its implementation.

Annexes

Annex 1 Guide on best practices of biofouling management in the Baltic Sea

Annex 2 Biofouling assessment protocol for leisure boats and marinas

Annex 3 Recommendations for mitigating potential risks related to biofouling of leisure boats

COMPLETE

GUIDE ON BEST PRACTICES OF BIOFOULING MANAGEMENT IN THE BALTIC SEA

B.T. Watermann, LimnoMar

K. Broeg, BSH

A. Krutwa, BSH

N. Heibeck

CONTENT

Abbreviations

AFS	Antifouling System
AIS	Alien Invasive Species
BFMP	Biofouling Management Plan
BFRB	Biofouling Record Book
BWMS	Ballast Water Management System
BWT	Ballast Water Treatment
CRMP	Craft Risk Management Plan
CRMS-Biofouling	Craft Risk Management Standard for Biofouling
CRMS-Vessels	Craft Risk Management Standard for Vessels
DWT	Dry film thickness, final thickness of paint layers applied in drydock
ECE	Economy Commission for Europe
FRC	Foul Release Coating
IMO	International Maritime Organisation
IWI	In-water inspection
IWC	In-water cleaning
MEPC	IMO's Marine Environment Protection Committee
MGPS	Marine Growth Prevention System
NIS	Non-Indigenous Species
PIT	Proactive in-water treatment e.g by heat application
PIC	Proactive in-water cleaning
PICC	Proactive in-water cleaning and capture
PPR	IMO's Pollution Prevention and Response sub-committee
RIT	Reactive in-water treatment, e.g. by heat application
RIC	Reactive in-water cleaning
RICC	Reactive in-water cleaning and capture
SPC	Self-Polishing Coatings
TBT	Tributyltin
VICT	Vessel in-water cleaning or treatment

1 INTRODUCTION AND BACKGROUND

Maritime transport is the most energy-efficient and environmentally friendly transportation sector. Nevertheless, the International Maritime Organization (IMO) aims at further reduction of atmospheric emissions and release of hazardous substances into the sea, as well as avoidance of introduction and spread of invasive species by ballast water and biofouling. In order to minimize the latter, improvement of biofouling management is one major issue which is addressed by the IMO Biofouling Guidelines (2011 Guidelines for the Control and Management of Ships‘ Biofouling to Minimize the Transfer of Invasive Aquatic Species, Resolution MEPC:207 (62)) as well as the IMO Biofouling Guidance for leisure boats (Guidance for Minimizing the Transfer of Invasive Aquatic Species as Biofouling (Hull Fouling) for Recreational Craft, MEPC.1/Circ.792). The Guidelines are currently evaluated by the IMO sub-committee Pollution Prevention and Response (PPR). Biofouling as well as inadequate treatment with antifouling paints also of recreational boats may pose significant **environmental risks**:

- Biofouling is an essential vector for introduction and **spread of non-indigenous species (NIS)** which might become invasive and thus represent a **threat to biodiversity** (Bax et al., 2003). Numerous studies have demonstrated that NIS can be transported from one region to another by attaching to hulls and niches of ships on global voyages (Hunsucker et al., 2015; Ruiz et al., 2011) and also on leisure boats, which play an important role in the secondary spread of NIS (Ashton et al., 2014; Davidson et al., 2010; Zabin et al., 2014).
- Biofouling **increases fuel consumption** by increasing hydrodynamic drag on hulls and propellers (Kellett et al., 2015; Schultz, 2007). Thus, **atmospheric** and, in case scrubbers are used, **waterborne emissions** are also increasing with the level of biofouling.
- Current practice of biofouling prevention mainly consists of the use of biocidal antifouling paints. This type of fouling prevention causes **continuous input of biocides** like copper or organic substances into waters due to erosion, ablation and self-polishing of antifouling paints in service. Rough in-water cleaning (IWC) on antifouling paints induces immediate release of biocides and **polymeric backbone/paint flakes** (Earley et al., 2014, Watermann & Eklund, 2019, Oliveira & Granhag, 2020).
- Biofouling **increases hydro-acoustic noise** due to imperfections of the propeller blades affecting cavitation (Renilson et al. 2013).

With regard to effective biofouling management, the shipping industry is currently facing a multitude of **challenges**:

- Existing **oversupply of ships** despite of decline in fleet growth leads to low freight rates, extended idle periods and layups where hull and niche areas are prone to fouling.
- Increasing **demand of flexibility** regarding trade routes hampers the selection of an optimal route-specific biofouling management concept.
- **Extended layup** periods and **slow steaming** between 8 – 12 knots facilitate biofouling because several Antifouling Systems (AFS) need a minimum speed to ‘wash-off’ the fouling (e.g. self-polishing antifouling).

Fuel costs are the key factor of operational costs, which increase with biofouling development on the hull already from biofilm stage. To reduce fuel consumption, fleet operators increasingly use IWC to remove fouling and thus, decrease friction. But, eroding or self-polishing AFS are not designed to be cleaned, resulting regularly in immediate release of biocides, removal of the upper paint layers, or even damage of the AFS (Earley et al. 2014, Davidson et al. 2016).

Besides the above mentioned increase in fuel consumption, there are further biofouling-related **economic implications** to be mentioned:

- Biofouling reduces the speed of ships and therefore the time required for a given route increases, resulting in **longer voyages** or increased fuel consumption for ships.
- Longer voyages mean increasing **crew costs** relative to the distance of travel routes.
- Biofouling increases **hydro-acoustic noise** which degrades the performance of sonar on fishery and military ships as well as scientific equipment on oceanic research and wreck searching vessels.
- Biofouling reduces dry dock intervals and thus, increase **dry docking costs** and idle periods.
- Heavy biofouling may lead to **refusal of a port of call**, forcing ship owners to perform cost-intensive hull cleaning in dry dock.
- Frequent cleaning shortens the service life of most AFS (McClay et al., 2015).

Due to the environmental and economic impact of biofouling, the pressure on the maritime industry is increasing to implement a holistic and adaptive biofouling management, including fouling prevention of hull and niche areas. Since 2018, national regulations requiring an effective biofouling management are in force in California, Australia and New Zealand. The latter are calling for international standards at IMO level (MPI, 2018).

Proactive fouling prevention strategies under the heading of “Clean before you leave” or ”Clean before arrival” are getting more attention. Here, non-biocidal coatings with high abrasion resistance are frequently cleaned which withstand the impact of multiple cleaning and also reduce the adhesion of fouling organisms comparable to rubber-like foul release coatings (Watermann, 2019).

Due to its characteristics as semi-enclosed brackish water sea with shallow connection to the North Sea and heavy maritime traffic, the Baltic Sea already faces strong anthropogenic pressures and impact. Effects are beside others eutrophication, pollution with hazardous substances, and introduction of invasive species. Thus, this Best Practice Guide aims at providing information and guidance for effective biofouling management strategies suitable for the Baltic Sea Region on the basis of international and regional experiences and research.

2 WHAT IS BIOFOULING MANAGEMENT?

A holistic biofouling management covers the following aspects:

- Development of a ship-specific Biofouling Management Plan (BFMP)
- Keeping of a Biofouling Management Record Book (BFRB)
- Choice of an adequate, ship- and operation-specific Antifouling System (AFS)
- Performance monitoring
- In-water inspections (IWI) and maintenance, e.g. in-water cleaning (IWC)
- Dry docking, e.g. renewal of AFS

For each aspect, it has to be considered that decisions are based on the specific characteristics of the ship, its travel routes and operation. Tailored approaches are key for the development of an effective biofouling management. Here, we present recommendations for practices which have been developed worldwide and are applicable for the specific conditions of the Baltic Sea.

For practical reasons, all best practice recommendations are divided into "commercial shipping" (CS) and "leisure boating" (LB).

3 BEST PRACTICE RECOMMENDATIONS COMMERCIAL SHIPPING (CS)

Based on data from the COMPLETE project, practical experiences, studies, reports, results from research and development projects worldwide as well as the first results from the evaluation of the IMO Biofouling Guidelines, best practice recommendations which are suitable for application in the Baltic Sea have been identified. This section presents the best practice examples for commercial shipping according to the biofouling management aspects summarized above.

3.1 Ship-specific Biofouling Management Plan (BFMP) and Biofouling Record Book (BFRB)

A Biofouling Management Plan (BFMP), specific for each ship, is a description of the ship's biofouling management strategy. Some countries and regions (Australia, New Zealand, and California) implemented regulations which require the submission of BFMPs prior to arrival. The requirements for a BFMP include a description of the vessel's biofouling management strategy and should be consistent with the IMO Biofouling Guidelines. It includes a description of the practices and AFS used for hull and niche areas. Biofouling has to be managed using one or more practices that are appropriate for the ship and its operational profile as determined by the owner, operator, master, or person in charge of the ship. Management practices must be described in the BFMP and completed actions must be documented in the BFRB (SLCC, 2018).

Due to the recent situation in maritime transport, periods in ports or off ports at anchor occur more frequently. Thus, transport of species on wetted hull surfaces is not only influenced by the quality of the biofouling management but as well by the operational profile of the ship. Consequently, the BFMP should not only contain information of the fouling prevention measures of the vessels but as well of the voyages of the last months and the time at port or anchorage (SLCC, 2017).

Actually, there are several templates for BFMP and BFRB at hand. All of them are under scrutiny and permanent discussion to validate their applicability and usefulness. The most popular template is that of the IMO Biofouling Guidelines (see Annex IMO template) which served as a base for other templates. A more detailed template has been published by IMarEST (see table 5) for further discussions and improvement. The state of California has amended the BFMP and BFRB since January 2018 for all ships calling at Californian ports, and requires completing their template at least 24 hours prior to arrival (SLCC, 2017 and 2018, or https://misp.io/). A similar procedure is in force for Australian and New Zealand ports.

Mandatory requirements based on national legislation of Australia, New Zealand and California enhanced the awareness regarding the necessity of adequate biofouling management. In contrast to the handling of ballast management systems (BWMS), which is performed by a trained crew, compilation and implementation of BFMP and BFRB is up to fleet management and crew. To increase the number of ships and fleets with ship-specific BFMPs, harmonisation and mutual recognition of the existing templates e.g. IMO, California, Australia, New Zealand will increase the acceptance of these regulations by ship owners. Furthermore, a harmonised procedure or implementation of BFMPs and BFRB can ensure global access to ports for ship owners, especially on the background of permanent changing shipping routes. On the other hand, if more port authorities require state of the art BFMPs and BFRPs, implementation of adequate biofouling management will increase.

The effectivity of biofouling management increases with the synchronization of ship, its performance, and operation with the respective biofouling management. BFMP and BFRB must be tailor-made to operate in an economic, efficient, and environmentally friendly way Therefore, it is recommended to test the effectivity of the BFMP by performance monitoring and IWI, especially if travel routes change and speed or idle periods differ from the considerations made during the development of the original plan. In this context, precise keeping of the BFRB is essential, because this is the only possibility to check the effectivity of management retrospectively.

3.2 Choice of ship- and operation-specific Antifouling System (AFS)

As already mentioned above, fouling development is strongly favoured by a discrepancy between selected AFS and the predicted operation profile of the ship. Deviations from this profile with respect to service speed, activity level, days at harbour or idle periods, as well as traded waters favour the development of fouling. The consequence is reduced antifouling performance.

On the other hand, there is the risk of significant unnecessary input of biocides and other hazardous substances to the marine environment, if AFS are chosen which contain higher concentrations of active substances than needed for an effective biofouling management.

3.2.1 Current situation in the Baltic Sea

Based on recent data, the amount of antifouling paints applied on ships navigating the Baltic Sea is roughly estimated as 7,500 tonnes per year (Baltic Lines, 2016). For mass calculations of released antifouling compounds, most studies estimate a mean leaching rate of 4 – 5 $\mu g/cm^2/day$. In the MAMPEC model, which has been developed to calculate the biocide concentration released by AFS, a leaching rate of 4 $\mu g/cm^2/day$ is used (van Hattum et al., 2006). Taking a leaching rate of 5 $\mu g/cm^2/day$ and 42,000 ships navigating in the Baltic Sea per year as basis, the input of paint compounds would amount to 44.4 tonnes of biocides and poly- and monomeric compounds (Watermann & Eklund, 2019).

Among the ships sailing the Baltic Sea and originating from 122 countries, 3% (approx. 300 ships per year) are registered by flag states with poor performance in Port State inspections. They are listed in grey and black lists according to criteria of the Paris MoU (Grimvall and Larsson, 2014). A few of these flag states did not sign the IMO AFS Convention (International Convention on the Control of Harmful Anti-Fouling Systems on Ships), and therefore, can be expected to still have organotin antifouling paints as their active AFS. In the COMPLETE biofouling questionnaire there was a response from a ship-owner clearly stating the ongoing use of TBT.

Concerning the input of microplastics caused by biofouling management, information is scarce. Studies by Hansen et al. (2014) and Lassen et al. (2015) assume a polishing or erosion rate of antifouling paints from commercial vessels of 70 – 80%. During the erosion/polishing process, the polymeric backbone is dissolving in seawater, ideally hydrolysing down to monomeric substances, but also releasing polymeric paint flakes. The mean portion of solid antifouling paint particles is estimated as 55% (OECD, 2009). That means that of the 7,500 tonnes of antifouling paints on ships sailing the Baltic Sea per year, 4,125 tons of microplastics per year would be released as paint particles.

As a conclusion of the above mentioned aspects, all commercial vessels entering and leaving the Baltic Sea, and those operating in the Baltic Sea must select AFS compliant with the IMO AFS-Convention, meaning that the active AFS must not contain organotin compounds, and, from October 2026 on, cybutryn.

3.2.2 Recommendations for ships in the Baltic Sea

Ships operating exclusively in the Baltic Sea may use **AFS with moderate biocide content** (max 20% of copper) **and moderate leaching rates** with a maximum of 10 $\mu g/cm^2/day$. According to the recommendations of manufacturers, these are appropriate for moderate climate and moderate fouling pressure. The latter has been proven for the Baltic Sea within several research projects (Watermann & Dahlström, 2018).

Of course, the choice of AFS is dependent on the operation profile of the ships, taking into account activity level, service speed and traded areas.

Ships with high activity level and average speed of > 10 knots may also use biocide-free hard coatings in combination with IWC, or biocide-free foul release coatings (FRC).

FRC are a viable non-biocidal alternative to the above mentioned conventional biocidal antifouling coatings for the use in the Baltic Sea. These coatings rely on surface properties to mechanically preventing fouling, preferably by extruding non-persistent silicone oils, by degradable waxes, or polyethylene glycols to its surface, thus reducing both settlement and adhesion strength of biofouling. Present results, included in Annex 2 of the Biofouling Management Roadmap, show that a non-biocidal foul-release coating was more effective than a self-polishing copper antifouling coating, even under idle conditions. In the COMPLETE project, coated panels were deployed near the Port of Gothenburg, in a relatively high salinity and high fouling pressure area within the Baltic Sea Region (North Kattegat Sea, in the Outer Baltic). Visual inspections were carried out monthly. By the end of 1 year, the foul-release coating had, on average, about half the level of biofouling according to the US Navy fouling rating scale (Naval Sea System Command, 2006) compared to a conventional copper antifouling coating. These results represent a worst-case scenario for the Baltic Sea Region, due to the relatively high salinity (20-35 PSU) and high fouling pressure in this area, compared to lower salinity (<10 PSU) and lower fouling pressure in Central and North/Eastern Baltic.

In the Baltic Sea, ferries operating all around the year in the Baltic Proper use anticorrosive coatings without antifouling paints (**biocide-free hard coatings**), because conventional AFS are too soft to withstand the abrasion caused by drifting ice in winter time.

Ferries with pure anticorrosive paints have to be cleaned in-water during the fouling season from April to October weekly or bi-weekly by divers to maintain a clean hull.

An additional option is the cleaning called “grooming” of suitable antifouling paints or hard coatings as **proactive fouling prevention strategy**. Several diving companies offer IWC with tools connected to capture, filtration and waste management systems (see also 3.4 In-water cleaning).

In combination with effective and fast responding onboard performance systems, reactive cleaning in the biofilm stage is another option.

A further option for ships trading constantly between the Baltic Proper and adjacent freshwater areas like the lake Saimaa, is the use of **biocide-free self-polishing coatings** (SPCs) which are offered on the market for a range of operational profiles.

Table 1 and 2 provide a summary of the applicability of AFS based on the operational profile of the ship (area of the Baltic Sea and activity level of the ship), and an overview of biocide-free coatings.

Table 1: AFS according to operational profile

Region	Ship activity level	Coating recommendation	Cleaning strategy
Western and Southern Baltic Sea	High	-Biocide-free SPC for high activity level -Non-toxic hard coating in combination with cleaning -FRC except operation in wintertime	Proactive grooming in the biofilm stage
Western and Southern Baltic Sea	Moderate	-Biocide-free SPC for moderate activity level -Non-toxic hard coating in combination with cleaning	Proactive grooming in the biofilm stage
Western and Southern Baltic Sea	Low	-Biocide-free SPC for low activity level -FRC in combination with cleaning (not for operation in wintertime)	Regular cleaning on FRC
Kattegat to Central Baltic Sea	High	-Biocide-free SPC for high activity level -Non-toxic hard coating in combination with cleaning -FRC except operation in wintertime	Proactive grooming in the biofilm stage
Kattegat to Central Baltic Sea	Moderate	-Biocide-free SPC for moderate activity level -Non-toxic hard coating in combination with cleaning -FRC in combination with cleaning (not for operation in wintertime)	Grooming, weekly grooming in the fouling season
Kattegat to Central Baltic Sea	Low	-Biocide-free SPC for low activity level -Non-toxic hard coating in combination with cleaning -FRC in combination with cleaning (not for operation in wintertime)	Grooming, weekly grooming in the fouling season
Eastern and Northern part of the Baltic Sea	High, moderate and low	-Non-toxic hard coating in combination with cleaning -FRC except operation in wintertime	grooming, weekly grooming in the fouling season

Table 2: Overview of biocide-free coatings for ships in the Baltic Sea

Coating	Techniques	Application	Benefits	Risks	Costs	Availability
Hard coatings in combination with IWC	Epoxy-silicone hybrids, abrasion resistant with foul release properties	Hull and cleanable niches	Long service life, durable, negligible input of paint flakes	Must be cleaned pro-actively in biofilm stage	Compara-ble to current antifouling paints	Several products on the market
FRCs, cleanable	Silicone based rubber-like polymers	Hull and cleanable niches	Long service life, durable, negligible input of paint flakes	Must be protected from mechanical impact, not suitable for ice conditions	Double price compared to current antifouling paints	Several products on the market
Biocide-free SPCs	Hydrolyzing polymer backbone and additives	Hull, exposed to water flow, not for niches	Smooth hull without release of biocides	Efficacy strongly depends on activity level and service speed. Continuous input of polymeric backbone	Compara-ble to current antifouling paints	Several products on the market tailored for different vessel types

3.2.3 Niche areas

Special attention has to be paid to the niches of ships, which are especially prone to fouling. Niches are not contributing to enhanced drag or increased fuel consumption. This is the reason why operators may neglect them in case fouling management is focused only on performance (Davidson et al. 2016). However, the results of the COMPLETE biofouling questionnaire showed that when an AFS is applied, niches are also considered.

Common niche areas are:

- Sea chests and gratings
- Seawater inlet pipes and internal systems
- Cathodic protection anodes
- Sonar domes, transducers and velocity probes
- Dry docking support areas/strips
- Propellers, shafts and struts
- Thrusters and thruster tunnels
- Retractable propulsion units
- Bilge keels and stabilizer fins
- Rudder, including hinges and stocks
- Internal ships' spaces (e.g. chain lockers, bilges, bait wells)

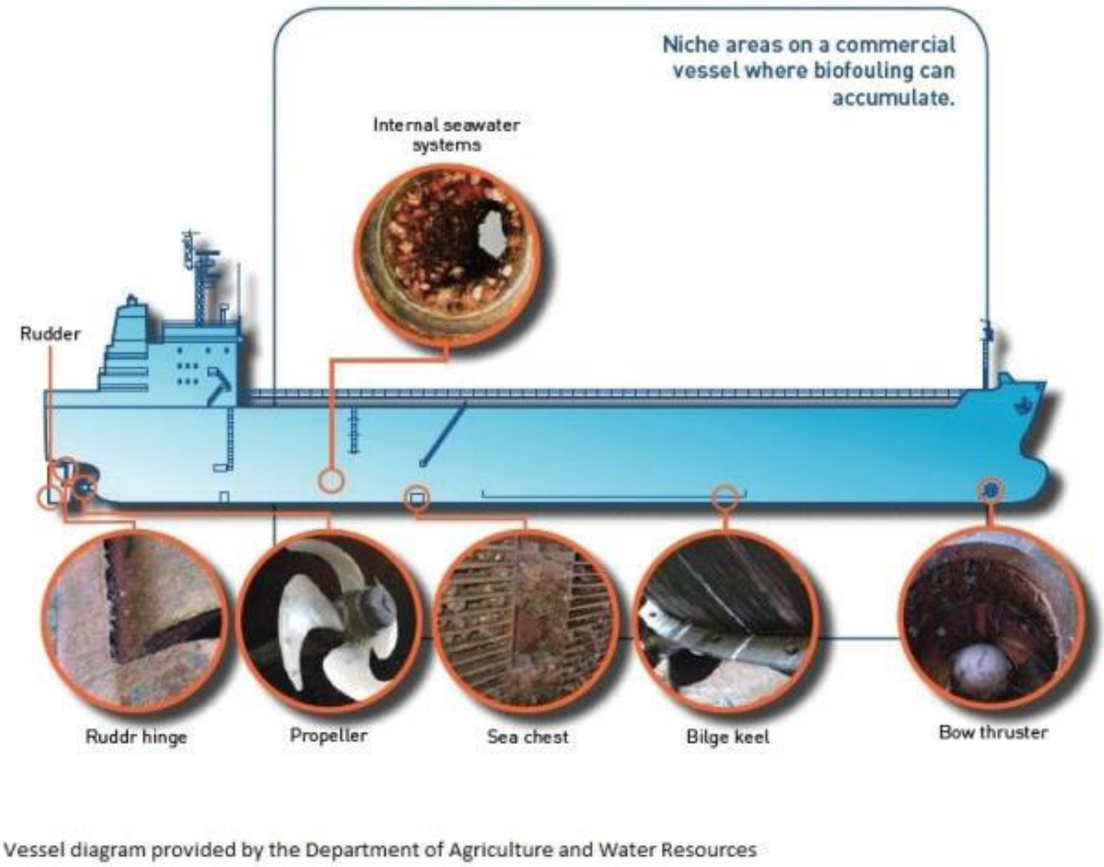

Fig. 1: Main niche areas on commercial vessels (MPI, 2018)

As niches are hot-spots of fouling, biofouling management must include effective fouling prevention techniques for these areas. Heat treatment of the cooling system, internal pipes and sea chest is an effective biocide-free technique which is offered for different dimensions of the internal system. In contrast to copper based anodes installed in the cooling systems, it can be regarded as the best environmental technique (Lewis et al. 2018).

Niche areas, for which the heat treatment cannot be used, have to be cleaned by divers, but accessibility of niche areas for cleaning is often difficult and has to be improved in newbuildings (see 3.4).

3.2.4 Performance monitoring

A powerful tool for biofouling management is the use of onboard performance systems, which deliver data on increased drag or increased fuel consumption at a given speed. Several shipping lines use their own performance systems and a couple of those are available on the market. The main data base consists of collecting and transmitting data on speed, fuel consumption, winds and currents to calculate the performance and get information on additional friction (Corradu et al. 2019).These systems are currently under validation as well as the use of the ISO Standard 190 30. This standard is called “Ships and marine technology — Measurement of changes in hull and propeller performance”. It defines a set of performance indicators for hull and propeller maintenance, repair and retrofit activities. The general principles and performance indicators are applicable to all ship types driven by conventional fixed pitch propellers.

Irrespective of the performance system in use, data of increased friction can be used for biofouling management purposes and for the decision of the right time for inspections and reactive cleaning.

3.3 In-water cleaning (IWC)

As no AFS can totally avoid biofouling, proactive or reactive IWC is a commonly applied component of biofouling management. In order to perform IWC in a sustainable manner, use of non-abrasive cleaning techniques, as well as capture and filtration of removed fouling in combination with waste disposal on land is crucial. Currently, the majority of cleaning is performed on biocidal antifouling paints, which are present on approx. 95% of commercial ships and leisure boats (Yebra et al., 2004; INTERTANKO, 2016). Biocidal antifouling paints are not designed for cleaning. They are too soft and the impact of cleaning removes, beside the attached fouling organisms, approx. 20 – 30 µm of the upper paint layers. During cleaning, immediately undissolved paint particles and dissolved along with undissolved biocides are released into the water. This has multiple additional implications:

- Mechanical removal of existing paint layers reduces the service life of the AFS and thereby the docking interval
- The impact of cleaning tools depends on the amount, composition and adherence of the fouling. The heavier fouling is, the higher the effort necessary to remove it. If the AFS is completely removed or damaged, these hull areas are prone to new settlements.
- Macrofouling communities contain propagules of algae and barnacles which are hard to capture 100%. Viable spores and larvae might invade ports and coastal areas (Woods et al., 2012; IMO, 2019; Scianni & Georgiades, 2019).

To avoid the problems summarized above, various countries and maritime organisations are working on standards and the development of best environmental practice for IWC. In table 4, examples of different approaches are shown. It is obvious that regarding IWC in the Baltic Sea either no regulations exist or existing regulations are not sufficient to minimize a potential impact. When a plume of copper pigment is released during cleaning, it is too late to stop cleaning. Therefore, precautionary assessment of the environmental risk of each IWC activity is essential as basis for granting permissions for IWC.

In addition, there are practical obstacles to consider. In case of heavy fouling, damage of the AFS is almost unavoidable as divers have to increase the pressure to remove the fouling. The results can regularly be inspected on ships previously cleaned in the dockyard: Some areas are free of fouling, some areas still exhibit fouling, on others the AFS has been removed down to the corrosion protective coating.

Actual considerations and discussions to overcome these problems can be summarized as follows:

IWC on biocidal antifouling paints should best be performed by:

- Pre- and post-cleaning inspections
- To avoid damage of the AFS, a reference area on the hull should be selected to test the cleaning tools with respect to efficacy, collection and measurement of undissolved paint particles and dissolved/undissolved paint biocides.
- More extensively developed fouling should be cleaned in dry dock.

- Capture of the removed fouling organisms should be mandatory and treatment by filtration shall use mesh sizes of at least 10 µm which is technically feasible.
- Reliable and validated reports on cleaning test on reference areas including measurement results of accredited laboratories as well as pre- and post-inspections of the hull and niches shall be submitted to the operator (Oliveira & Granhag, 2020)

IWC or hull cleaning in dry dock without proper capture of biofouling waste may contribute to the spread of invasive species (table 3) as the survival of removed fouling organisms might be high (Woods et al. 2012).

Table 3: Survival rate of removed fouling organisms during IWC and dry-dock cleaning

Survival rate of removed fouling organisms %

	Dry dock	in-water
• All organisms	37.5 ± 8.6	29.2 ± 7.2
• Algae	71.1 ± 17.1	66.7 ± 16.7
• Anenomes	0	90.5 ± 4.8
• Ascidians	41.9 ± 17.1	95.1 ± 9.4
• Barnacles	33.7 ± 12.2	15.8 ± 6
• Bivalves	52 ± 16	81.7 ± 9.2
• Bryozoans	34.6 ± 17.3	51.4 ± 9.5
• Polychaetes	12.3 ±2	5.5 ± 2.9
• Sponges	0	90.7 ± 6.5

Woods et al. 2012

IWC and dry dock cleaning without effective capture and filtration systems may also lead to input of biocides and polymers (Watermann, 2019).

In tables 4 and 5, best practice IWC techniques are listed, which are available through cleaning companies in the Baltic Sea (https://balticcomplete.com/maps and BSH Biofouling Management Database). Two techniques include capture of the removed fouling and removed paint particles. The ship-based technique operates without any capture, claiming that since this technique is suitable for biofilms only, no capture is provided. But, in order to avoid species introduction, capture is necessary as even biofilm may contain NIS.

For the Baltic Sea, which is already heavily polluted by hazardous substances, an AFS should be selected which is suitable for cleaning without releasing polymers and biocides. The coatings most suitable for cleaning can be found in table 2.

Table 4: Overview of IWC methods for ships

Method	Techniques	Application	Benefit	Risk	Costs	Availability
Diver operated cleaning device	Rotating brushes, high pressure-jetting, blades - with external capture and filtration	Hull and niches if accessible	Effective, control of cleaning effort, access to most niches, optical control	Application only in ports or sheltered waters without waves, currents, and turbidity	high	Baltic Sea ports depending on permits
ROVs	Rotating brushes, high pressure-jetting, with internal capture by filtrating bags	Hull	Effective, control of cleaning effort, optical control	Application only in ports or sheltered waters without waves and currents. Control of bag capacity limit needed.	low	Baltic Sea ports depending on permits
Ship-based ROVs	Rotating brushes and hydro-jetting	Hull	Effective, control of cleaning effort, optical control	Exclusively applicable on biofilms, no capture of organisms and paint particles	high	Everywhere when laying idle in calm waters depending on permits

Table 5: Capture and treatment of biofouling waste from IWC

Method	Techniques	Application	Benefit	Risk	Costs	Availability
Capture and filtration system connected with cleaning device	Vacuum application for capture and use of sieves with different mesh sizes, filtrate disposed on land	Hull, propeller and niches	One system with perfect connection, effective capture and filtration	Must be reliable in all types of water, including harbour water with high content of suspended matter	Rel. high	Few companies operating in the Baltic Sea
Capture, filtration, and collection in separate units (barges, tankers) for treatment of effluents	Use of sieves with different mesh sizes, filtrate disposed on land	Hull and propeller	Effective capture and filtration, high capacity	barge or tanker have to be towed alongside, special areas in ports have to be offered	Rel. high	Only one company operating in the Baltic Sea
After separate collection, filtration and treatment in BWMS	Filtration and UV treatment, filtrate disposed on land	Hull, propeller and niches depending on cleaning tool	Type approved BWMS	Few risks due to approved techniques	Costs in addition to cleaning 10 €/m^3	Few companies operate in the Baltic Sea
After separate collection treatment in dockyard facilities on land	Filtration with sieves and UV treatment	Hull, propeller and niches depending on cleaning tool	Approved techniques for dockyard waste water treatment	Connectivity with cleaning tools, risk low when pumped out of barges or tankers	50 – 200 €/m^3	Several dockyards along the Baltic Sea coast

If IWC is combined with capture and filtration systems, removed fouling organisms and paint particles are waste which has to be disposed on land. In most countries, this waste is classified as hazardous waste, because it contains a multitude of paint-bound biocides, and other toxic substances like additives and polymers. This concerns waste from cleaning on all biocidal antifouling paints.

Furthermore, it has to be taken into account that dissolved biocides **are not retained** and thus, released into the harbour basin during cleaning. Therefore, the best environmental management practice is the cleaning on abrasion resistant, non-biocidal hard coatings in combination with capture and filtration of the cleaned material and subsequent waste treatment and disposal.

3.3.1 Permits for IWC

Due to the common practice of IWC off the coast, a couple of countries developed guidelines and standards for IWC.

Currently, no harmonized procedure exists for the Baltic Sea. COMPLETE PLUS, the next phase of the COMPLETE project, aims at developing and drafting a scheme for granting permissions for IWC in the Baltic Sea as basis for discussions at HELCOM level.

3.3.2 Niches

Divers are able to clean all **externally accessible** niche areas like sea chests, thrusters, stabilizers etc. with hand held lances using hydro-jetting. Nevertheless, capture of removed fouling is challenging.

Precondition for the inspection and cleaning of niches is their accessibility which is up to now not in the focus of shipbuilders. Diving companies therefore claim to facilitate the accessibility of all niches for inspection and cleaning in new-built ships.

Recommendations for a better accessibility of niches are:

1. Easy access to rudder pintle. If the area is covered by a door, it should be hinged and should have sufficient diver access (minimum 400 mm diameter). Securing bolts, which can easily be removed and reinstalled in-water should be used
2. For tail-shaft wear down measurements, an easy access by holes, large enough for the diver’s hands and equipment should be established. The minimum size for hand holes is around 200mm diameter
3. Securing of all sea chest gratings by bolts only and hinges for all gratings
4. Marking and sizing of all securing bolts
5. Counting and sizing of all drain holes

Finally, prior to launching a newbuilding or after maintenance in dry dock, photographs of all external apertures and fittings such as sea chest arrangements, overboards, transducers and thrusters etc. should be taken and be kept on board. All niche areas should have a clear numbering system so that divers can easily identify them in the future. Information should be available on board the vessel to be used when required for diving operations.

3.4 International recommendations for biofouling management

Up to now, several templates, guidelines and recommendations for biofouling management have been developed.

Their basic strategies can be summarized as:

- Implementation of IMO biofouling guidelines with ship-specific BFMP and BFRB and submission of documentation prior to arrival in ports of countries with regulation in place
- Biofouling management by proactive cleaning of hull and niches on biofilm stage ideally with capture of removed fouling (Proactive in-water treatment e.g by heat application (PIT), Proactive in-water cleaning (PIC), Proactive in-water cleaning and capture (PICC), 'Clean Before You Leave' documentation by BFRB
- Biofouling management by reactive cleaning (Reactive in-water treatment e.g by heat application (RIT), Reactive in-water cleaning (RIC), Reactive in-water cleaning and capture (RICC)) , 'Clean Before Arrival', documentation by BFRB
- Installation of performance system onboard, as in-house technology of shipping line or external provider.

In addition to these biofouling management recommendations, the risk of species introduction by ships can be estimated based on:

- Their duration of stay in ports or coast line.
- Their operational profile (in case of the Baltic Sea: operating exclusively in the Baltic Proper like most ferries, or entering and leaving the Baltic Sea in regular or irregular intervals like all cargo ships).

(modified after MPI, 2018; Scianni & Georgiades, 2019)

4 BEST PRACTICE RECOMMENDATIONS LEISURE BOATING (LB)

Actively minimizing the biofouling of leisure boats can greatly reduce the risk of spreading invasive species and can also improve fuel efficiency, operating speeds and manoeuvrability (IMO, 2012).

Therefore, the IMO developed the Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft for owners and operators of recreational craft less than 24 metres in length. All boats can potentially transfer harmful aquatic organisms, even a trailered boat that is normally kept out of the water can act as vector (Johnson et al. 2012).

In contrast to commercial ships, leisure boats stay most of the time when they are in water fixed at berth. The majority of boaters in the Baltic Sea are day-sailors, and a minority are so called 'blue-water' sailors who are moving across the whole Baltic Sea, leaving the region or coming back from other biogeographic regions (Martin et al. 2019). Spread of species can even occur when boats are sold. Marine organisms might hide in humid niches where they survive for several weeks. A similar problem can result from motor boats which are transported by trailers from one water body to another. If these boats are not thoroughly cleaned before being moved on a trailer, organisms can be transported (Dalton & Cottrell, 2013). The best documented example is the transport of zebra and quagga mussels by motorboats from central Europe to the Baltic Sea region including adjacent freshwater areas (De Ventura et al. 2016).

Thus, the effective biofouling management of leisure boats to avoid introduction and spread of species is dependent on the operational profile of the boat. It is up to the boat owners and marinas to implement strict rules of cleaning boat and niche areas before each transport (Mueting & Gerstenberger, 2011). The European code of conduct on recreational boating and invasive alien species is characterized by the terms 'Check - Clean - Dry' which is propagated by the European Boating Association (EBA, 2016).

Due to the extended periods moored at berth, all leisure boats have some biofouling, even if recently cleaned or treated with AFS. The development of biofouling is influenced by factors such as:

- Knowledge of type, age and condition of AFS and hull cleaning practices
- Operating profile, including speeds, time underway compared with time moored or anchored
- Water temperature, biofouling pressure and where the craft is normally kept (e.g. on land, in a marina or on an estuarine mooring)
- Visited marinas and biogeographic regions
- Design and construction, particularly areas that are more susceptible to biofouling (e.g. rudders, propellers and propeller shafts)
- The awareness of the problem by boat owner and marina

4.1 Boat-specific Biofouling Management Plan (BFMP) and Biofouling Record Book (BFRB)

A first step to improve biofouling management of leisure boats is the recommendation to have a certificate on board which delivers information about the actual AFS (specification, age and condition). In contrast to the IMO Guidance, the certificate should already be applied to boats > 8m, which is the common length of boat around the Baltic Sea. In addition, receipts of cleaning actions and receipts or documentation by marinas on the cleaning before overland transport should be indicated in the log-book, which has to be present on each boat sailing coastal waters as appropriate surrogate to the BFRB.

Since several years, an International Certificate for Operators of Pleasure Crafts is under discussion (ECE, 2010). The EBA considers that the standards provide a reasonable and appropriate level of competence for sailing in recreational boats with due regard to the safety of navigation and crew, and the protection of the environment. The EBA urges governments to adopt this standard. It may be worth to include this initiative for the development of an international certificate which covers demands of safety, biosecurity and environmental behaviour (EBA, 2019).

4.2 Choice of boat- and operation-specific Antifouling System (AFS)

For leisure boats mainly located in the Baltic Sea, a biocide-free AFS or an AFS appropriate for the regional fouling pressure in combination with good maintenance are the best ways for preventing biofouling accumulation (Lindgren et al. 2018; Lagerström et al. 2020). In addition, regularly operating boats between marine and fresh waters may help to reduce the accumulation of biofouling, because many marine fouling species do not easily survive in fresh or brackish water and vice versa. Nevertheless, interviews with boat-owners revealed that the recommendation to use appropriate AFS according to fouling pressure and region requirement may meet some serious obstacles:

- The choice of antifouling paint and biofouling management of leisure boats is not driven by economic reasons and rational considerations but often by tradition.
- Most boat owners have no exact knowledge of their AFS. The active layer may be known but applied in excess, the old layers are often unknown.
- Apart of speed boats, fouling of niches creates no adverse effect on speed and manoeuvrability and is thus, often unconsidered.

(Martin et al., 2018; Watermann & Dahlström, 2018; Bergmann et al., 2019).

Application of an inappropriate AFS may result in the accumulation of biofouling or unnecessary release of biocides into the sea. Therefore, following state of the art recommendation is an essential contribution to improve the environmental health of the Baltic Sea.

The background for the choice of the appropriate AFS is the operational profile of the boat and the visited waters respectively their fouling pressure. In-line with the legislation implemented e.g. in Sweden (Fig. 2) is the use of AFS with:

- higher copper content in the Western Baltic Sea,
- low copper content in the Central, and
- biocide-free in the Eastern part of the Baltic Sea and in freshwater.

The salinity of the Baltic Sea decreases from West to East. Along this gradient, the fouling pressure decreases. Hard-shelled calcareous fouling can be found in the Western and Southern Baltic Sea, whereas in the Central and the Eastern part fouling is composed of soft organism and more typical for freshwater (Lagerström et al. 2020).

Nevertheless, data showed that many boat owners apply excessive paint layers despite paint manufacturer's recommendations to repaint only on hull areas with fouling development (Eklund & Watermann, 2018). To avoid the use of AFS with excess copper, recommendations based on exposure trials around the Baltic Sea have been outlined:

- From **Kattegat to the Central Baltic Sea** AFS are effective with copper release rates of 5°µg/cm^2/ day. In biofouling hot spot areas the efficacy can be enhanced by zinc oxide (Lindgren et al. 2018; Wrange et al. 2020).
- In the **Eastern part of the Baltic Sea (East coast of Sweden)** antifouling paints with leaching rates of 2 µg/cm^2/ day shall be effective.
- In the **Eastern and Northern part of the Baltic Sea and adjacent freshwater areas** biocide-free coatings in combination with cleaning effectively prevent fouling. Suitable coatings include silicone-based foul release coatings and epoxy-silicone hybrids as hard, abrasion resistant coatings.

However, biocide-free foul release coatings (FRCs) have been shown to be effective in the whole Baltic Sea (Waterman & Dahlström, 2018). Table 6 provides a summary of AFS for leisure boats.

As in ships, niche areas of leisure boats are hot spots of fouling and deserve special attention.

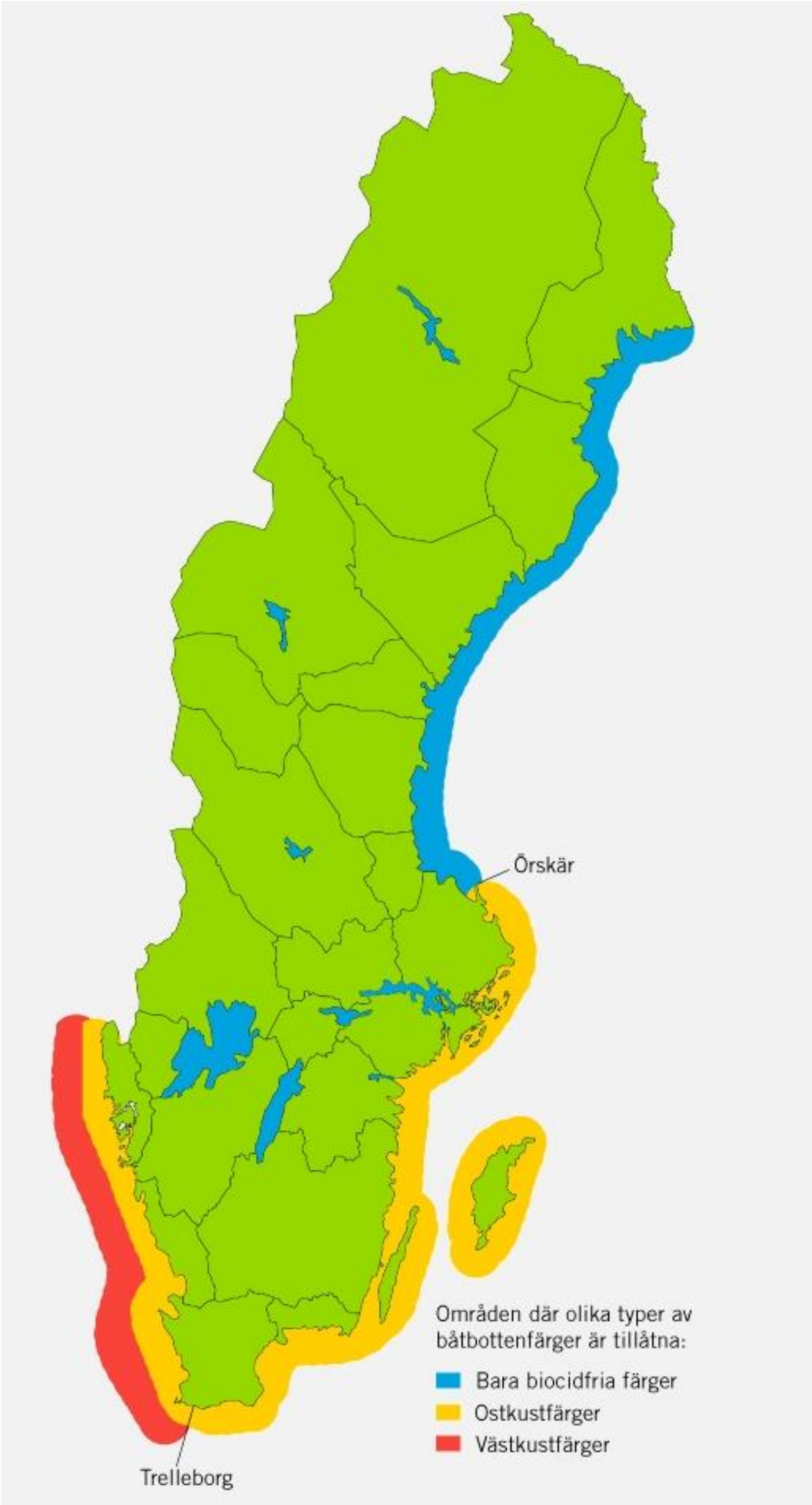

Fig. 2: Regional authorization for application and use of AFS along the Swedish Coast, Red: Biocidal AFS with high copper content, yellow: Biocidal AFS with low copper consent and blue: biocide-free AFS. Source: www.kemi.se/bekampningsmedel/biocidprodukter/vanliga-typer-av-biocidprodukter/batbottenfarger--om-du-maste-mala

Table 6: Overview of AFS for leisure boats in the Baltic Sea

Coating	Techniques	Application	Benefits	Risks	Costs	Availability
Hard coatings in combination with IWC	Epoxy-silicone hybrids, abrasion resistant with foul release properties	Hull and cleanable niches	Long service life, durable, negligible input of paint flakes	Must be cleaned pro-actively in biofilm stage	Comparable to current AFS	Several products on the market
Foul release coatings (FRC)	Silicone based rubber-like polymers	Hull and cleanable niches	Long service life, durable, negligible input of paint flakes	Must be protected from mechanical impact, not suitable for ice conditions	Double price compared to current AFS	Several products on the market
Biocide-free SPCs	Hydrolyzing paint matrix without biocide release	Hull	Smooth hull without release of biocides	Efficacy strongly connected with activity level, and speed	Comparable to current AFS	Several products on the EU-market tailored for different boat types
AFS with copper release of 5µg/cm^2 per day	Hydrolyzing paint matrix and biocide release	Hull and niches	If boat is active, fouling prevention	Input of biocides	Varying costs depending on copper content	Many products on the market

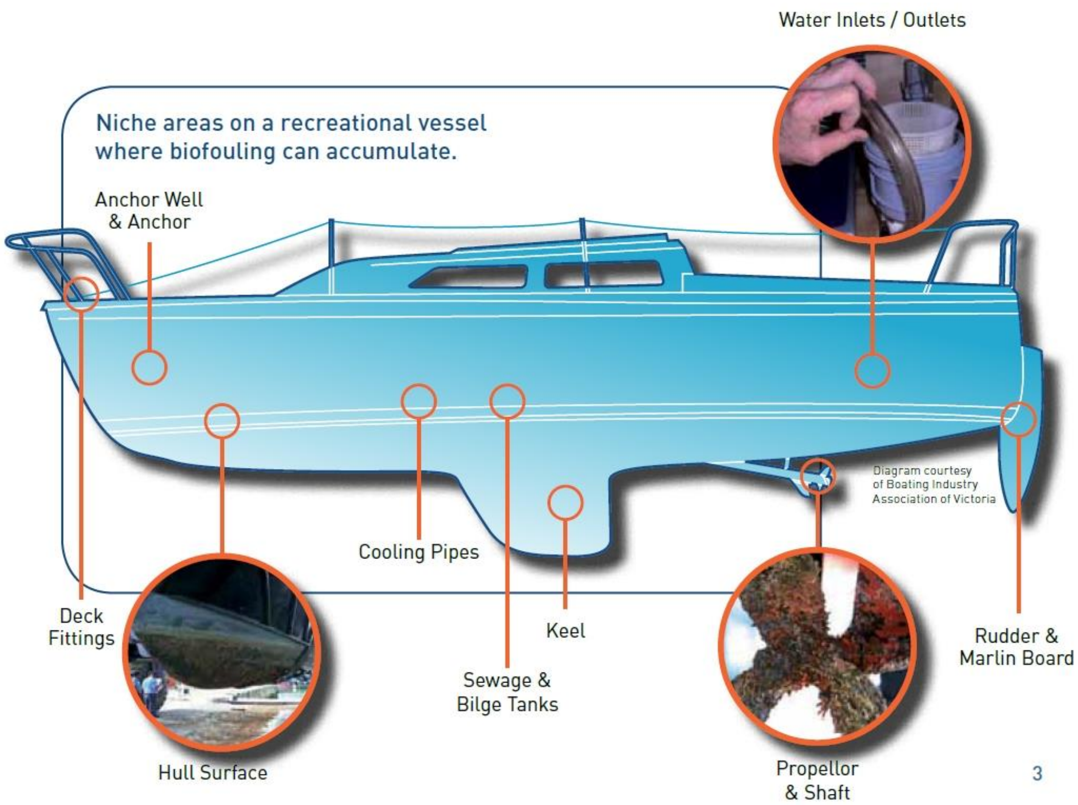

Fig. 3: Niche areas of leisure boats (MPI, 2018)

4.3 Cleaning of leisure boats

4.3.1 Current situation in the Baltic Sea

As mentioned above, maintenance and cleaning are essential aspects to consider for an effective biofouling management of leisure boats. If cleaning is not performed in an environmentally and sustainably manner, it might pose risks for the Baltic Sea environment by release of antifouling paint particles, biocides, polymeric backbone, and invasive species (Bighiu et al. 2017; Martin et al. 2018, 2019). It is common practice to clean the hull at the end of the season by high-pressure washing, often without necessary protection measures and collection of waste water.

Despite their ban on small boats in the EU in 1989, organotin compounds (OTCs) are still being released into the environment e.g. due to their presence in historic paint layers on leisure boats. Paint samples scraped from leisure boats from three countries around the Baltic Sea were analyzed for total tin (Sn) and OTCs (Lagerström et al. 2017). The hull paint samples had high tin concentrations and results showed that tributyltin (TBT) was detected in all samples with concentrations as high as 4.7 g (as Sn)/kg paint. TBT was however not always the major OTC. Triphenyltin (TPhT), which is as hazardous as TBT, was present in many samples from Finland.

Ytreberg et al. (2016) published results based on a new developed XRF-method which revealed that over 10% of Swedish leisure boats (n = 686) contained >400 mg/cm^2 of tin in their antifouling coating layers. For comparison, one layer (40 mm dry film) of a TBT-paint equals ~ 800 mg Sn/cm^2. Even though the XRF analysis did not provide any information on the speciation of tin, the high concentrations indicated that these leisure boats still had old, remaining OTC coatings present on their hull. The risk for leaching of organotin compounds into the environment arises during maintenance work such as scraping, blasting and essentially during high pressure hosing activities (Koroschetz & Soler, 2018).

Moreover, high loads of copper were detected even on boats sailing in freshwater, despite the more than 20 years old ban in Sweden, Denmark and Finland.

The use of copper-based AFS contribute to the contamination of marina soils and adjacent marine sediments (Eklund et al. 2010; Eklund & Eklund, 2012), mainly due to improper maintenance practice. In addition, AFS with copper as the main biocide are used in excess on leisure boats leading to an unnecessary input during service (Eklund & Watermann, 2018). The application of AFS with copper contents ranging from 10 -30% on leisure boats around the Baltic Sea is estimated as 400 t/y (Watermann & Eklund, 2019).

Bighiu et al. (2017) revealed in biofilm waste from boat hulls coated with biocidal AFS a content of 28 g copper/kg dw and 171 g zinc/kg dw. Together with the waste water, biofilms are washed to the boatyard soil or directly into the adjacent water bodies. Apart of essential inputs of antifouling biocides and paint particles, leisure boats may harbour rich macrofouling communities, when they are not moved and/or the antifouling fails (Fig. 5).

A number of studies on the input of microplastics from cleaning of leisure boats have been performed in the Baltic Sea and the Norwegian coast (Magnusson et al. 2017; Lassen et al. 2015; Sundt et al. 2014). Obviously, the degree of protection measures influences the input of paint particles into the adjacent water bodies significantly. There is a multitude of studies indicating that in leisure boat harbours the retention and collection of antifouling paint particles originating from scraping, dry sanding, and high pressure-washing outside of washing areas is insufficient (Eklund et al. 2010, Eklund & Eklund, 2012; Eklund et al. 2014b, Lagerström et al. 2017).

4.3.2 Recommendations for cleaning

To minimize environmental risks posed by cleaning of leisure boats, the following **recommendations** should be considered:

The cleaning practice for leisure boats must be regarded during service in water and out of water as an interim cleaning in the middle of the season or before moving the boat to another water region via land (table 7). Along the Swedish East coast numerous cleaning stations (approx. 20 stations) offer IWC with brushes and capture of fouling by underwater floating foils beneath the stations. A crucial aspect is the type of coating on which cleaning is allowed. Actually, some Swedish municipalities allow IWC on boats with antifouling paints older than 12 months, which cannot be regarded as recommendable practice. In other countries like Germany IWC on biocidal antifouling paints is not permitted but permits for cleaning on biocide-free paints can be applied for at lower water authorities. The best practice is cleaning on abrasion resistant, non-biocidal hard coatings which release no biocides during the cleaning and where the abrasion of paint flakes is minimal (Watermann & Eklund, 2019). Table 7 summarizes cleaning methods for leisure boats.

Niche areas of leisure boats are of high importance for the transfer of species as motorboats and to a lesser degree sailing boats are trailered for weekends or summer holidays from freshwater lakes to the Baltic Sea and vice versa. Apart of the cleaning effect by varying between freshwater and marine waters, brackish water organisms like Zebra- and Quagga mussels can be transported and survive in a wider range of salinities. As some niche areas on leisure boats are hard to access, the best technique to remove fouling of these areas turned out to be high pressure-jetting with hot water with duration at each critical point of several seconds. Leisure boats have no facilities to enclose the internal cooling system. For the treatment of the internal cooling system, mobile tools to inject hot water have been developed and may be offered on the market in the near future (Cahill et al., 2019a and b).

Table 7: Best cleaning and fouling prevention practices for hull and niches of leisure boats

Method	Techniques	Application	Benefits	Risks	Costs	Availability
Stationary IWC	Rotating brushes, capture by underwater foil	Hull	Smooth hull without fouling	Only effective when cleaning in biofilm stage, niches not covered	Approx. 10-13 €/m boat length	Stations in Sweden and in Finland
HP-Jetting with capture and treatment	Hot water >60°C for 5 sec.	Hull and niches	Cleaning of niches possible	Too fast, too short application, using cold water	Approx. 10 €/h	Nearly every marina with slip way and hp-washer
Hp-jetting with capture and filtration	Hp-jetting with or without rotating nozzles	Hull and niches	Cleaning of niches possible	Risk of overspray	Approx. 20 – 40 €	Boat must be lifted out of water and the area must be available
Enwrapping foils to hamper the settlement of fouling organisms	Rough or smooth foils wrapped around the hull at berth	Hull and niches	Easy to apply	Only applicable in boxes	Approx. 1- 15 € /m boat length	Available on the market around the Baltic Sea
Inflatable hull enclosures to hamper the settlement of fouling organisms	Inflatable foil enclosed around the hull	Hull and niches	Easy to apply	Only applicable in boxes	250.00 €/m boat length	Internet order

Further recommendations can be also found in the COMPLETE report “Recommendations for mitigating potential risks related to biofouling of leisure boats” compiled by Keep the Archipelago Tidy Finland (2020).

5 REFERENCES

Abraham, M., Westphal, L., Hand, I., Lerz, A., Jeschek, J., Bunke, D., Leipe, T., Schulz-Bull, D. (2017): TBT and its metabolites in sediments: Survey at a German coastal site and the central Baltic Sea. Marine Pollution Bulletin 121 (2017) 404–410.

Ashton G., Davidson I., Ruiz, G. (2014): Transient small boats as a long-distance coastal vecor for dispersal of biofouling organisms. Estuarine and Coasts, 37, 1572–1581.

Bax, N., Williamson, A., Aguero, M., Gonzalez, E., Geeves, W. (2003): Marine invasive alien species: a threat to global biodiversity. Mar. Policy 4, 313–323.

Baltic Lines (2016): Shipping in the Baltic Sea – Past, present and future developments relevant for maritime spatial planning. Prog. Rep. 35 pp.

Bergmann, K., Ziegler, F.(2019): Environmental impacts of alternative antifouling methods and use patterns of leisure boat owners. Int. J. Life Cycle Assessm., 24, 725–734.

Bighiu, M.A., Eriksson-Wiklund, A.K., Eklund, B. (2017): Biofouling of leisure boats as a source of metal pollution. Environ. Sci. Pollut. Res., 24, 997–1006.

Bohlander, J. (2009): Review of options for in-water cleaning of ships. MAF Biosecurity New Zealand, Technical Paper No 2009/42, 38 pp.

Cahill, P., Hickey, C., Lewis, P., Tait, L., and Floerl, O. (2019a). Treatment Agents for Biofouling in Internal Pipework of Recreational Vessels. MPI Technical Paper No: 2019/03, 68 pp.

Cahill, P., Tait, L., Floerl, O., Bates, T., Growcott, A., and Georgiades, E. (2019b). Design and assessment of a thermal treatment system for fouled internal pipework of recreational vessels. Mar. Pollut. Bull., 139, 65–73.

COMPLETE (2020): Recommendations for mitigating potential risks related to biofouling of leisure boats, Keep the Archipelago Tidy Finland, 10 pp.

Corradu, A., Baldi, F. Oneto,L., Cipollini, F. (2019) : Estimating marine fouling speed loss with ISO 19030: Pros and Cons of the Standard. SNAMES, 38th. Ann. J., 51–63.

Daehne, D., Fürle, C., Thomsen, A., Watermann, B., Feibicke, M. (2017): Antifouling biocides in German marinas: Exposure assessment and calculation of national consumption and emission. Integr. Environ. Ass. Manag. 9999, 1–14.

Dalton, L.B., Cottrell, S. (2013): Quagga and zebra mussel risk via veliger transfer by overland hauled boats. Managem. Biol. Invasions, 4, 2, 129–133.

Davidson, I., Scianni, C., Hewitt, C., Everett, R., Holm, R., Tamburri, M., Ruiz, G. (2016): A Mini-review: Assessing the drivers of ship biofouling management – aligning industry and biosecurity goals. Biofouling, 32, 4, 411–428.

Davidson I.C., Zabin C.J., Chang A.L., Brown C.W., Sytsma M.D., Ruiz G.M. (2010): Recreational boats as potential vectors of marine organisms at an invasion hotspot. Aquatic Biology, 11, 179–191.

De Ventura, L., Weissert, N., Tobias, R., Kopp, K., Jokela., J. (2016): Overland transport of recreational boats as a spreading vector of zebra mussel *Dreissena polymorpha*. Biol Invasions, 18, 1451–1466

Dugan, J. E., Walter, M., C. Culver. (2002): Evaluating the Health Risk Posed by the Invasive Chinese mitten crab. Final Report to National Sea Grant Aquatic Nuisance Species Research and Outreach Project R/CZ-160.

Earley PJ, Swope BL, Barbeau K, Bundy R, McDonald J. ,Rivera-Duarte I. (2014): Life cycle contributions of copper from vessel painting and maintenance activities. Biofouling,. 30, 51–68.

EBA (2016): European Code Of Conduct On Recreational Boating And Invasive Alien Species, Brussels, 17 pp.

EBA (2019): EBA Position Statement - International Certificate for Operators of Pleasure Craft, 1–4.

ECE (2010): International Certificate for Operators of Pleasure Craft. ECE/TRANS/SC.3/147/Amend.1, 1–4.

Egardt J., Nilsson, P., Dahllöf, I. (2017): Sediments indicate the continued use of banned antifouling compounds. Mar. Pollut. Bull., 125, 282–288.

Eklund, B., Elfström, M., Gallego, I., Bengtsson. B.-E., Breitholtz, M. (2010): Biological and chemical characterization of harbour sediments from the Stockholm area. J Soils Sediments, 10, 127–141.

Eklund, D., Eklund, B. (2012). Contamination of boat yards – a compilation of surveys performed in Swedish coastal municipalities. Förorening av båtuppläggningsplatser – en sammanställning av utförda undersökningar i svenska kustkommuner, Institute of Applied Environmental Research, Stockholm University. ITM rapport 208. (In Swedish)

Eklund, B., Johansson, L., Ytreberg, E. (2014a): Contamination of a boatyard for maintenance of pleasure boats. J. Soils Sediments, 14, 955–967.

Eklund, B., Eklund, D. (2014b): Pleasure Boatyard Soils are Often Highly Contaminated. Environ. Managem., 53, 930–946.

Eklund, B., Watermann, B. (2018): Persistence of TBT, and copper in excess on leisure boat hulls around the Baltic Sea. Environmental Science and Pollution Research, 25, 14595–14605.

Filipkowska, A.A., Kowalewska, G.G., Pavoni, B.B. (2014). Organotin compounds in surface sediments of the Southern Baltic coastal zone: a study on the main factors for their accumulation and degradation. Environ. Sci. Pollut. Res., 21 (3), 2077–2087.

Grimvall, A., Larsson, K. (2014): Mapping shipping intensitiy and routes in the Baltic Sea. Havsmiljöinstitutet, Rep. 5, 6 pp.

Hansen, E., Sörensen, G., Mikkelsen, S., Kjölholt, J., Möller Christensen, F., Lassen, C., Kjellerup, U. (2014): Survey of copper(I)oxide, copper(II)sulphate and copper(I)chloride. Danish Environmental Protection Agency, Project No.1538, 95 pp.

Hearin, J., Hunsucker, K.Z., Swain, G., Stephens, A., Gardner, H., Lieberman, K., Harper, M. (2015): Analysis of long-term mechanical grooming on large-scale test panels coated with an antifouling and a fouling-release coating. Biofouling, 31, 8, 625–638.

Hearin, J., Hunsucker, K.Z., Swain, G., Stephens, A., Gardner, H., Lieberman, K. (2016): Analysis of mechanical grooming at various frequencies on a large scale test panel coated with a fouling-release coating, Biofouling, 32, 5, 561–569.

HELCOM (2009): Hazardous substances of specific concern to the Baltic Sea. Baltic Sea Environ. Proc. 119, 96 pp.

HELCOM (2014): Activity Report, Baltic Sea Environ. Proc. 146.

HELCOM (2017a): The integrated assessment of hazardous substances – supplementary report to the first version of the 'State of the Baltic Sea' report. Available at: http://stateofthebalticsea.helcom.fi/about-helcom-and-the-assessment/downloads-and-data/

HELCOM (2017b): HELCOM indicators – TBT and imposex, HELCOM core indicator report, 23 pp.

HELCOM (2018). HELCOM Assessment on maritime activities in the Baltic Sea 2018. Baltic Sea Environment Proceedings No.152. Helsinki Commission, Helsinki. 253 pp.

Hunsucker, K.Z., Ralston, E., Gardner, H., Swain, G. (2019): Specialized Grooming as a Mechanical Method to Prevent Marine Invasive Species Recruitment and Transport on Ship Hulls. In: Makowski, C. & Finkl, C.W. (eds.) Impacts of Invasive Species on Coastal Environments: Coasts in Crisis. Coastal Education and Research Foundation, Springer, chapter 7, 2–20.

IMO (2011): Guidelines For the Control and Management of Ships' Biofouling to Minimize the Transfer of Invasive Aquatic Species, MEPC 62/24/Add.1, Annex 26, 1–27.

IMO (2012): Guidance for Minimizing the Transfer of Invasive Aquatic Species as Biofouling (Hull Fouling) for Recreational Craft. MEPC, 1/Circ. 792, 1–7.

IMO (2019): Hull scrapings and marine coatings. London, 33 pp.

Johnson, L.T., Fernandez, L.M., Lande, M.D. (2012): Crossing boundaries: Managing invasive species and water quality risks for coastal boat hulls in California and Baja California. UCCE-SD, Tech. Rep. 2012-1,16 pp.

INTERTANKO (2016): Guide to Modern Antifouling Systems and Biofouling Management. London, 20 pp.

Kellett P., Mizzi K., Demirel Y.K., Turan O. (2015). Investigating the roughness effect of biofouling on propeller performance. In: International Conference on Shipping in Changing Climates, 2015-11-24 - 2015-11-26. Newcastle (UK): Technology and Innovation Centre.

Kymenvaara, S., Anker, H.T., Baaner, L., Ekroos, A., Gipperth, L. & Seppälä, J. (2017): Regulating antifouling paints for leisure boats – a patchwork of rules across three Baltic Sea countries. Nordic Environmental Law Journal, no. 1, pp. 7-31.

Lagerström, M., Strand, J., Eklund, B., Ytreberg, E. (2017): Total tin and organotin speciation in historic layers of antifouling paint on leisure boat hulls. Environ. Pollut. 220, 1333–1341.

Lagerström, M., Ytreberg, E., Wiklund, A-K., Granhag, L. (2020): Antifouling paints leach copper in excess – study of metal release rates and efficacy along a salinity gradient. Preprint, 1–22.

Lindgren, J.F., Ytreberg, E., Holmqvist, A., Dahlström, M., Dahl, P., Berglin, M., Wrange, A.-L., Dahlström, M. (2018). Copper release rate needed to inhibit fouling on the west coast of Sweden and control of copper release using zinc oxide. Biofouling, 34, 453–463.

Lassen, C., S. Foss Hansen, K. Magnusson, F. Norén, N. I. Bloch Hartmann, P. Rehne Jensen, T. Gissel Nielsen and A. Brinch (2015). Microplastics - Occurrence, effects and sources of releases to the environment in Denmark. Environmental project No. 1793, Danish Ministry of the Environment–Environmental Protection Agency (Denmark): 204 pp.

Magnusson, K., Eliasson, K., Fråne, A., Haikonen, K., Hultén, J., Olshammar, M., Stadmark, J., Voisin, A (2017): Swedish sources and pathways or microplastics to the marine environment. A review of existing data. IVL Svenska Miljöinstitutet, Report C 183, 89 pp.

Martin, D.M., Bergman, K., Harju, A.A., Koroschetz, B., Salminen, E., Solér, C. Ziegler, F. (2018): Understanding antifouling practices and consumption patterns. In: Strand, H., Solér, C., Dahlström, M. (eds.) Changing leisure boat antifouling practices in the Baltic Sea, 74–86.

Martin, D.M., Harju, A.A., Salminen, E., Koroschetz, B., (2019): More Than One Way to Float Your Boat: Product Use and Sustainability Impacts. J. Macromark., 39 (1), 71–87.

McClay, T., Zabin, C., Davidson, I., Young, R., Elam, D. (2015): Vessel Biofouling Prevention and Management Options Report. Rep No CG-D-15-15, 54 pp.

Molnar, J.L., Gamboa, R.L., Revenga, C., Spalding, M.D. (2008): Assessing the global threat of invasive species to marine biodiversity. Front Ecol Environ, 6, 33 pp.

Morse, J.T. (2009). Assessing the effects of application time and temperature on the efficacy of hot-water sprays to mitigate fouling by *Dreissena polymorpha* (zebra mussels Pallas), Biofouling, 25:7, 605–610.

MPI (2018): Guidance document for the craft risk management standard for biofouling. MPI, New Zealand, 30 pp.

Mueting, S.A., Gerstenberger, S.L. (2011): The 100th Meridian Initiative at the Lake Mead National Recreation Area, NV, USA: Differences between boater behaviors before and after a quagga mussel, Dreissena rostiformis bugensis, invasion. Aquat. Invasions, 6, 2, 223–229.

Naval Sea Systems Command (2006). Chapter 081 – Waterborne underwater hull cleaning of Navy ships. In: Nav Ship's Tech Man. Washington (DC).

Normant M., Chrobak M., Skóra K. (2002): The Chinese mitten crab *Eriocheir sinensis* - An immigrant from Asia in the Gulf of Gdańsk. Oceanologia, 44(1), 123–125.

OECD (2009): Emission scenario document on coating industry. OECD series on emission scenario documents Number 22. Organisation for Economic Co-operation and Development. 201 pp.

Ojaveer H, Jaanus A, MacKenzie BR, Martin G, Olenin S, (2010): Status of Biodiversity in the Baltic Sea. PLoS ONE 5(9): e12467.

Oliveira, D.R., Granhag, L. (2020): Ship hull in-water cleaning and its effects on fouling-control coatings. Biofouling, DOI: 10.1080/08927014.2020.1762079.

Parks, R., Donnier-Marechal, M., Frickers, P.E., Turner, A., Readman, J.W. (2010): Antifouling biocides in discarded marine paint particles. Mar. Pollut. Bull., 60, 1226–1230.

Ruiz, G. M., Fofonoff, P. W., Steves, B., Foss, S. F., and Shiba, S. N. (2011): Marine invasion history and vector analysis of California: a hotspot for western North America. Divers. Distrib., 17, 362–373.

Ruczyńska, W.W., Szlinder-Richert, J.J., Drgas, A.A. (2016). The occurrence of endocrine disrupting compounds in off-shore sediments from the southern Baltic Sea. Environ. Sci. Process. Impacts 18 (9), 1193–1207.

Schultz, J. (2007): Effects of Coating Roughness and Biofouling on Ship Resistance and Powering. Biofouling, 23, 331–341.

Scianni C., Georgiades, E.(2019): Vessel In-Water Cleaning orTreatment: Identification of Environmental Risks and ScienceNeeds for Evidence-Based Decision Making. Front. Mar. Sci. 6, 467.

Seebens, H., Gastner, M.T., Blasius, B. (2013): The risk of marine bioinvasion caused by global shipping. Ecol. Letters, 9 pp.

Soroldoni, S., Braga Castro, I., Abreu, F., Duarte, A.F., Choueri, R.B., M.R.B., O.O., Fillmann, G., Lopes Lepes Pinho, G. (2018): Antifouling paint particles: sources, occurrence, composition and dynamics, Water Research. doi: 10.1016/j.watres.2018.02.064

Stanley, J.A., Wilkens , S., McDonald, J.I., Jeffs, A.G. (2016): Chapter 136, Vessel Noise Promotes Hull Fouling. In: Popper, A.N., Hawkins, A. (eds.), The Effects of Noise on Aquatic Life II, Advances in Experimental Medicine and Biology 875, Springer, New York, 1047–1104.

State of California-State Lands Commission, Marine Invasive species Program Annual Vessel Reporting Form. SLC 600.12, (Revised 08/17). 10 pp.

State of California-State Lands Commission (2017): Guidance Document for: Biofouling Management Regulations to Minimize the Transfer of Nonindigenous Species from Vessels Arriving at California Ports. California Code of Regulations, title 2, section 2298.1 et seq. September 19, 2017 California State. 17 pp.

Sundt, P., Schulze, P.E., Syversen, F. (2015). Source of microplastic-pollution to the marine environment. rep. no. M-321. mepex 108.

Suzdalev, S., Gulbinskas, S. & Blažauskas, N. (2015): Distribution of tributyltin in surface sediments from transitional marina-lagoon system of the south-eastern Baltic Sea, Lithuania. Environ. Sci. Pollut. Res. 22: 2634.

Tribou, M., Swain, G. (2010): The use of proactive in-water grooming to improve the performance of ship hull antifouling coatings, Biofouling, 26:1, 47–56.

Turner, A. (2010): Marine pollution from antifouling paint particles. Mar Pollut Bull., 60, 2, 159–71.

van Hattum, B., Baart, A., Boon, J. (2006): Emission estimation and chemical fate modelling of antifoulants. In: Konstantinou, I. (ed.) Antifouling paint biocides. The Handbook of Environmental Chemistry, 5, 0, Water Pollution, Springer, Berlin, Heidelberg, New York, 103–118.

Watermann, B., H.-D. Berger, H. Sönnichsen & P. Willemsen (1997): Performance and Effectiveness of Non-Stick Coatings in Seawater. Biofouling 11(2), 101–118.

Watermann, B., B. Daehne, S. Sievers, R. Dannenberg, J.C. Overbeke & O. Heemken (2005): Bioassays and selected chemical analysis of biocide-free antifouling coatings. Chemosphere 60, 1530–1541.

Watermann, B., Dahlström, M. (2018): BONUS CHANGE Recommendations towards regulations for a sustainable antifouling practice in the Baltic Sea. 44 pp.

Watermann, B., Eklund, B. (2019): Can the input of biocides and polymeric substances from antifouling paints into the sea be reduced by the use of non-toxic hard coatings? Mar. Pollut. Bull. 144, 146–151.

Watermann, B. (2019): Hull performance management and biosecurity by cleaning, Ship & Offshore, 3, 18–20.

Watermann, B.T. (2019): Propeller Polishing Condition and Definitions, http://www.limnomar.de/eigenedateien/standards%20propeller%20polishing%20final%20version-09-08-19(1).pdf

Wrange, A.-L., Barboza, F.R., Ferreira, J., Eriksson-Wiklund, A.-K., Ytreberg, E., Jonsson, P., Watermann, B., and Dahlström, M. (2020). Monitoring biofouling as a management tool for reducing toxic antifouling practices in the Baltic Sea. J. Environm. Manag., 264, 110447.

Xi, Z., Qingyi, X., Chunfeng, M., Zijan, C., Guangzhao, Z. (2015): Inhibition of marine biofouling by use of degradable and hydrolysable silyl acrylate copolymer. Ind. Eng. Chem. Res. 54, 39, 9559–9565.

Woods, C.M.C., Floerl, O., Jones, L. (2012): Biosecurity risks associated with in-water and shore-based marine vessel hull cleaning operations. Mar. Pollut. Bull. 64, 1392–1401.

Yebra, D.M., Kiil, S., Dam-Johansen, K. (2004). Antifouling technology - Past, present and future steps towards efficient and environmentally friendly antifouling coatings. Prog. Org. Coatings 50, 75–104.

Ytreberg, E., Bighiu, M.A., Lundgren, L., Eklund, B. (2016): XRF measurements of tin, copper and zinc in antifouling paints coated on leisure boats. Environ. Pollut. 213, 594–599.

Zabin C., Ashton G.V., Brown C.W., Davidson I.C., Sytsma M.D., Ruiz G.M. (2014): Small boats provide connectivity for nonindigenous marine species between a highly invaded international port and nearby coastal harbors. Manag. Biol. Invas., 5, 97–112.

Interreg
Baltic Sea Region

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

COMPLETE

BIOFOULING ASSESSMENT PROTOCOL FOR LEISURE BOATS AND MARINAS

COMPLETE WP 2.2

2019

CONTENT

INTRODUCTION

This protocol has been developed as a part of the COMPLETE-project (Completing management options in the Baltic Sea Region to reduce risk of invasive species introduction by shipping) funded by the Interreg Baltic Sea Region Programme. The aim of this protocol is to identify the potential risk of non-indigenous species (NIS) transfer by leisure boats and trailers in the Baltic Sea region. The sampling methods were tested in Finland during summer 2018, and the final protocol was developed according to the field-testing experience.

The protocol consists of the following sub tasks:

1. **Questionnaire**
2. **Sampling in marinas**
3. **Post season examination of fouling levels of leisure craft**

1. QUESTIONNAIRE

The questionnaire for leisure boaters in the Baltic Sea region (Appendix 1) will address such questions as the movement of leisure boats in the Baltic Sea region, anti-fouling method of choice, the use of trailer, cleaning procedures etc. The aim of the questionnaire is to obtain background information of the potential risk of transferring NIS by leisure boats and trailers via biofouling. The questionnaire is available online in respective language versions (link in Appendix 1), but it can also be printed out and answered as a paper version in boating events and marinas, for example.

2. SAMPLING IN MARINAS

Sampling in marinas by settling plates and scraping samples will address the question to what extent marinas represent a risk in introducing invasive species via leisure boats through biofouling in the Baltic Sea.

2.1 Material and methods

2.1.1 Location and subdivision of areas

The sampling should be conducted in a marina which is popular amongst boaters. The sampling should be carried out without disturbing the activity in the marina.

The sampling in a marina should be conducted in two subareas: 1) **inner marina** and 2) **outer marina**. The inner marina should be located close to the shoreline and sheltered by e.g. anthropogenic or natural structures, such as piers or banks. The outer marina should be located at the edge of a marina, further away from the shoreline, and it should be more exposed. The sampling spot in both subareas must be at least 1,3 m in depth to enable the sampling done properly. GPS location of each of the sampling site should be recorded by using a WGS84 coordinate system.

2.1.2 Settling plates

The settling plates (Figure 1) mimic hull surfaces to further indicate the potential risk of a non-indigenous species being spread through marinas. PVC is widely used as a settlement surface in biofouling studies and is therefore used as the material of the sampling plates in this protocol.

The methodology used in this protocol follows close to that of OSPAR/HELCOM port survey protocol (2015). The size of a settling plate should be 15.0 x 15.0 cm. The plates are attached to a polypropylene cord so that one plate set consists of two plates (Figure 2). The two plates should be attached to the cord at depths of 0.5 m and 1.0 m measured from the water surface. Each plate should have a hole drilled in the middle where the cord is attached. The hole should have a diameter of 0.5 cm and cord a diameter of 0.4 cm. To prevent the cord of being cut by the edges of the plate, a plastic tube or duct tape should be placed in between the cord and the plate. The plates should be secured at desired depths with knots or zip ties. The plates should be deployed horizontally to the sampling site since horizontally orientated plates have been observed to support a higher percentage cover of biofouling than vertical plates (Tait et al. 2016). One subarea should be equipped with three plate sets, in other words six plates in total per subarea.

A weight (e.g. a small brick) should be attached at the end of the cord to ensure that the set stays vertical. The plate sets should be attached to a buoyant wharf, berth or pier in a place where they will be safe from damage caused by passing boats. In case the plate sets are attached to a stationary pier, a buoy should also be attached to the set to secure that the plates remain submerged at desired depths.

Three settling plate sets should be deployed to each subarea in the beginning of the boating season. Since the growing season varies in length and timing in the Baltic Sea region, the sampling periods have been determined different for different areas. The length of the sampling season depends on in which basin the marina is located in. The Baltic Sea has been divided into 17 sub-basins by HELCOM (Subbasins 2018, HELCOM Monitoring and Assessment Strategy). For the use of this protocol these basins were grouped into three groups based on both salinity and surface water temperature averages during spring and fall since these factors are considered to be the most important ones affecting the fouling rates and species compositions in the Baltic Sea.

In this protocol, group A. includes the southwestern basins of the Baltic Sea, group B. includes the mid-basins and group C. includes the northern basins (Table 1). The sampling period for **group A. is 6 months** (suggested start at April until the end of September), **group B**. has a sampling period of **5 months** (suggested start in early May until the end of September) and **group C.** has a sampling period of **3 months** (suggested start in the beginning of June until the end of August).

The settling plate sets should be removed gradually in each subarea. The sampling period should be divided evenly into three shorter time periods. At the end of each shorter period one plate set should be removed in each subarea. The gradually performed removal provides information of species emergence and abundance during the boating season. Group A. should remove a plate set every eight weeks, group B. should remove a set every six or seven weeks and group C. should remove a set every four weeks (Table 1).

After the plates are removed, the fouling rates should be determined in relative abundance by placing a grid on the panel, dividing the area to four sub-quadrats each a size of 6.5 x 6.5 cm. The fouling rate of the panel is then analysed using a 5% interval (Dziubińska and Janas, 2007). If the percentual coverage exceeds 100 % because of organisms growing on top of each other, it should be noted when estimating the fouling rate.

The organisms on the plates should be identified with a microscope to species level or the lowest taxonomic level possible. The species on the plate should be listed and the individual abundances counted, at least for NIS. In case the native species' abundances are not counted, the most dominant species should be documented to control the type of the species assemblage.

The plates should be handled carefully to prevent the loss of organisms. In case an unknown species is found, it should be first photographed and then preserved in e.g. ethanol for further studies.

Figure 1. Settling plates.

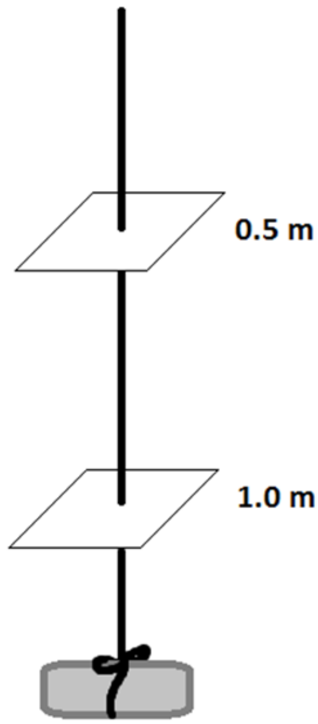

Figure 2. A settling plate set.

Table 1. The grouped division of the sub-basins in the Baltic Sea.

Group	HELCOM-ID	Name	Suggested sampling period	Suggested plate removal interval
A.	SEA-001	Kattegat	6 months (April-September)	8 weeks
	SEA-002	Great Belt		
	SEA-003	The Sound		
	SEA-004	Kiel Bay		
	SEA-005	Bay of Mecklenburg		
	SEA-006	Arkona Basin		
B.	SEA-007	Bornholm Basin	5 months (May-September)	6-7 weeks
	SEA-008	Gdansk Basin		
	SEA-009	Eastern Gotland Basin		
	SEA-010	Western Gotland Basin		
	SEA-011	Gulf of Riga		
	SEA-012	Northern Baltic Proper		
C.	SEA-013	Gulf of Finland	3 months (June-August)	4 weeks
	SEA-014	Åland Sea		
	SEA-015	Bothnian Sea		
	SEA-016	The Quark		
	SEA-017	Bothnian Bay		

2.1.3 Scraping samples

Since the plates provide a horizontally oriented surface for biofouling, additional scraping samples should be taken on vertically oriented berth surfaces or other structures present. Three scraping samples should be taken in each subarea when the settling plates are deployed and during each plate removal.

The scraping tool is a hand dredge (Figure 3). The mesh size of the net bag is 0.1 cm and the sharp edge of the dredge should be at least 10.0 cm wide. It is important to record the size of the surface sampled for future reference. When scraping, the sharp edge should be placed on the sampled surface in 1.0 m depth measured from the water surface and drawn upwards until it meets the surface. As the tool is drawn against the surface, the sharp edge scrapes the biofouling species and they fall into the net. Organisms fallen in the net should be identified to the lowest taxonomic level possible, listed and abundances counted with a microscope. If there are no structures present with a surface reaching 1.0 m depth, the sample is taken in the closest possible depth. In case an unknown species is found, it should first be photographed and then preserved in e.g. ethanol for further studies.

Figure 3. Scraping sample tool.

2.1.4 Salinity

The surface salinity should be recorded in each subarea when the plates are deployed and removed. Additional environmental information (such as: surface temperature, chlorophyll a, waves etc.) can be obtained e.g. through the EU Copernicus portal.

2.1.5 Optional enhancements for sampling in marinas

The methodology in this protocol is considered to represent the minimum requirements for monitoring marinas (in case of NIS being present and spread). To further increase accuracy and to better meet scientific integrity, additional methodology is presented here.

a) Additional settling plates can always be added to increase sample size to better meet requirements for statistical analysis. It is also recommended to add settling plates on different depths, *additional* to the two presented in this protocol (0.5 m and 1.0 m) if monitoring is conducted in marinas or harbours in deeper waters.

b) Replacing settling plate sets. When a settling plate set is removed, a new set can be deployed to increase sample size.

c) Sediment sampling is highly recommended as a complimentary methodology that will give wider knowledge of the area. If possible, the soft benthos could be sampled by using the OSPAR/HELCOM port survey protocol (2015) methods. Three samples per subarea should be taken mid-season.

3. POST SEASON EXAMINATION OF FOULING LEVELS OF LEISURE CRAFT

The importance of the task lies in mapping the overall risk of NIS introduction by examining the general fouling level of the vessel, photographing the fouled surfaces and sampling biofouling communities on the hull or niche areas of the vessel.

Optimally, most leisure boats are removed from the harbours and lifted out of the water after the season (at least in the northern parts of the Baltic Sea), which gives an opportunity to examine a good number of leisure boats in a more precise manner.

At its best, the post season examination should be conducted on leisure craft from marinas where settling plates were deployed to allow comparison between the two. To sample boats from a specific marina will more than often be challenging, since many popular marinas do not provide winter service and most boats are taken from the water elsewhere.

Further challenges for examination of leisure crafts consists of receiving permits to photographing and sampling from boat owners and personnel at the respective dockyard. Since boat owners are not obligated to participate, getting a good sample size might be challenging. The time for a thorough sampling might be restricted to only a few minutes because the companies managing boat lifting want to make their working time efficient. Also, one might more than often find it hard to sample hull surfaces, since the very common use of antifouling paints greatly reduces (or entirely blocks) biofouling. Therefore, recognizing unpainted structures and so-called niche areas, such as outboard motors, small cracks and crevices require closer attention. The niche areas could represent potential hiding spots for species and should be examined with care, especially when coming across a vessel that shows high levels of fouling.

Aiming for the future, there has been some discussion of the possibility to restrict or even prohibit the use of copper based antifouling paints in leisure crafts in the Baltic Sea region, due to the harmful effect of Cu in nature (Lagerström et al. 2018). A recent initiative towards such a progression was made by the CHANGE -project, funded by BONUS 2014–2017. The projects policy recommendations include the phasing-out of biocidal antifouling products in the Baltic Sea on leisure crafts before 2030 (BONUS CHANGE Summary report, 2018). Therefore, examining active vessels for non-indigenous species might be more crucial than before.

3.1 Material and methods

3.1.1 Estimation of fouling rate

The fouling rate of the hull should be determined at the end of the boating season in agreement with the boater as the boat is taken up and prepared for winter. The fouling rate should be estimated on each vessel according to a ranking system (Table 2). The observed area should only include the boat surface that has been submerged, below the waterline. If the boat is not taken up, the estimation should be done for the surface area visible underwater. There is currently no ranking system developed specifically for the Baltic Sea region. The ranking system used in this protocol was introduced in a study by Floerl et al. in 2005 to estimate the fouling rate of boat hulls in New Zealand. This model is intended for vessels that are in the water but was considered just as effective when analysing vessels out of sea. Therefore, only minor modifications in the fouling descriptions were executed on the original ranking system.

When estimating the fouling rate, the length of the vessels should be recorded or at least reported in categories (**0 to 5 m**, **5 to 10 m** and **10 to 24 m)** to gain a rough estimation of the fouling surface area, since it is practically impossible to sample and analyse the entire coverage. Vessels over 24 m are not considered as recreational boats according to the EU Directive 2013/53/EU. The length of the boat could have an effect on the vessel's potential to carry and spread NIS species, since surface area increases with vessel size, thus providing more area for biofouling.

Table 2. Fouling scale ranks based on the ranking system by Floerl et al. (2005).

Rank	Description	Visual estimate of fouling cover
0	No visible fouling. Hull entirely clean, no biofilm on the previously submerged parts of the hull.	Nil
1	Slime fouling only. Previously submerged hull areas partially or entirely covered in biofilm, but absence of any macrofouling.	Nil
2	Light fouling. Hull covered in biofilm and 1–2 very small patches of macrofouling (only few taxa present).	1–5 % of surfaces that have been submerged
3	Considerable fouling. Presence of biofilm, and macrofouling still patchy but clearly visible and comprised of either one single or several different taxa.	6–15 % of surfaces that have been submerged
4	Extensive fouling. Presence of biofilm and abundant fouling assemblages consisting of more than one taxon.	16–40 % of surfaces that have been submerged
5	Very heavy fouling. Diverse assemblages covering most of the hull surfaces.	41–100 % of surfaces that have been submerged

3.1.2 Photographing the fouling areas and documentation of vessel

Simultaneously with the fouling rate estimations, the fouling species on boat hulls should be photographed for later identification after boating season. In this protocol the photographing methodology follows close to that of Zabin et al. 2014. In the respective study all observations were conducted underwater, but the methodology is also suitable to be used on vessels on land. The recommended procedure in this protocol is to photograph the boats when they are lifted from the water and prepared for the winter. In case the boats are not lifted after the season, the photographing should be done with an underwater camera mounted on an angled pole as according to Zabin et al.

The size of one photographed hull surface area should be 8 x 12 cm (Zabin et al. 2014). Depending on the fouling rate estimations (Table 2), there are two ways of photographing the hull surfaces. If the fouling rate is ranked 0-3 (no visible fouling - considerable fouling), photographs should be taken of random fouling patches covering the hull, yet eight photographs in maximum.

If the fouling rate is ranked 4-5 (extensive fouling - very heavy fouling), photographs should be taken along transect lines. The first transect line should be set on one side of the hull running from bow to stern just below the waterline (Figure 4). Eight photographs of the hull surface along the transect line should be taken randomly. The size of one photographed area should be 8 x 12 cm. A parallel transect line should be set at the bottom of the craft as near to the keel line as possible. Another eight photographs should be taken at random sites along this transect.

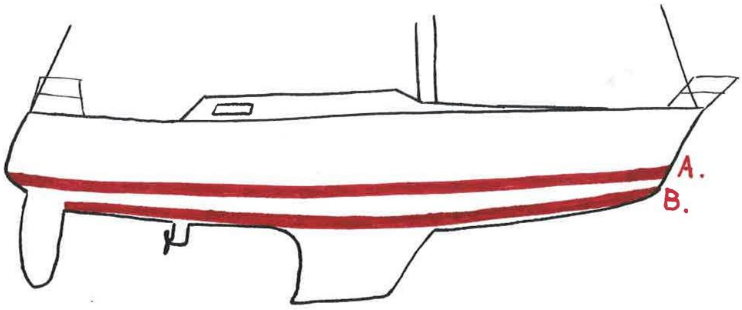

Figure 4. Side view of a boat with two transect lines. The transect line A. is just below the waterline and B. is at the bottom of the boat.

Since many vessels are treated with antifouling paint, the fouling will often only concentrate on specific untreated structures. These niche areas on vessels are: fender, mooring, rudder, ladder, mooring line, water intake, anchors, outboard motors, bow thrusters, anodes and knot meter. The niche areas should be checked for fouling and photographed if biofouling organisms should grow on them. Additionally, small cracks and crevices require closer attention. The photographed area on these niche areas should also be 8 x 12 cm, if possible.

To achieve an overview of the community types growing on the hull, the organisms in the photographs should be identified to the lowest taxonomic level possible and the percentage cover estimated. In case the species identification from photographs is too challenging, the percent cover of coarse taxonomic groups should be estimated.

General information concerning the vessel should be recorded. At least the following information should be recorded**: type of boat, size of boat**, **material and occurrence and type of antifouling paint**. If possible, the boat owner who has agreed to have their vessel's fouling surface photographed should also answer the questionnaire (Appendix 1.) and the answers should be joint with the photographs and samples. Yet it might be a challenge to get in touch with the boat owners, since they might not be present when the boat is lifted and prepared for winter by a respective company.

3.1.3. Sampling of leisure craft

When possible, sampling of leisure craft is highly recommended. Photographing vessels will only give a general idea of the overall fouling rates and very few species can be recognized by photographs alone. Scraping samples are therefore a necessary part of examining the vessels. The biggest issue is that permits may be hard to receive, since not all boat owners are present when their boats are lifted out of the water for the winter.

Scraping samples should be taken *after* the vessel has been photographed. Since fouling can be scarce due to usage of antifouling paint, samples should be taken from several niche areas to give an as accurate indication of the species community as possible. The scraping samples should be taken with a spatula on a small (ca. 2.0 x 2.0 cm) area. Depending on the fouling rate estimations (Table 1), if the fouling rate is ranked 0-3 (no visible fouling - considerable fouling), scraping samples should be taken of random fouling patches covering the hull and the niche areas. If the fouling rate is ranked 4-5 (extensive fouling - very heavy fouling), eight samples should be taken along each transect line that were used when photographing the hull. Along with the hull samples, the niche areas should be sampled, too. Optimally, the samples should be labelled and stored in separate sampling jars. The samples should be preserved in e.g. ethanol. The sampled species should be identified to the lowest taxonomic level possible with a microscope. In case an unknown species is found, it should first be photographed and then preserved for further studies.

REFERENCES

BONUS CHANGE PROJECT (2018), *Changing antifouling practices for leisure boats in the Baltic Sea, The final publishable summary report*

Copernicus, European Union’s revolutionary Earth Observation and Monitoring programme, accessed 11.3.2019, <https://www.copernicus.eu/en>

Floerl, O., Inglis, G. J. & Hayden, B. J. (2005). A Risk-Based Predictive Tool to Prevent Accidental Introductions of Nonindigenous Marine Species. *Environmental Management* **35**: 765–778

Dziubińska, A. & Janas, U. (2007). Submerged objects - a nice place to live and develop. Succession of fouling communities in the Gulf of Gdańsk, Southern Baltic. *Oceanological and Hydrobiological Studies* **36**: 65–75

Lagerström, M., Lindgren, F. J., Holmqvist, A., Dahlström, M. & Ytreberg, E. (2018). In situ release rates of Cu and Zn from commercial antifouling paints at different salinities. *Marine Pollution Bulletin* **127**: 289–296

OSPAR/HELCOM Port Survey Protocol (2015), *Joint Harmonised Procedure for the Contracting Parties of HELCOM and OSPAR on the granting of exemptions under International Convention for the Control and Management of Ships’ Ballast Water and Sediments, Regulation A-4*

Tait, L., Inglis, G., Seaward, K., Spong, K. & Wilkens, S. (2016). Optimising settlement arrays for surveillance of non-indigenous biofouling species. MPI Technical -Paper No: 2016/70. Prepared for Ministry for Primary Industries, New Zealand

Zabin, C. J., Ashton, G. V., Brown, C. W., Davidson, I. C., Sytsma, M. D. & Ruiz, G. M. (2014). Small boats provide connectivity for nonindigenous marine species between a highly invaded international port and nearby coastal harbors. *Management of Biological Invasions* **5**: 97–112

APPENDIX 1.

Biofouling survey and boater questionnaire

Questionnaire Biofouling of leisure boats

The questionnaire is available online in different languages:
https://linmantis60.bsh.de/limesurvey/index.php/835883?lang=en

The link to the questionnaire will also be published on the COMPLETE project home page:
www.balticcomplete.com

The printable English version of the Questionnaire

About

Within the EU INTERREG Baltic Sea Region project COMPLETE we are collecting data on biofouling of leisure boats, antifouling strategies, cleaning procedures and facilities. The aim of the project is to compile information on best practices and deliver knowledge and user-oriented tools for efficient regional biofouling management in the Baltic Sea Region.

For this purpose, cooperation of local marinas and boat owners is essential. We would be grateful for your knowledge and advice. Please, take 10 minutes of your time to fill out the form. Thank you in advance!

Date survey completed _____/_____/_____ (dd/mm/yyyy)

Part A: Boat details

1. Type of boat:

□ Sailboat

□ Powerboat/Motorboat

□ Fishing boat

□ Other (Please, specify!) ____________________________________

2. Length of boat:

□ 0 to 5 m

□ 5 to 10 m

□ From 10 to 24 m

□ Over 24 m

3. Hull type:

□ Wood

□ Aluminium

□ Fiberglass

□ Other (Please, specify!) ____________________________________

4. Do you use a trailer?

□ Yes

□ No

5. Do you use the same trailer in sea **and** fresh water?

□ Yes

□ No

Part B: Use of the boat and main mooring place (with reference to the last sailing season)

Home port/ main port: ____

1. How often did you use your boat during the last sailing season?

□ Daily

□ Weekly

□ Monthly

□ Occasionally (less than monthly)

□ Never

2. Was your boat moored at any kind of structure (port, marina, yacht club, landing stage etc.)?

□ Yes

□ No

3. If yes, where did you moor your boat?

□ It was moored for the entire season at the same location (port, marina or others).

□ It has a main location, but it was moored at different locations during the season.

□ It does not have a main location; it was moored at different locations during the season.

Please, give the names of mainly used locations: ____________________________________

4. How much time did your boat spend at the main location?

□ All year long

□ All sailing season long

□ Part of the sailing season

□ Occasionally

Please, specify in which location: _________

Average lay time (in days): _____

Longest lay time (in days): _____

4. How often did you get your boat out of the water during the sailing season?

□ Daily

□ Weekly

□ Monthly

□ Few times a season, (less than monthly)

□ Only at the end of the season

□ Never

Part C: Antifouling

Definition **antifouling system** (by IMO - International Maritime Organisation): Anti-fouling system means a coating, paint, surface treatment, surface, or device that is used on a ship to control or prevent attachment of unwanted organisms.

1. Is the boat treated with any kind of antifouling system?

□ Yes

Name of applied antifouling -system (in case of paint self-mixture, please indicate the composition!): ___________________________

If applied, please indicate the concentration of biocide:

Date of application: _____

□ No

□ I don't know, I have just bought the boat / the boat is not owned by me.

2. Do you apply a different or special antifouling system of niches, tubes, propeller etc.?

□ Yes (Please, specify!): _____

□ No

3. How often do you apply/renew the antifouling system?

□ Every 6-10 years

□ Every 4-5 years

□ Once every 2-3 years

□ Once a year

4. Do you make use of consultation for necessity, choice and application of antifouling systems?

□ Yes (Please, specify!): _____

□ No, I do it on my own.

5. Are there any regulations for the application of antifouling systems or enforcement implemented in your place?

□ Yes (Please, specify!): _____Which administration is involved? :_____

□ No

□ I don’t know.

Part D: Cleaning

1. How often do you clean your boat of biofouling (cleaning intervals)?

□ Several times a year

□ Every 12 months

□ Every 24 months

□ Every 36 months

□ Every 60 months or less often

2. Where do you clean your boat (cleaning facility)?

Place, country: ______

Type of the facility (if possible, please name the facility): ______

3. Which cleaning technique do you use? (several answers possible)

□ Routine hull cleaning with hard and soft brushes / sponges

□ Professional hull cleaning with pressure washer / disc sander

□ Professional hull cleaning followed by antifouling painting

□ None

□ Other cleaning technique (Please, specify!): ___________________________

4. Where do you carry out the cleaning of your boat?

□ In water

□ On boat ramp

□ In dry dock

□ On land

□ Other (Please, specify!): _______________________________________

5. Where is the removed material from the hull disposed?

□ In water

□ Recycling waste containers

□ I do not know (I do not personally clean the boat).

□ Other (Please, specify!): ____________________________________

Part E: Recommendations/experiences

Please, provide the following recommendations based on your experience:

1. Antifouling system recommended: _________________________
2. Cleaning procedure recommended: _________________________
3. Cleaning facility recommended: _________________________
4. Other recommendations/best-practice/experiences: _________________________
5. Please, also provide information on bad experiences with antifouling systems, cleaning etc.: _________________________

Part F: Journeys (with reference to the last sailing season)

Please, indicate the type of journey for each area: none, short (daily trips from the home marina), weekender (few day trips), long trips (to one destination/port further away), long tours (long trips with multiple destinations/ports, staying always for only a few days).

	None	Short	Weekender	Long trips	Long tours
Baltic Sea:					
Denmark	○	○	○	○	○
Germany	○	○	○	○	○
Poland	○	○	○	○	○
Russia (Kaliningrad)	○	○	○	○	○
Russia (Petersburg)	○	○	○	○	○
Lithuania	○	○	○	○	○
Latvia	○	○	○	○	○
Estonia	○	○	○	○	○
Finland	○	○	○	○	○
Sweden	○	○	○	○	○
Other:					
North Sea	○	○	○	○	○
Norwegian Sea	○	○	○	○	○

Mediterranean Sea	○	○	○	○	○
Red Sea	○	○	○	○	○
Black Sea	○	○	○	○	○
North Atlantic Ocean	○	○	○	○	○
Extra/Other destinations	○	○	○	○	○

2. How many days was your longest trip? (from start point to destination) ....

3. What was your average velocity? ....

4. How many voyages (leaving the main port) do you have per year? ....

Part G: Non-indigenous species in the Baltic Sea

1. Have you ever heard about the problem of the biological invasions by marine organisms?

□ Yes

□ No

□ Yes, but not in the Baltic Sea

2. Have you ever seen unusual organisms, perhaps non-indigenous species, attached on your boat?

□ Yes

□ No

3. Which part of the boat might be capable to transport and spread organisms in your experience?

□ The hull

□ The anchor and other awash elements of the boat

□ Onboard areas of the boat with stagnant water

□ Other (Please, specify!): ____

4. Have you ever thought of reporting an "unknown" species to any marine authority?

□ Yes

□ Yes, but I do not know to whom to report it.

□ No

5. Are you familiar with the IMO guidelines GUIDANCE FOR MINIMIZING THE TRANSFER OF INVASIVE AQUATIC SPECIES AS BIOFOULING (HULL FOULING) FOR RECREATIONAL CRAFT?

□ Yes

□ Yes, and I apply the guidance (Please, outline shortly your experiences!): ___________________________________

□ Yes, but I do not apply any guideline.

□ No

The compilation of the data of this questionnaire is carried out anonymously.

Nevertheless, if you want to get in contact with the COMPLETE project team and for further information please contact:

Federal Maritime and Hydrographic Agency (BSH)

Dr. Annika Krutwa

Bernhard-Nocht-Str. 78

20359 Hamburg

Germany

Email: biofouling@bsh.de

Phone: +49 40 3190-7482

THANK YOU VERY MUCH FOR YOUR COOPERATION AND SUPPORT!

APPENDIX 2.

Equipment list for settling plate deployment and field sampling

Settling plates and scraping samples:

- plate sets
- buoys (if needed)
- labels with contact information (attached to plate sets)
- labelled zip lock bags for the plates and
- jars for the scraping samples
- salinometer
- hand dredge
- hand held depth sounder
- ethanol (or other)
- field protocol
- GPS tracker
- extra cord
- cooler with cold blocks for the samples

Post season examination of boat hull fouling levels:

- digital camera
- 25 m transect line (labelled at 1 m intervals)
- frame (8.0 x 12.0 cm)
- spatula
- labelled jars for the samples
- field protocol
- ethanol (or other)

APPENDIX 3.

Contact information

Keep the Archipelago Tidy Finland

Atte Lindqvist

atte.lindqvist@pssry.fi

+35840 458 9495

Jutta Vuolamo

jutta.vuolamo@pssry.fi

+35840 458 9156

COMPLETE

RECOMMENDATIONS FOR MITIGATING POTENTIAL RISKS RELATED TO BIOFOULING OF LEISURE BOATS

Compiled by: Keep the Archipelago Tidy Finland

2020

CONTENT

1. DEFINITIONS

Anti-fouling coating	A paint or coating that inhibits, blocks or eliminates the attachment of unwanted biofouling organisms.
Anti-fouling system	A coating, paint, surface treatment, surface or device that is used on a vessel to control or prevent attachment of unwanted organisms[1].
Biocide	Biocidal products are used to control unwanted organisms that are harmful to human or animal health or to the environment, or that cause damage to human activities. These harmful organisms include pests and microorganisms[2].
Biofouling	Accumulation of organisms on surfaces or into structures that are submerged or exposed to the aquatic environment.
In-water cleaning	The physical removal of biofouling from a vessel while in the water.
Movable structure	In this protocol, movable structures refer to parts of the vessel that are separate from the boat hull, e.g. fender, ladder, mooring line, bucket, anchors and outboard motors.
Niche areas on vessels	Surfaces or structures that might differ of the hull material, e.g. rudder, water intake, bow thrusters, anodes, knot meter, small cracks and crevices.
NIS	Non-indigenous species. Any species transported intentionally or accidentally by humans outside its native range[3].
Removed (biofouling) material	The biofouling organisms that have been detached from the vessel.
Vessel	In this document a vessel represents a recreational craft operating in the Baltic sea with maximum length of 24 m.

[1] Definition by International Maritime Organization (IMO)
[2] Definition by European Commission
[3] Definition by International Council for the Exploration of the Sea (ICES)

2. INTRODUCTION

This guidance provides biofouling management recommendations for recreational boaters to help minimize the risk of transferring non-indigenous species (NIS) from biofouling as well as niche areas in the Baltic Sea. The guide aims to share information of such practices that reduce the biofouling on recreational vessels and boat trailers which contributes to reducing the potential of NIS spreading in new habitats.

This guide was produced as a task of the COMPLETE project, funded by the Interreg Baltic Sea Region Programme in 2019. The abbreviation "COMPLETE" stands for Completing management options in the Baltic Sea Region to reduce risk of invasive species introduction by shipping (www.balticcomplete.com). The management recommendations provided in this document act as a precaution in preventing the NIS spreading in the Baltic Sea region. The recommended practices are compiled in this document are heavily influenced by previous literature, such as a guidance document for minimizing the transfer of NIS in recreational crafts, provided by the IMO[4].

2.1 Background

Leisure boats and ship hulls have been observed to act as potential vectors to transfer NIS through the establishment of species communities enabled by biofouling. However, the potential of recreational boats or trailers spreading NIS has not, to our knowledge, yet been studied in the Baltic Sea region.

The type of biofouling might potentially affect the extent of the risk of spreading NIS. Larger biofouling organisms, such as barnacles, can potentially create surfaces for establishment to other, smaller, organisms. Such biofouling represents a greater risk in introducing NIS and it is therefore important to prevent their growth by using the strategies this guidance provides.

Harmful biofouling NIS have been earlier introduced also in the Baltic Sea. The most well-known is the bay barnacle, *Amphibalanus improvisus* (Figure 1.), which was introduced in the late 19th century, most likely by shipping. Since its introduction, the bay barnacle has become a dominant species with a substantial economic impact, due to its efficiency to attach on ship hulls. Increasing fuel consumption and the constant need for hull cleaning and application of antifouling systems are notorious effects of biofouling. Another NIS that might be a potential threat to the Baltic Sea is *Mytilopsis leucophaeata,* a dreissenid bivalve*,* which has been recorded in very high abundances (28 000 ind/m2) close to the nuclear power plant in Loviisa, Gulf of Finland[5]. Outside the boarders of the Baltic Sea, the zebra mussel (*Dreissena polymorpha*) and the quagga mussel (*Dreissena bugensis*) are examples of very harmful introductions. These species have altered entire ecosystems in the Northern American freshwater areas. The economic effect of these species is enormous, since

[4] IMO, 2012. Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft, MEPC.1/Circ.792

[5] Laine, A. O., Mattila, J. and Lehikoinen, A. (2006). First record of the brackish water dreissenid bivalve *Mytilopsis leucophaeata* in the northern Baltic Sea, *Aquatic Invasions* 1: 38–41

they attach and clog pipe surfaces and other infrastructure and can cause damages costing millions of dollars annually[6].

Considering the scale of effect in previous encounters, it is highly important to regard the risk and beware that similar introductions are very likely in the future.

Figure 1. Amphibalanus improvisus thrives in the Baltic Sea. Photo: Maiju Lehtiniemi

Figure 2. The zebra mussel, Dreissena polymorpha*, is an expensive threat to freshwater habitats. Photo: Dan Minchin/aquaNIS*

[6] U.S. Fish & Wildlife Service, The Cost of invasive species, fact sheet: http://www.fws.gov, January 2012, accessed 10.9.2019

3. STRATEGIES

This guidance presents strategies that eliminate, prevent or disturb the growth of biofouling on leisure craft and trailers. The strategies described in this guide apply as recommended practices for recreational boats and their trailers. According to EU directive, vessels with a length under 24 m are considered recreational boats[7]. Each strategy should first be evaluated by the respective boat owner to find the most suitable strategy for one's vessel or trailer.

Practically these strategies are a combination of inspection and cleaning. The boat owner should *inspect* the rate of biofouling growth regularly and *clean* the vessel or trailer when necessary.

The guidance concentrates only to describe the best practices for biofouling management without specifying safety requirements of each strategy. However, health risk precautions are recommended to take into consideration when, for instance, applying, maintaining or removing antifouling paints.

3.1 Cleaning practices for boats

The vessel can be cleaned mechanically of biofouling. The cleaning is recommended to be performed on all the submerged surfaces such as the hull, niche areas and movable structures. The intensity of biofouling growth on vessels can vary in the Baltic Sea depending on several different physical, chemical and biological factors[8]. Different cleaning practices can be combined or used on different vessel surfaces since the success of each practice can depend on the type and extent of biofouling. The respective boat owner should estimate the necessity of cleaning regularly.

Apart from guidance provided by IMO, very few areas and harbours have specific cautionary guidance for the possibility of NIS spreading. It is worth considering the risks whenever visiting harbours abroad. Therefore, it is highly recommended cleaning the hull *prior* to a longer voyage and *before* leaving the area visited (“clean before you leave”).

Mechanical cleaning equipment:

- brush
- scrape
- sponge
- boat turf carpet
- pressure washer
- hull cleaning machine
- stationary boat washer

[7] DIRECTIVE 2013/53/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 20 November 2013 on recreational craft and personal watercraft and repealing Directive 94/25/EC

[8] Strand, H., Solér, C. & Dahlström, M. 2018. Changing leisure boat antifouling practices in the Baltic Sea - results from the Bonus Change project

Whether the cleaning of the hull is applied on land or in water, the removed material, apart from biofilm and slime should be treated as waste and not be allowed to enter the water. Ideally, the boat is lifted from the water when cleaning, since it is easier to collect the removed material on land. On land it is important to avoid the cleaning waters running to the nearest waterway or ending up in storm water drains since they often run directly into the nearest waterway. Some hull cleaning machines and stationary boat washers provide an enclosed system where the removed material does not reach the open water.

The slime layer on the vessel is recommended to be cleaned as often as possible to hinder the attachment of heavier fouling organisms. Preferably, **one should never use a hull cleaning machine if the vessel was painted with antifouling paints containing biocides**. This is especially important if the hull was treated with self-polishing paints (so called “soft” paints) that are designed to wear off with water friction.

In case the vessel has not had a significant change to the craft’s operating profile, the biofouling species are likely to be of domestic origin and the risk of new NIS to the area being found on the vessel should be low. Vessels travelling to further destinations e.g. abroad might have been exposed to species that are not present in the home country or port area. Before a trip to a further destination the boat should be inspected of biofouling and cleaned to reduce the amount of biofouling and hinder the establishment of NIS. The boat should also be cleaned shortly after the trip and ideally the removed material should not be allowed to enter the water. The in-water cleaning procedure should always be done according to the regulations that are in force in the respective nation.

Information on national regulations in the Baltic Sea Region will be available in COMPLETE output 4.1.1. “Database on legal aspects and regulation of biofouling practices in BS States”.

Figure 2. Drive-in boat wash for large recreational vessels such as sail boats. Photo: Keep the Archipelago Tidy

Figure 3. High pressure wash is efficient for covering the rinsing of all niche areas. Photo: Keep the Archipelago Tidy

Figure 4. Cleaning scrape for the removal of barnacles and other biofouling organisms. Photo: Keep the Archipelago Tidy

3.2 Antifouling coating

Antifouling coatings can be divided into biocidal and biocide-free coatings. The biocidal coatings function chemically, i.e. they release chemicals, such as copper, that harm organisms. Biocide-free coatings act as physical barriers creating a surface that fouling organisms have difficulties to attach to.

Biocidal antifouling paints are regarded harmful to marine life due to negative effects copper and zinc have on fecundity, mortality and hormonal functions[9]. The percentage of copper and zinc vary greatly between paints, with high copper (<34.5% cu) paints often recommended for areas with high fouling, such as the west coast of Sweden. However, studies show that these agents are used in excess in several paints and that an increased release rate in high copper -paints doesn't necessarily increase their antifouling properties, with lower release rates being just as efficient in both low- and high fouling areas[10]. Also, the findings of the CHANGE-project show that an amount of 4 percent of copper is enough to prevent heavy fouling in the Baltic Sea. The CHANGE-project also compared several commercial antifouling paints, concluding that paints with 7.5% copper were just as efficient as high copper (34.5% cu) paints, regardless of area[8]. According to the EU regulation[11], all biocidal products require a permit and their active ingredients must be approved. The authorization of biocidal products is done nationally and therefore it is important that the boat owner investigates the instructions of the product before appliance. Moreover, some marinas and yacht clubs have their own regulations regarding the usage of anti-fouling coatings on vessels, and they should be taken into consideration by local boaters.

It is recommended for boat owners to record information about the used anti-fouling coating: the brand, type, biocide concentration and date of application.

3.3 Lifting the boat from the water

Lifting the boat from the water protects the hull of biofouling. This can be done by using e.g. boat lifts. The longer the boat is out of the water, the more efficient impact, since drying damages most of the aquatic organisms.

3.4 Cleaning of the boat trailer

The boat trailer has also the potential to spread NIS especially since its surface is rarely treated with any antifouling system**. After the trailer has been in contact with the water or marine environment, it should be inspected thoroughly for biofouling or other organisms present.** Surfaces on trailers that should be inspected include for example: frame, axle, tires, lights, licence plates, wires, cavities and niches. As some parts of the surface might be difficult to inspect visually, it is recommended to feel them out carefully with hands or fingers.

The trailer should be cleaned of all biofouling before transporting it to another water system. This can be done by using similar mechanical cleaning equipment as for boats, e.g. brush, scrape, sponge or pressure washer. It is recommended to give the trailer a rinse with a pressure washer, even if the

[9] Bighiu, M. 2017. Use and Environmental impact of antifouling paints in the Baltic Sea, Academic Dissertation, Stockholm University

[10] Lindgren, J. F., Ytreberg, E., Holmqvist, A., Dahlström, M., Dahl, P., Berglin, M., Wrange, A-L. & Dahlström, M. 2018. Copper release rate needed to inhibit fouling on the west coast of Sweden and control of copper release using zinc oxide, *Biofouling* 34: 453–463

[11] Regulation (EU) No 528/2012

fouling rate is low, since several species are not visible to the naked eye. It is also recommended to let the trailer dry before transporting it to a new waterway.

The cleaning of the boat trailer should be taken very seriously, since it is widely acknowledged that trailers represent a significant vector for NIS-introductions[12]. There is a risk with trailers because they can be transported overland large distances within and perhaps outside of the Baltic Sea area. It is especially important to remove snagged weeds where some NIS can be attached in large numbers. For example, legislations to prevent secondary introductions of the zebra- and quagga mussel are in place in some states of the US, enforcing prevention programs and regulations. These very often include managing overland pathways, to which trailers are included[13].

4 KEEP RECORD OF ANTIFOULING STRATEGIES AND REPORT NIS

Whether you use mechanical cleaning, anti-fouling coating or other practices to keep the vessel clean, it is recommended to keep record of the management type, schedule and plans. Destinations and voyages are also recommended to be recorded in the logbook in case of a severe NIS outbreak.

Recommended records include:

1. Type of antifouling used (paint, Ultrasonic device etc.)
    - Paint: brand, type, biocide concentration, date of application
2. Hull cleaning (how often, which methods used)
3. Voyage destination and route (including different marinas visited in country/area)
4. Mooring duration at specific marinas (hours)

Contact local environmental authority if you confront an unknown NIS. Note its location and if possible, remove the organism for conservation and/or photograph the organism.

[12] Rothlisberger, J. D., Chadderton, W. L., McNulty, J. & Lodge, D. M. 2010. Aquatic Invasive Species Transport via Trailered Boats: What is Being Moved, Who is Moving it, and What Can Be Done, *Fisheries Magazine* 35: 121–132
[13] California Department of Fish and Wildlife, https://www.wildlife.ca.gov/Conservation/Invasives/Quagga-Mussels, accessed 6.11.2019