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NORA moving forward: Developing an oyster restoration network in Europe to support the Berlin Oyster Recommendation

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Abstract

1. The Native Oyster Restoration Alliance (NORA) supports the protection and ecological restoration of the native European oyster, *Ostrea edulis*, and its habitat across its current and historical biogeographical range. NORA works to overcome barriers to the conservation, restoration, and recovery of the European oyster by providing a platform for the NORA community to collaborate and participate in knowledge exchange. NORA seeks to support responsible restoration practice, in compliance with biosecurity and sustainability.
2. Against this background, the NORA community formulated a series of specific recommendations, the Berlin Oyster Recommendation, to support native oyster restoration by developing and applying best practice with the aim to recover healthy and resilient marine ecosystems. In combination with the Standards for Ecological Restoration (SER) and the Restoration Guidelines for Shellfish Reefs, the Berlin Oyster Recommendation is a relevant tool for successful and sustainable oyster restoration in Europe.
3. The establishment of NORA working groups will support the implementation and further development of the six corresponding recommendations. Current NORA working groups cover site selection, biosecurity, production, and monitoring. The site selection working group will address the identification of suitable sites for oyster restoration to support policy relevant decision making and the conservation, reinforcement, or reintroduction of native oysters. The biosecurity working group will develop biosecurity guidelines for native oyster restoration in Europe. The production working group will assess the potential of standards for seed oyster production and supply in order to enhance production appropriate for restoration purposes. In close collaboration with the Native Oyster Network – UK & Ireland (NON), the monitoring working group will produce a monitoring guidelines handbook to provide metrics and methods that will be suitable across the range

of *O. edulis* projects in Europe for the documentation of restoration success and ecosystem recovery.
4. The Berlin Oyster Recommendation was examined and interpreted by NORA experts in the context of the further development of joint guidelines for the practice of successful and sustainable native oyster restoration.

KEYWORDS
ecological restoration, Native Oyster Restoration Alliance, Ostrea edulis

1 | INTRODUCTION

The Native Oyster Restoration Alliance (NORA) is a growing network of professionals working in science, technology, nature conservation, restoration, commercial aquaculture, and policymaking who recognize the importance of the habitat created by the native European oyster, *Ostrea edulis*, and the benefits of restoring oyster habitat throughout its historical range (Pogoda et al., 2019). Native oyster populations have dramatically declined or disappeared in most European waters. The species and the habitat it provides are listed under the Convention for the Protection and Conservation of the North-East Atlantic and its resources (OSPAR) as threatened and/or declining (OSPAR, 2008, 2013), and biogenic reefs are protected under the EU Habitats Directive (92/43/EEC; Habitats Directive, 1992). The motivation to restore native oysters arises both from a recognition of the direct and indirect biodiversity value associated with the oyster and the habitat that it forms, respectively, and from a recognition of the oyster as a keystone species with wide-ranging potential for ecosystem functions and services (Figure 1). The founding purpose of NORA was to facilitate the exchange of knowledge and to provide a forum for open dialogue regarding transboundary issues, in order to overcome barriers to the wider uptake and successful implementation of oyster restoration in Europe. NORA is a dynamic network open to a variety of stakeholders. The mission statement provides a formal statement of aims and values that can be applied by the NORA community and implemented via NORA working groups. Over the first 2 years of NORA, since the Berlin Oyster Recommendation was drafted (Pogoda, Brown, Hancock, & von Nordheim, 2017; Pogoda et al., 2019), the structure and aims of NORA have been developed further and clarified. Growing beyond the initial ambition of facilitating information exchange between projects and practices in Europe, a clear interest in the further development of joint guidelines for the practice of native oyster restoration was indicated during NORA 2 in Edinburgh 2019. We seek here to outline these developments.

2 | NORA MISSION STATEMENT

The Native Oyster Restoration Alliance (NORA) supports the protection and ecological restoration of the native European oyster, *O. edulis*, and its habitat in areas of its current or historical distribution. NORA works to overcome existing barriers to the conservation, restoration, and recovery of the European oyster by providing a platform for the NORA community to collaborate and participate in knowledge exchange. NORA seeks to support responsible restoration practice, in compliance with biosecurity and sustainability.

3 | NORA COMMUNITY

Active knowledge transfer has been established within the growing NORA community, which connects institutions, experts, and practitioners from research, nature conservation, and commercial production, as well as ecological consultants, policy advisors, and local stakeholders (see www.noraeurope.eu). There are annual meetings to present results, to discuss and exchange experiences between active restoration projects and oyster producers, and to increase cooperation between them. The community is represented via the advisory board and will collaborate on defined topics in specific working groups. In addition, the NORA Secretariat maintains communications, organizes conferences, and coordinates the activities of the working groups.

FIGURE 1 The native European oyster, *Ostrea edulis*. As an ecosystem engineer and an ecological keystone species, it provides a range of ecosystem functions and services

3.1 | Advisory Board

Following the successful funding of a NORA Secretariat, a NORA Advisory Board was established to represent a cross section of the European countries and marine environments where restoration is being implemented, as well as respective expertise from marine policy, conservation, research, and the oyster production industry. The Advisory Board seeks to steer and inform the work of the Secretariat in supporting the wider NORA community.

3.2 | Working groups

At NORA 1 in Berlin 2017, several themes were identified as key knowledge gaps and immediate action items. These were expressed both in the Berlin Oyster Recommendation (Pogoda et al., 2017, 2019) and through the establishment of working groups that address the implementation and further development of the six corresponding recommendations (Figure 2). Current working groups are site selection (addressing recommendations 2, 3, 4, and 6), biosecurity (addressing recommendations 1, 3, 4, 5, and 6), production (addressing recommendations 1, 3, 4, and 6), and monitoring (addressing recommendations 4, 5, and 6).

3.2.1 | Site selection working group

The site selection working group proposes to engage closely with marine nature conservation policy and local stakeholders to identify specific challenges that impede the designation of restoration sites on local, regional, and European scales. This includes producing an inventory of current *O. edulis* habitats in Europe and, simultaneously, defining their respective statuses. It is the intention for the working group to provide habitat maps with suitable sites for environmental regulators and relevant stakeholders to consider modifications to current protection levels or management that will allow the conservation, reinforcement, or reintroduction of native oysters. Restoration suitability maps will also allow the potential of large-scale transborder projects, for which international collaboration is of relevance, to be assessed.

3.2.2 | Biosecurity working group

The biosecurity working group will produce and provide biosecurity guidelines for native oyster restoration in Europe. These will focus on different aspects and phases of practical restoration action, such as seed oyster production and substrate translocation, and in general on the prevention of the further distribution of *Bonamia* and other marine pathogens, diseases and invasive species. As NORA includes different marine environments, such as estuaries, coastal waters, and offshore areas, all known diseases will be considered as well as the anticipation of unexpected diseases or invasive species, potentially driven by climate change and elevated sea temperatures. The working group will identify existing biosecurity protocols and, where necessary, translate and adapt them for the ecological restoration of *O. edulis*. Furthermore, specific monitoring metrics will be defined to ensure optimum biosecurity standards are maintained.

3.2.3 | Production working group

The production working group compiled a comprehensive list of issues and limitations encountered in *O. edulis* hatcheries and breeding ponds. A combination of development, adaptation, and upscaling of the various existing production techniques and structures is necessary to increase production into the many millions of oysters that would be required for extensive and international restoration of

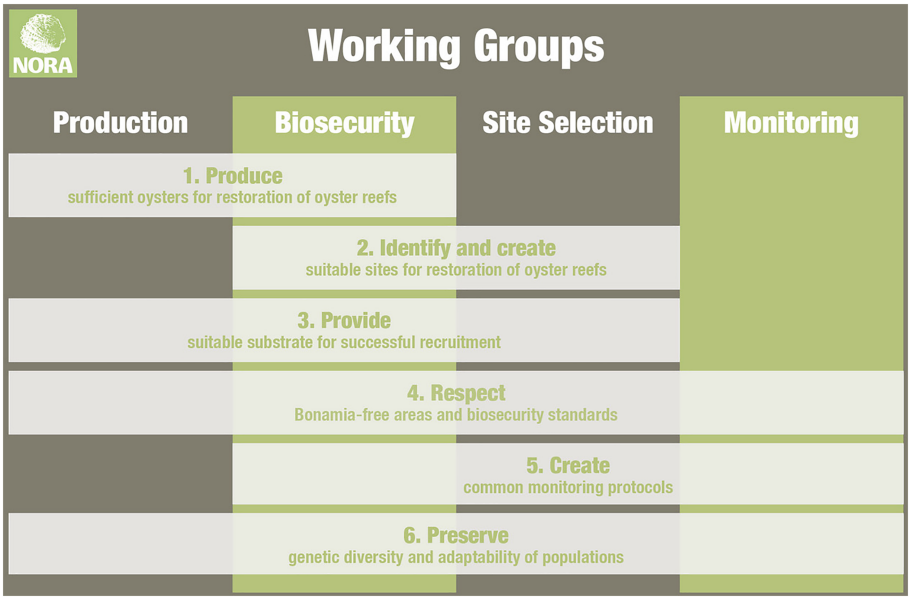

FIGURE 2 Native Oyster Restoration Alliance (NORA) working groups addressing the six corresponding recommendations of the Berlin Oyster Recommendation

recruitment-limited *O. edulis* habitats in Europe (e.g. Colsoul et al., 2020; Westby, Geselbracht, & Pogoda, 2019). Suggested measures include rearing protocols, interactions with wild populations, spatting pond best practice, water quality, specific pathogen-free (SPF) production, and certification, amongst others. The group will focus on the further inclusion of relevant stakeholders and provide support for practical exchange and collaboration. The working group will assess the potential of biosecurity and genetic diversity standards for seed oyster production and supply to enhance trust in restoration using seed, especially in areas where the species is being reintroduced.

3.2.4 | Monitoring working group

In close collaboration with the Native Oyster Network – UK & Ireland (NON), the monitoring working group will produce a monitoring guidelines handbook for native oyster restoration in Europe. This handbook aims to support restoration practitioners, academics, community groups, and government agencies by recommending monitoring metrics and methods that will be suitable across the range of *O. edulis* restoration projects in Europe. This handbook seeks to provide the necessary additional methods for a European context in addition to those proposed for US oyster species by Baggett et al. (2014). The handbook is a key step in supporting consistent and comparable data collection across all European projects, which will facilitate learning what does or does not work, how to define restoration success, and how to support all ecological restoration projects with a range of practical monitoring methods, from the most simple to the state of the art.

4 | INTERPRETATIONS AND IMPLICATIONS

In combination with the Society for Ecological Restoration (SER) International Principles and Standards for the Practice of Ecological Restoration (Gann et al., 2019) and the Restoration Guidelines for Shellfish Reefs (Fitzsimons, Branigan, Brumbaugh, MacDonald, & zu Ermgassen, 2019), the Berlin Oyster Recommendation (Pogoda et al., 2017, 2019) is a relevant tool for successful and sustainable native oyster restoration in Europe. Its practical implementation revealed requests by stakeholders (e.g. within project planning and permitting) for clarification and specific interpretation of some wording within the original document. We provide clarifying guidance as follows.

4.1 | Recommendation 1: Produce sufficient seed oysters for restoration of oyster reefs

The Native Oyster Restoration Alliance seeks to achieve a substantial, stable, and sustainable supply of seed oysters in compliance with ecosystem health and biosecurity, as well as genetic diversity standards, that meet the requirements of ecological restoration. Spat collection in the wild remains a relevant production technique for local restoration; however, the translocation of individuals between distant geographical regions should be avoided to prevent importing pathogens or invasive non-native species. This also reduces the potential admixture of genotypes poorly adapted to local conditions and genetic homogenization. European hatcheries and breeding ponds currently produce only a fraction of the spat required for present and future habitat restoration and marine conservation. NORA has identified the need for precise definitions of spat demand for restoration at local and pan-European levels, both quantitatively and qualitatively. The integration of producers and practitioners in ecological restoration efforts is therefore an important process to indicate whether supply can be achieved through hatcheries and breeding ponds with a significant increase in production (Colsoul et al., submitted). In the context of ecological restoration, NORA seeks to define:

- expectations in terms of the genetic diversity of seed oysters;
- expectations in terms of the certification of pathogen-free production;
- expectations in terms of products from hatcheries and breeding ponds, e.g. spat on shells, spat on reef modules, and single seeds; and
- other criteria to be considered in the production process of seed oysters for ecological restoration.

4.2 | Recommendation 2: Identify and create suitable sites for the restoration of oyster reefs

The Native Oyster Restoration Alliance seeks to support ecological restoration as outlined in the mission statement, which refers to the recovery of degraded or destroyed habitats. A number of the current strongholds for native oysters in Europe remain tightly coupled to sustainable usage by coastal communities, wild shellfish fisheries, or managed mariculture of some kind, as well as to remote locations and regions with little cultural history of oyster exploitation (e.g. Sweden). As a result of continuing disturbance and removal, oyster fishery-linked restoration involves potential challenges but also provides several unique benefits: the engagement of knowledgeable and highly skilled local stakeholders who support *O. edulis* recovery; access to and knowledge of local breeding populations from which to develop restoration; and a viable and tangible link to ecologically sustainable food production that can be communicated to local communities and funders. This is in addition to the many other potential ecosystem functions and services that *O. edulis* can provide. The utilitarian conservation model is not new, and although there are some controversies associated with this model, with appropriate conservation management it is associated with some of the most successful habitat recovery and expansion programmes globally, in both terrestrial and aquatic systems (Wiens & Hobbs, 2015). Accordingly, NORA offers a platform to address these challenges and identify potential synergies. There is, however, a strong interest across the NORA community to

invest in ecological restoration where there is no direct connection to a fishery to gain major ecosystem service benefits from the recovery of the habitat.

4.3 | Recommendation 3: Provide suitable substrate for successful recruitment

In substrate-limited areas, the successful restoration of the European oyster depends on the availability of suitable substrate to increase the recruitment of oyster larvae (Westby et al., 2019). Using bivalve or other mollusc shells as settlement substrate is a common practice, but the movement or translocation of any kind of substrate poses the risk of importing pathogens or invasive non-native species and should be operated with full biosecurity precautions. Moreover, obtaining such shell in suitable quantities is both financially and logistically challenging for upscaling restoration efforts. Substrate sources should fulfill sustainability criteria, e.g. using abundant native shell material from seafood processing and not using damaging methods of shell extraction. NORA will also seek to discourage *O. edulis* shell mining for other usages, e.g. feed supplements for farming. The use of alternative substrates such as stone and gravel should consider the environmental impact and the potential of nature-based or nature-orientated materials. Such materials may be as suitable as shell for restarting the natural regeneration of oyster populations (Colsoul et al., 2020). NORA will seek to support restoration projects through developing a network to identify potential sources of, and recommendations for treatment of, any material to be used for restoration.

4.4 | Recommendation 4: Respect *Bonamia*-free areas and apply biosecurity standards

Developing and achieving restoration goals whilst avoiding the spread of *Bonamia ostreae* and potential threats from *Bonamia exitiosa* (Helmer et al., 2020; Sas et al., 2020) is of prime concern, and requires biosecurity codes of conduct and recommended best practice. To enable this, the NORA working group will gather current best practice, research, and expertise to develop pan-European standards for biosecurity in native oyster restoration projects. These standards will be a part of a restoration guide to address key knowledge gaps in launching native oyster habitat restoration projects in Europe, as an annex to the global Restoration Guidelines for Shellfish Reefs (Fitzsimons et al., 2019). Alongside biosecurity information, the guidelines will provide codes of conduct and recommendations for:

- identifying disease and invasive species threats;
- biosecurity of translocation, including an auditing form;
- disinfection procedures; and
- shell curing and sterilization.

Biosecurity standards are essential for excluding negative impacts of oyster restoration through the introduction of invasive non-native species and disease. It is recommended that all NORA community projects therefore adopt and implement the methods proposed in the guidelines.

4.5 | Recommendation 5: Create common monitoring protocols

The NORA community is collaborating to provide a guidelines handbook to monitor and evaluate the performance of oyster habitat restoration in Europe. These guidelines will build upon the work of Baggett et al. (2014) and provide recommendations of both metrics and methods to be used in nearshore as well as offshore restoration projects, and include subtidal, intertidal, and cage-based monitoring.

- Common components within monitoring protocols are essential for determining European-level restoration success, as they ensure a minimum standard of monitoring that allows comparison between projects (Fitzsimons et al., 2019, 2020).
- It is recommended that all NORA community projects therefore adopt the methods and metrics proposed in the guidelines handbook.
- The European monitoring guidelines will propose universal oyster project and environmental metrics, designed to provide a minimum baseline of metrics that should be monitored in all projects.
- European-relevant ancillary monitoring considerations will also be recommended where funding and expertise allows for the implementation of these metrics and methods.
- The European handbook will also provide restoration goal-based metrics designed to enable an assessment of the ecosystem functions and services provided by oyster restoration projects.

4.6 | Recommendation 6: Preserve genetic diversity and adaptability of populations

In order to preserve the maximum adaptive potential within the species and to preserve any local adaptation within populations of *O. edulis*, NORA seeks to ensure the preservation of the genetic diversity of restored populations, particularly as hatchery-produced seed is likely to be used on a large scale. The biological characteristics of spermatozoa (which cluster in spermatozeugmata; Suquet, Queau, Le Grand, Ratiskol, & Pouvreau, 2017) and the brooding of larvae make this species particularly sensitive to a loss of diversity when produced in hatcheries. The adaptability of the resulting populations to current and future changes of their environment strongly depends on maintaining genetic variability. An estimation of effective population size of seed produced in a hatchery or breeding pond based on genetic markers (Lallias, Boudry, Lapègue, King, & Beaumont, 2010) is therefore needed to avoid inbreeding and the eventual depletion of genetic variability when wild populations are enhanced with captive-reared oysters (i.e. the Ryman–Laikre effect). This is of prime importance for the restoration of extinct populations; however, the effect of hatchery seed supplementation on the effective population size of recipient wild populations is likely to be low (Gaffney, 2006).

The remaining natural populations are genetically differentiated, showing a pattern of isolation by distance (Diaz-Almela, Boudry, Launey, Bonhomme, & Lapegue, 2004) and high effective population sizes (Vera et al., 2016). It should also be noted that the use of single-recruitment wild cohorts may also result in genetic sweepstake effects (Hedgecock et al., 2006; Taris, Boudry, Bonhomme, Camara, & Lapegue, 2009). Connectivity between populations should be promoted as it also contributes to maintaining global genetic diversity. The use of local broodstock is recommended in order to preserve any current genetic structure that results from neutral and potentially selective evolution of natural populations. Transplanting individuals between distant geographical regions should be avoided to prevent the eventual introgression of genotypes that might be less well adapted to local conditions.

5 | CONCLUSION

The Native Oyster Restoration Alliance is a dynamic network of a wide range of actors that provides the combined focus on current and future restoration-related challenges. Hence, it seeks to adapt and develop related guidelines for practitioners, and to support collaboration and communication throughout the network. Additional working groups, such as the two designated NORA working groups focusing on historical ecology and on outreach will also strengthen the network and its benefits for ecosystem recovery in the future. In the long term, NORA seeks to facilitate the recovery of native oyster habitat and associated services on an ecosystem scale in Europe.

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