EUROPEAN NATIVE OYSTER HABITAT RESTORATION HANDBOOK

UK & IRELAND

NOVEMBER 2020

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NATIVE OYSTER NETWORK UK & IRELAND

Environment Agency

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The Native Oyster Network is a community of academics, conservationists' oystermen and NGOs who are working together to restore self-sustaining populations of native oysters. The Network was established in 2017 by the Zoological Society of London and University of Portsmouth. The Native Oyster Network is supported by the John Ellerman foundation. Website: **https://nativeoysternetwork.org/**

UNITED NATIONS DECADE ON ECOSYSTEM RESTORATION 2021-2030

This handbook supports the goals of the UN Decade on Ecosystem Restoration (2021-2030), find out more about this UN Decade here: **https://www.decadeonrestoration.org/**

The ecological and societal benefits of restoring marine habitats has become more widely recognised over the past decade. This has meant that marine habitat restoration has become a priority for the general public and government agencies.

European native oysters in Quiberon Bay, France. Photo: Stephane Pouveru.

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CONTENTS

EXECUTIVE SUMMARY

This European Native Oyster Habitat Restoration Handbook aims to provide foundational and practical guidance on the restoration and conservation of native oysters (*Ostrea edulis*) and native oyster habitat across the UK and Ireland. The guidance outlined throughout the Handbook is also of relevance to projects across the native oyster's biogeographic range.

The Handbook includes an introduction to native oyster restoration, information about starting a restoration project, current methods of restoration in practice, biosecurity recommendations and an outline of how to effectively communicate a restoration project. This publication has been written as an *Ostrea edulis* specific annex to the "Global Restoration Guidelines for Shellfish Reefs" (Fitzsimons *et al.* 2019), providing a detailed overview of information relevant to the restoration of the European native oyster, whilst adhering to international standards of ecological restoration. Produced by the Native Oyster Network – UK & Ireland in collaboration with the European Native Oyster Restoration Alliance, this handbook aims to be accessible for both small scale, feasibility projects, as well as larger, more established projects, providing access to the knowledge captured within the Networks.

Globally, an estimated 85% of oyster reefs have been lost, making oyster reefs one of the world's most imperilled marine habitats. The native oyster is now functionally extinct in many areas around Europe, having declined by over 90%. As we enter the UN decade on "Ecosystem Restoration" (https://www.decadeonrestoration.org/) and 'Ocean Science for Sustainable Development' 2021-2030, we recognise humanity's dependence on healthy, robust and functioning marine ecosystems. With the challenge of a climate crisis and faced with a growing world population, we need to protect and restore ecological systems that provide nature-based solutions and resilience to these challenges.

To reverse the current trajectory of the European native oyster towards extinction, and restore this once abundant coastal habitat with the many ecosystem services it provides, requires the UK and European community to substantially increase the ambition, scale and number of restoration projects.

Additional Network publications including, "European Native Oyster Biosecurity Guidelines" and "European Native Oyster Monitoring Handbook" will be available on the Native Oyster Network and Native Oyster Restoration Alliance websites here: https://nativeoysternetwork.org/resources/ and at https://noraeurope.eu/nora-publications/.

HANDBOOK CONTEXT

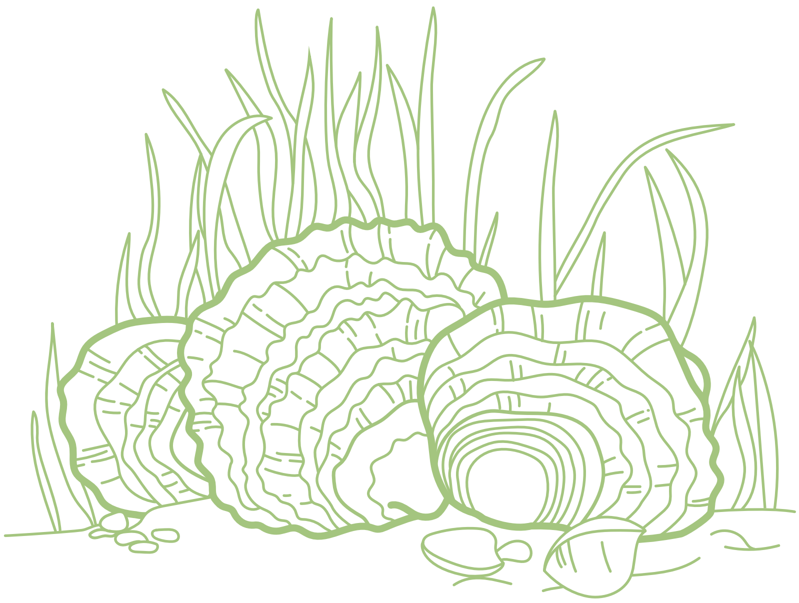
Marine habitat restoration

Over the past decade, the field of marine habitat restoration in Europe has grown significantly. This is due to increased awareness of the extent of the degradation of our valuable marine habitats, including native oyster reefs, salt marshes, seagrasses and kelp, combined with our ability to identify the value that our marine habitats provide.

The UK Government's 25 Year Environment Plan commits to 'securing clean, healthy, productive and biologically diverse seas and oceans' and European directives (e.g. Natura 2000) recognise reefs as a priority habitat.

There are two different approaches to restoring marine-habitat; reducing pressure on systems and allowing natural recovery or taking positive action to restore marine habitats and species. This handbook is focusing on the latter. The production of this handbook was commissioned by the Environment Agency, as part of the cross-agency Restoring Meadow, Marsh and Reef (ReMeMaRe) initiative. The vision of the initiative is for restored estuarine and coastal habitats that benefit people and nature, with a mission to restore at least 15% of our priority habitats along the English coast by 2043 in line with the Defra 25 Year Environment Plan time frame.

This handbook will be part of a quartet of restoration guidelines, along with those developed for salt marsh and seagrass habitats, and for the beneficial use of dredged sediments.



Foreword

by Roger Proudfoot, Estuary and Coast Planning Manager for the Environment Agency, and Chair of the UK Healthy, Biologically Diverse Seas Evidence Group.

The virtual functional extinction of the native oyster from UK waters shows the dramatic impact that our voracious appetite for seafood has had on the marine environment. Whole seabed habitats that supported a wide range of species providing untold ecosystem services, that we historically benefitted from, have been virtually destroyed in a century.

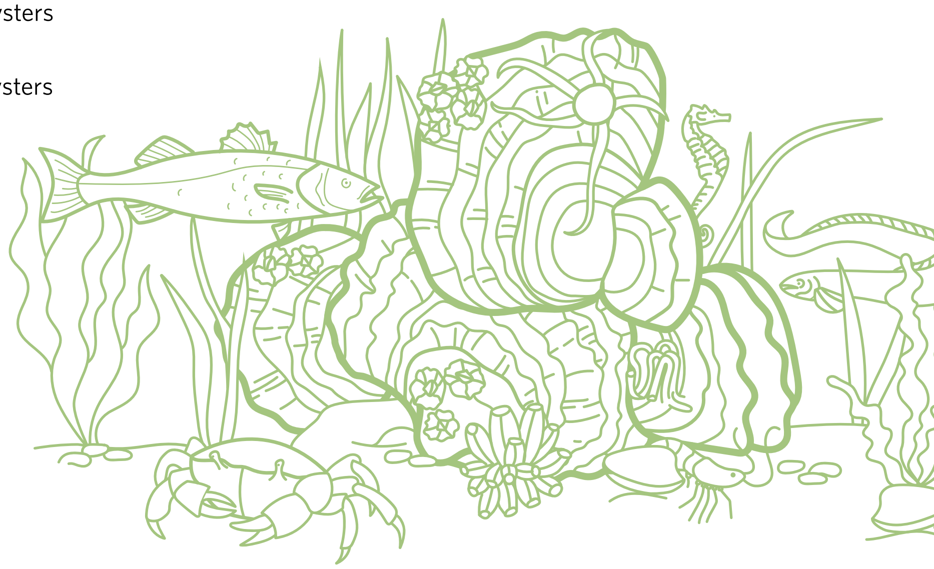
A keystone species whose reef structures developed over thousands of years wiped out in a relative instant. We know this from historical studies of shellfish harvesting that have charted this decline and our current monitoring of the seabed that struggles to find functioning native oyster beds let alone anything looking like an native oyster reef.

We know that oysters provide wide ranging benefits not least the food source that they can provide and the biodiversity benefits that their reef structures can create. We want to restore the species and these benefits, and this guidance sets out how to do that in practice. An enthusiastic collaboration of scientists working in the field, the UK & Ireland Native Oyster Network and the Native Oyster Restoration Alliance, supported by the Environment Agency has brought this guidance together and hopefully represents an important first step in this species recovery. Restoration is not without its challenges and the guidance sets out how to go about meeting these head on whether it is the biosecurity that is needed to restore the oysters in our seas or the way in which we communicate our projects to stakeholders to get their buy-in. All the latest knowledge is captured in this one manual.

Thank you to all our collaborators and we look forward to seeing the guidance being used to generate more native oyster restoration projects throughout the UK and Ireland and the first signs of nationwide recovery of this magnificent mollusc!

GLOSSARY

- **Abiotic:** the non-living factors in an environment that will influence oyster populations, such as sunlight, temperature, wind patterns, tides, currents and precipitation.
- **Allee effect and depensation:** when a decrease in the breeding population results in the reduction in production and survival of offspring.
- **Baseline:** the condition of an area or native oyster population prior to an activity taking place.
- **Biogenic reef:** a three-dimensional structure made of living organisms, often colonised by other species, that protrudes above the seabed.
- **Biotic:** factors associated with, and interactions between, living organisms.
- **Blue carbon:** refers to the carbon stored in marine ecosystems.
- **Broodstock:** the group of sexually mature native oysters used in aquaculture or in restoration projects for the purpose of reproduction and larval supply.
- **Cultch:** any substrate, such as rock or shell, that a juvenile native oyster is attached or may attach to.
- **Donor site:** a location from which adult or juvenile oysters are removed and translocated to a recipient site.
- **Ecosystem service:** the benefits provided by native oysters to humans.
- **Epibiota/Epibiont:** an organism or group of organisms that live on the exterior shell of native oysters.
- **Gametogenesis:** the process in which cells undergo meiosis to form gametes (sex cells).
- **Geogenic origin:** reefs formed by non biogenic substrata.
- **Oyster reef:** the biogenic concretions arising from the seabed formed by live and dead native oysters, providing a habitat with high surface complexity.
- **Recipient site:** a location to which adult or juvenile oysters are translocated from a donor site.
- **Recruitment:** the settlement and survival of native oysters such that they contribute to the overall population.
- **Recruitment-limited environment:** a body of water or restoration area that lacks sufficient broodstock to produce larval supply needed to populate existing or planned reefs.
- **Reference ecosystem:** an existing or historical native oyster ecosystem that is considered to best demonstrate the desired attributes of naturally occurring populations prior to degradation, and that enables the desired end point of restoration projects to be determined.
- **Regulating orders:** allow management rights to designated natural shellfisheries.
- **Seed:** a term commonly used in the shellfish industry to describe oysters added to a restoration site to begin or augment a population.
- **Settlement:** the process whereby native oysters in the larval stages settle out from the water column onto suitable substrates and undergo metamorphosis, permanently cementing themselves to the surface.
- **Several orders:** allow legal ownership of certain named shellfish species in a private shellfishery.
- **Shell budget:** the quantification of the relationship between the accretion and loss of shell substrate.
- **Spat:** the term used to describe juvenile oysters that have attached to a hard substrate following the free-swimming larval phase.
- **Spat-on-shell:** juvenile oysters that have settled, naturally or intentionally in aquaculture settings, onto the empty shells of the same or another shellfish species.
- **Substrate:** the hard material, often shells, small stones or large rocks, that juvenile native oysters are able to settle upon. This can be naturally occurring or intentionally deployed to encourage recruitment settlement.
- **Substrate-limited environment:** an area that lacks the required settlement substrate (cultch) to allow for substantial settlement of native oysters larvae from the water column.
- **Translocation:** the movement of populations of native oysters, adult, juvenile or larval, from one location to another that could be considered a different body of water.



This publication is intended to provide foundational information to serve as a useful starting point for native oyster habitat restoration.

Native oyster photographed by diver in Swanage, UK. Photo: Paul Naylor, Marine Photo.

CHAPTER 1
NATIVE OYSTER RESTORATION: AN INTRODUCTION

CHAPTER AUTHORS

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KEY SUMMARY POINTS:

- **Native oyster reefs are among the most threatened marine habitats in Europe; in the UK and Ireland populations have declined by 95%. With this decline we have lost the ecosystem services and functions provided by the habitat.**
- **In a European context, a comprehensive definition of native oyster reefs is lacking. However, a definition of the habitat is critical in ensuring that there is universal understanding of the aims of habitat restoration.**
- **The significant decline of native oyster populations across Europe has highlighted that active intervention is required for recovery of this species from the brink of extinction.**

INTRODUCTION

The field of native oyster *Ostrea edulis* restoration in the UK and Europe has grown in momentum over the past ten years. This increased momentum has resulted from a recognition that our current management systems are maintaining a depleted environment. Native oyster restoration in Europe is at an early stage in comparison to countries such as the United States and Australia; practitioners and restoration networks are seeking to gain knowledge and facilitate information sharing to build upon our current efforts.

Restoration practitioners in the **UK and Europe are striving towards the establishment of resilient and self-sustaining populations of native oysters**, which in turn provide clean water, healthy fisheries, plentiful biodiversity and reignite our cultural heritage with the species. It is anticipated that this handbook will assist practitioners in establishing and developing both new and existing restoration projects.

This introductory chapter provides information about the decline of the species, formation of native oyster reefs, why native oysters should be restored, the ecology and biology of the species and the current restoration efforts across the UK and Europe.

THE DECLINE OF THE NATIVE OYSTER

Native oysters have been cultivated and fished around the coastline of the United Kingdom for millennia. Their ability to survive out of water for extended periods and to be extracted from one location to be re-laid on another, meant that during the Roman occupation the trade in oysters stretched from Scotland to Rome. Oyster movements and translocations have continued since, as they continued to be fished, traded, and eaten in both coastal and inland regions. Native oysters once formed vast reefs along the coastlines of Europe, forming a dominant ecological feature of our coastal marine habitat. The Piscatorial Atlas, created in 1883, portrays the known distribution of native oyster reefs around the coast of the UK, English Channel and the North Sea, illustrating just how widespread this habitat was (see Figure 1.1).

Oyster densities in areas new to fishery exploitation appear to have been high. In the 1780s, the 20 mile long reef in the Firth of Forth, Scotland, were estimated to produce as many as 30 million oysters per year, employing up to 60 boats each manned by 5 workers. At a national level, the peak production period for Great Britain's native oyster fishery was the mid-1800s; this was also the period when many major oyster reefs were fast being depleted.

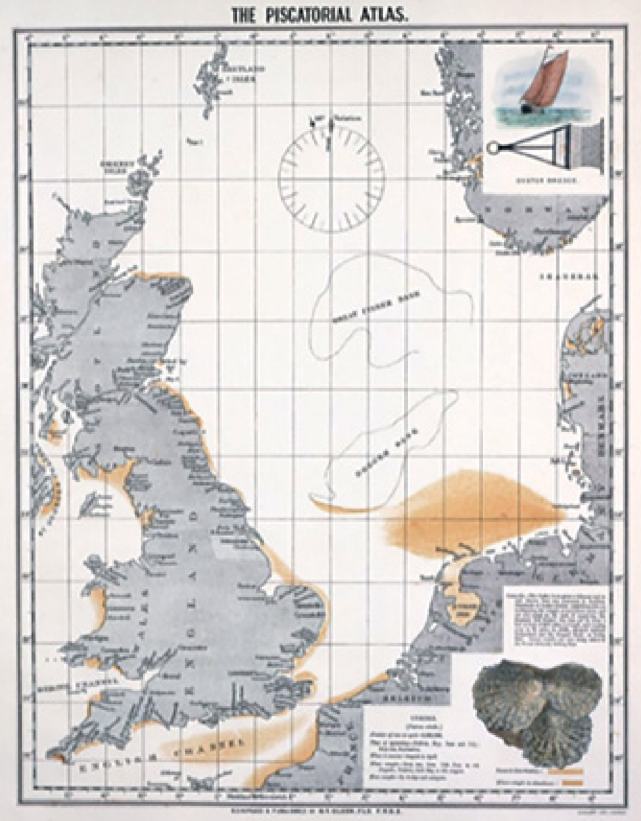


Figure 1.1: Olsen's Piscatorial Atlas of the North Sea 1883, depicting the known populations of native oysters at the time.

One report alleges that, in 1864, 700 million oysters were consumed in London alone. In 1863, the Mumbles oyster fishery in South Wales supported 70-80 local vessels and up to 250 workers dredging for oysters, that could catch up to 20,000 oysters per boat in a single day. In Cornwall during the 1800's, up to 700 fishers targeted oysters in the Fal estuary. These fisheries would have also supported thriving secondary industries such as oyster merchants and boat makers, as well as providing a source of protein for the local population.

Native oyster populations in Europe faced collapse in the mid-1900s due to historical overfishing, habitat loss, pollution, disease, and the introduction of invasive species (see Figure 1.2). Native oyster reproduction, especially on the fringes of the species' natural range, is often sporadic and highly influenced by population density. As populations continued to decline, many became subject to the Allee effect and depensation, meaning that even where fishing pressure was removed, they were unable to recover; with the result that the native oyster became locally and functionally extinct throughout much of its natural range. Native oyster reefs are now among the most threatened marine habitats in Europe; in the UK and Ireland populations have declined by 95%, with remnant populations found in the south east of England, west coast of Scotland and the south coast of Ireland.

NATIVE OYSTER HABITAT

Native oysters are highly gregarious, meaning that oyster larvae prefer to settle where other oysters are present. Oysters require a hard substrate on which to settle, such as shell material, and therefore have the potential to form a structured habitat. Native oyster habitat is known as oyster reefs or beds (hereafter reefs) (see Box 1.1). Native oysters are also able to settle on the shells of other species, stones and woody debris.

Native oyster reefs are formed when large numbers of living oysters and dead shells form an extensive biogenic habitat on the seafloor. Oyster reefs typically form on mixed substrate, in shallow waters less than 10m, although they have been found to depths of up to 80m.

Records of what a 'pristine' native oyster biogenic habitat looked like: how densely oysters were clustered together and the species they supported, are extremely rare for native oysters. Indeed, known and fished beds would have been subjected to some form of physical alteration decades or even centuries before scientific descriptions took place. The descriptions of density that do exist vary widely and almost certainly reflect impoverished populations, for example, in 1877 Möbius stated that "oysters growing together in clumps are rare". An average of 1 live oyster per m^2 was recorded in the Fal oyster fishery in 1924, while just 0.001 live oysters per m^2 were recorded in a relic oyster population in northern Strangford Lough, Northern Ireland. On the other hand, fishery records suggest high densities of oysters were available on new fishing grounds.

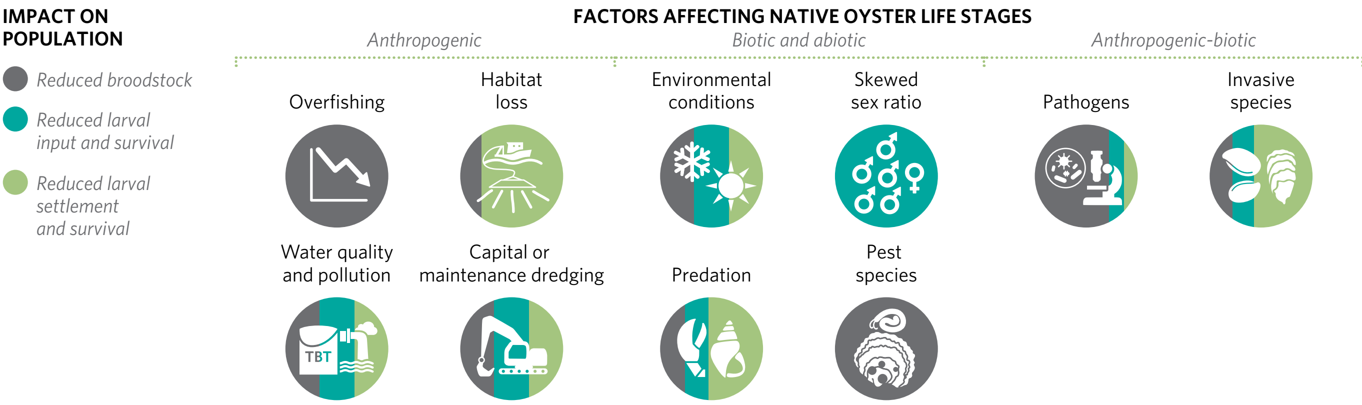


Figure 1.2: Drivers of native oyster decline (adapted from Helmer *et al.* 2019).

Figure 1.3: Image of *Ostrea edulis* reef located along the Bulgarian Black Sea coast. Photo: Dragos Micu (See Todorova *et al.* 2009).

Figure 1.4: *Ostrea edulis* forming reef structures. **Image 1:** *Ostrea edulis* 'clocks' in Strangford Lough, Northern Ireland. Photo: José M. Fariñas Franco. **Image 2:** Intertidal *Ostrea edulis* in Isle of Wight, England. Photo: Andrew Hunt.

Intertidal concretions of native oysters have recently been observed in Scotland, west coast of Ireland and Northern Ireland (see Figure 1.4), providing habitat and refuge for a diversity of organisms, such as juvenile fish, crabs, sea snails and sponges. Reefs of native oysters have also been recorded along the Bulgarian Black Sea coast, Todorova *et al.* 2009 (see Figure 1.3) describe "The reef aggregations forming barriers parallel with the shore between 7 and 23m depth. Individual reefs are massive, erect biogenic structures attaining 7m height, 30-50m length and 10m width and develop on rocky or shelly flat bottoms. Smaller oyster reefs may also occur on rocky offshore reefs or as a sponge-like structure adhering to rocky vertical drop-off faces."

BOX 1.1: WHAT IS A EUROPEAN NATIVE OYSTER REEF?

Given the degraded status of native oyster habitats throughout most of its range, and the lack of historical surveying prior to impacts from the many centuries of oyster fishing in Europe, a comprehensive definition of oyster reefs in the European context is lacking. Yet a definition of the habitat is critical in ensuring that there is universal understanding of the aims of habitat restoration. In the simplest terms, oyster reefs or beds can be defined as a substrate with a veneer of living oysters, providing a habitat with high surface complexity, on a substrate which may be dominated by dead oyster shell. The threshold density and spatial extent of oysters that delineates a reef is not clearly defined, both due to the lack of available baseline, and because such thresholds are universally challenging to define for reefs (see Baggett *et al.* 2014 for further definitions in the U.S. oyster context). OSPAR have defined "oyster beds" as "*Ostrea edulis* occurring at densities of 5 or more per m^2 on shallow mostly sheltered sediments (typically 0–10m depth, but occasionally down to 30m). There may be considerable quantities of dead oyster shell making up a substantial portion of the substratum." It is clear from historical documents that oyster reefs support a distinct associated community of other species, which may in the future also prove useful in defining the habitat. Literature from the US makes a distinction between reefs and beds as a function of height, this is not relevant in the European context where, for example, *Sabellaria alveolata* encrustation formations, which are typically not greater than a few cm in height, are classified as reefs under the EU Habitats Directive.

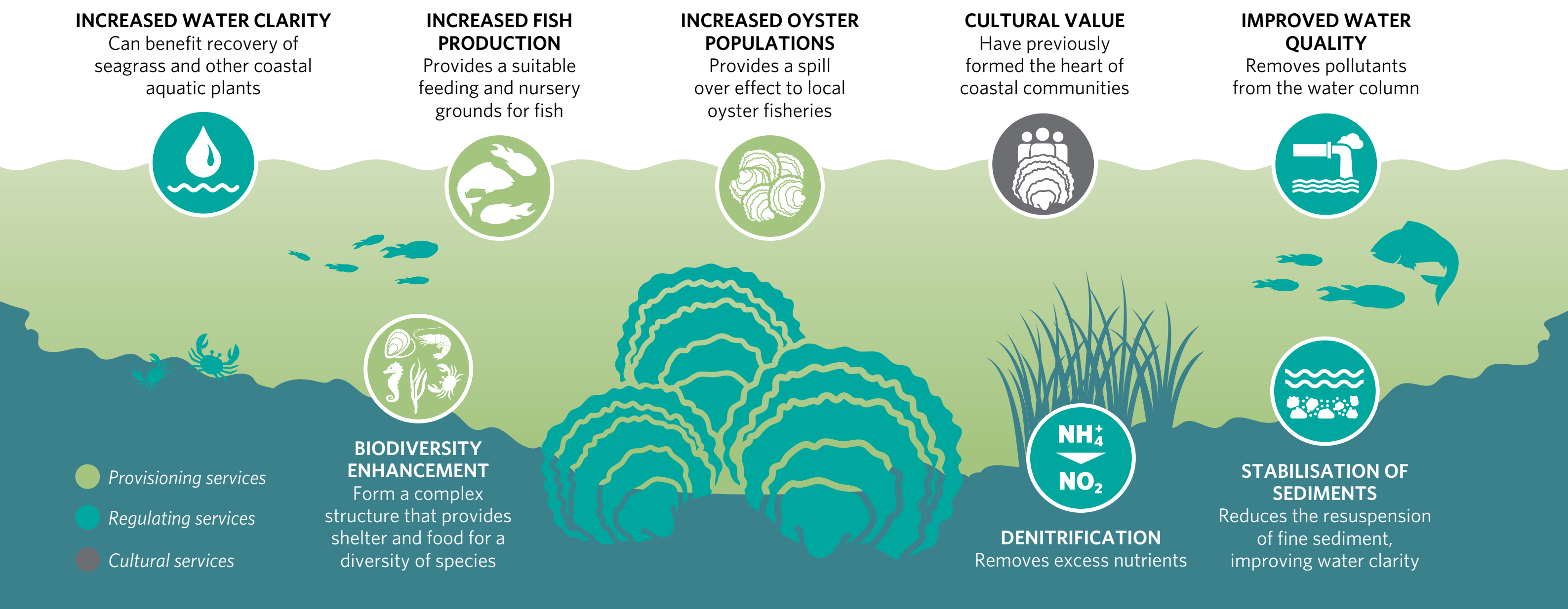


Figure 1.5: Ecosystem services provided by *Ostrea edulis*.

BOX 1.2 EU HABITAT MANUAL DEFINITION OF REEFS

Reefs can be either biogenic concretions or of geogenic origin. They are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions.

Biogenic concretions are defined as concretions, encrustations, corallogenic concretions and *bivalve beds* originating from dead or living animals, i.e. biogenic hard bottoms which supply habitats for epibiotic species.

Joint Nature Conservation Committee (JNCC) Marine Habitat Classification biotope description for '*Ostrea edulis* beds on shallow sublittoral muddy mixed sediment' (SS.SMx.IMx.Ost) also provides a list of the characterising species associated with native oysters (https://mhc.jncc.gov.uk/biotopes/jnccmncr00000788).

WHY RESTORE NATIVE OYSTERS?

The significant decline of native oyster populations across Europe has highlighted that active intervention is required for the recovery of this species from the brink of extinction. Interest in native oyster restoration started to gain momentum over the past decade. Conservation actions range from protecting extant populations from disturbance, to restoring the species and the habitat they create to areas from which they have been extirpated.

There has also been a growing understanding and recognition of the ecosystem service benefits provided by native oysters when in abundance (see Figure 1.5). Oysters filter particles from the water column. A single oyster can filter up to 200 litres of seawater per day, which can significantly improve water quality and clarity. Oysters can also assimilate excess nutrients and promote microbial activity in the underlying sediments to denitrify nitrates and nitrites, thus removing them from the water body. The unique three-dimensional habitats created by native oysters support a higher biodiversity and biomass of species than the surrounding sediment/seabed. Oyster reefs can increase fish production by providing a protective nursery ground for juveniles, that acts as a refuge from predation and provides a source of food through increasing the abundance of prey. Protected restoration areas can provide spill-over of larvae that may seed and support sustainable fisheries.

BOX 1.3: CARBON SEQUESTRATION OF OYSTER HABITATS

Quantification of carbon deposition or sequestration by oyster habitats is extremely challenging. To fully understand the role of the native oyster in carbon stabilisation, the routes of carbon loss and gain must be identified. Quantification of the balance between the two enables us to begin to understand the full shellfish carbon picture. Oysters respire, releasing carbon, while the biochemical process of calcification both releases carbon and leads to the capture of carbon in the calcium carbonate shell. In common with other bivalve shellfish, the native oyster filter feeds by removing particles from the water column, these are digested and deposited to the seabed as either faeces or pseudofaeces – both of which contain carbon. The native oyster has the capacity to enhance the deposition of carbon, potentially trebling carbon downdraw through biodeposition alone (compared to deposition rates in the absence of oysters). Changes in flow as a result of the 3D structure of an oyster reef would be expected to induce passive sedimentation of particles from the water column, as demonstrated for other bivalve species.

Through biodeposition and passive sedimentation carbon may be stabilised, and along with shell assimilation, integrated into the oyster reef as it grows over time. Further to these real-time factors a number of long-term processes must also be considered such as erosion, microbial activity and bioturbation. Understanding all parts of the carbon picture for the native oyster is key to determining the value of habitat restoration in terms of carbon sequestration.

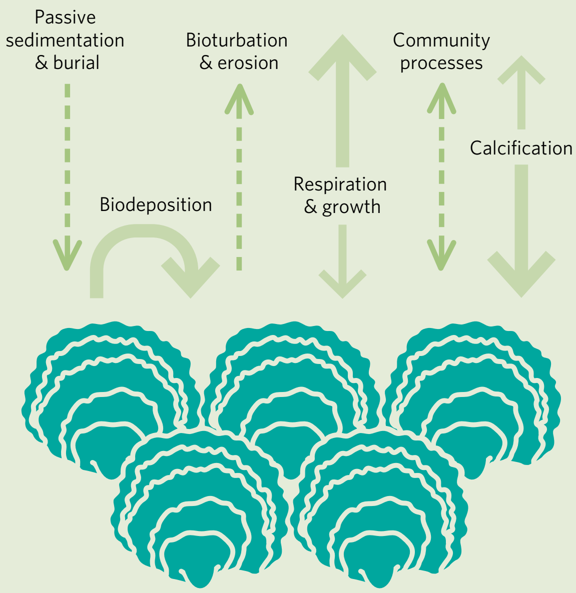


Figure 1.6: Conceptual carbon budget of *Ostrea edulis*. Directionality of arrows indicates carbon deposition (downward) or carbon release (upward), arrow size gives qualitative indication of relative size of carbon flow. (Figure modified from Lee *et al.*, 2020).

ECOSYSTEM SERVICE KNOWLEDGE GAPS

Despite the growing recognition of the ecosystem service benefits of restoring native oysters, and the long history of harvesting and culturing the native oyster, the ecosystem service benefits of this species specifically are poorly quantified (Table 1.1). Identified knowledge gaps include the long-term carbon sequestration capacity of native oyster reefs (see Box 1.3), quantification of nutrient cycling services such as denitrification, phosphate burial and carbon assimilation in shell tissues.

While there are currently no estimates of nutrient loss (denitrification) and sequestration (assimilation in shell and burial) for the native oyster, measurements from the eastern oyster (*Crassostrea virginica*) can provide some insight into the potential scale of this ecosystem service (Table 1.2).

Whilst ecosystem process and function data from comparable species provide us with a tool to better understand the potential ecosystem services and function of native oyster habitat, we still lack datasets specific to the native oyster. Such data is needed to increase confidence in the degree of ecosystem service benefits it may provide.

Table 1.1: Summary of available evidence for ecosystem service provision by a range of different oyster species including, *Ostrea edulis*, *Ostrea angasi*, *Crassostrea gigas* and *Crassostrea virginica*. Evidence relating to *C. virginica* is presented only for comparison and for identifying data gaps. (Table adapted from zu Ermgassen *et al.* 2020).

		OYSTERS			
	Ecosystem services	*Ostrea edulis*	*Ostrea angasi*	*Crassostrea gigas*	*Crassostrea virginica*
Provisioning	Fisheries production/ nursery function	–	–	–	●
	Shellfish harvest	●	●	●	●
	Shell extraction	–	○	–	●
Regulating services	Clearance rate	●	○*	●	●
	In situ evidence of improved water clarity	–	–	–	●
	Coastal protection	–	–	○	●
	Carbon sequestration	–	–	–	●
	Sediment stabilization	●	–	○	●
	Denitrification enhancement	–	–	●	●
Cultural value	Biodiversity	●	○	●	●
	Cultural harvest practices	●	○‡	–	●
	Religious significance	○‡	–	–	–
	Recreational	–	–	–	●

*Clearance rate assessed in larvae only.
‡ Historical.

Table legend:
● indicates strong evidence (multiple peer reviewed studies)
○ indicates some evidence (few studies/local knowledge)
– indicates No Data.

BENEFICIARIES OF NATIVE OYSTER RESTORATION

With native oyster restoration projects now established across Europe, there is growing evidence of the many beneficiaries of restoration (see Figure 1.7).

Oyster restoration is a high conservation priority at the national, European, and global level. Native oysters have been identified as one of the most threatened species that requires conservation action in the UK.

The decline of the UK's native oyster population by 50% over 25 years was instrumental in its classification as a priority species in the UK's Biodiversity Action Plan. This national action plan is part of the UK's contribution to meeting global biodiversity targets set by the UN Convention on Biological Diversity. See Table 1.3 for a breakdown of the native oyster conservation designations in the United Kingdom and Ireland.

Table 1.2: Nitrogen, phosphorus and carbon annual removal rates for eastern oysters (*Crassostrea virginica*) showing mean, median ± range (min and max) reported values. Negative values indicate net loss of the nutrient. (Table adapted from Watson *et al.* 2020).

	Ecosystem process/ function	**NITROGEN[1] (g N m-2 yr -1)**				**PHOSPHORUS[2] (g P m-2 yr -1)**				**CARBON[3] (g C m-2 yr -1)**				References
		Mean	*Med*	*Min*	*Max*	*Mean*	*Med*	*Min*	*Max*	*Mean*	*Med*	*Min*	*Max*	
Eastern American Oyster reefs (*Crassostrea virginica*)	**Burial**	2.1	0.6	0	7.8	2.3	0.7	0	8.4	-10.5	4	-71	21	(Fodrie *et al.*, 2017[3]; Newell *et al.*, 2005[1,2])
	Denitri-fication	16.4	3.7	2.7	55.6	-	-	-	-	-	-	-	-	(Kellogg *et al.*, 2014[1])

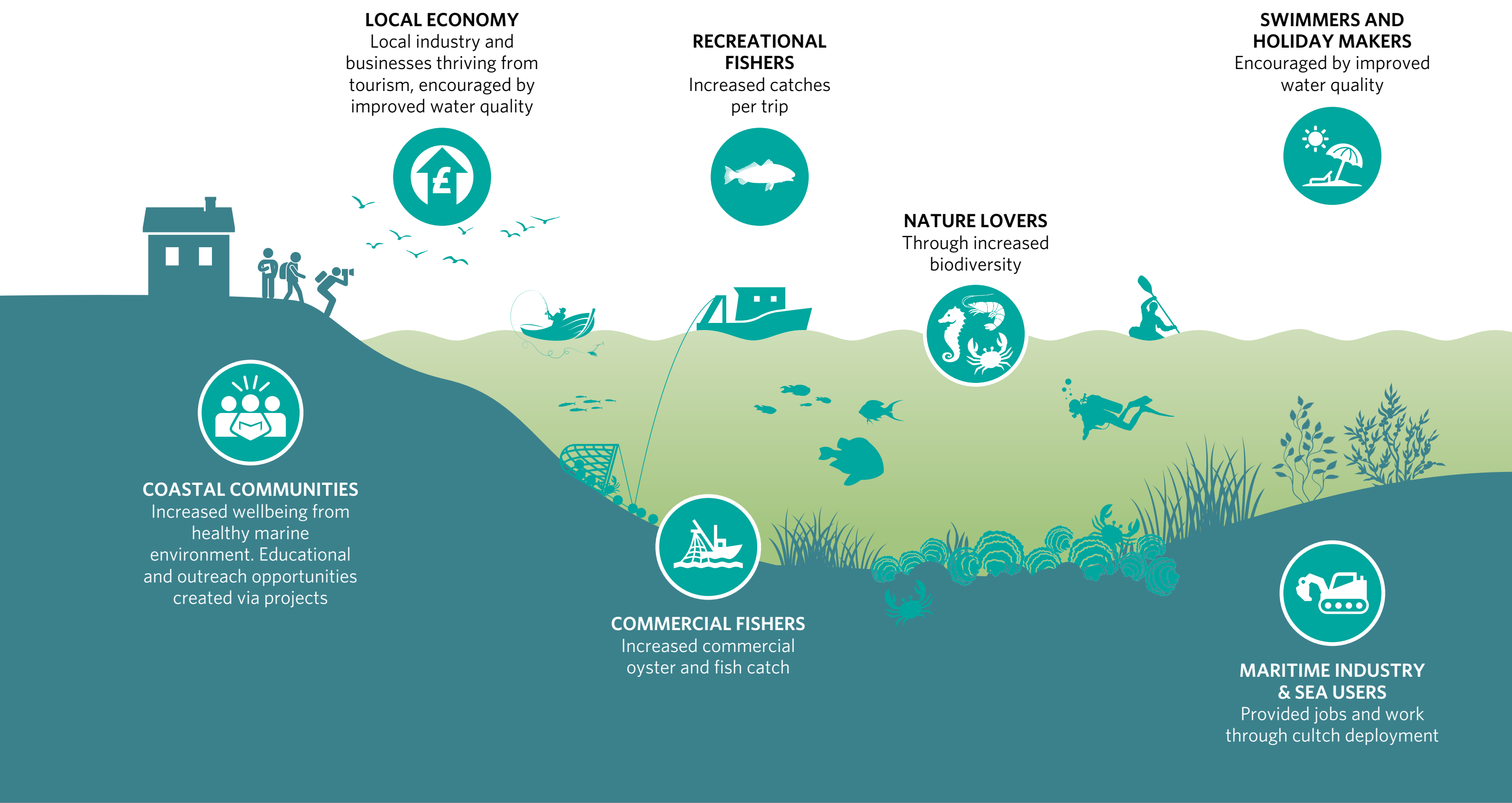


Figure 1.7: Beneficiaries of native oyster restoration.

Table 1.3: Native oyster conservation designations.

NATIVE OYSTER CONSERVATION DESIGNATION	REGION
OSPAR (Convention for the Protection of the Marine Environment of the North-East Atlantic). List of **Threatened and/or Declining Species and Habitats**. OSPAR agreement 2008-6, OSPAR Commission 2009), (Region II – Greater North Sea and Region III – Celtic Sea).	**NE Atlantic signatory countries**
EU Special Area of Conservation (SAC) Features. EU Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna also known as the **Habitats Directive**. **Note:** There is no specific feature for native oysters, but their habitats might come under subtidal sub features (in England) of 'Reefs' or 'Subtidal Sandbanks', 'Estuaries' or 'Large Shallow Inlets and Bays'. Additionally, in England, it may receive some associated protection under 'A5.4 Subtidal Mixed Sediments' as an 'Supporting Habitat' in some SPAs.	**European Union**
UK Biodiversity Action Priority species. UK Biodiversity Action Plan (1994).	**United Kingdom**
Constituent or characterising species of marine community types within qualifying interests (Annex I (Habitats Directive) Habitats) for Special Conservation Areas (SACs). European Communities (Birds and Natural Habitats Regulations 2011 (S.I.No. 477 of 2011). **Note:** e.g. "*Ostrea edulis* dominated community" is listed within the Qualifying Interest (QI) "Estuaries (1130)" in Lough Swilly SAC (site code 002287) and its distribution specifically mentioned as a conservation objective (CO) and target to maintain Favourable Condition Status (FCS) for the site.	**Ireland**
Species of Conservation Importance (SOCI). Marine and Coastal Access Act 2009.	**England & Wales**
Feature of Conservation Importance (FOCI). Marine and Coastal Access Act 2009.	**England & Wales**
Species of principal importance for the purpose of conservation of biodiversity. Natural Environment and Rural Communities Act 2006.	**England**
Biodiversity Action Plan priority species. Environment (Wales) Act 2016.	**Wales**
Species of principal importance in Wales (Section 7). Environment (Wales) Act 2016.	**Wales**
Scotland's Priority Marine Features (PMF'S). Scotland National Marine Plan, Scottish Government, 2015. **Note:** Species regarded as being "most sensitive to the impacts of seabed disturbance" and whose conservation objectives include "recover". Native oyster and sub-littoral mud in low or reduced salinity (lagoons) protected under legislation.	**Scotland**
Scottish Biodiversity List (incorporating 2007 updates and 2012 categorisation).	**Scotland**
Native oyster listed in Scottish Natural Heritage's Action Framework. Scottish Natural Heritage 2007.	**Scotland**
Northern Ireland Priority Species List (March 2010). NIPS Review 2019-2020 (Consultation 2020). Wildlife and Natural Environment Act (Northern Ireland) 2011. **Note:** A list of threatened species requiring conservation action in Northern Ireland, part of Northern Ireland's Biodiversity Strategy (2002). List updated in 2004 forming the basis for Northern Ireland's Species Action Plans (SAPs). Later updated to include UK priority species, including *Ostrea edulis*. The list is currently under review.	**Northern Ireland**
pMCZ Feature Habitat Component. Marine Act (Northern Ireland) 2013. **Note:** Native oyster (*Ostrea edulis*) beds included as component habitats of Proposed Marine Conservation Zones (pMCZ) Feature Habitats (Sublittoral (Subtidal) sand). Could be part of Priority Marine Feature (PMF) Habitats (e.g. Intertidal mudflats).	**Northern Ireland**
Northern Ireland Priority Habitats: Actions and objectives of **Northern Ireland Habitat Action Plan – Sublittoral Sands and Gravels** indicated of relevance to native oyster Ostrea edulis UK species action plan. NIPS Review 2019-2020 (Consultation 2020). Wildlife and Natural Environment Act (Northern Ireland) 2011.	**Northern Ireland**

BOX 1.4: NATIVE OYSTER HABITAT, RANGE, AND APPEARANCE

Range: Pan-European, including the northeast Atlantic from the south of Norway through to the Mediterranean Sea, as far as the Black Sea. See Figure 1.8 for biogeographic range map of the distribution of the native oyster.

Habitat: Estuaries and sea lochs as well as open coastal seas typically at a depth of ~50m. Primarily subtidal, colonising mixed hard substrates in particular shell material.

Appearance: Round to oval shape, with a distinctive flat dorsal vale and curved ventral valve.

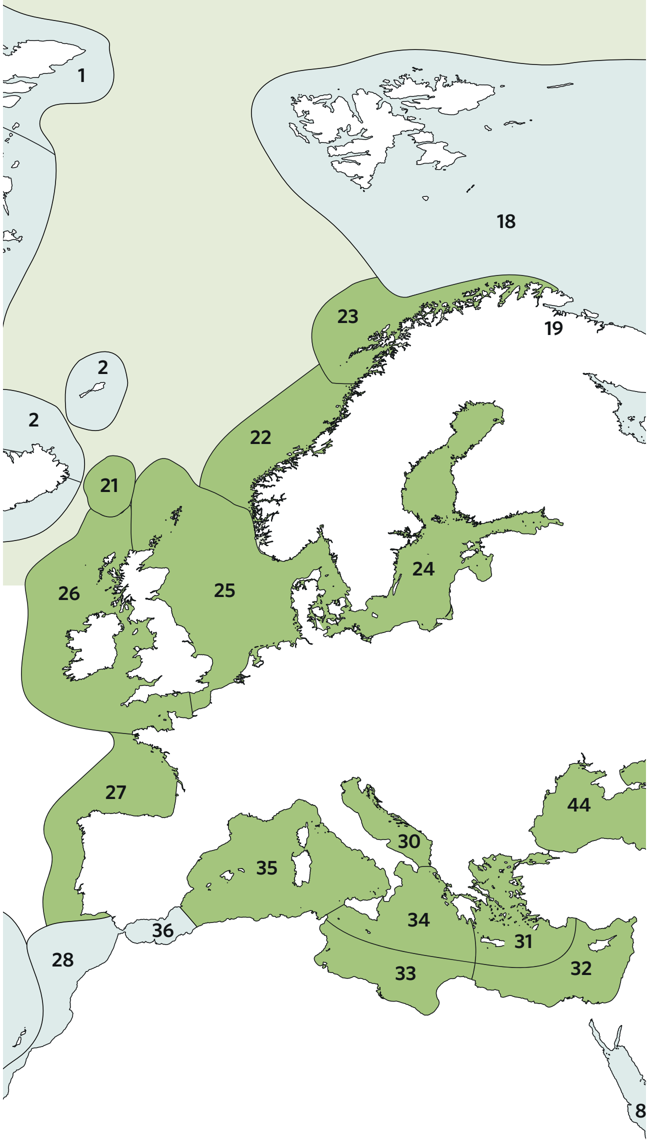
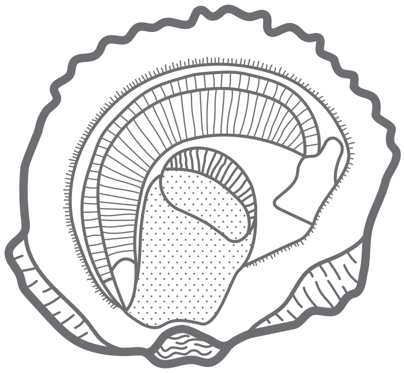


Figure 1.8: Marine ecoregions map adapted from Spalding *et al.* 2007. The known biogeographic range of *Ostrea edulis* is shaded in green. *Ostrea edulis* will only exist in areas within these ecoregions with suitable abotic and biotic habitat characteristics, see Table 2.2.



NATIVE OYSTER ECOLOGY AND BIOLOGY

The native oyster has a rounded, rough shell, typically with a pale yellow or green colouring (see Figure 1.9), with light brown or blue concentric bands, although colouring can vary. Oysters are filter feeders; they use their valves to pump water across hair-like gill structures to filter out microscopic algae and small organic particles from the surrounding water. A native oyster has a typical life span of 5-10 years, though they can live up to 30 years, and grow up to 15cm in shell height. Individuals typically reach sexual maturity at three to four years of age, instances of larval brooding, thus maturity, have been recorded in oysters younger than this (18-24 months old).

Figure 1.9: Image of native oyster *Ostrea edulis*. Photo: Jose B Ruiz.

BOX 1.5: PACIFIC OYSTER – *CRASSOSTREA GIGAS*

The Pacific oyster *Crassostrea gigas* (also known as *Magallana gigas*) can also be commonly found around the coastline of the UK and Ireland.

The Pacific oyster was introduced into UK waters in 1965, to replenish the low fisheries stocks of the native oysters. It now forms significant reefs in Cornwall, Devon and elsewhere in the south of England as well as the North Sea coast of Europe. While the Pacific oyster is an important source of income through fisheries and aquaculture, it is also legally defined as an invasive non-native species (INNS), classified as medium risk.

Appearance: Pacific oysters have an elongated shell with sharp curved edges, characterised by pink or purple striations (see Figure 1.10).

Habitat: The species is typically established in the intertidal zone in coastal areas and muddy estuaries, whereas native oysters are located in the lower intertidal and predominantly sub-tidal zone.

Both native oysters and pacific oyster have been found co-inhabiting within the lower intertidal zone in areas of the UK and Ireland including the Solent, Essex, Strangford Lough, Cornwall and Devon.

Figure 1.10: Pacific oyster *Crassostrea gigas* in the Wadden Sea, The Netherlands. Photo: Tom Ysebaert.

Native oyster reproduction

Native oysters are characterised by slow growth rate and sporadic recruitment success. This can partly be explained by their reproductive cycle. As protandrous hermaphrodites, juvenile native oysters begin to develop as male but then alternate between genders after each breeding attempt.

Native oyster spawning typically begins when the surrounding water temperature reaches between 15-18˚C. In the UK this is typically around May to June, however, the time of year will vary with biogeographic range, climate change and annual fluctuations. Reproduction starts when sexually mature adult males release spermatozeugmata, a structure containing multiple sperm connected by a matrix, into the water column (Figure 1.11). This formation of sperm allows it to be retained closer to the seafloor, where it is more likely to encounter a female. If successful, a receptive mature female will draw in the sperm, and will rapidly release her unfertilised eggs into brood chambers in their mantle cavity, where they are fertilised internally.

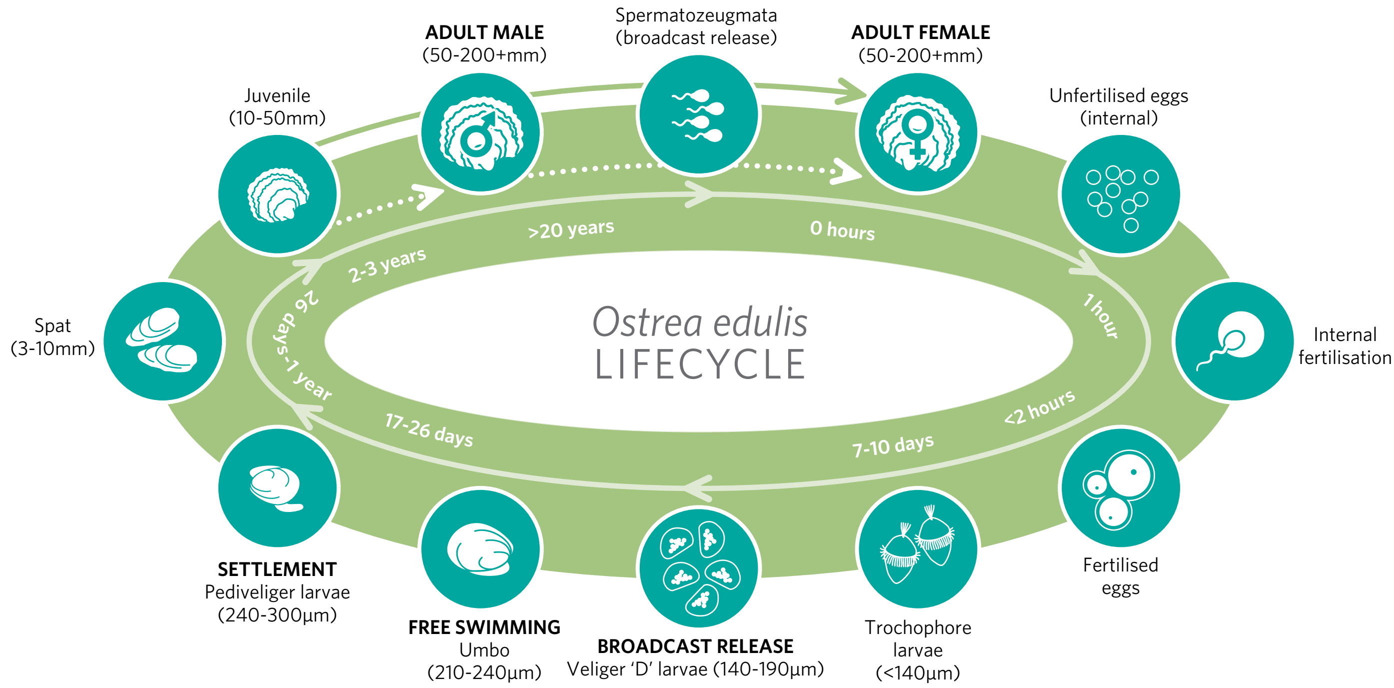


Figure 1.11: Life cycle of *Ostrea edulis*, adapted from Helmer *et al.* (2019).

The fertilised eggs remain in the brood chamber, for a week to ten days. The now shelled veliger 'D' larvae are then ejected into the water column. Sex-changing of the parent oyster can occur the moment after the oyster has released its gametes. This is how several spawning events can occur within individuals functioning as both sexes in a single breeding season.

The shelled veliger larvae spend one to two weeks in the water column, after which they metamorphose into pediveliger larvae. At this stage, the larvae start to actively seek a suitable settlement site in the form of a hard substrate. Pediveliger larvae have a visible foot, which upon finding a suitable site, secretes a liquid cement that secures the oyster. The oyster then undergoes further metamorphosis, whereby the foot is reabsorbed. Oysters become immobile once they have settled on a hard substrate. Within 48hrs of settlement, the oyster spat begins filter feeding and then will grow to a size of 1-2cm in the first year.

CURRENT NATIVE OYSTER RESTORATION EFFORTS

In recent years UK and European networks have been established to coordinate the rapidly growing interest in restoring native oyster ecosystems.

The European Native Oyster Restoration Alliance (NORA) was established during an international workshop on native oyster restoration hosted by the German Federal Agency for Nature Conservation (BfN) and the Alfred Wegener institute (AWI) in Berlin in November 2017. During this workshop, key issues for successful Europe-wide restoration were identified and summarised in the "Berlin Oyster Recommendation". Since this inaugural workshop, NORA has hosted conferences and set up working groups to address key topics in restoration practice and bottlenecks to scaling such as: site selection, biosecurity, monitoring and oyster production.

The Native Oyster Network – UK & Ireland was co-founded by the Zoological Society of London (ZSL) and the University of Portsmouth in 2018, with funding from the John Ellerman Foundation. The aim of the Native Oyster Network is to facilitate an ecologically coherent and collaborative approach to native oyster restoration.

Both Networks aim to increase the awareness of the cultural and environmental value of native oysters and to promote information sharing and effective communication between participants from government regulators to restoration practitioners and the aquaculture industry.

FURTHER READING

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zu Ermgassen, P., Hancock, B., DeAngelis, B., Greene, J., Schuster, E., Spalding, M. and Brumbaugh, R.D. (2016). Setting Objectives for Oyster Habitat Restoration Using Ecosystem Services: A Manager's Guide. The Nature Conservancy, Arlington VA.

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Pogoda, B., Brown, J., Hancock, B., Preston, J., Pouvreau, S., Kamermans, P., Sanderson, W., Nordheim, H. V. (2019). The Native Oyster Restoration Alliance (NORA) and the Berlin Oyster Recommendation: Bringing back a key ecosystem engineer by developing and supporting best practice in Europe. Aquatic Living Resources, 32, 13.

Watson, S.C.L., Preston, J., Beaumont, N.J. and Watson, G.J. (2020). Assessing the natural capital value of water quality and climate regulation in temperate marine systems using a EUNIS biotope classification approach. Science of The Total Environment, p.140688.
https://doi.org/10.1016/j.scitotenv.2020.140688

Figure 1.12: Fieldwork to deploy native oysters in Loch Craignish, by Seawilding – Native Oyster Restoration. Photo: Dan Renton.

CHAPTER 2
GETTING STARTED: RESTORATION PROJECT PLANNING, PERMITTING, LICENSING AND FUNDING

CHAPTER AUTHORS

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KEY SUMMARY POINTS

- **Before starting a restoration project a comprehensive feasibility study and site selection process is recommended.**
- **Selected sites should fall within the range of biological and environmental tolerances of the native oyster to maximise restoration success.**
- **Logistics and licence requirements of a project can require considerable investments in time and resources, or present significant barriers to progress.**
- **Setting clear goals and targets for restoration projects enables success and progress to be measured, and the purpose of the project to be clearly communicated.**
- **Consult with a wide range of stakeholders from the project conception to ensure local ecological knowledge is incorporated into the project design and to ensure greater stakeholder engagement and support.**

INTRODUCTION

As restoration of the European native oyster habitat gains momentum across the UK and Europe, responsible **principles** for shellfish restoration have been set out in the NORA “Berlin Oyster Recommendations” and top-level **guidelines** are provided by the Global Restoration Guidelines for Shellfish Reefs handbook. There are, however, unique challenges to setting up a European native oyster habitat restoration project, including: a lack of existing healthy target or reference ecosystems; the vastly diminished natural stock; development of a consistent, biosecure, supply of oysters; the multinational extent of its geographical range; and legislative and licensing barriers to habitat restoration practices common in other countries. To support native oyster restoration projects in the UK and Ireland (and beyond), this chapter provides a practical and detailed guide to starting native oyster restoration projects and to addressing some of these issues. This chapter builds on the Global Restoration Guidelines for Shellfish Reefs, Chapters 3 and 5 and we recommend these are referred to alongside the guidelines presented here.

RESTORATION PROJECT PLANNING

It is important to identify the focus of a restoration project from the outset, in order to facilitate clear communication with funders, licensing and permitting authorities, resource users and community groups. **Goal-based** project planning is recommended to provide a framework whilst ensuring the best chance of achieving the highest level of recovery possible. A typical project timeline provides an aid to planning projects and setting out realistic deliverables and milestones (Figure 2.1). A ‘getting started’ flow chart is provided to aid decision making during the feasibility, site selection and licensing phases of a restoration project (Figure 2.3). The stakeholders to be included in consultation are recommended to help ensure projects access a wide range of knowledge and expertise and generate the social license needed to succeed.

TYPICAL TIMELINE

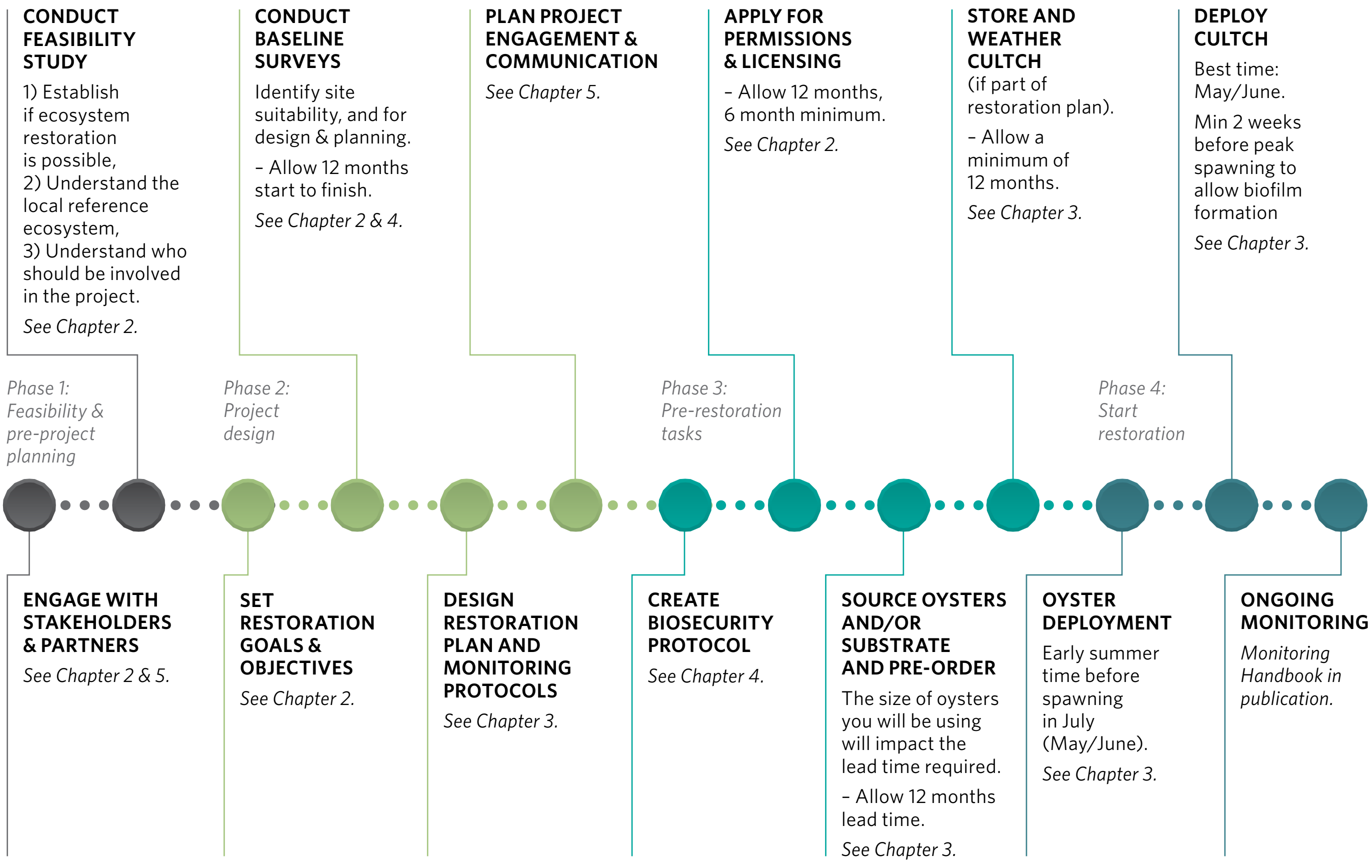


Figure 2.1: Generalised, but typical, timeline of a native oyster restoration project.

Project timeline

The establishment of a native oyster restoration project requires a series of steps to be completed before active works can commence. Figure 2.1 sets out the approximate timeline assuming that funding is in place. When planning and delivering the project, it is always sensible to think at least one year ahead, particularly if using cultch as this usually requires a minimum period of 12 months for the weathering process to meet biosecurity requirements.

Setting restoration goals and objectives

International standards of ecological restoration recognise the need for setting clear targets, goals and objectives by which success can be measured (see Box 2.1), and encourage development of both **social** and **ecological** targets. This approach recognises that individual projects and practitioners will have different motivations ranging from developing sustainable fisheries to enhancing local biodiversity.

Goal setting helps turn a restoration vision into an achievable project. Once decided, objectives then translate goals into clear, distinct and measurable components and can be helpful in determining the restoration strategies to implement and set the stage for future adaptive management if objectives aren't met.

For further guidance on goal setting see the global guide and the further reading at the end of this chapter. A case study from the Solent Oyster Restoration Project is given in Table 2.1.

BOX 2.1: DEFINING TARGETS, GOALS AND OBJECTIVES

Project Target: This describes the site and native ecosystem to be restored and is broad, general and should be inspiring.

Goals: A project will normally have several goals, and these describe the level of recovery and outcomes desired, both in social and ecological terms. Goals are open, can be discussed and agreed upon with stakeholders.

Objectives: These are specific and discrete measurable outcomes or changes that are needed to achieve each goal. Often relate to distinct aspects of site or project time frame and are useful tools to assess progress and manage the restoration project.

Table 2.1: Setting and describing goals, objectives and indicators: An example from the Solent Oyster Restoration Project, Blue Marine Foundation, UK (used from 2015-onwards).

GOALS	OBJECTIVES	INDICATORS
TARGET: to restore the status of *Ostrea edulis* in Solent waters so that a healthy, self-sustaining native oyster population is present that will provide a number of key ecosystem services		
1 Create a source of *O. edulis* larvae through the use of broodstock nurseries, targeted to active restoration sites	**Obj 1:** Demonstrate an increase in larval abundance beside *O. edulis* nurseries.	Oysters spawning in nurseries.
	Obj 2: Demonstrate survival of *O. edulis* in nurseries.	Mortality rate.
	Obj 3: Demonstrate an increase in biodiversity around *O. edulis* nurseries.	Species richness of mobile fauna.
		Species abundance of mobile fauna.
		Total biomass of all fish species.
		Biomass of recreational/commercially important fish species.
2 Restore *O. edulis* and their habitat in areas protected from fishing	**Obj 1:** Lay cultch in order to improve seabed conditions for *O. edulis.*	Total reef area.
		Reef height.
		Total cultch deployed.
	Obj 2: Reseed *O. edulis* to recreate oyster reefs and increase the population in the Solent.	Total number of *O. edulis* reseeded.
		Total number of live *O. edulis.*
	Obj 3: Demonstrate the survival of restored *O. edulis* population.	Survival of shellfish.
		Environmental conditions.
	Obj 4: Demonstrate recruitment of *O. edulis* to restored reefs.	Number of recruits of *O. edulis* increased from baseline.
3 Demonstrate the benefits restored *O. edulis* reefs provide	**Obj 1:** Demonstrate an increase in fin fish around restored *O. edulis* reefs.	Total biomass of all fish species.
		Biomass of recreational/commercially important fish species.
	Obj 2: Demonstrate an increase in marine biodiversity associated with restored reefs.	Species richness of benthic flora/infauna.
		Species abundance of benthic flora/infauna.
		Species richness of mobile fauna.
		Species abundance of mobile fauna.

GOALS	OBJECTIVES	INDICATORS
TARGET: To create opportunities for the local economy, community and uses the Solent through oyster reef restoration		
4 Demonstrate the benefit of *O. edulis* restoration to the local economy	**Obj 1:** To demonstrate benefits to the local economy.	Stories/testimonials. Qualitatively describe benefits to the local economy.
		No. of local full-time jobs to deliver project.
		No. of local contractors engaged.
		Total no. of full-time jobs within the entire project (Local + National + International).
5 Engage the community in long-term stewardship of the restored *O. edulis* reefs	**Obj 1:** Demonstrate engagement by the local community.	Volunteer hours donated.
		Attendees at public/consultative meeting.
		Community and partner organisations improve skills/confidence to implement large scale marine restoration.
		Create opportunities for young people to develop skills.

Figure 2.2: Solent Oyster Restoration Project (Blue Marine Foundation & University of Portsmouth) team in consultation with local fishers to refine site selection during oyster deployment. Photo: Blue Marine Foundation/Morven Robertson.

PROJECT FEASIBILITY STUDY

It is important to take time to assess the feasibility of a project to determine if restoration targets and goals can be achieved in the proposed restoration location. This is covered in greater detail elsewhere (e.g. the global guide and further reading texts), but includes three broad steps that this chapter aims to support:

1. **Establish if ecosystem restoration is possible within the desired location(s)** – *this step involves feasibility studies, site selection processes and determining if there are significant ecological, logistical, legislative or financial barriers to restoration;*
2. **Understand the local reference ecosystem** *or the ecological target that will be used to guide the restoration process (known as the ecosystem target) and;*
3. **Understand who should be involved in the project** – *in what context and at which stage.*

Restoration is recommended in areas known to have supported native oyster populations historically, however, there is a suite of further environmental, biological, ecological and logistical criteria that need to be considered to determine if restoration is possible or realistic within a location. These include determining the presence and extent of a range of **threats**, such as fishing pressure, pollution, invasive species, diseases or pests and taking steps to manage or mitigate if required. Understanding the physiological requirements and tolerances of the native oyster is important, as the **physio-chemical characteristics** of the site need to fall within these (e.g. salinity, current speed), or be improved to do so by active restoration interventions (such as improving substrate). Figure 2.3 (Getting started decision tree) aims to help restoration practitioners consider some of the main factors in determining the feasibility of a project within a specific location, however, each project should conduct their own comprehensive study.

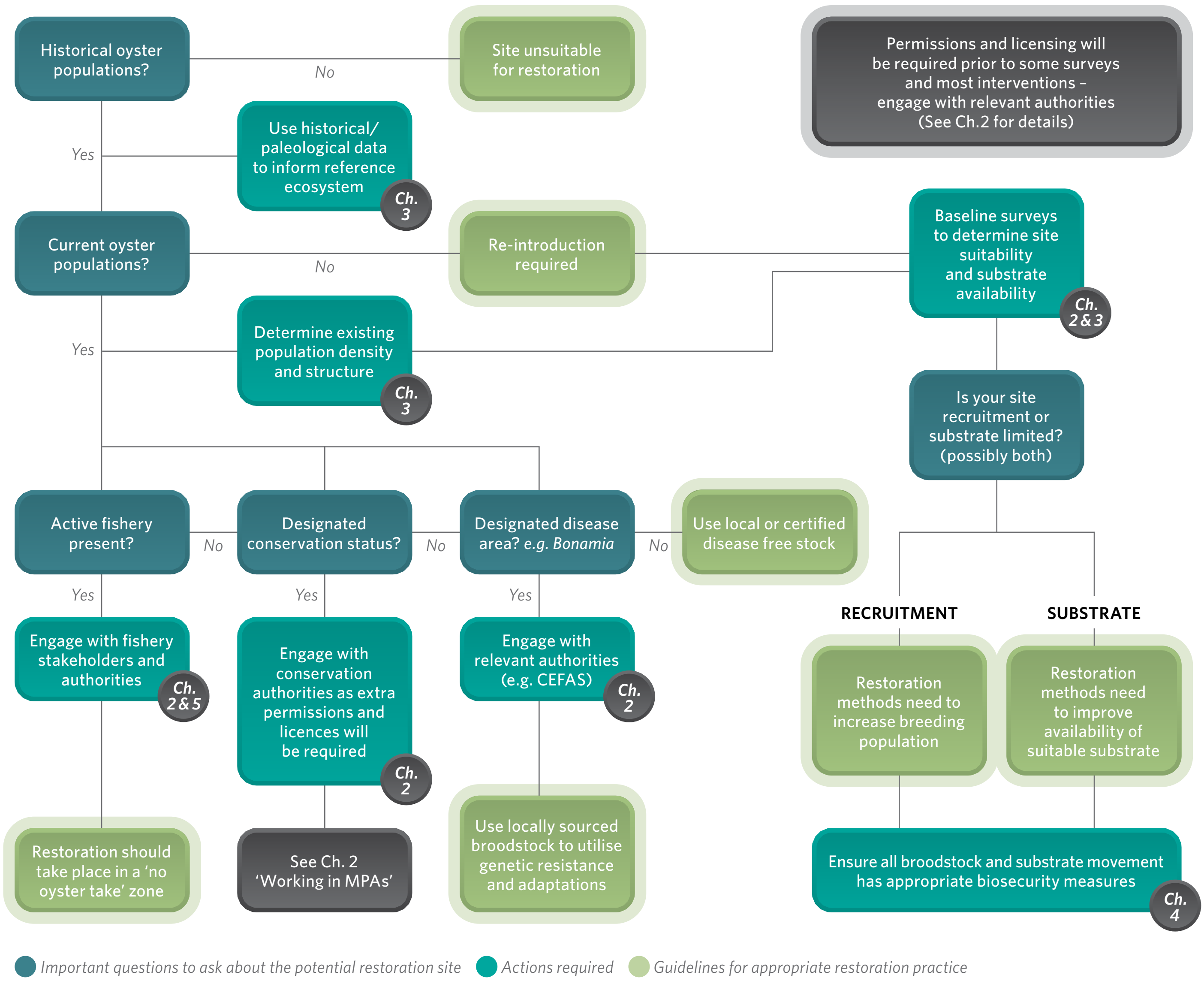


Figure 2.3: Getting Started Decision tree Infographic. This flow diagram is a decision making tool to help guide practitioners through the feasibility and planning state.

IDENTIFYING RESTORATION LOCATIONS AND SITE SUITABILITY

Conducting baseline surveys

Baseline surveys are a crucial part of planning any proposed restoration project. They enable site suitability to be determined and help with decisions about optimal sites within proposed locations for a restoration project. This phase should not be missed out in a rush to get work underway. It is important to characterise a range of relevant abiotic parameters (e.g. depth, seabed substrate type, salinity), the presence of invasive species (particularly the American slipper limpet *Crepidula fornicata* and Pacific oyster *Crassostrea gigas*) and pests (e.g. European sting winkle *Ocenebra erinaceus*) at the proposed location. It is also essential to establish the presence, distribution, and abundance of existing native oyster populations as this will inform project planning and will influence whether it is necessary to source oysters. The level of survey carried out will depend on the resources available. It may be helpful for projects to seek partnerships with universities and other institutions as this could widen the range of parameters that can be investigated. Having good baseline qualitative and quantitative data also provides the benchmark against which future changes can be measured and project successes or failures can be identified.

Having a baseline knowledge of the biological, ecological and physical characteristics of the site will help to determine if it meets the requirements for native oysters to survive, grow and reproduce. It will also help inform that actions are carried out at the right times and in the right places. A comprehensive feasibility study can also assist in discussions with key regulators and be used as evidence when applying for funding.

If undertaking a baseline survey that involves the removal of sediment from the seabed (e.g. a grab survey), there may be the need to register for a marine licence exemption from the Marine Management Organisation, Natural Resources Wales, DAERA or Marine Scotland. If undertaking such a survey in a marine protected area, contact the relevant Statutory Nature Conservation Body (see permitting and licensing requirements section on page 26).

BIOTIC AND ABIOTIC CHARACTERISTICS OF NATIVE OYSTER HABITAT

The establishment of a healthy native oyster reef is determined by four life-history processes: **survival**, **growth**, **reproduction** and **recruitment**. Reproduction refers to the capacity to produce offspring; recruitment denotes the successful larval settlement and metamorphosis to spat in a specific site. These four processes are influenced by a range of **abiotic** (e.g. sea bed dynamics, water depth, salinity, water temperature, water oxygen content, current velocity, concentration of suspended particles in the water column, substrate) and **biotic** (e.g. sufficient levels of phytoplankton, predation, diseases, and population density) factors, which are characterised in Table 2.2 and detailed in the following paragraphs.

Case studies of national and local site selection are given in Box 2.2

Survival depends on environmental factors such as large-scale and small-scale sea bed dynamics, oxygen content, salinity and predation. Salinity may be a factor to take into account in certain coastal areas, close to the outflow of rivers, but is generally not limiting. Oxygen can be limiting in areas that are stratified, either due to temperature or salinity. This is most likely to occur in areas with limited water movement (e.g. enclosed bays with limited exchange) or in very deep areas. Substrate is important as muddy sediment presents risk of smothering or loss of native oysters by sinking. Bed dynamics is one of the most defining factors determining if habitat is suitable, but currently poorly understood and quantified. The presence of sandwaves (detectable in multi-beam recordings) is an indication that areas are likely too dynamic for the long-term establishment of native oyster reefs. It is advisable to carry out field tests if possible, as currently fundamental knowledge on ripple behaviour is lacking and numerical models are therefore not entirely reliable.

Growth is mainly determined by phytoplankton and the concentration of suspended particulate matter (SPM). Most nearshore areas have sufficiently high nutrient concentrations, hence primary production, to ensure a sufficient food supply. However, areas that regularly experience prolonged periods of stratification may have limited supply of food at depth, even if primary production levels at the surface are sufficiently high. It is therefore essential to get near bed phytoplankton concentration data and not rely on surface data alone. Additionally, high concentrations of inorganic matter may restrict the feeding efficiency. Short periods (couple of days) of high concentrations of SPM (e.g. due to a storm event) are unlikely to pose a problem, as native oysters can simply temporarily shut down or reduce their filtration rate. However, prolonged periods or frequent periods of SPM concentrations higher than 60mg/l (Table 2.2) are detrimental for growth.

Reproduction requires a parent population and the right water temperature for spawning. Temperature explains a major part of the variation of larval occurrence. The best prediction of gametogenesis and subsequent swarming of larvae appears to be the "temperature sum". The temperature sum (also known as growing degree days, heat units or thermal time) can be described as the accumulated temperature, when higher than a threshold temperature, over a period of time. For example, the temperature sum for the initiation of spawning is somewhere between 404 and 554 degree days. This value may vary amongst populations adapted to different temperature climates. For most coastal and marine waters around the UK, temperature is unlikely to be a limiting factor for spawning, although the timing of spawning and the peak of larval occurrence may vary. Information about the likely spawning and swarming period is essential where deployment of settlement substrate is planned.

Recruitment depends on water temperature, the quantity of larvae in a specific area and the presence of suitable substrate for settlement. Recruitment is determined by the size of the parent population that produces the larvae and serves as substrate, and by the water motion that determines larval retention in a specific area. For restoration initiatives it is important to ensure that there is sufficient suitable settlement substrate in the area. Fresh shell material appears to be most effective, although larvae will attach to many other hard substrates. If there is not enough suitable settlement substrate in the area it is important to provide substrate to kickstart the formation of oyster reefs. Once native oysters are established in the area, the shells of live oysters present will act as settlement substrate.

Two things need to be taken into account when deploying settlement substrate. Firstly, it needs to stay in place. Loose shells (either live or dead) can easily be dislodged by currents or wave action. Generally, waves dislodge material from the sea bed and currents subsequently transport this. If the restoration area is calm (e.g. a sheltered bay), it is possible to put loose shell material down. This is generally preferable as this is the cheapest way of covering a relatively large area. If the bed shear stress levels are too high it is possible to encase shell material in gabions, or even in weighted gabions (gabions filled partially with stones of greater density than shell material). It may require field tests or tests in engineering facilities to determine the optimal method. If a site is easily accessible, tests in the field are preferable. For inaccessible offshore sites it is important to collect accurate information on bed shear stress (either from field measurements or from accurate numerical models) and relate these to available information about critical bed shear stress for various constructions. Secondly, the substrate needs to stay above the sediment.

More challenging is understanding the potential local larval retention or larval supply from nearby sources. As the native oyster is functionally extinct in many European locations, larval supply is generally limited, unless a restoration site happens to be close to a relict population or a population in an adjacent basin. If larvae are transported out of the restoration site within the planktonic period of the larvae, the site cannot develop to a self-sustaining population. Simple dispersal models (even if they do not contain information on the larval behaviour) are useful tools.

Table 2.2: Abiotic and biotic habitat suitability characteristics, relevance to various life-history processes and their ranges for the European native oyster (*Ostrea edulis*). Based on Smaal *et al.* (2017) where information is available.

ABIOTIC AND BIOTIC CHARACTERISTIC	SURVIVAL	GROWTH	REPRODUCTION	RECRUITMENT	RANGE
Sediment composition				X	Fine sand (> 63µm) and firm silty sand or silty gravel. All with shells and stones.
Suspended sediment (mg/l)		X			< 60
Temperature winter, Tmin (˚C)	X				> 3
Temperature summer, Tmax (˚C)			X		< 30
Oxygen conditions (mg/l)	X				> 3.5
Salinity	X				25–35
Food concentration (chl*a* in µg/l)		X			Growth > 0.5, Gonad development > 1.68
Larval retention				X	Larvae must remain near point of release.
Predation	X				High numbers of predators can decimate a population.
Competition		X			Competition for food can reduce growth and reproduction.
Water Depth	X				Intertidal – 80m
Current velocity (m/s)				X	0.25-0.8
Bed shear stress (tau N/m^2)	X				Average < 1, Max < 10
Sea Bed mobility (cm/day)	X				< 0.8

BOX 2.2: NATIONAL SCALES OF SITE SELECTION: A CASE STUDY FROM ENGLAND

The Environment Agency has developed a GIS layer depicting the native oyster reef potential area in England, which provides a national 'high level' indication of where native oyster reefs could potentially be restored based on three key environmental variables: current speed (Low Energy sites, < 130Nm^{-2}), broadscale habitat type (Subtidal mixed sediments; EUNIS Level 3 = A5.4), and depth (only subtidal areas were included) (see Figure 2.4). Some further areas were removed based on expert judgement and their close proximity to major ports, which were therefore considered unsuitable for native oyster reef restoration.

It should be noted that the map derived by the Environment Agency should be considered as an initial aid to identifying sites, as it is based on large-scale modelled data and may not be accurate at the local level. **Note:** The modelling went to 1nm from the coast.

Furthermore, the location of significant activities (such as dredging), marine assets (such as submarine cables) and ecological risks (such as disease control areas), which could restrain a location's potential, have not been considered. Areas outside of those identified on the Oyster Restoration Potential and Marine Protected Areas map, may also be suitable for restoration.

The native oyster potential layer is also now available to download here:

https://data.gov.uk/dataset/31530300-0f98-42ac-9b68-b6c980f5383c/native-oyster-bed-potential

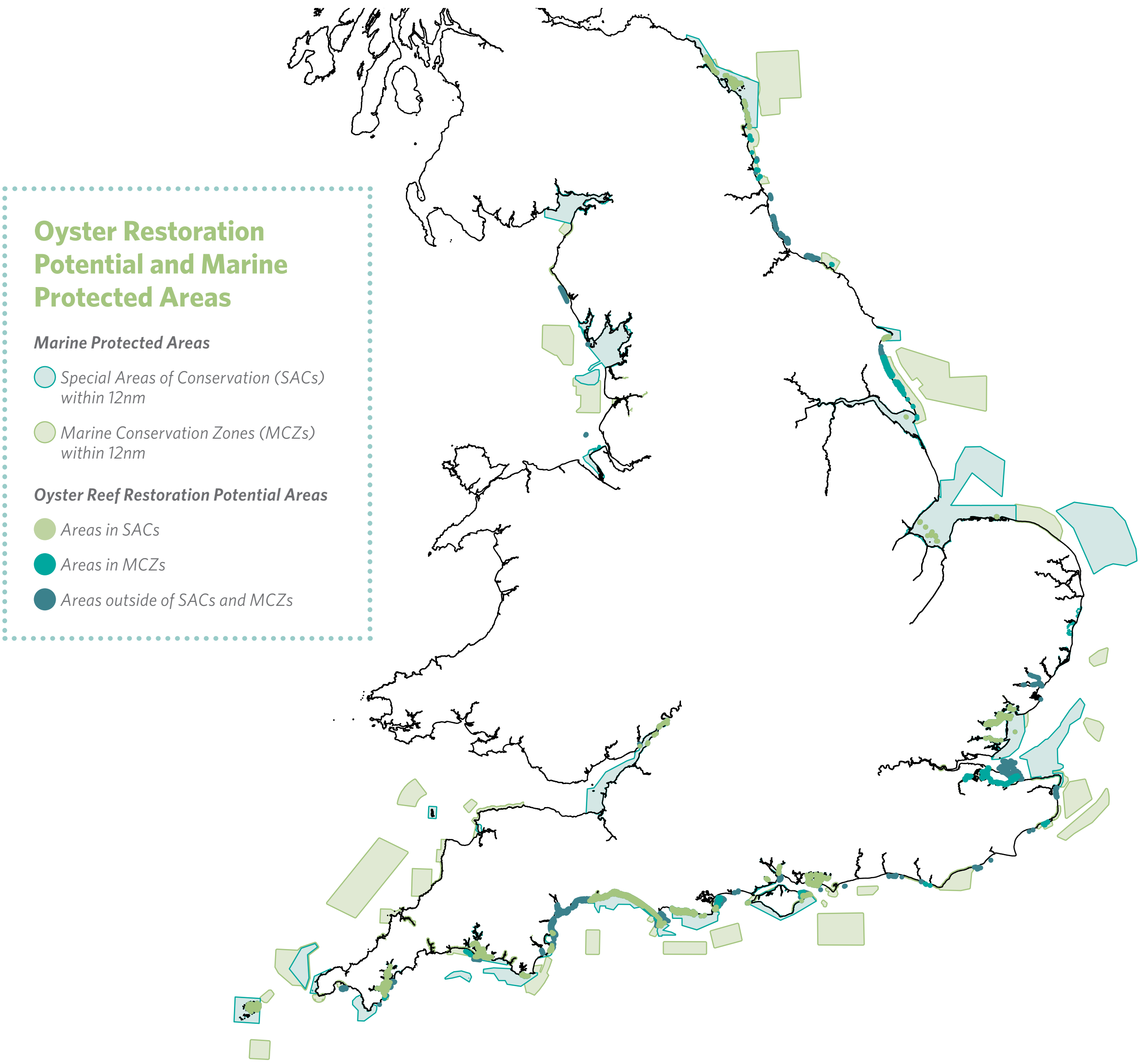


Figure 2.4: Large scale national restoration site selection for England: Potential native oyster restoration sites in MCZs. Information has been derived from data that is made available under the European Marine Observation Data Network (EMODnet) Seabed Habitats project (www.emodnet-seabedhabitats.eu), funded by the European Commission's Directorate-General for Maritime Affairs and Fisheries (DG MARE). Information has been derived from the Natural England Marine Evidence Database (Sep 2019).

WORKING IN MARINE PROTECTED AREAS

Marine Protected Areas (MPA) by their definition are designated to protect marine features of nature conservation importance. In most MPAs in the UK and Ireland, these protected features do not usually include the native oyster in their citations due to them being largely extirpated. It is important to consider at the outset that the restoration of native oysters within MPAs cannot be to the detriment of those designated conservation features that are listed and which there is statutory duty to protect. See Table 2.3 for a summary of MPAs in the UK.

For native oyster restoration in MPAs, most restoration will take place on the seabed in areas of A5.4 Subtidal mixed sediments (Box 2.2, Figure 2.4). In England, this can be a sub feature of the Estuaries, Large Shallow Inlets and Bays or Subtidal Sandbanks feature of a Special Area of Conservation (SAC), or the supporting habitat of an Special Protection Area (SPA). Scotland, Wales and Northern Ireland do not have SAC sub features. In Marine Conservation Zones (MCZs), 'A5.4 subtidal mixed sediments' can be a designated feature, or the site can be directly designated for native oysters.

Note: Adding cultch (shell fragments, stones or similar) to the seabed will change the particle size of the underlying sediment, and so this will have to be addressed when applying for licences for restoration in an MPA.

Table 2.3: Marine Protected Areas in the UK.

DESIGNATION	ABBRV.	JURISDICTION	LEGISLATION
Marine Conservation Zone	MCZ	UK	Marine and Coastal Access Act 2009. Marine Act (NI) 2013.
Nature Conservation Marine Protected Area	NCMPA	UK (Scotland)	Marine (Scotland) Act 2010; Marine and Coastal access Act 2009.
Site of Special Scientific Interest	SSSI	UK	Wildlife & Countryside Act 1981.
Area of Special Scientific Interest	ASSI	UK (N. Ireland)	Environment (Northern Ireland) Order 2002.
Special Area of Conservation	SAC	EU	EC Habitats Directive 92/43/EEC 1992 (UK: Conservation of Habitats and Species Regulations 2017).
Special Protection Area	SPA	EU	EC Birds Directive 2009/147/EC
Ramsar Site		International	Ramsar Convention 1976.

To determine how best to work within the MPA and avoid detrimentally impacting the designated features, it is suggested to have early contact with the statutory nature conservation agency. The nature conservation agencies put together site specific packages of advice (Conservation Advice) that sets out:

- Designated or qualifying features;
- Habitats and species that they are dependent on and where they occur;
- Conservation objectives;
- Minimum targets each feature needs to achieve to meet the conservation objectives;
- Features which may be sensitive to human activity;
- Condition of the designated or qualifying features;
- Evidence-base.

The Conservation Advice packages support the management bodies, such as those who issue licences, to put in place appropriate measures to achieve favourable condition for each MPA feature. It will be necessary to conduct an assessment to determine the extent of the impact and benefits from the proposed restoration activities on the conservation features. In a SAC, SPA or Ramsar site this will usually take the form of the Habitat Regulation Assessment (HRA), and/or an MCZ assessment. If the restoration is directly connected with or necessary to the management of the site then an HRA might not be required. However, an equivalent assessment process should still be undertaken to ensure the project will not have an adverse effect on the features of the site. It is important to refer to the Conservation Advice when completing these assessments. An example of how this works is in the Blackwater, Crouch, Roach and Colne Estuaries MCZ, detailed in Box 2.3: Case study of the Essex Native Oyster Restoration Initiative (ENORI).

WORKING WITH FISHERIES

If a wild native oyster fishery is present in or around the restoration site, there are a number of actions that can be taken to enhance both the native oyster population and the environment. Historically, most restoration initiatives were undertaken with fishery aims and there are a number of lessons and techniques that can be learnt from the resulting literature. Indeed, OSPAR highlighted that a number of the remaining larger populations of native oysters have been conserved to the present day mainly through being managed as a fishery. In present day fisheries, establishing broodstock sanctuaries protected from harvesting can act as sources of larvae for settlement on other oyster reefs in the area. These can also provide areas for enhancing biodiversity by enabling the sessile, delicate organisms and other species that are impacted by disturbance to become established. Regulations can also be assessed to see where measures could be taken to enhance stocks, for example, placing undersized oysters in no take areas or monitoring for invasive non-native species. Extensive aquaculture techniques such as artificial spat collection and growing on juveniles, or establishing spatting ponds can also be explored to eliminate the need for bringing in stock elsewhere and protecting the genetic integrity of the population. A key to this is engaging fishers in plans and steering groups.

Introduction of byelaws or Statutory Instruments may offer a mechanism for protecting stock where there is no wild fishery present. Harvesting may be a secondary, long-term aim even if biodiversity and environmental goals are primary. No harvesting should take place until a restored population is proven to be self-sustaining and resilient to a temporary depletion in condition. This will include assessing year-on-year recruitment trends, age/size class distribution, sex ratio amongst other parameters. Even then, protected sanctuary areas for broodstock should be established to enable the population to supply fished areas whilst remaining self-sustaining. Realistic timescales for this may be up to 20–25 years. Integrated fisheries management is key both within and outside restoration sites to support ecologically and commercially sustainable fisheries.

BOX 2.3: WORKING IN MPAS, WITH EXISTING FISHERIES & IMPLICATIONS FOR SITE SELECTION – A CASE STUDY FROM THE ESSEX NATIVE OYSTER RESTORATION INITIATIVE (ENORI)

The Essex Native Oyster Restoration Initiative (ENORI) is a collaboration between oystermen, nature conservation NGOs, government and academia operating in the Blackwater, Crouch, Roach and Colne Estuaries MCZ (BCRC MCZ). The estuarine complex also is protected under SAC, SPA, SSSI and Ramsar designations for its conservation importance. The case study provides an example of how restoration can occur within MPAs and can work alongside a fishery, and the implications this has for restoration site selection within the boundaries of the site specific Conservation Advice.

Working with a wild fishery:

Together ENORI are working to recover self-sustaining populations of native oysters in the Essex estuaries which will ultimately support a sustainably managed fishery. The Tollesbury & Mersey Native Oyster Company has targeted recovering native oysters in the Blackwater Estuary, Essex, since it bought back the rights to the grounds from 'big business' in the 1980s. With success on their several orders, the Company reached out to Essex Wildlife Trust in late 2000's to help them with the public grounds which were being depleted. The public native oyster ground was closed to oyster fishing and in 2013, using the evidence of native oyster numbers provided by the oystermen and Essex Wildlife Trust, the area was designated a MCZ with the two conservation objectives to recover native oysters and native oyster reefs. To deliver this, a spatial management plan has been developed and incorporated as the MCZ Flexible Permit Byelaw. This sets out a defined area, closed to oyster fishing, where native oyster reef restoration takes place. Activity in this 'Restoration Box' (see Figure 2.5) includes the improvement of the seabed (as described below) to support recruitment and the translocation of mature native oysters from the private fishery to create a broodstock sanctuary which allows spill-over into the wider MCZ. In the wider MCZ, the public fishery remains closed until the native oyster population has recovered to favourable condition and demonstrates resilience. At that point a temporary depletion of condition will be allowed through a permitted fishery.

Restoration in an MPA:

The BCRC MCZ site was designated with the conservation objectives of restoring both native oysters and native oyster beds (the habitat). The MCZ designation overlaid the existing SAC for being an internationally important example of coastal shallow estuarine system with a mosaic of intertidal and subtidal habitats including estuarine sediments (Figure 2.5). The BCRC MCZ is considered to be both substrate deficient and recruitment deficient for native oysters. As such it was proposed by ENORI to deploy cultch to the seabed in an effort to increase the available substrate for recruitment. Adding shell and gravel could have had a detrimental impact on the SAC by altering the estuarine sediments. Following the Conservation Advice areas of 'subtidal mixed substrate' were targeted for cultch deployment to avoid a detrimental impact on the designated conservation feature of the estuarine sediments and which was approved through a Habitat Regulation Assessment.

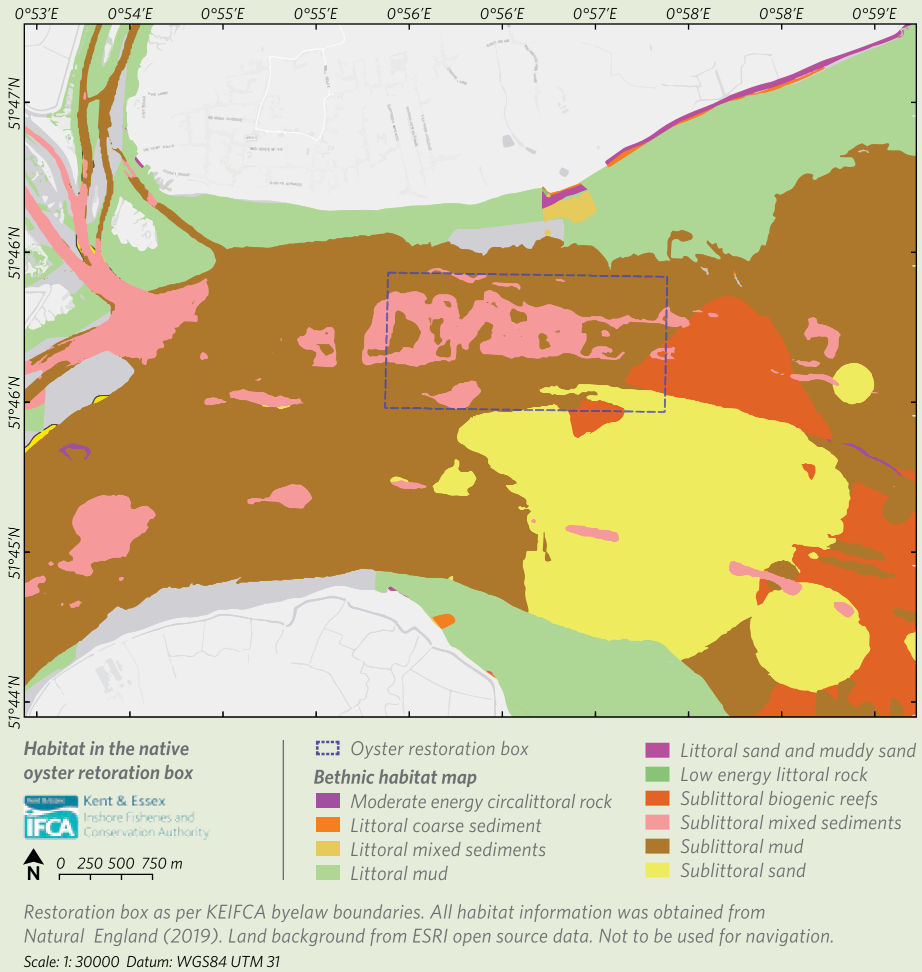


Figure 2.5: Above; Blackwater Crouch, Roach and Colne MCZ map with sediment type and 'Restoration Box' delimited in blue dashed line. Right; ENORI working with Essex Oyster Fishermen to deploy broodstock to the seabed. Photos: ENORI/ZSL.

ESTABLISHING A REFERENCE OR TARGET ECOSYSTEM

In order to measure change resulting from restoration work, a reference ecosystem (i.e. a pristine or relatively unimpacted example) needs to be identified as the restoration target to compare progress to. Ideally, one of the metrics typically used to assess success of the restoration program is the "return of naturally diverse assemblages" and ultimately a convergence towards a natural, pre-impacted ecosystem associated with the species to be restored. However, few, if any, of the remaining native oyster populations in Europe have not been impacted by human activities – it is therefore difficult to identify what pristine native oyster habitat should look like. Although pristine native oyster reefs no longer exist in European waters, there is building evidence that historically they did exist, and if left undisturbed, extant native oyster populations have the potential to form biogenic 3D reef structures (see Chapter 1).

In the absence of extant reference habitats, it might be necessary to resort to other reef building bivalve species with similar ecological functionality to establish a baseline we can use as a 'biodiversity target' to assess success of native oyster restoration efforts.

Subtidal shellfish habitats, such as those formed by horse mussels (*Modiolus modiolus*) and native oysters, have been described as one of the richest and most diverse in the North Atlantic and both habitats have been known to co-exist, or represent alternate states of a climatic succession. Therefore, horse mussels are potentially a good reef building bivalve to use as a candidate reference ecosystem in the absence of new evidence of natural native oyster reefs. A case study for the use of temperate horse mussel *Modiolus modiolus* biogenic reefs as a reference ecosystem as part of The Dornoch Firth Environmental Enhancement Project (DEEP) project is given in Box 2.4.

Alternatively, and more realistically, monitoring success of an ecological native oyster restoration programme should probably focus on determining if the restoration attributes (e.g. high biodiversity and distinct epifaunal assemblages that characterise biogenic reef habitats, as defined in the EU Habitats Manual, see Chapter 1) can be assessed by monitoring change relative to surrounding, bare substrate habitats. The JNCC '*Ostrea edulis* beds on shallow sublittoral muddy mixed sediment' habitat type SS.SMx.IMx.Ost biotope description provides another option for use as a reference ecosystem.

BOX 2.4: REFERENCE ECOSYSTEM EXAMPLE FROM THE DEEP RESTORATION PROJECT, SCOTLAND, UK

The Dornoch Firth Environmental Enhancement Project (DEEP)

The Dornoch Firth is an estuarine inlet in north east Scotland, and is of high environmental value, both at an international and national level. In 2013 DEEP began as a collaborative project between business (the Glenmorangie Company), higher education (Heriot-Watt University) and society (represented by the Marine Conservation Society) focusing on restoring native oysters to the Dornoch Firth.

Traditionally, success in restoration can be measured in terms of replication of ecosystem function, structure, biodiversity and community composition as metrics of convergence, either against an unimpacted site in the same system or a past pre-impact state. The problem in the Dornoch Firth, as with many other areas in the UK, is that oysters, although present and exploited since at least the Mesolithic, were completely fished out in the 1800s. Baseline data on oyster habitats is therefore lacking.

Other bivalve habitats however can be used to understand biodiversity convergence towards the natural community to be restored. The horse mussel *(Modiolus modiolus)* is a large, slow growing bivalve that builds reefs in North West Europe and there is growing evidence that native oyster habitats and horse mussel habitats shared closely overlapping subtidal niches (see Figure 2.6 and Figure 2.7). Horse mussel reefs exist in areas relatively unimpacted by fishing and therefore present an opportunity to study the biodiversity of 'pristine' subtidal biogenic shellfish habitats. Studies indicate that even at low densities horse mussel aggregations reach high biodiversity values. Experiences from horse mussel reef studies and the recovery wheel from SER (Figure 2.8b) were applied to understand the key attributes needed to reach the ecological restoration objectives:

1. Creating complexity in the reef: clumping, adding cultch and enhancing accumulation of bio deposited material.
2. Biodiversity indices monitoring will provide a clear idea of progress towards a climax, stable state.
3. Biotic assemblages and biodiversity metrics are strongly dependent on environmental conditions and likely to be site-specific.

Overall, within the context of the rapid global increase in protection and restoration of bivalve shellfish habitats, site and density-specific values of diversity are probably the best targets for conservation management and upon which to base monitoring programmes.

Ostrea edilus shell present — *Modiolus modiolus present (spot dives)*
Ostrea edilus shell absent — *Modiolus modiolus reef habitat extent*

Figure 2.6: Map of the Dornoch Firth showing presence/absence of *Ostrea edulis* shell and location of *Modiolus modiolus* reefs.

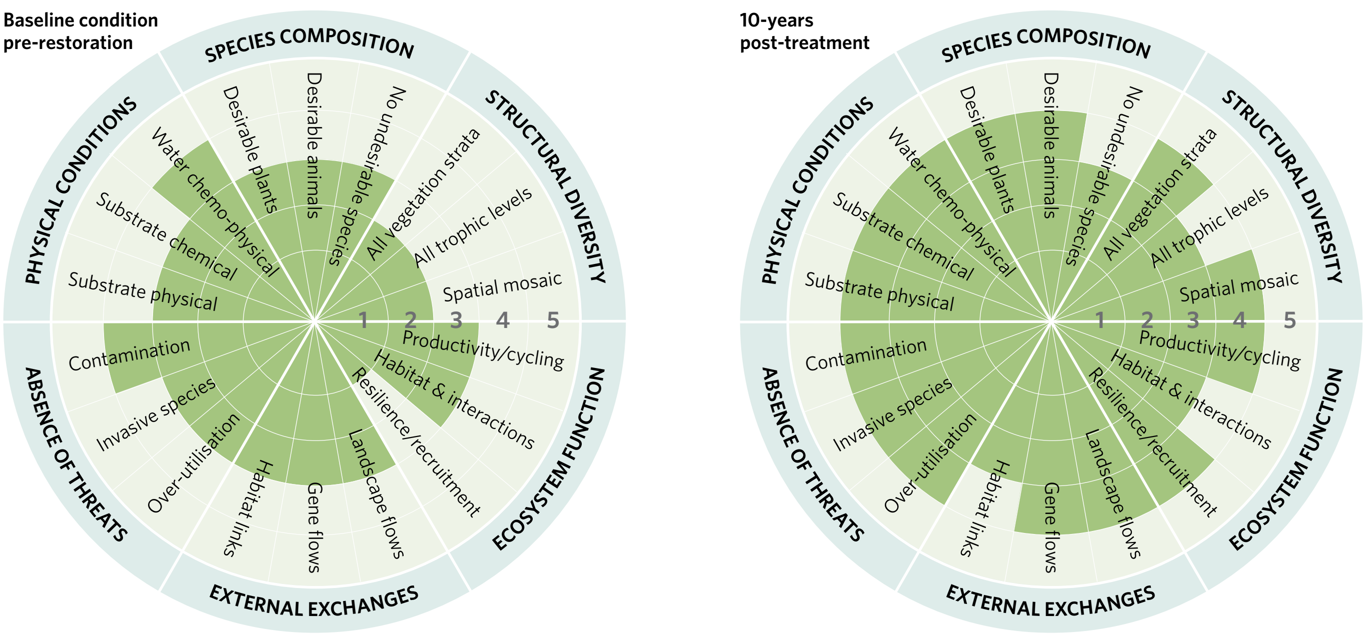
Figure 2.7: Native oyster shells with old attachment to horse mussels *Modiolus modiolus* shell (top). Live clump of horse mussels from Strangford Lough, N. Ireland (bottom). Photos: José M. Fariñas-Franco.

Key ecosystem attributes of a reference ecosystem

To help formulate a reference ecosystem, the ecosystem attributes desired as an outcome of a restoration project must be clearly defined. See Figure 2.8a for a description of generic ecosystem attributes used to characterise a reference ecosystem and an example of how a recovery wheel can be used as a tool to map ecosystem restoration progress (blank templates are available at https://www.seraustralasia.com/standards/appendix5.html or as an online tool http://seraustralasia.com/wheel/wheel.html. The recovery wheel is designed to work with a 5 star system that denotes the level or recovery across the ecosystem attributes, see Gann *et al*. (2019) for further details. It is important that the 5 star ratings are adapted by practitioners to be site and scale specific.

ATTRIBUTE	DESCRIPTION
Absence of threats	Direct threats to the ecosystem such as overutilisation, contamination, or invasive species are absent.
Physical conditions	Environmental conditions (including the physical and chemical conditions of soil and water, and topography) required to sustain the target ecosystem are present.
Species composition	Native species characteristic of the appropriate reference ecosystem are present, whereas undesirable species are absent.
Structural diversity	Appropriate diversity of key structural components, including demographic stages, trophic levels, vegetation strata and spacial habitat diversity are present.
Ecosystem function	Appropriate levels of growth and productivity, nutrient cycling, decomposition, species interactions, and rates of disturbance.
External exchanges	The ecosystem is appropriately integrated into its larger landscape or aquatic context through abiotic and biotic flows and exchanges.

a) Key ecosystem attributes table: Description of the key ecosystem attributes used to characterise the reference ecosystem, as well as to evaluate baseline condition, set project goals, and monitor degree of recovery at a restoration site.



b) Recovery Wheel: The ecological recovery wheel is a tool for conveying progress of recovery of ecosystem attributes compared to those of a reference model. In this example, the first wheel represents the condition of each attribute assessed during the baseline inventory stage of the project. The second wheel depicts a 10-year-old restoration project, where over half its attributes have attained a four-star condition.

Figure 2.8: a) Key ecosystem attributes table and b) recovery wheel for monitoring restoration projects against a reference ecosystem. Recovery wheel kindly provided by the Society for Ecological Restoration. Blank recovery wheel templates available to download from the Society for Ecological Restoration: https://cdn.ymaws.com/www.ser.org/resource/resmgr/custompages/publications/ser_publications/recovery_wheel.pdf.

KEY STAKEHOLDERS TO INVOLVE IN A PROJECT

Identifying key stakeholders and engaging with them in the early stages of project development is key to establishing a successful project, (see Figure 2.9). Engagement with stakeholders can reduce conflict and promote project success through increased understanding and support, increased opportunities to engage with local ecological knowledge and local natural resources management strategies. Early engagement can also increase a sense of ownership in the community, hence result in greater voluntary protection and compliance with management of the restoration site(s).

The first stage in a stakeholder engagement process is to identify key stakeholder groups and put in place mechanisms to promote diversity, equality and inclusivity. This can be achieved through a rapid stakeholder assessment. To conduct a rapid stakeholder assessment, follow these simple steps:

1. Convene an interdisciplinary work group which represents a variety of areas of expertise, such as ecology, fisheries management, regulation, hydrology, economics, political science and engineering.
2. Define the geographic boundaries and scale of interest. This will vary depending upon biophysical aspects of the restoration project, hydrology, jurisdiction, and location of stakeholders who are benefiting or impacted by the project. It may be worth considering a scale larger than the project site itself, as restoration may impact ecosystem service values at a larger scale.
3. List the ecosystem service/ecological benefits that will result from the upcoming restoration/protection project(s). Consult with the interdisciplinary work group to determine which benefits are most likely.
4. List all relevant stakeholders to the project, including beneficiaries and those who may be impacted negatively, and those who have the power to influence the success or failure of the project.
5. Determine the relative importance of each ecosystem service benefit, based upon expected number of beneficiaries and magnitude of benefit.
6. Understand and be able to effectively communicate potential trade-offs in ecosystem service delivery.

Note that while steps one through six are listed sequentially, the process is iterative and may involve circling back to previous steps as additional information is gained.

Although the focus above is on ecosystem service motivated projects, this approach can equally be applied to projects with the goal of enhancing biodiversity or reversing habitat loss. Timelines should ideally permit for the project design to be influenced by the stakeholders, adequate time should therefore be incorporated into the timeline at the start of a project. This can run concurrently with exploration of logistical considerations. It is recommended that approximately two to three months be assigned to complete a rapid stakeholder assessment.

Stakeholder engagement is a time consuming process, but it is one that should not be overlooked as good stakeholder engagement can make the difference between project success and failure. In building a relationship with stakeholders, it is important to be honest and open about the potential risks and trade-offs that inevitably arise in designing and undertaking a habitat restoration project. Not all restoration projects succeed at the first attempt, but with clear communication and expectation management, failure of a restoration action does not mean failure of a restoration project. As oyster restoration efforts inevitably require a long timeline to achieve success, this is all the more important.

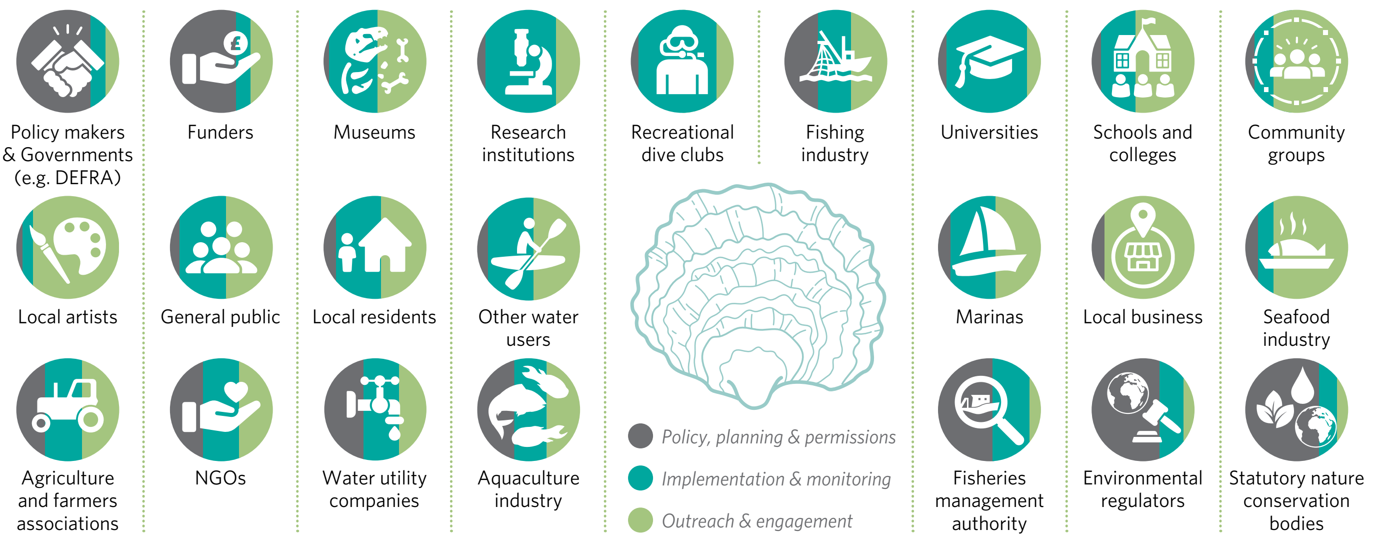


Figure 2.9: Potential stakeholders to consider involving in design and delivery of a native oyster restoration project.

PERMITTING AND LICENSING REQUIREMENTS

Seeking early engagement with key regulators or statutory bodies is of utmost importance for any proposed restoration project. Whilst there are policy, governance and legal aspects which are common to all UK administrations and Ireland, there are also differences and it is the responsibility of the restoration practitioner to ensure that they seek advice and follow required procedures. Even where restoration is planned for a privately owned area of seabed, practitioners must engage with the key regulators as licenses for deployment of oysters, cultch and/or structures onto the seabed are still required. Developing a working relationship with the relevant agencies and statutory nature conservation bodies as early as possible in the project planning stages is essential. Practitioners should be prepared for permission and licensing requirements to change during the life of the project and as the project activities are scaled up. As restoration is a relatively new field in the marine environment, the policy and permissioning frameworks may evolve over time.

Below is a summary of the licences and permissions that may be required to complete restoration in UK and Irish waters. There are four broad areas of jurisdiction, which include:

Marine licensing and marine planning (this involves all activity in the sea and on the seabed).

Nature conservation (for all activity that takes place within a designated MPA).

Fisheries & Aquaculture (relates to movement and management of fished or farmed marine species).

Water quality (relates to activities that impact or are impacted by water quality).

Waste (relates to storage and management of waste materials such as shell for cultch).

It is advisable that licence and permissions requirements are researched in more detail and the competent authorities relevant to the restoration locality are consulted early on in the project planning. An overview of the competent authorities and advisor agencies for nations across the UK and Ireland is given in Table 2.4. The underpinning legislations and inshore and offshore relevant authorities are provided in Figure 2.10.

Table 2.4: Competent authorities and advisory agencies for areas requiring licensing and permissions in the UK & Ireland.

	ENGLAND	WALES	N. IRELAND	SCOTLAND	IRELAND
Marine Management & Licences	MMO	Natural Resource Wales	DAERA Department of Agriculture, Environment and Rural Affairs	Marine Scotland	Aquaculture and Foreshore Management Division
Foreshore and seabed leases	Crown Estate	Crown Estate	Crown Estate	Crown Estate Scotland	DHPLG (Department of Housing, Planning and Local Government)
Assessing impacts in MPAs	Natural England	Natural Resources Wales	DAERA Department of Agriculture, Environment and Rural Affairs, Marine and Fisheries Division	SNH	NPWS (National Parks and Wildlife Service), Marine Institute & BIM (Bord Iascaigh Mhara – Ireland's Seafood Development Agency)
Inshore Fisheries	IFCA	Welsh Assembly Government	The Inshore and Environment Branch of DAERA	Marine Scotland	BIM & Marine Institute
Aquaculture and shellfish movement	CEFAS & FHI	CEFAS & FHI	DAERA	Marine Scotland & FFS	Marine Institute & BIM
WFD & Water Quality	Environment Agency	Natural Resources Wales	NIEA (Northern Ireland Environment Agency)	SEPA	EPA (Environmental Protection Agency)

MARINE MANAGEMENT, LICENSING, NATURE CONSERVATION AND FISHERIES AUTHORITIES

ENGLAND

INSHORE & OFFSHORE:

Marine Planning & Licensing:
The Marine Management Organisation (MMO) delivers planning, licensing activities and enforcement functions in English waters from mean high water springs.

Aquaculture:
The Fish Health Inspectorate (FHI) within Centre for Environment, Fisheries and Aquaculture Science (CEFAS) provides authorisation in England.

Fisheries:
Inshore Fisheries and Conservation Authorities (IFCA) manage inshore fisheries out to 6nm, MMO manage fisheries from 6-200nm (both under the Marine and Coastal Access Act 2009).

Marine Conservation:
Natural England (from 0-12nm, territorial waters) and The Joint Nature Conservation Committee (from 12 to 200nm, offshore waters) advise on the designation and management of marine protected areas.

NORTHERN IRELAND

INSHORE: DAERA has devolved competence over

- Marine conservation
- Marine planning
- Marine licensing
- Fisheries & Aquaculture

Nature Conservation:
DAERA designates and advises on MCZs, SACs and SPAs under the Marine Act (Northern Ireland) 2013 and The Conservation (Natural Habitats, etc.) Regulations (Northern Ireland) 1995.

Marine Licensing:
DAERA Marine and Fisheries Division carry out licensing and enforcement functions in NI territorial waters, under the Marine and Coastal Access Act 2009.

Fisheries and Aquaculture:
Administered by DAERA under Fisheries Act (Northern Ireland) 1966. *Exception – Development and licensing of aquaculture and shellfisheries in Lough Foyle and Carlingford Lough.

OFFSHORE: Marine Conservation:
The Secretary of State designates MCZ, SACs and SPAs under the Marine and Coastal Access Act 2009 and The Conservation of Offshore Marine Habitats and Species Regulations 2017. JNCC advises on the designation and management of offshore MPAs.

MMO has executive competence over marine licensing. DAERA has devolved competence over Fisheries and Marine Planning.

SCOTLAND

INSHORE:
Scottish Parliament has devolved competence over

- Marine conservation
- Marine planning
- Marine licensing
- Fisheries & Aquaculture

OFFSHORE:
Scottish Parliament has executive competence over

- Marine conservation
- Marine planning
- Marine licensing

Devolved competence over

- Fisheries & Aquaculture

MMO for non-devolved matters.

Nature Conservation & Fisheries, Management and Licensing:
Administered by Marine Scotland Under Marine (Scotland) Act 2010.

Nature Conservation:
NatureScot (formerly known as SNH) advises on the designation and management of MPAs to the edge of their territorial waters. Marine (Scotland) Act gives marine Scotland the power to designate nature conservation MPAs.

Management and Licensing:
Marine Scotland (MMO for non-devolved matters).

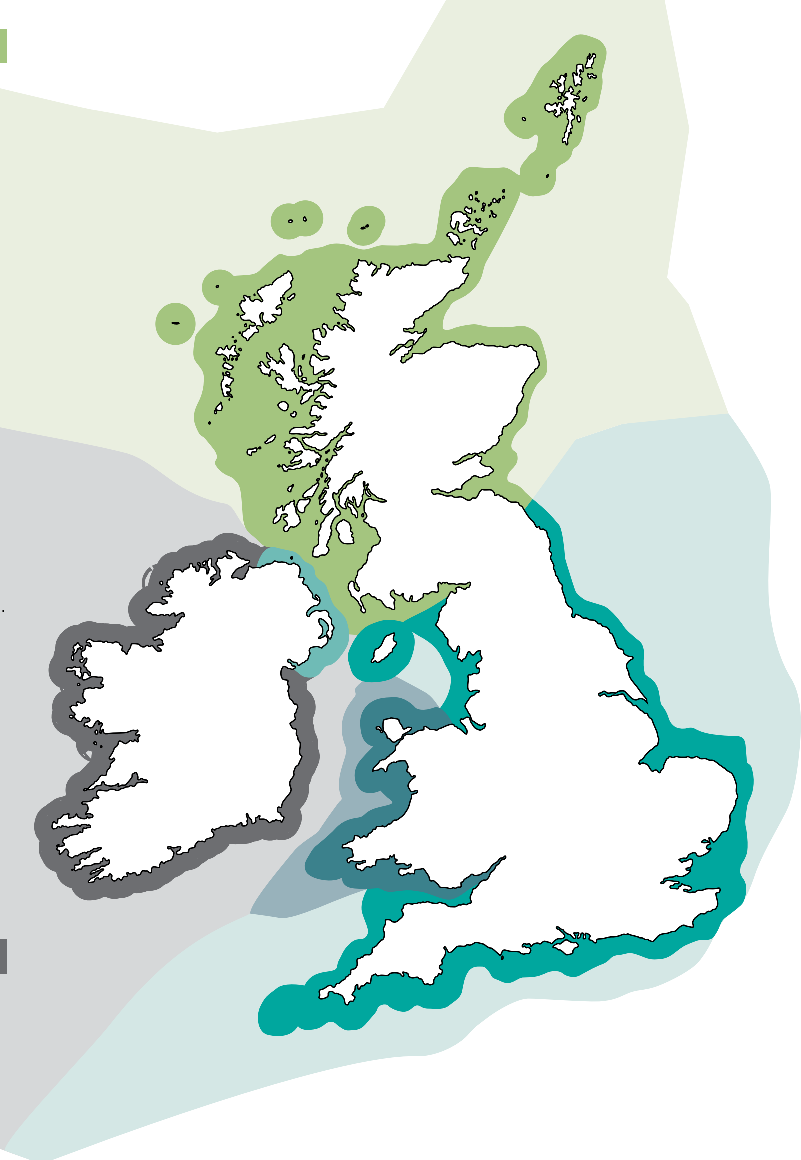
REPUBLIC OF IRELAND

INSHORE & OFFSHORE:
Irish Government has executive competence over

- Marine conservation
- Marine planning
- Marine licensing
- Fisheries & Aquaculture

Management, Licensing and Fisheries:
Inland Fisheries Ireland (IFI) licence oyster fisheries and manage oyster beds under the Inland Fisheries Act 2010. Management may be devolved to Oyster Co-operatives through a Fishery Order (IFI) or Aquaculture and Foreshore Licence under the Fisheries (Consolidation) Act 1959, Section 278 (5)(a) and Fisheries Amendment Act 1997 respectively.

Nature Conservation:
National Parks and Wildlife Service (NPWS) are the competent authority for conservation of nature including management of SACs and SPAs and implementation of the EU Habitats Directive (European Commission (Birds and Natural Habitats) Regulations 2011 (SI 477/2011)).



WALES

INSHORE & OFFSHORE:
The Welsh Government has devolved competence over

- Marine conservation
- Marine planning
- Marine licensing
- Fisheries & Aquaculture

Nature Conservation & Fisheries Management:
Welsh Ministers designate MCZs under UK Marine and Coastal Access Act. NRW advise on the designation and management of marine protected areas (from 0-12nm, territorial waters) and in collaboration with JNCC (from 12-200nm, offshore waters).

Management and Licensing:
NRW administers and determines marine licence applications on behalf of the Welsh Ministers.

Note
The Northern Ireland and Welsh Government can ask MMO to undertake functions on their behalf.

Adapted From SPICe briefing (2009) comparison of UK and Scottish Marine Bills using additional data and updated information.

Maps not to scale.

Figure 2.10: Marine Management, licensing, nature conservation and fisheries authorities for coastal and offshore waters, UK and Ireland, with underpinning legislation.

The following list below gives an example of the range of licences that could be required before authorisation is granted for a native oyster restoration project:

Marine licence: If the activity is not listed under the exempt activities a licence will be required to deposit substrates on the seabed from the appropriate authority (e.g. MMO or Marine Scotland).

Crown Estate lease: The Crown Estate and Crown Estate Scotland owns virtually all of the UK's seabed from mean low water to the 12-nautical-mile (22 km) limit and more than half of the UK's foreshore. Permission or a lease from the Crown Estate will be necessary if working in this area.

Marine Conservation Assessment: If the project takes place within or near a MCZ, it is likely an MCZ assessment will be required to deem if the activity may significantly affect the features of the MCZ. Refer to the appropriate authority for assessing impacts in MPAs (Table 2.4).

Habitats Regulations Assessment: Competent authorities must undertake HRAs to consider whether a proposed development plan or programme is likely to have significant effects on a European site designated for its nature conservation interest (SAC and SPA).

Areas or Site of Special Scientific Interest consent: As the owner or occupier of an (A/SSSI), notice must be given and the competent authorities permission (consent) received before anyone can carry out a planned activity on it or allow anyone else to carry out a planned activity on it.

Water Framework Directive assessment: Many activities need approval before they can go ahead. A WFD assessment is required as part of an application to the public body that regulates and grants permissions for activity within one nautical mile of the coast.

Aquaculture Business Authorisation: When producing, handling, translocating or restoring native oysters it is advisable to receive an authorisation from the regulator. Before setting up a fish, shellfish or crustacean farm, an aquaculture production business application to the Fish Health Inspectorate (or equivalent) is required to prevent the introduction and spread of infectious diseases.

Further details of the licensing processes for the UK and Ireland Nations are available as a pdf on the Native Oyster Network website: https://nativeoysternetwork.org/resources/

FUNDING RESTORATION PROJECTS

The main funding questions are: scale, time frame, partners, management, co-funding issues and volunteer/in kind contributions. A minimum five year project is necessary for restoration but most funders only support for two to three years. Therefore, it is unlikely all the funds required will come from one source. Often funders only fund 50% and prefer to co-fund. Project can be divided into packages to help target different funders.

For example, smaller funders may initiate a native oyster restoration project and this can be used to provide pilot data for funding a larger project.

Examples of the types of funding streams available to a native oyster restoration project include:

- European funding bodies e.g. the EU Life +.
- UK Government e.g. Natural England, NatureScot, Marine Institute Ireland.
- Research grant e.g. NERC https://nerc.ukri.org/ or BBSRC https://bbsrc.ukri.org/.
- Trusts/Charities e.g. Seachangers.
- Lottery funding e.g. National Heritage Lottery Fund (NHLF).
- Corporate companies.
- Individual giving.
- Crowdfunding, via websites e.g. Just Giving.

Tips:

- Identify funder priorities, e.g. education, community project.
- Research previous grantees and award amounts.

FURTHER READING

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Gann, G. *et al.* (2019) *International principles and standards for the practice of ecological restoration.* Second edition. Restoration Ecology, 27(S1), pp. S1–S46. doi: 10.1111/rec.13035.

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CHAPTER 3
NATIVE OYSTER RESTORATION IN PRACTICE

CHAPTER AUTHORS

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KEY SUMMARY POINTS

- **Determining if an area is recruitment or substrate limited, or both, will allow the most appropriate restoration techniques to be selected.**
- **Native oysters can be obtained from hatcheries, spatting ponds, fisheries or by natural recruitment.**
- **Seabed reef deployments can be supplemented with small-scale initiatives that are ideal for outreach and community engagement.**

INTRODUCTION

This chapter describes the techniques that can be implemented to achieve restoration success across Europe, as well as some that are used for other species but are yet to be fully developed for the European native oyster. A combination of these techniques may be required to maximise restoration success and outreach or engagement in the project. While considering the appropriate restoration techniques, it is of utmost importance to follow the biosecurity procedures outlined in Chapter 4.

At the outset it is important to understand whether the restoration site is substrate or recruitment limited – it can often be both. In most areas of Europe and the UK native oyster populations have declined to the extent that insufficient larvae are produced, i.e. the system is recruitment limited. In this case the focus of restoration needs to be on building a breeding population. Spat collectors or small-scale pilots can be deployed to obtain a measure of settlement rates or alternatively plankton surveys may be undertaken. If larvae are available in sufficient numbers, they need suitable substrate on which to settle. The shell base of historical reefs have been widely removed through dredging or deliberate mining for shell. Agricultural practices have also increased the amount of silt and mud in the nearshore area which reduces the hard substrate available for oyster larvae to settle, leading to substrate limitation. The appropriate techniques to address these issues are highlighted in this chapter. Monitoring of metrics associated with these techniques for oyster restoration is detailed in Baggett *et al.* (2014).

SOURCING NATIVE OYSTERS IN THE UK

It is important to consider early on in the project planning process where and how to responsibly source native oysters for restoration. Oyster supply is a key limiting step in oyster restoration projects. Sourcing oysters from outside the local area can present significant biosecurity risks, which are time consuming and costly to address and impossible to eliminate completely. When considering using wild stocks, the impact on the donor site must be considered first. The use of wild stocks to supply the demand from restoration has the potential to further damage the remaining populations. While this source may still represent an option for projects at the pilot phase, projects must ensure that the stock selection process is conducted responsibly and in accordance with legislation and biosecurity protocols. Ultimately the long-term solution must be increased production from hatcheries, local spatting ponds and collection of local wild spat.

As demand grows, the existing supply chain may struggle to facilitate large-scale production for large-scale restoration, especially if project timelines fail to factor in appropriate lead times.

Maintaining genetic diversity

Beyond the biosecurity threats from disease and invasive species, translocations of native oyster stock can also have implications for the genetic diversity within the species. Historically there have been many translocations of oysters across the UK and Ireland to sustain and boost fishery stocks, and a degree of genetic homogeneity already exists due to both this national scale movement of stocks, and disease or fishery driven population crashes. However, studies also demonstrate there is relatively high diversity and geographical differentiation in the genetic population structure across the native oyster's biogeographic range. Genetic differentiation has been linked to both adaptations and disease resilience at local scales. For this reason, it is important that restoration practices, at a minimum, maintain local or regional genetic diversity and adaptations. In addition, restoration projects should seek to utilise breeding techniques that maximise the genetic diversity in the offspring to enable resilience to future change.

SOURCES OF NATIVE OYSTERS

Hatchery

An oyster hatchery is a facility where adults are conditioned to reproduce and spawn, and larvae are reared until metamorphosis (with or without settlement). The juveniles usually remain at the hatchery until they are large enough to be transferred to commercial farms. These hatcheries usually include facilities for production of large quantities of algae to feed all stages of the production cycle. Hatcheries can provide juveniles not only for aquaculture, but also for restoration programmes. Juveniles raised in a hatchery can be released into the wild to supplement the natural populations. Care needs to be taken when sourcing stock from a hatchery, to establish whether the seed supplied has been in open contact with the surrounding water body before being shipped. If so, biosecurity protocols equivalent to being moved from the open water body must be applied (see Chapter 4). Alternatively, projects can consider buying biosecure hatchery stock and growing them out locally for 18 months to two years.

Spatting ponds

Spatting ponds are large pits that are typically dug to a depth of 2m and 25m in both length and width (but can be modified to required size) (see Figure 3.1). They are filled with seawater from the adjacent waterbody, often relying primarily on gravity to fill and drain them, with pumps for assistance. Mature oysters are placed in the ponds during the spawning season and the water column is monitored daily for larvae and food availability. Ceramic plates can be placed into the pond to give an indication of when larval settlement has begun. As soon as settled spat are observed the settlement material is added to the ponds. Bags of shell and other material are hung at the edges or in the ponds to accumulate a surface biofilm and enable settlement. Biofilms are formed when bacteria and microalgae adhere to hard surfaces and secrete a slimy extracellular matrix. Attachment to this community has been shown to increase the settlement success of numerous marine organisms including oyster larvae. Once settlement has taken place the spat-on-shell can either be deposited onto the restoration site or on-grown in aquaculture systems to reduce mortality rates.

Figure 3.1: Spatting ponds used to produce native oysters in Galway Bay, Ireland. Photos: Luke Helmer.

Wild spat collection

Collecting spat from wild populations and on-growing them in ponds or parcs was a method adopted by the French when the oyster industry started to collapse in the mid-1800s. A range of spat collectors have been trialled including shell cultch, bundles of twigs, limed tiles and commercially made collectors such as coupelles. If using coupelles, the black, perforated design is more suitable for native oysters than the orange, solid design. Once coated or 'limed', the coupelles are usually deployed in arrays on metal frames to maximise the available surface areas (Figure 3.2). If available, hydrodynamic models within the local system can provide information regarding possible recruitment hotspots and inform the placement of collectors.

Wild stocks and fisheries

Wild fisheries can also supply broodstock (see Figure 3.3). Movement of such oysters should ideally take place within the same body of water, and if this is not possible, appropriate biosecurity risk assessment and practice should be planned into the project timeline and budget. Projects should consider that moving large numbers of oysters may be inhibitively costly, time consuming and risky. Any removal of oysters from the seabed should take place in accordance with regulations and bylaws put in place by the local fisheries authority (i.e. for England; Inshore Fishery and Conservation Authority (IFCA)), and there is an onus on the project to establish, for ethical and reputational reasons, that the broodstock is sustainably sourced. See Table 3.1 for benefits and considerations for each of these sources.

Figure 3.2: Deployment of limed spat collectors (coupelles) on an A-frame in Essex, England and settlement observed on collectors in Quiberon Bay, France.
Photos: Matt Uttley (top), Jean-François Tauget (bottom).

Figure 3.3: Small-scale fishing vessel dredging for native oysters in the Solent, England.
Photo: Blue Marine Foundation.

BOX 3.1: CURRENT ISSUE:

Intertidal stocks and hand gathering

The effects of unrestricted shore gathering can be particularly devastating to a recovering population. An example of this was highlighted in Strangford Lough, Northern Ireland, during the mid-2000s. The Strangford intertidal ($75km^2$) population had been rejuvenated from a standing stock of < 10,000 to > 1.2 million native oysters through a combination of commercial stock spawning events and larval retention in the northern basin (see Figure 3.4). However, within a period of three years, hand gathering had reduced the intertidal population to approximately < 400,000 native oysters. A particularly poignant example of the total removal gathering practiced by the hand gathers was recorded at the remote site of Ballyreagh, Northern Ireland, where approximately 300,000 native oysters with no size discrimination were collected. This site has never recovered with < 10 native oysters recorded in 2018. If the conservation and restoration of the native oyster is to be maximised, the practice of unregulated intertidal harvesting needs to be urgently addressed. A recovering species is unlikely to attain a self-sustaining status if these unsustainable practices continue unchecked and active management is not introduced. As these shellfish do not pass through appropriate depuration processes, as is required for commercial fisheries, there is an increased risk to human health if they are consumed.

Figure 3.4: Native oysters in the intertidal zone that are at risk of hand gathering in Strangford Lough, Northern Ireland. Photos: José M. Fariñas Franco.

Table 3.1: Summary of the current native oyster sources, as well as the benefits and considerations to be taken into account when selecting a supply.

SOURCE	BENEFITS	CONSIDERATIONS
Hatchery: Juveniles	Contained production means a greater level of control is possible for environmental conditions increasing survival and larval development success. Manipulation of environmental conditions to allow for reproduction to occur year round. Control over fouling/invasive species and disease transfers is possible if biosecurity measures are in place.	Reduction in genetic diversity if limited number of broodstock used. In some US hatcheries, breeding oysters are taken from wild populations and replaced after spawning with different locations used each season to maintain genetic diversity. Potential mixing of species if the hatchery produces multiple species. Costs and expertise associated with hatchery rearing can be high. Scale, producing large quantities of larvae is yet to be streamlined. Once water from the surrounding environment is used to feed the oysters the system is no longer biosecure, therefore purchasing before this point may be financially beneficial and save time.
Ponds: Juveniles	Large scale setting of juveniles. Large numbers of broodstock can be used, resulting in greater genetic diversity within larvae. Greater chance of successful settlement if multiple ponds are used.	Biosecurity – unwanted species will settle alongside the target oyster species therefore spat should be produced locally. Successful settlement is not guaranteed and can be sporadic. Limited control over environmental conditions within the ponds (can't control external weather). Pond water level can be adjusted to reduce the effects.
Wild spat collection: Juveniles	Removes costs associated with purchasing oysters. If placed locally the oysters collected will have adaptations suited to survival in the area. Limited impact on the benthic environment.	Location of deployment – navigational, logistical and larval recruitment. Permissions required to deploy structure. Translocations, of oysters and equipment, between water bodies should not take place – this will ensure fouling/invasive species and diseases are not transported. Can only be applied where sufficient stock is available for sufficient recruitment to occur. Scale is required in low recruiting areas to harvest sufficient numbers.
Wild stock/ fisheries: Broodstock	If oysters are sourced from the same body of water that they will be released into, biosecurity measures are not required. (**Note:** it is suggested that purchasing broodstock oysters from fisheries be a last resort if all other sources are not feasible). Local stock may have adaptations suited for survival in the area and existing genetic structure in the population is maintained.	Potential translocations of fouling/invasive species and disease if the source is not local. The processes required to make stock biosecure are costly and time consuming. Damage to the seabed where destructive dredging techniques are used. Sourcing from dive fisheries reduce this impact. Purchasing wild oysters may put pressure on the natural stocks, further reducing the larval supply.

IDENTIFYING APPROPRIATE RESTORATION ACTION

The restoration techniques chosen and the scale at which they are delivered will depend on factors outlined in Chapter 2. The following section outlines techniques available to restoration projects once the project goals have been established and the larval and/or substrate limitations identified.

LARGE SCALE DEPLOYMENTS

Deployment densities

Given the lack of a reference baseline of native oyster density for most locations, projects should give careful consideration to setting targets for reef densities. The end goal of restoration is often a sustainable population, and it is not yet known how this relates to density or area of oyster reef habitats. As such, an adaptive approach will likely be required in setting target densities. The initial target density should be informed where possible by historical records, ecological data, and stakeholder input. The latter is likely to be important in particular where restoration efforts are co-located with fisheries, given the potential for oyster density to interact with disease prevalence.

The density achieved immediately after deploying oysters, especially for spat-on-shell or juveniles, will need to be substantially greater than the intended established density. Natural mortality, stress related mortality, predation, and redistribution by currents or tides all contribute to the attrition or redistribution of some of the deployed oysters.

Surveys in the Solent showed that as few as 5% may be retained after one year when relaying juvenile oysters (25-30mm in size) directly onto the seabed. Similarly, in the Dornoch Firth, densities of 10-15g oysters reduced by > 50% in three months due to tidal redistribution in a 2kn tide. It is likely that the use of shell or stone material, to create stable reef structures, can increase the rugosity of the seabed and therefore retention on the target area (see techniques outlined elsewhere in this chapter).

Taking into account the lower of these retention values, practitioners would need to take the retention rate of 5% into account when setting their deployment density (Table 3.2.). Retention of oysters will be different at each project site. Therefore, practitioners are encouraged to run small scale pilot studies in order to understand the hydrodynamics, rate of retention, predation or mortality for the site and accommodate for losses associated with these issues, feeding the results into potential retention calculations.

Table 3.2: Example of the relationship between deployment and long-term densities using a conservative retention estimate.

TARGET DENSITY (OYSTERS/M²)	RETENTION OF OYSTERS (OYSTERS/M²)	DEPLOYMENT DENSITY (OYSTERS/M²)	DENSITY ACHIEVED AFTER ONE YEAR (OYSTERS/M²)	TARGET MET?
	5%		0.00	No
		10	0.5	No
		20		Yes

Getting oysters on the ground

It is not possible, nor ecologically desirable to achieve a uniform density across an entire restoration area, but there are methods that can be employed to increase the accuracy of deployments. The simplest way to reseed single oysters, or spat-on-shell, is from a vessel with appropriate lifting gear. With an experienced skipper a vessel can run several transects up and down the selected relaying area at a set speed.

The number of oysters to be deployed from the vessel for each transect or 'dump' can then be calculated. For example, if the boat was travelling at 1 m per second, one oyster would be dropped every second along the transect. This would achieve reef density of 1 oyster per m², see Table 3.3. If the depth of water is sufficient to allow a degree of dispersal through the water column then the same principle can be applied to deploying batches of, for example, 50 oysters at intervals.

Table 3.3: The following table provides an example of how oyster deployment efforts can be conducted to achieve the approximate desired density if deploying from the back of a vessel. These calculations can be applied to any quantity of oysters required.

RELAYING AREA (M^2)	RESEEDING DENSITY (OYSTERS/ M^2)	TOTAL NUMBER OF OYSTERS	TRANSECT LENGTH	NUMBER OF TRANSECTS	NUMBER OF OYSTERS/ TRANSECT	BOAT SPEED (M/S)	RESEEDING RATE (OYSTERS/ SECOND)
XY	p	N	X	Y	n = N/Y	v	n/v
1,000	20	20,000	100	10	2,000	2	40

To provide greater accuracy when delivering oysters from a boat in deeper water projects, Australian researchers have designed a chute system that pipes the oysters to depth and allows a greater number of oysters to be deployed than by using divers alone. Oysters are loaded onto a tray adjoining the delivery funnel and are then gradually pushed into the delivery mechanism. High pressure water is also fed through the pipe to prevent blockages. The oysters flow down the flexible pipe to the end controlled by a diver (Figure 3.5). With some modification this system can be used to deploy oysters without the aid of a diver. For smaller-scale, experimental or outreach-orientated projects, oysters can be deployed into plots or directly onto prepared reefs by divers using bags of oysters.

Deployment – timing and presence of live oysters or substrate

Timing of seabed deployment is possibly the most critical factor in ensuring survival of oysters and for efforts aimed at receiving larval recruitment, it can be the difference between success or failure of a project. Placing large amounts of juvenile oysters on the seabed at times of the year when predators, such as crabs (e.g. *Carcinus maenas*), are in high abundance in coastal waters will result in unnecessary mortality. When deploying substrate, doing so too early can result in algal turf and other organisms settling before the oysters begin to search for suitable substrate and metamorphose. Alternatively, deploying too late in the season won't allow for sufficient biofilm formation and will mean the larvae are likely to either disperse and settle elsewhere, or not settle at all due to a lack of suitable substrate. Either of these scenarios will mean that recruitment will be below potential levels in the intended restoration area.

Numerous factors, including temperature, lunar cycle and food availability influence the timing, health and quantity of larvae released by female oysters, but an indication of the peak in activity can be observed from previous documentation and comparing that with current observations. This is likely to vary across the biogeographic range of the native oyster, as well as locally with changes in climatic conditions. It is recommended that larval abundance surveys be conducted in the intended area to be restored, at least for the season prior to deployment of larger scale aspects of the project. Concepts such as the number of degree days expected can also be taken into consideration to maximise recruitment from deployment activities.

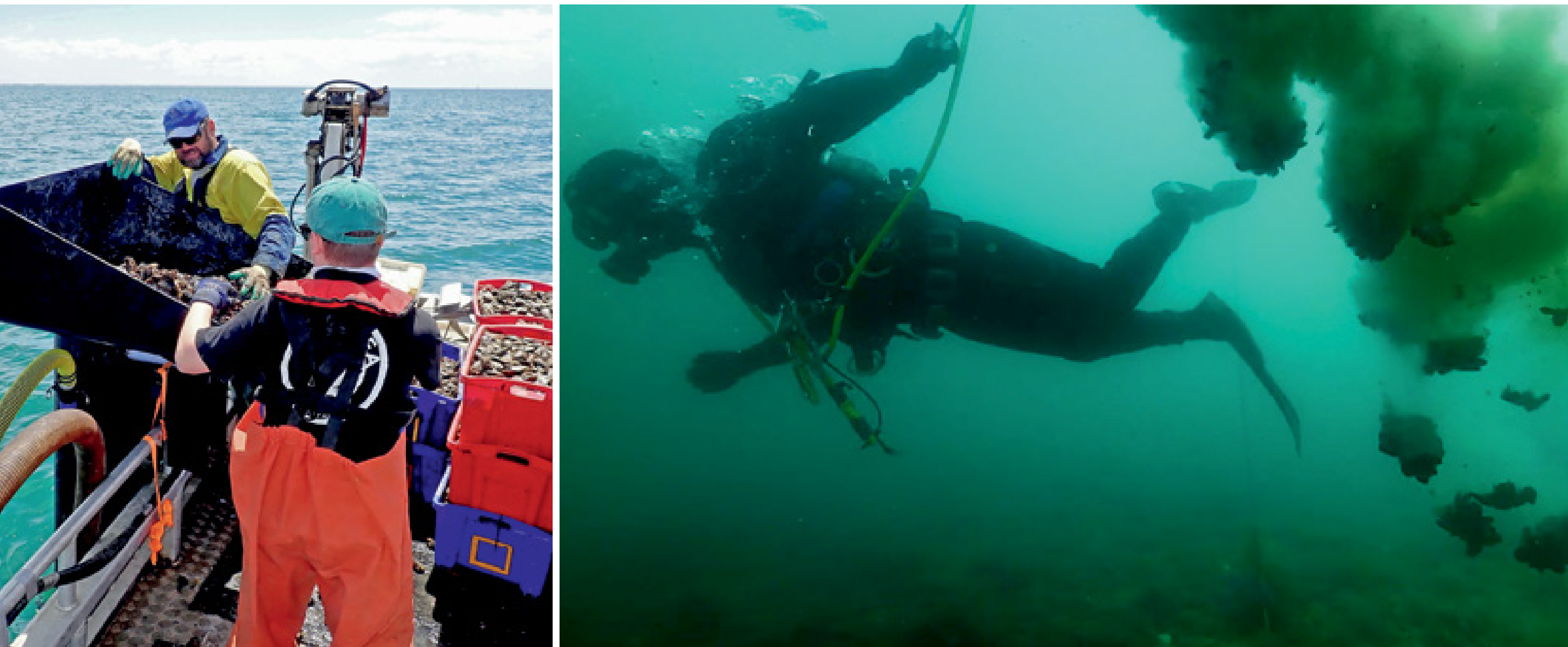

Figure 3.5: Chute system designed to allow for more accurate deployments used in Port Phillip Bay, Australia. Photos: Nature Conservancy.

Figure 3.6: Mixed reef with established populations of native oysters, Pacific oysters and blue mussels in the Dutch North Sea. Photos: ARK Nature.

An important factor when attempting to encourage or enhance recruitment is the presence of bivalves and particularly living native oysters (adults or spat), which is likely to strongly enhance settlement. On shellfish reefs in the Dutch North Sea, native oysters are found attached to other species of live bivalves such as Pacific oysters and blue mussels *(Mytilus edulis)* (Figure 3.6).

Determining shell budget

The amount of shell, or alternative suitable settlement substrate, naturally occurring in potential restoration areas is a key factor in determining how to progress with seabed deployments. It is also an important metric to record as the reef develops and gives an indication of available substrate for future recruitment. If an area considered for restoration contains a large amount of subtidal mixed sediment, including live oyster or shells, then it may not require a large deposit of additional material in order to make it attractive for future larval settlement, or in order to retain the newly deposited oysters. However, for areas of poor quality subtidal mixed sediment then the addition of large quantities of shell or alternative material are required to provide reef foundations, allow for settlement of larvae and to prevent dispersal of oysters deployed in the area. The shell available in an area can be determined when conducting initial benthic surveys (Chapter 2).

As reefs establish, there will be both gain and loss of shell material through natural processes, but ultimately the gain needs to exceed the rate of loss. Shell budgets are calculated as the amount of shell gained against the amount of shell lost over time (Powell *et al.* 2006).

This is calculated by monitoring the shell available at the site over time and can be measured by deploying quadrats into the area and removing all material on top of the seabed. Material buried under the sediment is not available to larvae and is therefore not considered within the shell budget. The volume of shell available is then calculated using the methods outlined in Baggett *et al.* (2014). A quicker assessment can also be conducted to establish the percentage cover of suitable reef substrate in a similar manner without requiring the removal of material, a gridded quadrat is often best for this measurement.

Sampling should be conducted prior to deployment to gather an indication of the baseline status of the area and to inform deployment decisions. Further sampling should take place one to two, and four to six years after deployment of the reef and/or oysters. Additional surveys may also be required after strong storm events.

WHAT TO DEPLOY AND DEPLOYMENT OPTIONS

Once a proportion of the larvae, often 50%, have developed a visible eyespot or settlement behaviour is observed on indicator plates, the larvae are either taken and placed into setting tanks containing shells in hatcheries, or large amounts of shell material are introduced into the spatting ponds.

Spat-on-shell

Spat can be set onto shell in a hatchery, spatting pond or from the wild in areas of high settlement densities (Figure 3.7).

Traditionally bivalve shells, in particular mussel, scallop and oyster shells are used, with the opinion amongst producers that mussel shell obtains the greatest settlement. However, for restoration, scallop and oyster shells may provide a more suitable solution as they are heavier and therefore less likely to be removed by tides and currents when placed onto the seabed or prepared reefs.

The shell material used will depend on availability, site dynamics (wave action, currents etc) and annual settlement of larvae. Trials should be conducted prior to large scale deployments.

Success and benefits:

- Each female native oyster releases in the region of 0.9 to 1.8 million larvae. A successful settlement can produce large quantities of settled oysters to be transferred to restoration sites.
- Shell material not utilised in the initial settlement provides suitable substrate for future settlement of wild larvae if deployed at the correct time.
- In a controlled environment (hatcheries) it is possible to increase the number of spat-on-shell produced (induction of multiple spawning events) and the level of biosecurity.
- In setting ponds, genetic variability is more easily retained by using a larger broodstock population.
- Cost effective.

Considerations:

- Larval settlement can be variable, both in hatcheries and spatting ponds, as many factors affect the success: topography, material, biofilm, chemical cues, etc.
- It is recommended to clean and treat shells thoroughly, following biosecurity protocols, since it is possible that disease organisms can persist on shells.
- Early losses may occur immediately following metamorphosis. Survival of settled spat is dependent on several factors such as diet, ration, stocking density and water flow rate.
- High mortality is to be expected once laid on the seabed, this would occur in the natural system.

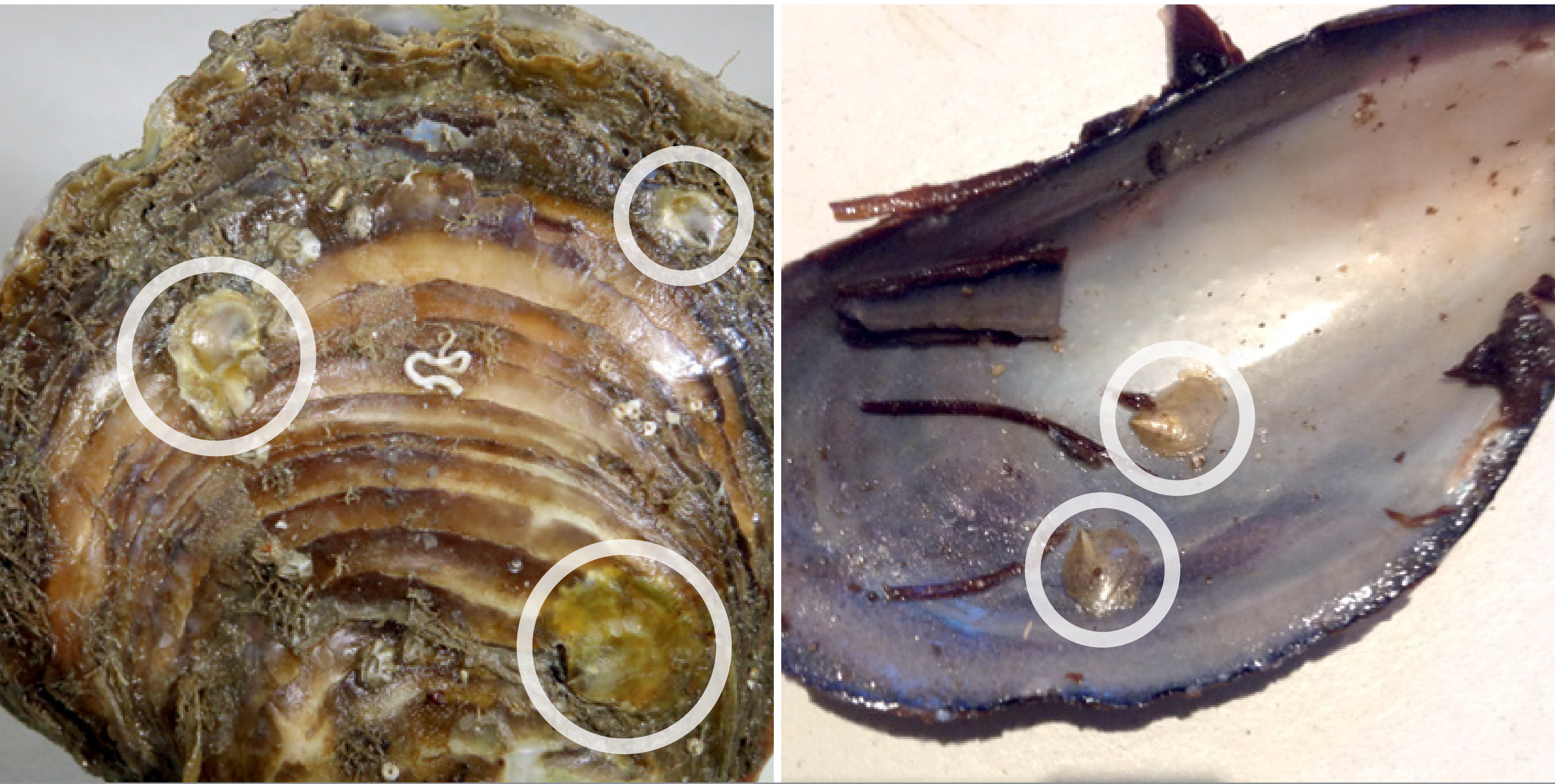

Figure 3.7: Native oyster spat settled onto an adult native oyster shell in the Solent (left) and onto blue mussel shell (right). Photos: Luke Helmer (left), Tony Legg (right).

SINGLE OYSTERS (JUVENILES AND ADULTS)

Juveniles

Single juvenile oysters, not attached to a substrate, are also known as "cultchless" spat. When produced using settlement substrate, the newly set spat need to be removed from the surfaces within 24h of attachment (for example by flexing plastic coupelles or with a razor blade), or more commonly, settled onto very small pieces of substrate that has been broken up and sorted to a size of approximately 1mm.

Success and benefits:

- Large quantities of oysters can be produced at a reasonable scale for deployment.

Considerations:

- Removing the settlement substrate also removes associated mass, making the oysters prone to unintended translocation in tides and currents.
- Small spat gain some protection from predation by being attached to larger shell substrates, therefore cultchless spat are likely to be subject to higher predation rates.

Adults

Deploying mature adult oysters is particularly key in recruitment limited environments as they can begin to provide an immediate supply of larval output to address this issue. Where there is a sustainable oyster fishery, it may be possible to purchase mature 'broodstock' oysters (> 50mm) to be translocated into an area that is protected from fishing pressures and make biosecure in large quantities providing a ready-grown source of potential larvae.

Success and benefits:

- Mature broodstock oysters offer the potential of spawning and larval output during the first year of deployment.
- Mature oysters have a good survival rate.
- The broodstock may provide chemical cues for the settlement of 'wild' spat in the system.

Considerations:

- Place mature oysters onto a hard substrate or a prepared seabed using cultch; oysters can be lost or become submerged on muddy or silty seabeds.
- Protection from poaching may be required.
- Adults being relayed away from the donor site must be subjected to rigorous biosecurity measures.

Reef substrate management and deployment

Finding the optimal settlement substrate is a trade-off between availability, price and aim of the project, examples of substrate are provided in Table 3.4. Once a substrate is selected, its efficacy in inducing settlement will depend on a number of factors related to the site, such as biofilm colonisation, hydrodynamics, the degree of competition from other species and the amount of sedimentation.

Deployment of stone aggregates or various shell types (cultch) offers settlement material in a substrate limited environment, where larval supply is not necessarily a limiting factor. Cheaper materials such as stone and gravel aggregates can raise the height from the seabed before higher cost shells and oysters are deposited on top. Individual requirements for gravel or shell type will differ with local regulations. Raising oysters off of the seabed reduces the effects of sediment smothering and associated mortality, as well as improving their physiological performance. In Essex the gravels used to elevate the oysters were required to be of a type naturally occurring in the estuary, which could come from a local land-based gravel pit.

Biosecurity is a consideration with the laying of cultch and all shells were weathered for 12 months regardless of processing to minimise risks posed by potential pathogens and invasive non-native species (Chapter 4). Heavy scallop shells were used for experiments in the Dornoch Firth to stabilise the substratum and increase oyster retention in order to establish if shell reefs could be recreated.

Success and benefits:

- Good settlement can be achieved on both stone aggregate and various shell types.
- Stone is cheap, readily available and requires no weathering if from a land based source (Chapter 4).
- Preliminary results indicate that shells can be deployed successfully to create stable reef structures. There may be initially movement with tidal currents but stabilisation may occur over winter, such that it becomes imbricated and consolidated with some sediment in-filling.
- Stone can be deployed as larger pieces which retain their three-dimensional structure, while shell, particularly lighter more brittle species, can break down into a more two dimensional 'pavement' over time.

Considerations:

- Shell must be purchased in advance to allow for 12 months weathering and/or other biosecurity treatments (see Chapter 4).
- Due regard needs to be given to waste legislation for the storage and treatment of animal by-products, which might govern processed shell use and treatment.
- A period of stabilisation may be necessary for material deployed to recreate oyster shell habitat before oysters are added to it. Deployment in larger 'dumps' rather than scattering can encourage shell to consolidate in mounds on the seabed.

Table 3.4: Cultch/substrate selection for native oysters.

SUBSTRATE TYPE	ACCESS TO LARGE QUANTITIES	LIKELY QUANTITIES OF SETTLEMENT	PREPARATION REQUIRED – CLEANING ETC
Shells (General)	Medium ease.	In the lab: 10-15% of larvae settled without suitable biofilm on shell but a much larger proportion can be expected to if a suitable biofilm is allowed to develop. In the sea: 1% of mature larvae settled on shell cultch laid by oyster farmers in the Oosterschelde (Netherlands).	It is generally not possible to guarantee the origin of shell accessed for restoration. Therefore, all shell is considered a potential biosecurity risk from a separate water body. As a result, all shell needs to be cleaned and cured to remove all biological material and any potential pathogens.
Cockle shell	Readily available from food processors in the UK.	ENORI deployed approximately 60 tonnes of cockle shell in Spring 2019. Preliminary small-scale grab sampling in Autumn recovered cockle shell but found no evidence of spat settlement but high levels of settlement on the controls (spat collector coupelles).	Shell is processed prior to delivery (cooked and meat removed). This is then weathered outside for 6-12 months to ensure there is no biological material remaining.
Scallop shell	Readily available from food processors in the UK.		Shell is pre-processed (cooked and meat removed). This is then weathered outside for 12 months to ensure there is no biological material remaining.
Mixed oyster shell (*C. gigas* and *O. edulis*)* *Use of Pacific oyster shell is not appropriate when the species is not present in the area	Readily available in small quantities via recycling programs.	ENORI deployed approximately 6 tonnes of mixed oyster shell in Spring 2019. Preliminary small-scale grab sampling in autumn recovered oyster shell and found evidence of spat settlement.	Unprocessed shell is weathered for 12 months before deployment.
Blue mussel shell	Can be difficult to access in some areas of the UK. Available from continental Europe but with high transport costs.	Producers who use spatting ponds indicate that the most settlement is observed on mussel shell, with a single pond able to produce up to 10 million spat on shell if conditions are favourable.	Shell is processed prior to delivery (cooked and meat removed). This is then weathered outside for 12 months to ensure there is no biological material remaining.
Stones/ Aggregates	Readily available.	In the lab: 8% of larvae settle without suitable biofilm but > 80% settle with a suitable biofilm. 360 tonnes of locally sourced fluvial gravel deployed in Essex by ENORI in 2019. Preliminary surveys suggest good settlement.	It is likely that licence requirements will dictate that gravels are of a type naturally occurring in the restoration area.
Live native oysters (*O. edulis*)	Adults: costly. Spat-on-shell: cheaper and easier to obtain in large quantities; but more costly than shell substrate.	In the lab: rapid settlement by 100% of larvae was observed when in the presence of adult native oysters.	The sourcing and cleaning of live native oysters should follow the guidelines detailed in Chapter 4.

Figure 3.8: The deployment of shell (cultch) from bags off the bow of a barge in the Dornoch Firth, Scotland. This method allows the shell to fall at one time and form a more consolidated mound on the seabed. Photo: Jean Paul.

BOX 3.2: SCALING UP FLAT OYSTER RESTORATION

Case study – Windara Reef

While native oyster restoration projects in Europe and the UK have thus far been experimental in scale, examples of larger scale restoration using a closely related species *(Ostrea angasi)* are available from projects in southern Australia. Windara Reef was established through a partnership between The Nature Conservancy, Government of South Australia, Yorke Peninsula Council, University of Adelaide and the local community. The purpose of the project was to build a self-sustaining flat oyster reef (*Ostrea angasi*) that delivers enduring ecological and community benefits, as well as economic prosperity. In 2014, the Government of South Australia announced a commitment to construct artificial reefs to increase recreational fishing and tourism opportunities across the state, shellfish reefs were not originally considered for the policy commitment. However, the publication of historical baselines for the area presented an alternative to artificial structures. After consultation, the commitment to establishing shellfish reefs, as a more sustainable solution to meet targets, was introduced. The initial investment supported the construction of a four-hectare pilot reef consisting of 60 separate concrete reef structures and a number of limestone reefs, seeded with juvenile oysters.

In 2015, an additional $990,000 (AUD) was secured from the Australian Government's National Stronger Regions Fund and provided a substantial proportion of the total funding, $3.7 million, that supported the construction of 20ha of shellfish reefs. Since 2016, 159 limestone reef rows have been constructed to form the reef base, seven million oysters have subsequently been placed on top of this. The design of the reef was developed based on limestone reefs constructed in Texas, USA (Half Moon Reef) and Port Phillip Bay, Australia. A timeline of construction, shellfish seeding and monitoring activities that have occurred throughout the life of the project are provided in Figure 3.9. Two construction phases each using slightly different methods were used:

Phase one: June 2017. An initial 850 tonnes of limestone boulders deployed over 4 hectares (Figure 3.10) using a long-reach excavator on a vessel, guided into place using long metal chains. Fifteen reef rows were constructed in this phase of construction and a combination of 80,000 mature and three-month old oysters (50mm) were seeded by hand by commercial divers onto eleven of the reefs.

Phase two: October 2018. A further 9,200 tonnes of limestone boulders deployed over 20 hectares (Figure 3.10) using a long-reach excavator on a 1,500-tonne capacity barge, guided into place using a chute system. A total of 144 reef rows of three lengths (10m, 18m and 34m), all 4-5m wide and 0.7m high, were constructed during this phase. Over seven million one-month old spat (2-5mm length) settled onto 4 tonnes of recycled oyster shell were then hand-spread onto 137 of the reefs by commercial divers.

Initial observations indicate extremely successful recruitment to the reef after just six months, with average densities of newly settled spat exceeding 3,500 per m^2. Settlement was greatest on the limestone between 40-80cm from the seabed with negligible settlement below 40cm, likely due to sedimentation and smothering. The vast majority of spat were observed on the underside of boulders as the exposed surface was monopolised by turf-forming algae, highlighting the importance of deployment timing.

PROJECT TIMELINE
Windara Reef

2016 2017 2018 2019

NOV	MAY	JUN	NOV	JAN	MAY	AUG-OCT	NOV	JUN	MAY	OCT	DEC
	1				2				3		
Baseline environmental surveys for design and planning	Baseline monitoring and engineering design	Phase 1 construction 15 reef rows covering 4 hectares	Fish monitoring BRUVS (Baited Remote Underwater Video System)	1st oyster seeding (30,000 Phase 1 reefs)	Post construction monitoring	Phase 2 construction 144 reef rows covering 16 hectares	Fish monitoring BRUVS	2nd oyster seeding (50,000 Phase 1 reefs)	Monitoring	3rd oyster seeding (7 million full 20 hectares)	Reef launch celebration

Figure 3.9: Project timeline for construction and monitoring of Windara Reef, South Australia. Timeline courtesy of The Nature Conservancy.

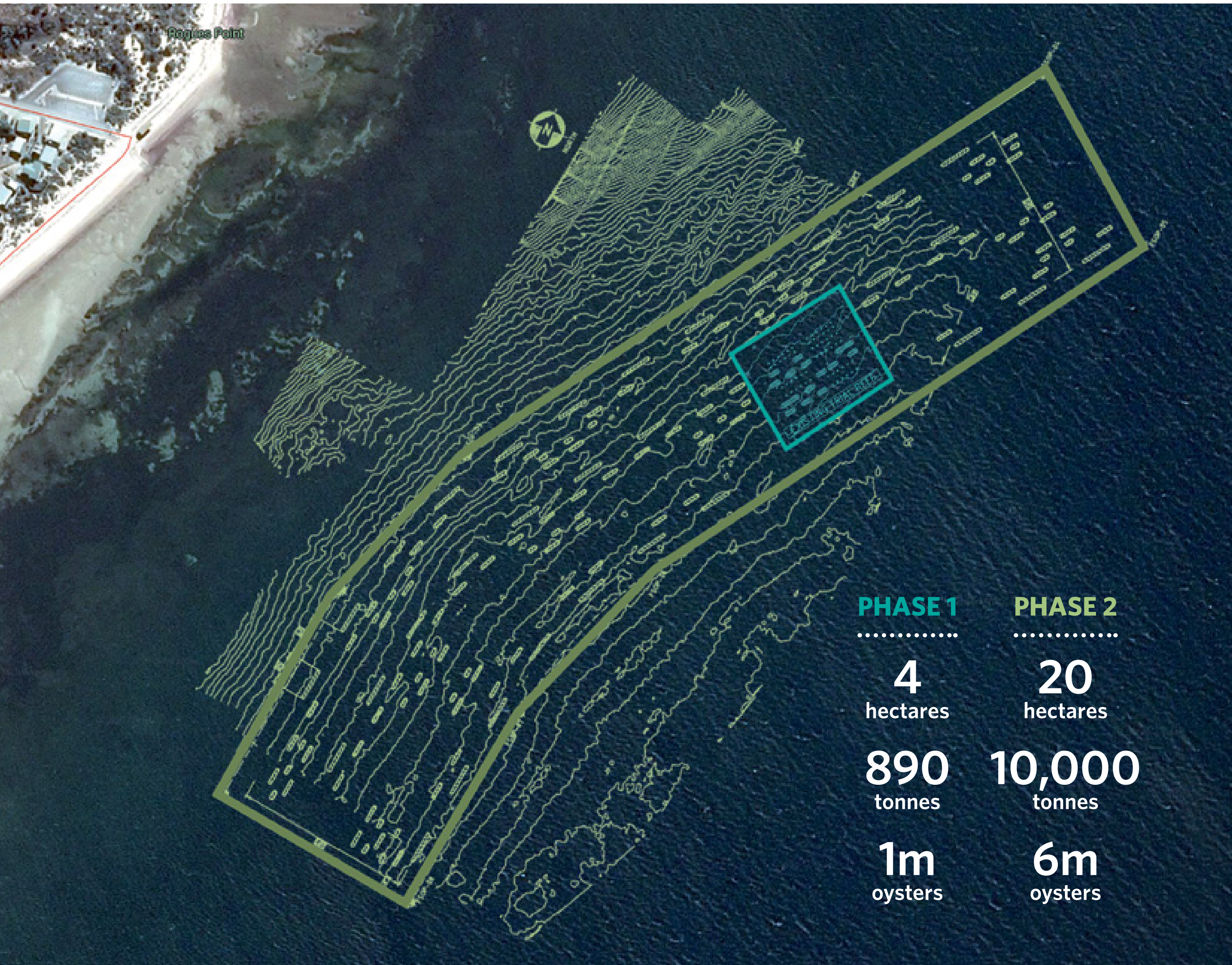

Figure 3.10: Project footprint for Phase 1 (Teal) and Phase 2 (Green) of Windara Reef, South Australia. Bathymertry of the area in proximity is shown with green lines. Image courtesy of The Nature Conservancy.

WHAT DOES SUCCESS LOOK LIKE?

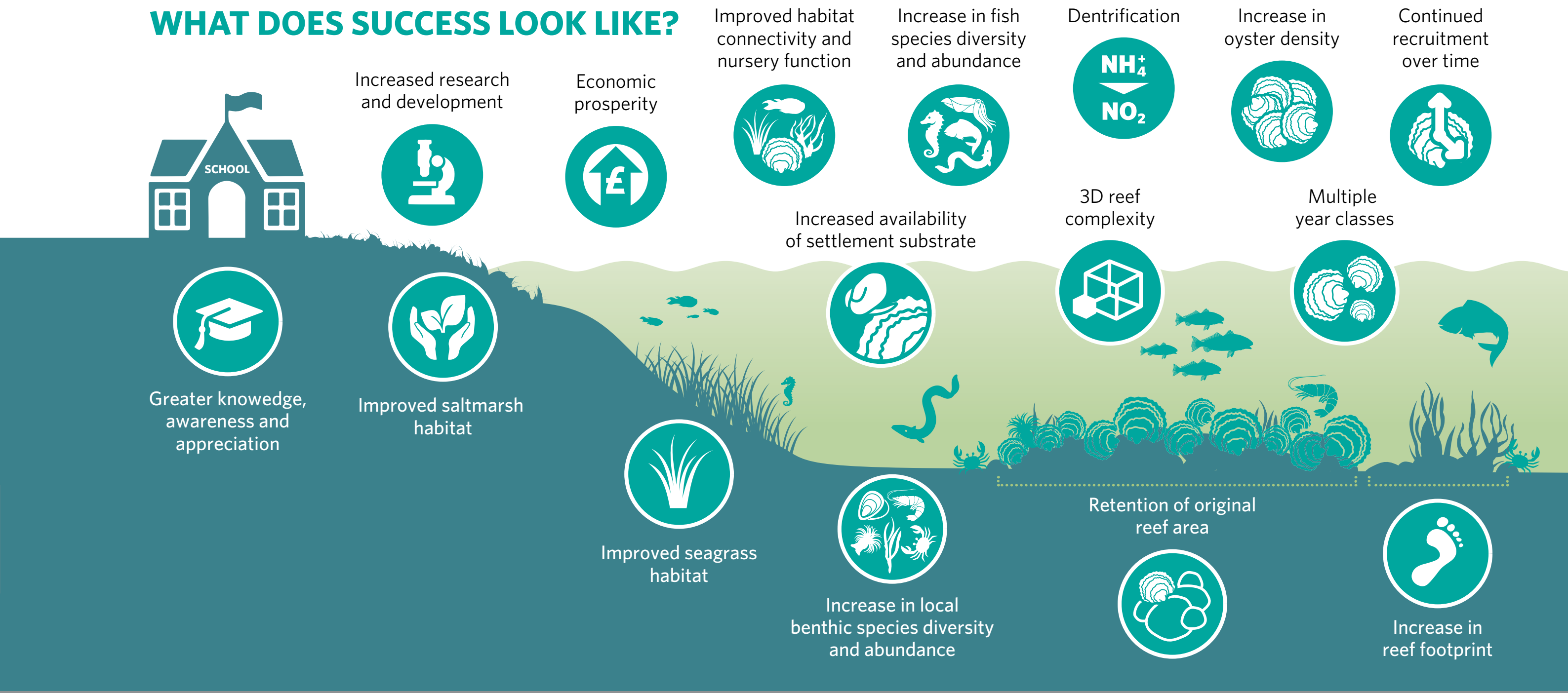

Figure 3.11: The measurable metrics that can be used to quantify the success of a native oyster restoration area or project.

SMALL SCALE TECHNIQUES TO COMPLIMENT LARGE SCALE RESTORATION

The following techniques, outlined in Table 3.5 and shown in Figure 3.12, can be used at various stages of restoration. They can provide an insight into site suitability with regards to oyster survival, growth, reproduction and recruitment prior to larger deployments, saving time and money in the long run. Additionally, some of the techniques can play a pivotal role in outreach and stakeholder engagement.

On-bottom methods

"On-bottom" describes techniques that involve depositing cage or concrete structures directly onto the seabed. These techniques offer a way of introducing oysters on a relatively small scale to compliment larger scale reef deployments, providing them with additional larval supply, as well as some form of protection to the reef. Alternatively, they can occur prior to large deployments as part of pilot studies to assess the suitability of an area.

Off-bottom methods

"Off-bottom" describes techniques that involve suspending oysters above the seabed and is a way of introducing oysters on a relatively small scale. However, during the phases where licence applications are taking place or the project is gaining momentum and funding, they can offer the ability to increase larval supply, grow oysters to a larger size and engage local communities, prior to the initiation of large, ecosystem scale restoration on the seabed.

Intertidal techniques

Despite many of the remnant populations occurring predominantly in subtidal habitats, the native oyster also inhabits intertidal areas of the foreshore.

A variety of techniques are available that offer mechanisms of encouraging intertidal settlement or growth, as well as those used to on-grow oysters for deployment onto reefs. Restoration efforts in the intertidal should, however, be aware that these oysters may be more prone to unregulated harvesting and to die off when exposed to extremely hot or cold conditions.

Wind farms and offshore areas

The offshore wind sector in the UK is expanding rapidly and is set to occupy significant areas of the coastal zone, creating opportunities for partnership with conservation and fisheries management initiatives. Offshore areas also offer potential sites that are not impacted by eutrophication and nutrient inputs to the extent coastal areas are.

Shell collection/recycling

Shell recycling schemes utilise the 'biological waste material' produced by shellfish consumption in the restaurant industry. These schemes are conducted on an enormous scale by numerous restoration projects in the United States. They can provide a fantastic opportunity for community engagement (see Chapter 5), while offering the necessary, and often scarce, settlement substrate and at the same time prevent this valuable resource from entering landfill.

It is important to note that shell material from restaurants and other sources is classified as a biological waste and poses the risk of introducing diseases and invasive species. Therefore, all local legislations should be adhered to and biosecurity measures put in place to prevent the inadvertent introduction of anything that will be of detriment to a project and its reputation.

Figure 3.12: The various small scale techniques that can be used for native oyster restoration. Photos: Blue Marine Foundation (top left), Agata Poniatowski (top centre left), Luke Helmer (top centre right), Tony Legg (top right), Zoë Holbrook (middle left), Luke Helmer middle middle), Luke Helmer (middle right), Kruno Bonacic (bottom left), Andrew Hunt (bottom middle), Onderwaterbeelden (bottom right).

Table 3.5: Benefits and considerations to assess during the decision-making process regarding method selection.

METHOD ON BOTTOM	SUCCESS AND BENEFITS	CONSIDERATIONS
On-bottom cages	Low mortality rates. Cages provide a suitable substrate/platform for many epifaunal species and communities, increasing biodiversity. Oysters in on-bottom cages are accessible for repeat monitoring to determine physiological performance such as oyster growth. On-bottom cages can provide a spawning broodstock that can release larvae into the restoration area.	Require weight or anchoring to reduce movement during storms or high tidal flows. May be necessary to use a surface/subsurface buoy to locate or seabed markers for divers to navigate. Accessing whole on-bottom cages regularly can be difficult and may require substantial vessels with an A-frame, winch or similar mechanism.
Concrete structures	Large structures provide a degree of protection and are likely to deter dredging activities in the restored reef area. Vertical complexity is provided instantly. Designs are constantly being adapted and updated to increase their effectiveness for a variety of applications.	Current legislative procedures can prolong or prevent deployment of larger structures including reef balls. Navigational routes must be considered when selecting locations for their deployment. Installation requires heavy lifting gear and appropriate vessels.

OFF-BOTTOM	SUCCESS AND BENEFITS	CONSIDERATIONS
Suspended broodstock	Accessible in most weather conditions and no divers or vessels are needed for access. High density populations allow for high fertilisation success. Great engagement tool, impacts of increased biodiversity can be easily demonstrated. Cage design and size can be modified to incorporate shelves, prefabricated plastic racks or remain empty to be used for oyster gardening.	High mortality in extreme weather conditions and post-spawning (July/August). Larger cages are difficult to work with when heavily fouled, lowering them during summer may reduce fouling and mortality. Using smaller cages at lower densities would enable more locations to participate if used for community projects. Unlikely to require a marine licence but there may be the requirement to register as an "aquaculture facility".
Oyster gardening	Perfect tool for community/citizen science projects and advocated for increased grassroots political engagement. Juveniles/spat-on-shell can be on-grown then transplanted onto seabed reefs.	Engage all local stakeholders from the beginning of the project. Can be used to engage with all levels of education. Unlikely to require a marine licence but there may be the requirement to register as an "aquaculture facility".
Floating oyster systems	Cages can be moved in response to weather, and environmental conditions. Protection from benthic predation.	Frequent turning and cleaning of floating bags are necessary to maintain water flow, growth and survival. Carrying capacity per floating bag should be tested and adapted.
Other suspended systems	Longlines are designed for deeper water and are adaptable even to offshore conditions. Protection from benthic predation. Floating culture systems can be moved easily. Depth at which oysters are suspended can be adapted to specific locality. Successfully used in aquaculture production sites to supply "natural" spat and manage all life stages (sample site: Mali Ston bay, Croatia).	These methods are currently only used in aquaculture settings and are yet to be developed for restoration purposes. Regular maintenance required due to increased biofouling. Closed containers required for prolonged periods where gilthead sea bream predation is an issue.
INTERTIDAL	**SUCCESS AND BENEFITS**	**CONSIDERATIONS**
Non-plastic structures and other habitats	Frequent access and monitoring of intertidal sites are much easier, less expensive and requires less equipment than a subtidal site – especially relevant for small scale and community projects. Great for outreach and engagement. Can provide direct shoreline protection and habitat enhancement (saltmarsh).	Elevation from the seabed has a positive effect on filtration rate (a key determinant of growth) of oysters. Some areas can have problems with trespassers. Finding remote sites that are unlikely to be tampered with can restrict access or require trust with private landowners. Obtaining permissions to place long-term structures can be challenging.

INTERTIDAL	SUCCESS AND BENEFITS	CONSIDERATIONS
Intertidal broodstock system	Inexpensive, a low-cost butyl rubber mat or tray system can be used to deploy the oysters on, or if conditions are suitable the brood can be laid directly onto the substrate. A high degree of accuracy can be applied to the positioning and density of broodstock. Intertidal water temperatures are often higher than subtidal during the spawning months, making spawning more likely. The brood can be translocated easily after spawning has occurred, to condition for the following year.	A substantial increase in wild standing stock can be achieved with relatively low numbers of fecund oysters. Strategic positioning of the brood site is vital for success. Particle tracking models, including wind influence, are necessary and the predicted locations must have sufficient settlement substrate. The intertidal brood should ideally be on secure private property to negate interference.
Intertidal on-growing of juveniles	Exposure during low tide increases the adductor muscle strength, thus the fitness and resistance to predation in the long term.	Regular thinning out is needed to allow for growth in the system.
ON LAND	**SUCCESS AND BENEFITS**	**CONSIDERATIONS**
Shell recycling schemes	Provide good community engagement and education opportunities. If managed appropriately these schemes can become self-sustaining even employing staff members to run the operations full time.	Biosecurity measures need to be put in place to ensure any shell material deployed has been cleaned and cured appropriately to ensure there is no risk of introducing invasive species or diseases. Certain shell types are more appropriate for different locations and to enable settlement.
DEEPER WATER	**SUCCESS AND BENEFITS**	**CONSIDERATIONS**
Wind farms and offshore areas	Little to no disturbance caused by human activities such as trawling or gravel extraction which may damage oyster stocks. Offshore environment less likely to suffer pollution and eutrophication events than coastal areas.	Modelling work is time consuming and costly. Establishing agreements regarding access and operational support for deployment and monitoring can be challenging. Working offshore is expensive. Retaining oyster habitat at the end of life decommissioning has yet to be negotiated. During the lifetime of the windfarm may be sufficient to seed other areas.

FURTHER READING

Baggett, L.P., Powers, S.P., Brumbaugh, R., Coen, L.D., DeAngelis B., Greene, J., Hancock, B. and Morlock, S. (2014). *Oyster habitat restoration monitoring and assessment handbook.* The Nature Conservancy, Arlington, VA, USA., 96pp.

Figure 3.13: Native oyster deployment in Loch Craignish, Scotland, by Seawilding Native Oyster Restoration. Photo: Dan Renton.

CHAPTER 4
BIOSECURITY IN NATIVE OYSTER RESTORATION

CHAPTER AUTHORS

Philine zu Ermgassen, Bérenger Colsoul, Alison Debney, Monica Fabra, Boze Hancock, Luke Helmer, Joanne Preston, William Sanderson and Åsa Strand.

KEY SUMMARY POINTS

- **The movement of people, equipment, materials, and oysters between locations carries with it the risk of moving harmful organisms, such as diseases and invasive non-native species.**
- **Translocation of material and oysters from one water body to another is never risk-free and should be avoided where possible.**
- **Never translocate material from a water body with an oyster disease or high impact invasive species present, to one where it is absent.**
- **Always undertake real-time assessment of the sites and oysters or cultch material, rather than assuming protocols are effective, and that existing test and survey results reflect actual status.**
- **Hatcheries producing certified oysters in disease-free areas can be used for both aquaculture or restoration purposes. Hatcheries producing uncertified oysters in disease designated areas can only be used for restoration purposes in their areas alone.**

INTRODUCTION: UNDERSTANDING THE BIOSECURITY RISKS

The "European Guidelines on Biosecurity In Native Oyster Restoration" published by the Native Oyster Network and NORA seeks to outline the suite of considerations associated with translocation. This section is a summary of the most salient points. For further detail visit the Native Oyster Network – UK & Ireland or NORA websites to download the full guidance.

Disease is a major threat to native oysters both in aquaculture and in the wild. In particular the haplosporidian *Bonamia ostreae*, which causes the disease bonamiosis, is still expanding its range in Europe and can cause up to 90% mortality when it arrives in a population. Similarly, invasive non-native species (INNS) are considered a key threat to biodiversity throughout European waters. Vectors include shipping and recreational boating, but a major cause has been shellfish movements. The presence or introduction of a disease or INNS species may negatively impact the conservation objectives for protected species and habitats. They also pose a threat to the success of native oyster restoration through; competition for food and space, predation, by being pest species, negatively impacting the biodiversity associated with healthy biogenic habitat, and reputational damage.

Native oyster restoration methods currently in practice include the translocation of cultch, spat attached to empty shells or pieces of shells (spat-on-shell), hatchery reared spat, or adult oysters (Chapter 3). Each of these methods carries with it the risk that species and/or pathogens are also translocated. It is important to acknowledge that the risk posed by the movement of oysters, cultch, equipment and people between sites may be significant. This need not prevent restoration activities, but it is important that restoration projects perform appropriate risk assessments of their activities with biosecurity in mind, and that protocols are developed to minimise risks where they are identified.

OYSTERS AS A VECTOR OF DISEASE AND INNS

Throughout recent history, oysters have been vectors of INNS and disease. That oysters are traded live, have complex shell structures, and may be returned to the water for further growth as opposed to being consumed on land, are all factors that have contributed to the significant number of unintentional translocations attributed to movement of commercial oyster species. To give some idea of the potential for oysters to be a vector of unintended species introduction, the European presence of more than sixty species native to the Pacific Northwest, can be attributed to movements of the Pacific oyster since the 1960's.

While most introduced species do not result in significant harm in their introduced range, a number of species associated with historical translocations of oysters have resulted in serious impacts for oysters and for the wider marine community. For example, the American slipper limpet (*Crepidula fornicata*), American oyster drill (*Urosalpinx cinerea*) and oyster pathogen (*Bonamia ostreae*) (see Figure 4.1), all entered European waters via shipments of oysters from outside Europe. *Bonamia ostreae*, as an example, has since spread to numerous locations throughout European waters, with devastating consequences for native oyster habitats and commercial producers. Whilst movement of shellfish is not the only vector of disease and INNS, projects to restore native oyster populations need to adopt rigorous biosecurity protocols in order to avoid an action with an intended positive ecological benefit, resulting in a negative impact.

WHICH DISEASES AND INNS POSE A RISK IN NATIVE OYSTER RESTORATION?

There have been few successful eradication attempts for marine non-native species or diseases in open waters. Therefore, the only reliable method of control is to prevent their introduction. There is no way to predict which species will become problematic in an introduced range. That said, there are certain attributes related to both the life history of the species and the condition of the receiving site which can indicate the likelihood of species becoming problematic, and invasion history from other locations can also be a useful indicator. Assessments of whether or not a species is likely to become invasive in a new location requires expertise. Fortunately, there are many statutory bodies throughout the UK and Europe which provide such assessments to the public (e.g. Non-Native Species Secretariat). These lists can be used to identify which species are of particular concern when considering where to source oysters or cultch material. Every introduction to a new area has the potential to become invasive. Therefore, while biosecurity protocols should prioritise the prevention of key identified problem species, they should also, under all circumstances, mandate cleaning any materials and equipment moved, to avoid accidental introductions.

BOX 4.1: INFORMATION ON THE KNOWN *OSTREA EDULIS* PATHOGENS

Several pathogenic species are of particular note in the context of native oyster restoration in Europe. These include the notifiable diseases of bivalves to the OIE and/or to the European Commission (EC) (Anonymous-a, 2018)[1] :

- Bonamiosis – *Bonamia ostreae* (OIE/EC – present in Europe)
- Bonamiosis – *Bonamia exitiosa* (OIE/EC – present in Europe)
- Marteiliosis – *Marteilia refringens* (OIE/EC – present in Europe)
- Denman Island Disease – *Mikrocytos mackini* (EC – not currently present in Europe)
- Ostreid herpesvirus infection* – Herpes virus OsHV-1-μvar (present in Europe) (notifiable in a few zones in Ireland and the UK only. While not currently listed as a susceptible host, there are reports of the virus present in *O. edulis* and as such this pathogen should also be considered as a precaution.

Although not notifiable, many other pathogenic species are known for *Ostrea edulis*, including:

- *Gyrodinium aureolum*,
- *Herrmannella duggani*,
- *Mytilicola intestinalis*,
- *Ostracoblabe implexa*,
- *Haplosporidium armoricanum*,
- *Hexamita inflata*,
- *Perkinsus mediterraneus*,
- *Pseudoklossia* (Genus of)
- *Papovaviridae* (Family of)
- *Nocardia crassostreae*
- *Vibrio* spp. (e.g. *V. alginolyticus*, *V. anguillarum*, *V. coralliilyticus*, *V. neptunius*, *V. ostreicida*, *V. tubiashi*

It is extremely important for restoration practitioners to be aware of the notifiable diseases and also that there are numerous other parasites and pathogens to which the native oyster is susceptible (Box 4.1). Some of these, such as *Marteilia refringens* and *Marteilia pararefringens* can be transmitted between the native oyster and blue mussels (*Mytilus edulis*), while OsHV-1 can be transmitted between native and Pacific oysters (*Crassostrea gigas*). It is the responsibility of the restoration practitioner to implement appropriate disease prevention and management protocols and to report any increased and unexplained mortalities to the relevant competent authority for investigation.

American slipper limpet *Crepidula fornicata*
Impact: Filter feeder that can compete with oysters and produce excessive biodeposits which can smother oysters.

American oyster drill *Urosalpinx cinerea*
Impact: Voracious predator of oysters, which can cause significant mortality, especially of juveniles.

Oyster pathogen *Bonamia ostreae*
Impact: Causes the disease bonamiosis by attacking the immune system of *Ostrea edulis* and can result in mass mortalities.

Figure 4.1: Examples of the impact of invasive non-native species (INNS) and pathogens, *Crepidula fornicata*, *Urosalpinx cinerea*, *Bonamia ostreae*, on the native oyster. Photo (left): Zoe Holbrook. Photo (middle): iNaturalist.org, Encyclopedia of Life creative commons CC BY-NC license. Photo (right): Fisheries Research.

It is difficult to avoid the risk of translocating known or potential INNS or diseases. More difficult still, is the prospect of unknown INNS and diseases. A disease may be subclinical in a population that has co-evolved with it, and therefore not apparent. Once transferred to a naive population it may cause high mortalities and disruption.

BIOSECURITY AS AN INTEGRATED PART OF RESTORATION PRACTICE

INNS and diseases can be moved between sites whenever people and equipment are moved, not only when oysters or cultch material are placed in the water. As such it is important that all people participating in oyster restoration activities, including science and monitoring, comply with standard 'Check, Clean, Disinfect, Dry' protocols (see Figure 4.2).

Check before you leave a site all equipment including wetsuits, vessel, boots, buckets etc. Remove all visible hitchhikers, sediment, and debris. If this occurs away from the site, ensure that all material is at least disposed of in a bin, not near a watercourse. Under circumstances of enhanced risk, disposal should be to a specified biological waste disposal route (possibly including incineration).

Clean all equipment including the vessel and bilge tank with freshwater. Do not let water drain back into the sea, as spores and eggs can persist for some time.

Disinfect – under circumstances of enhanced risk, a biocide/disinfectant should also be used.

Dry all equipment thoroughly, ideally in sunlight, before moving to a new marine location.

Restoration projects should make biosecurity a central theme in all activities. All activities should be subject to a biosecurity risk assessment, and protocols should be put in place for all common activities. This can also function as a useful awareness building and learning exercise if engaging the volunteers or students. Projects should apply a Precautionary Approach when planning their activities.

Stop the spread

The success and reputation of a restoration project can be negatively impacted by accidental introductions of invasive species and pathogens. Project equipment such as vans, boats and field kit can all be vectors for their transmission, which will ultimately damage the marine environment and wildlife.

CHECK

Check your equipment, clothing and boats after carrying out fieldwork for fouling material. Ensure that you remove anything that you find and dispose of it in the appropriate manner.

CLEAN

Clean all fieldwork items thoroughly with freshwater as soon as possible. Ensure that you pay attention to items such as fieldwork clothing, restoration equipment, trailer wheels and areas that are damp or hard to reach.

DIS INFECT

Disinfect – where the risks are higher, include disinfection as part of cleaning procedures.

DRY

Dry – ensure that you drain water from any water remaining on fieldwork items, and equipment such as a trailer and boat. Try to dry all equipment for as long as possible before next usage.

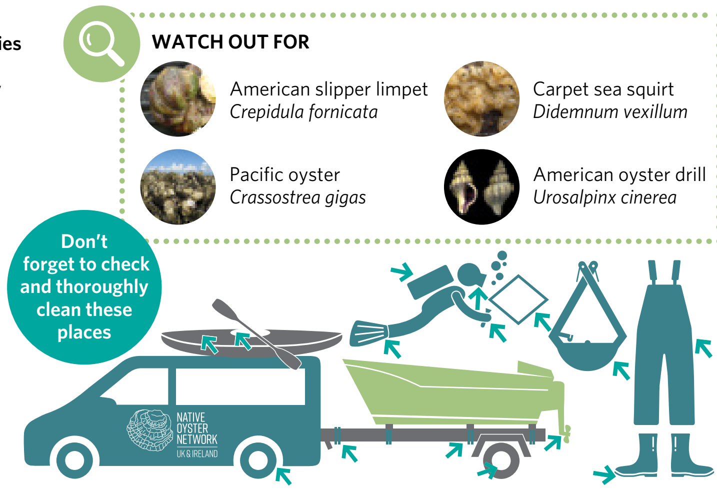

Figure 4.2: Biosecurity considerations to prevent transmission during restoration practice and fieldwork: Areas to be vigilant with when cleaning after carrying out fieldwork for oyster restoration projects: Check – Clean – Disinfect – Dry.

BOX 4.2: EXAMPLES OF INTERNATIONAL, NATIONAL, AND SUBNATIONAL RESOURCES RELATING TO BIOSECURITY

International:

Marine biosecurity has an international legislative framework: The European Union Member States, Council Directive 2006/88/EC (24/10/2006) sets out animal health requirements for aquaculture animals and products, and on the prevention and control of certain diseases in aquatic animals (https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32006L0088).

The OIE Aquatic Animal Health Code (2019) provides standards for the improvement of aquatic animal health worldwide (https://www.oie.int/en/standard-setting/aquatic-code/access-online/) and the Regulation (EU) 2016/429 ('Animal Health Law') sets rules to control transmissible animal diseases and that have broad impacts on public or animal: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0429&from=EN.

National:

The Aquatic Animal Health (Scotland) Regulations 2009, AAH (England and Wales) Regulations 2009, and AAH (Northern Ireland) Regulations 2009 implement Council Directive 2006/88/EC (as amended) in the UK. NB: EU Directive 2006/88/EC will be replaced by Regulation 2016/429 from April 2021 (https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX:32016R0429).

Some useful advice on Marine Biosecurity Planning, INNS and marine diseases can be found at http://www.nature.scot and CEFAS http://www.cefas.co.uk.

Subnational:

On a regional level, Inshore Fisheries and Conservation Authorities or communities may produce Biosecurity Action Plans to manage shellfish (e.g. North western Inshore Fisheries and Conservation Authority Biosecurity Plan https://www.nw-ifca.gov.uk/app/uploads/NWIFCA-Biosecurity-Plan.pdf

LEGISLATIVE OBLIGATIONS

The impacts of the introduction of shellfish diseases and INNS have long been acknowledged, and international institutions have developed legislation and reporting systems to address these threats (see Box 4.2 for some examples). It is the responsibility of all restoration practitioners to ensure that they are aware of and adhere to relevant legislation on biosecurity and disease management. They should also be aware that legislation and guidance function on a variety of scales (Figure 4.3 illustrates the many levels of regulation).

Note: It is the responsibility of the restoration practitioners to seek advice from the relevant competent authorities and ensure that they meet legal requirements. Failure to do so can result in legal consequences.

GOING BEYOND LEGISLATIVE REQUIREMENTS AND 'OWNING' THE RISK

Maintaining a high level of biosecurity in restoration work is imperative both for ecological success, and to maintain a social licence for such activities. Working with stakeholders and the public to ensure that these risks are understood, should be built into project plans. For example, it is not uncommon for the public to misunderstand the biosecurity threats and believe that they are helping the ecology of the area by disposing of their own waste oyster shells directly into the wild. As such shells have clearly not been subjected to translocation protocols, they present the very real risk of accidentally introducing pests and diseases. Working with stakeholders can prevent such misunderstandings and increase engagement with projects.

Restoration practitioners should also bear in mind that most existing national policies and legislative frameworks relevant to translocations for restoration are based on risk profiles of the aquaculture industry. Restoration, however, potentially carries far higher risks because oysters are returned prematurely to the ecosystem. Given this, statutory routine monitoring may be less frequent than desired. Even with the most stringent testing and biosecurity procedures, it remains possible that a disease agent or INNS may be or become present at the restoration site where translocations have occurred (Figure 4.4). Therefore, restoration projects should take responsibility for the biosecurity of their operations and apply a greater stringency than may be legally required.

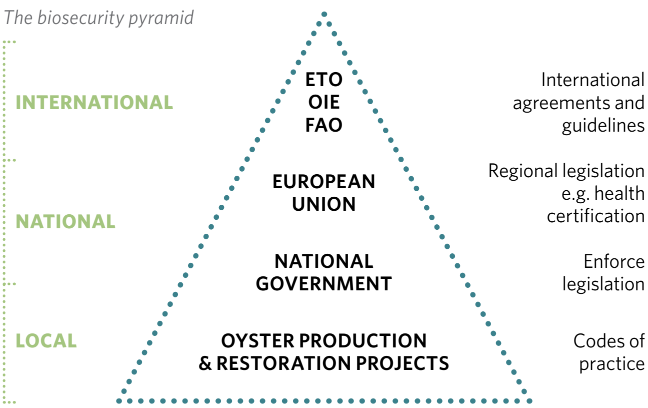

Figure 4.3: Legislation and policy regarding biosecurity function at a variety of scales, all of which projects should be aware of and seek advice on. Figure adapted from Oidtmann *et al.* (2011).

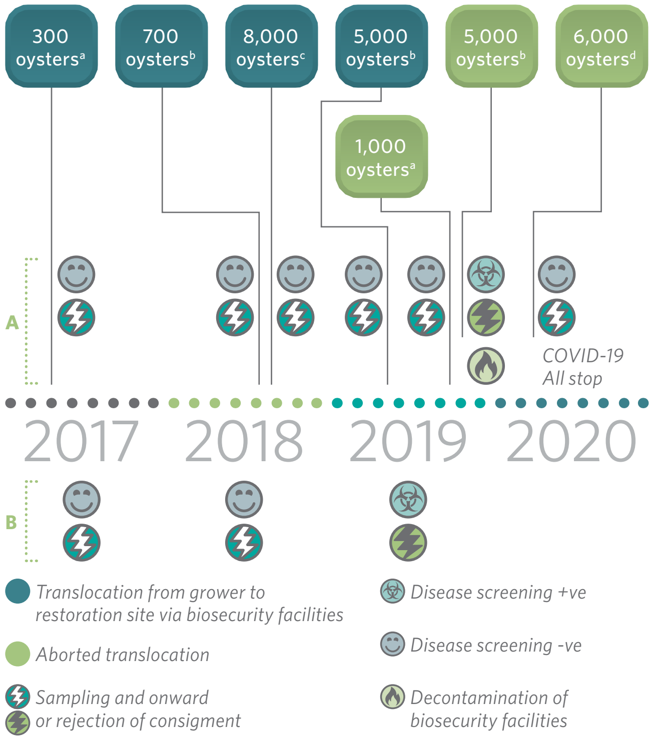

Figure 4.4: Schematic of biosecurity disease-screening activity of a restoration project based on a redacted but real case study. A = independent project-based testing of consignments translocated between oyster growers and the restoration site (via closed-circuit biosecurity holding facilities). B = project-based confirmatory testing of restoration site. All project testing (A&B) in addition to favorable (for disease) statutory government testing and accreditation of suppliers. Despite screening of all consignments, confirmatory annual screening of restoration site and rejection of consignment that tested positive for *Bonamia ostreae*, the restoration site tested positive in 2019 for said disease. Superscript letters indicate the four different suppliers.

BIOSECURITY GUIDELINES FOR NATIVE OYSTER AND CULTCH TRANSLOCATION

Introduction

Given that all translocations carry with them a risk of accidental introduction, it is important that avoiding the risk by avoiding translocations be considered in project planning. If projects decide to proceed with translocations despite the inherent risks, comprehensive protocols, and actions to mitigate and reduce the risks should be developed on the project level. It is critical that;

1. The relevant authorities (see Chapter 2, Table 2.4) are informed of all planned activities, and;
2. Projects seek advice from, and work in partnership with, the relevant authorities throughout the project.

Projects should seek to exceed the legally mandated standard. Native oyster restoration in the UK and Europe is still in its infancy and the science to support best practice protocols has not yet been fully developed. Consequently, a project's translocation protocol should be well documented with relevant data collected to demonstrate the efficacy of the protocol.

Translocating live oysters from open areas

Before deciding whether translocation of oysters or cultch is the appropriate action, it is important to weigh up the following considerations:

1. **Why risk translocation?** Consider why you want to translocate. Are there local stocks that could be used? Can the project timeline be adapted to allow for the use of hatchery reared stock or local spat collection?
2. **Are there local sources?** Identify local sources. If possible, use oysters from local sources and environments.
3. **If translocating:**
   i) Do not consider donor sites outside of the native range of the European native oyster.
   ii) Do not consider donor sites with high-risk invasive species or diseases that are not present at the receiving site.
   iii) Minimise the physical distance between the donor and recipient site.
   iv) Avoid large movements across latitudinal gradients.
4. **Physical and chemical cleaning.** If translocation is decided upon, both physical and chemical cleaning of the oysters is likely to be required.
   i. Cleaning is a time-consuming process and adequate time and manpower must be factored into the translocation plan.
   ii. The sensitivity of the young oysters may mean that many biosecurity treatments are inappropriate. In the case of spat that have spent time in the water outside the hatchery setting, hatchery reared, or locally sourced spat may be the only option.

Note: Translocation also refers to movements from hatcheries where oysters have been in contact with unsterilised seawater.

Where projects determine that translocation is the necessary approach, and the necessary resources (time, space and personnel) have been acquired to undertake translocation in a biosecure manner, the following steps should be taken.

Risk assessment

The first step in scoping appropriate donor sites should be desk based to reduce resource usage and gain a high-level overview of potential sites. The disease status of both the donor and recipient sites must be considered. Comprehensive existing OIE, EU and local regulation surrounding the testing, movement and monitoring of pathogens and disease should be adhered to as an absolute baseline (reference Box 4.2). Project managers should contact their regulators directly for a comprehensive search of available data on pathogens and invasive species. Some useful data on non-native species can be found within the JNCC Marine Recorder Snapshot, or from the National Biodiversity Network Atlas or local survey data.

It is also important to consider what non-native species are present in areas with high connectivity to the donor areas (e.g. adjacent waterbodies, ports, or bays). There is a high risk of these spreading into the donor site.

Donor site surveys

Once a potential donor site has been identified, it is recommended that the current disease status of the site be confirmed through further testing, unless statutory testing is known to have taken place recently. Without exception, animals must only be moved to recipient sites from donor sites with equal or higher health status. Pathogen screens should be done using recommended methods (e.g. https://www.oie.int/en/animal-health-in-the-world/information-on-aquatic-and-terrestrial-animal-diseases/).

Similarly, for INNS, once a potential donor site has been identified, it is recommended that a site survey be undertaken to ensure that the information assessed is current and accurate. Particular care should be paid to potential and high-risk INNS. The JNCC Marine Method Finder has a list of suitable monitoring approaches for each habitat.

Should an aggressive INNS such as *Didemnum vexillum* or a notifiable shellfish disease be recorded at the donor site, then oysters should not be translocated from the site. If less aggressive non-native species are identified from previous data or surveys of the donor site, then a marine biosecurity plan may be an option to identify measures that can reduce the risk of non-native species introduction. This may be required by regulators and/or competent authorities before consent is given for the translocation.

Guidance on authoring such a plan has been produced by Cook *et al.* (2014), see key references.

Physical cleaning

If the origin and donor sites have been found suitable by the preceding steps, oysters obtained for translocation should be first inspected, then physically cleaned and inspected again to ensure no visible epibiota persists. This process should be completed at the donor site to ensure epibiota is not transferred elsewhere. It is also recommended that treatment and transport of oysters takes place in the late autumn to late winter to minimise initial amount of epibiotic growth.

Figure 4.5: The exterior (left) and interior (right) of a native oyster infested by a boring sponge (*Cliona celata*). Photos: Luke Helmer.

Oysters with associated heavy infestations of boring sponges (e.g. *Cliona celata*, see Figure 4.5) will have holes that can be difficult to clean. These should be discarded responsibly at the donor site.

Physical cleaning can be done by hand (scrape/scrub off) and/or mechanical methods, such as cement mixers or shellfish cleaning machines. If mechanical treatment (as opposed to cleaning by hand) is undertaken, a large sample size of the treated oysters should be closely examined in order to determine that the epifauna have been effectively removed. Repeat treatment should be undertaken if epibiota are discovered.

Following physical cleaning, oysters should be left to recover in filtered seawater for a minimum of three days before undergoing chemical treatment. Wastewater should be disposed of appropriately. **Note:** no amount of physical cleaning will remove harmful biota present within the oyster itself.

Spat are more sensitive than older oysters so physical and chemical cleaning is not recommended. Spat-on-shell that have been exposed to open water should only be moved within the same water body as long as the donor site has an equal or higher health status compared to the recipient site.

Chemical treatment

The purpose of chemical treatment is to reduce the risk of INNS transfer by killing shell epibiota that may have survived the physical cleaning of the oysters. Remaining epibiota might include scraps of clonal organisms such as sponges, bryozoans, sea squirts or certain types of seaweed, as well as hardy spores and resting/reproductive stages of other organisms (see Figure 4.6).

Some organisms such as keel worms, barnacles and other bivalves can clamp-shut to avoid ingress of fluids and are therefore able to survive the chemical treatment just as well as the oysters. Care should be taken in the physical cleaning stage to make sure that the tubes of keel worms are removed or broken open, that barnacles are removed or broken open and that there are no small bivalves hidden in the hinge-line of the oysters.

Various chemicals have been used for the surface sterilisation of oysters and they range in their expense and availability, including hypochlorite, formaldehyde, and commercial fish-farm treatments such as Virkon™. There is not a clear evaluation of the relative effectiveness of different treatments, but the obvious abiding principle is that it should be toxic to the epibiota in the concentration and exposure time used. Exposure-times can vary, and bulk dunking methods have been used. Dunking methods may be more preferable and efficient with younger oysters (< 10g) because the shells appear to seal-shut well. Sponging oysters with the chemical treatment (whilst using appropriate Personal Protective Equipment) might be deemed more appropriate in larger adult oysters where the gape of the shell may be worn or damaged and therefore less likely to seal well if fully submerged in a chemical bath.

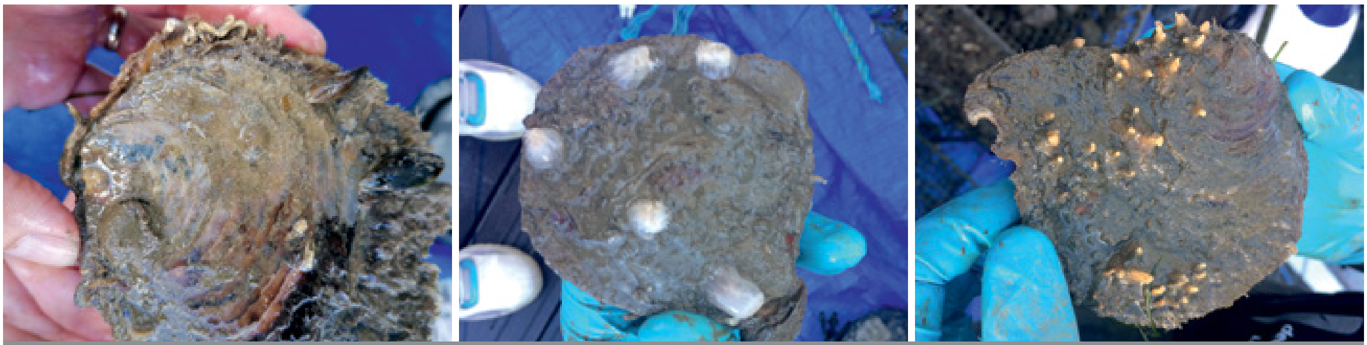

Figure 4.6: Examples of bryozoans (left), anemones (centre) and sponges (right) on uncleaned native oysters that may remain even after physical treatment. Photos: Luke Helmer.

Turrell *et al.* 2018 undertook a thorough review of the literature regarding chemical treatments of oysters in order to develop recommendations for moving *C. gigas* from an aquaculture site with a high risk INNS (*Didemnum vexillum*). A complete review of the tested options and the resulting impacts on the target INNS and the shellfish are provided in their report. The method recommended for field tests as a result of the review was immersion in freshwater (salinity < 2ppt) for at least 24 hours.

Quarantine

Following treatment, oysters should be kept in tanks and the bottom of the tanks inspected for recently dead or living organisms.

Due diligence

There is currently no agreed method that, when applied, renders living oysters completely biosecure for translocations. It is therefore critical that each translocation attempt validates the efficacy of the biosecurity measures undertaken with a thorough screening.

While disease screening is one of the first steps undertaken when determining whether a stock is suitable for translocation, a further screening for diseases may be undertaken prior to stock released into the wild. As a minimum, this should include all of the notifiable diseases (For native oysters: bonamiosis (*Bonamia ostreae* and *Bonamia exitiosa*) and marteiliosis (*Marteilia refringens*), as well as oyster herpes virus), following the relevant OIE recommended procedures.

Contributing to improved biosecurity guidelines

Rendering living oysters' low risk for translocation is costly and the efficacy of actions is not well documented. We therefore urge projects to submit their experiences to the Native Oyster Network or NORA Secretariat.

There are guidelines for hatchery production that stipulate broodstock from areas with notifiable disease should not be used as broodstock to produce spat destined for disease free areas (see section on 'biosecurity guidelines for European native oyster hatcheries'). It should be noted that there is a substantial longer-term restoration advantage in using broodstock from high disease load areas that have likely developed a degree of tolerance to diseases such as Bonamiosis. This will require methods to ensure disease free offspring that still carry the genetic resistance. These methods are the subject of active investigation.

TRANSLOCATING SHELL CULTCH OR OTHER SUBSTRATES

Materials commonly used as substrate for reef construction are shell cultch or stones/aggregates and stones. Rock that is not from the sea is not a biosecurity risk. Though project managers will need permits from their regulatory authorities before deploying any substrate to a restoration site. All material used for restoration should be free of contaminants such as pesticides, oil and heavy metals.

It is unusual to have a supply of shell from the local water body. If such a supply exists, it is unusual to be confident that no shell from animals outside the local water body can enter the shell supply chain. If these conditions are met with a high degree of certainty regulators may concede to allowing the shell to be returned to the water untreated. Generally, the source of all the shell being supplied cannot be guaranteed, so the shell must be treated as though it was from a high biosecurity risk area. In this case, the shell must be treated to ensure that living marine organisms or spores of pathogens can no longer contaminate the material. What is deemed suitable treatment should be agreed with the relevant authorities. The most common treatment is to weather (expose to the elements) the material for a minimum of 12 months, turning the shells every two months where material is deposited < 15cm high, and twice monthly if deposited more deeply. Any rock or other material dredged from the ocean should be treated in the same way.

As with all other stages of biosecurity practice, it is the responsibility of the project to ensure that the treatment has been effective in removing any unwanted organisms and spores. This may include visual examination of the material. As a general guideline, material should be weathered until there is no evidence of residual biology remains, dried or otherwise. Effective method of assessment and the appropriate sample size for assessing the status of the clutch material should be agreed with the relevant authorities.

BIOSECURITY GUIDELINES FOR EUROPEAN NATIVE OYSTER HATCHERIES

Introduction

Where no reliable and large sources of wild seed are available, reef restoration depends on seed brought in from different sources. This demand can be addressed by hatchery production. Hatchery production is not in itself biosecurity risk free. Projects seeking to use hatchery reared seed should inform themselves of the biosecurity measures in place when considering hatchery partners and should confirm or seek to develop in partnership with the hatchery, the degree of biosecurity controls required. This section introduces the steps that are commonly taken in hatchery settings and is designed to support informed communication between practitioners and hatcheries. Those seeking greater detail of hatchery protocols may visit the Native Oyster Network – UK & Ireland or NORA websites to download the full biosecurity guidance and see the publications recommended in further reading at the end of this chapter.

Biosecurity Measures Plan (BMP)

All Aquaculture Production Businesses (APB's), including hatchery operations, must be authorised by the competent authority. Although licensing and permitting procedures depend on the hatchery characteristics (e.g. site, region, species farmed, aim and scale of production), an essential requirement for ABP authorisation is an approved Biosecurity Measures Plan (BMP). The BMP describes defined measures to prevent or reduce the risk of introducing diseases/pests into the hatchery, spreading diseases/pests within the hatchery or the transfer from the hatchery to the aquatic environment, via three steps:

1. Identification of major routes for potential disease/pest transmission in oyster hatcheries (Table 4.1).
2. Risk assessment for each disease/pest transmission route.
3. Definition of measures to minimise the risk of disease/pest transmission.

Table 4.1: Level, means and routes of transmissions of pests and disease through a hatchery.

LEVEL OF TRANSMISSION	MEAN OF TRANSMISSION	ROUTES OF TRANSMISSION
Entry-level	Livestock	e.g. import of wild broodstock.
	Feed/algae	e.g. purchase of algal paste from external suppliers.
	Water	e.g. intake of water.
	Equipment	e.g. admission of gear from outside the hatchery.
	People	e.g. entry of the hatchery by visitors.
	Settlement substrates	e.g. transfer of shells.
Internal level	Livestock	e.g. movement of broodstock, larvae or spat between production area.
	Feed/algae	e.g. algal cultures.
	Equipment	e.g. sharing of gear between production areas.
	People	e.g. movement of staff between different production areas.
Exit level	Livestock	e.g. discard of mortalities.
	Water	e.g. discharge of water.
	Equipment	e.g. disposal of wastes.
	People	e.g. exit of the hatchery by visitors.

As part of their daily operations, hatcheries should organise and maintain routines that enable the operators to observe and trace any potential transmission events. Stringent record keeping should be basic practice for any hatchery operation and must take into account shellfish movements, mortalities, disposal of stock, stock health, water parameters and water quality. These factors, and the list of tasks assigned to each of them, fall within the Standard Operating Procedures (SOP) of a facility and allow for appropriate emergency response plans to be developed. Should an event occur that triggers the emergency response plan, and therefore requires intervention, actions can be taken to halt further spread or contamination both within and onward out of the facility.

All native oyster hatcheries will have to produce unique and personalised BMPs and SOPs, since they will have to deal with different biosecurity challenges. The level of biosecurity in hatcheries can range between very strict and moderate, depending on both the aim/purpose of the production, and the disease status of the donor stock and designation of the receiving site. These factors also have important implications for translocation of broodstock and hatchery output.

Translocation of native oysters, in the context of bonamiosis or other diseases affecting this species, can be reasonably undertaken in terms of biosecurity as long as they originate from areas which have an equal (or higher) health status as the receiving area. For the same reason, a water body with a greater disease designation than the hatchery location should not be considered as a potential source of broodstock. It is unnecessary and illegal to transfer oysters from a diseased area to a disease-free area; therefore, this practice is not considered.

For example:

- Hatcheries producing **certified oysters** in **disease-free areas** can be used for both aquaculture or restoration purposes. *This hatchery could only receive oysters from other disease-free areas, but hypothetically they could export oysters to areas of any disease designations.*
- Hatcheries producing **uncertified oysters** in **disease designated areas** can only be used for restoration purposes. *This hatchery could not export any oysters except to (very) local areas. In this 'local to local' scenario, broodstock could possibly be disease-resistant, maximising the chance of self-sustaining wild population of O.edulis. Hypothetically this hatchery could receive oysters from any area.*

Note: It is recommended that both donor and receiving sites are located in the same region as the hatchery, in order to avoid, as much as possible, the translocation of invasive non-native species between different areas.

WORKSHOP CONTRIBUTORS

In January 2020 the Native Oyster Network – UK & Ireland and Native Oyster Restoration Alliance co-hosted a "European Native Oyster Biosecurity Workshop" at Heriot-Watt University during which these guidelines were developed. The workshop was supported by Wetlands International Europe via the EU Life grant, University of Portsmouth, and Environment Agency.

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CHAPTER 5
PUBLIC ENGAGEMENT AND COMMUNICATIONS FOR RESTORATION PROJECTS

CHAPTER AUTHORS

Celine Gamble and **Luke Helmer**, Emma Ackerley, Sophie Locke, Christopher Ranger, Dan Renton, William Sanderson, Oliver Tully and Matt Uttley.

KEY SUMMARY POINTS

- **Scheduling time to develop your project communication plan is fundamental to successfully communicate your restoration project.**
- **There are a range of communication and engagement tools to choose from, it is advised that you select appropriate method(s) based on the desired outcome or goal.**
- **The best camera is the one you have with you. Taking photos, be that on a phone, DSLR camera or anything in between, is invaluable, allowing others to be shown the ongoing project work and for project staff to reflect when looking back through albums.**

INTRODUCTION

Informing others about the restoration work being conducted is an essential element of developing networks, awareness and impact of any project. It may even be included within the project's funding requirements. If outreach is conducted in an effective manner it can help projects engage with and receive help from volunteers, inform and persuade policy or decision makers, share knowledge and streamline processes, access and secure funding sources, or improve ocean literacy of the local community. Used efficiently, a combination of outreach and engagement mechanisms can be a powerful way of scaling up the impact of a project to get more hands on deck and ultimately more oysters in the water. By reaching out to the local community a sense of stewardship can be established, in turn increasing the number of people involved in spreading the word, saving time and money.

Communication Planning

It recommended to schedule time to strategically develop project communications and engagement plans at the outset of your restoration project. A top-line communications and engagement plan may have been included in your funding application, and when funding has been awarded it is advised to revisit and further develop your plans. The global Restoration Guidelines for Shellfish Reefs handbook, Chapter 9, includes detailed planning steps for communication planning. Furthermore, the Reef Resilience Network has developed materials on strategic communication for conservation, which provides all the tools needed to successfully plan project communications. It is advised to refer to these materials when creating a communications and public engagement plan.

As highlighted in Chapter 2, it is recommended to engage with your identified project stakeholders (Figure 2.9) at the beginning of your project, and continue to do so throughout the project development. It is useful to build a team of key contacts relevant to the communication aspect of your project, such as by developing a communications steering group, and develop your communication and engagement plans in collaboration with them, holding regular meetings. Figure 5.1 shows a check list of the communications planning process, from establishing your project communication goals and objectives, assessing the context of your efforts, identifying your audience, creating your messages and finally creating a summary of your communications plan and subsequently measuring your impact.

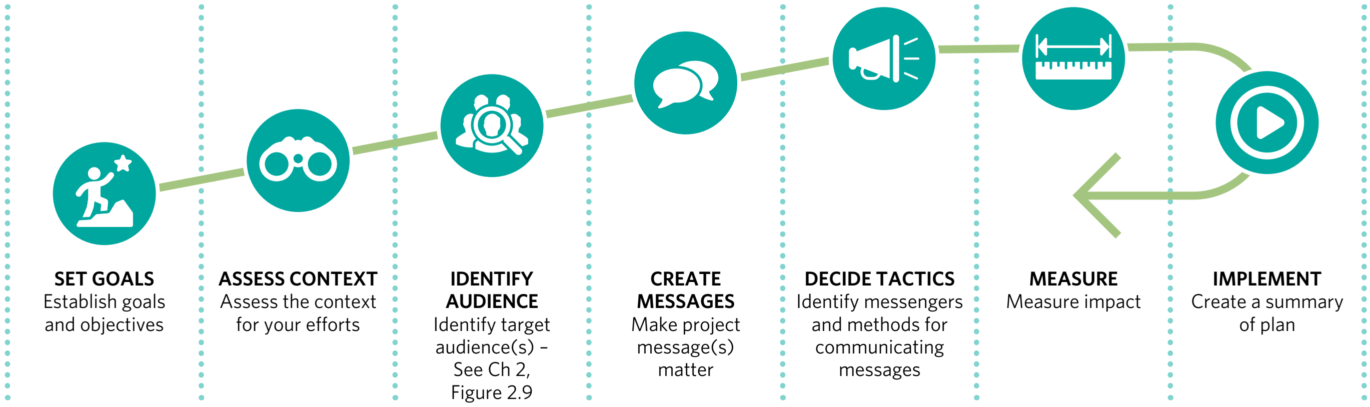

Figure 5.1: Communication planning process. Figure modified from materials originally developed by Kristen Maize/ Reef Resilience Network.

ENGAGING WITH THE MEDIA

Attracting the attention of mainstream media, the standard media that the majority of people use to consume news, can be difficult. A quick online search for 'oysters' typically brings up recipes or key seafood restaurants to enjoy them with a glass of Champagne. Therefore, it is important to reframe oysters in a way that people begin to view them as living animals that have an ecological, as well as economic, role to play.

Explaining the vast array of benefits that oysters provide whilst they are alive, to humans, is one way to do this. From the water filtration potential to habitat creation and nursery function, to job creation through restoration efforts, there are numerous ways to make oysters relatable to everyone. It is beneficial that most people have heard of oysters for one reason or another and that makes life easier than having to explain an obscure animal. The rewards can be seen when there is change in perception, from "oh, they are just living rocks" to "oooh, they are the superheroes of the seas!" and this requires clear and well directed messaging.

Three things a journalist will always need are an easy-to-understand piece of copy that they can pull a story from; high resolution visual assets such as videos or images, as well as a spokesperson they can interview for an original source. Making sure to collect as much visual material as possible when conducting project work will prove extremely useful for a variety of outreach mechanisms at a later date. Journalists also love nothing more than to "get out of the office" – so if there is restoration activity planned, invite them. They love to get involved and get their hands dirty and this also opens up opportunities for nature broadcasts like BBC *Countryfile* or BBC Radio 4's *Farming Today* programme.

Outside of mainstream media, there will also be specialist science outlets, such as Mongabay, BBC *Wildlife Magazine* or *New Scientist*. These are some examples of where scientific papers or reports can be pitched. Invite them along to conferences and work with publication journals to send science papers under embargo to make the news agenda. There are lots of exciting topical elements to oysters – climate change, biodiversity decline, plastics and more.

Lastly, if the project has access to a press or communications officer or PR agency, get them involved and inform them well in advance of a story opportunity so they can help shape it. If in doubt, remember the acronym TRUTH, which helps determine if there is a story: is it Topical, is it Relevant, is it Unique, what Trouble or problem does it overcome and what is the Human element – why might someone new to the topic care?

Tip: Getting appropriate celebrities to become ambassadors can be very useful in promoting the project.

Figure 5.2: Dr Joanne Preston being interviewed by the media about the Solent Oyster Restoration Project (top image). Photo: Luke Helmer. Alison Debney being interviewed during ENORI spat collector deployment (bottom image). Photo: ZSL.

ENGAGEMENT TOOLS

There are a range of different methods and tools to engage with project stakeholders and audiences that have been identified using the planning tools previously described.

Table 5.1 provides a summary of existing outreach and engagement mechanisms that can be employed to deliver a variety of material to a range of audiences.

Table 5.1: Summary table of the existing outreach and engagement mechanisms available to restoration projects, how they are delivered and to which audience, as well as the relative financial and time investments required. Costings and time investments are relative and not specified amounts. The costs indicated by 👥 are instances where existing staff can factor these activities into their time, therefore no additional staff funding is required.

ENGAGEMENT	DELIVERY	AUDIENCE	COST	TIME
Educational outreach	**In Person and online:** School visits. Site visits. Work experience. **How?** Presentations, Seminars, Lesson plans, Webinar, Via Skype/Zoom etc. **Tips** Turn oyster monitoring into a game for students: give organisms points (-ve for invasives).	Primary/ Secondary Schools. High Schools. Colleges. University. Academic conferences.	👥 - £ 👥 - £ 👥 - £ 👥 - £ 👥 - £££	Initial investment (Lesson planning, gathering material) 🕓🕓🕓 **Once material is in place** 🕓
Community engagement	**In person:** Hands on physical work. **How?** Shell recycling, Oyster monitoring, Leaflets & posters. **Tips** Providing basics such as tea and biscuits goes a long way to boosting morale and securing returnees.	General public. Public talks.	👥 - £	🕓🕓
Festivals	**In Person** Festivals, such as seafood and science. County Fairs. **How?** Festival stand. Public talks. **Tips** Streamline the gear needed for events so they can be displayed and put away quickly and easily into a couple of bags/suitcases.	General public. Seafood restaurants.	Initial cost of designing and purchasing stand visual displays ££ Cost of attending 👥 - £	🕓🕓 Travel

ENGAGEMENT	DELIVERY	AUDIENCE	COST	TIME
Volunteers and Citizen Scientists	**In Person** **How?** Site visits. Field work. Lab work. **Tips** Build up a rapport with those helping, be that individual volunteers or school, colleges or universities to supply a consistent work force.	General public. University Students. Community partnerships.	👥 - £	From 🕒 to 🕒🕒🕒 One day visits to one week work experience to summer placement
Infographics	**In person and online** **How?** Display boards. Pull up banners. Online media. **Tips** Example of where to create easel.ly .	General public. Social media users. Funders.	👥 - ££	Initial investment 🕒 Once in place 🕒 to maintain and update
Website/ Web page	**Online** **How?** WordPress. Via Network websites. **Tips** Lots of images, regular updates.	General public. Project partners. Science community.	👥 - ££	Initial investment 🕒🕒🕒 Continuous 🕒
Newsletters	**Online** **How?** Email. Mailchimp. **Tips** Keep these online to reduce waste. Engage with the NON and NORA, send updates to be included in newsletters shared with the restoration community.	Project partners. Volunteers. Project funders and supporters.	👥 - £	🕒 Continuous
Merchandise	**In person and online orders** **How?** Project clothing. Crowdfunder rewards. Mail delivery. Celebrity endorsement. **Tips** Make rewards sustainable and desirable, not something people will want to throw away.	Project restoration practitioners. Local supporters. Volunteers.	£ - £££ Proportionate to the number of orders	Initial investment designing and ordering 🕒 - 🕒🕒 Then continuous

ENGAGEMENT	DELIVERY	AUDIENCE	COST	TIME
Media – Images & Video	**Online** **How?** Outreach film. Student projects. Youtube Channel. Presentations that can be uploaded to the NON/NORA profiles. **Tips** Regularly take progress images & videos. Work with local media student projects.	General public. Funders. Government agencies. Project volunteers.	Images – 👥 – £ Documentary/ Film – ££ – £££	🕓🕓
Local Working group	**Quarterly meetings** **How?** Local venue that can accommodate projector screens. **Tips** Hosting in the evening allows for a wider range of stakeholders to attend.	Key stakeholders are outlined in Chapter 2, Figure 2.9.	£ Hiring a venue for the evening	🕓
Social media	**Online** **How?** See summary of platforms below in Box 5.1. **Tips** Follow examples of others with large followings. Select appropriate and impactful Hashtags (#OysterLove) Tagging other accounts Hootsuite.	General public. Science community. Industry.	👥 – £ Some costs can be associated with producing infographics but photos on phones works extremely well.	Continuous 🕓

BOX 5.1: SOCIAL MEDIA PLATFORMS

Below are some of the more commonly used platforms for shellfish reef restoration projects. These platforms are likely to change, come into or go out of fashion and may not even exist in the future, but represent our best advice in 2020.

Facebook – still the most used platform with 2.6 billion active users in 2020. Facebook groups are a good way of keeping in touch with project participants and can be 'closed' so only people specifically added can see the content.

YouTube – often forgotten as a platform, but very powerful and a great way to house and share videos.

Instagram – focussed on images and can be good for reaching a younger audience.

Twitter – tends to be more important for researchers, journalists and politicians. Journalists love Twitter and get many of their stories from it.

LinkedIn – could be suitable for some projects, as it is often used by consultants, engineers, and government workers.

ResearchGate – is a social networking site for scientists and researchers to share papers, ask and answer questions, and find collaborators.

Milkywire – a crowdfunding platform that allows funders to sponsor project representatives or 'Impacters' who upload content about their project and day-to-day activities. Great for turning those likes into something meaningful.

COMMUNITY OUTREACH

Case study: Craignish Restoration of Marine and Coastal Habitats (CROMACH)

Aim: to promote, protect and restore the well-being of Loch Craignish, which lies just outside the Loch Sunart – Loch Sween Marine Protected Area for flapper skate and inside the Argyll Hope Spot.

In 2016, the Ardfern community in Argyll on the west coast of Scotland, formed the CROMACH volunteer group with over sixty members. The community lead project relies on the active support and goodwill of the tight-knit local residents, of which there are approximately 600.

A weekend of dive surveys was organised with local volunteer divers to search for live native oysters or relic native oyster reefs and initiate the pilot project. Once a grant was secured to drive the pilot project forward, volunteers helped to monitor juvenile native oysters, donating their time and equipment. Building on this momentum, a meeting was organised to discuss the aims and delivery of the project, over 100 people attended the meeting which was held at the local village hall.

In 2019, the Ardfern Yacht Centre subsequently agreed to suspend oyster nurseries beneath the marina pontoons, enabling citizen science and outreach activities to take place with primary schools, now funded by sponsorship from local businesses. The project is currently planning further outreach, including a programme of talks, volunteer dive-surveys, species identification training days.

The project has a high level of community engagement because people care about the marine environment and welcome a chance to become actively involved see Figure 5.3). Local buy-in along with community ownership has helped secure sustained interest in the project and the long-term commitment of stakeholders to the protection and sustainability of the restored native oyster reefs.

Tips: Make sure to stay GDPR compliant with any form of personal data collection, be that surveys or health and safety volunteer sheets.

WORKING WITH SEAFOOD FESTIVALS

Case Study: Cuan Beo (Living Bay)

Aim: to raise awareness of the importance of water quality in the catchment, to support the protection of the environment for future generations and to highlight the local, national and international relevance of Galway Bay oysters.

The site is nationally and internationally renowned for its oyster fisheries, with the inner bay oyster fishery having been documented as far back as 1500 years ago, while archaeological evidence suggests that oysters formed an important part of life here for almost 4000 years.

The bay and the native oyster hold a special place in the hearts of residents around Galway Bay. To engage a large and diverse audience, the Cuan Beo policy was to piggy-back on existing festivals in the region, thereby enhancing the event with education, heritage and food but also reaching established audiences with our key message on the importance of water quality in Galway Bay.

Locally, the Clarinbridge Oyster Festival has been running for 65 years and attracts large audiences to the region annually. In 2019, Cuan Beo introduced an education and outreach event – an interactive evening of celebration of the native oyster in Galway Bay that was targeted at local residents. The free event explored the past, present and future relationship between the native oyster and Galway Bay communities, framing the importance of the native oyster in an environmental, economic and international context. The evening included talks about the maritime future of Galway Bay as well archive footage of the oyster festival from as early as 1962. Traditional cookery demos and a display of local fish produce was prepared by local chefs for attendees. The evening also included an international dimension with an invited speaker attending from the Solent Oyster Restoration Project and video footage from the Billion Oyster Project in New York. Local support agencies including the Marine Institute, Local Area Waters and Community Group, Inland Fisheries Ireland and EU-EMFF FLAG West had information stands at the event. The evening culminated with a historic 'All Ireland Tasting' of the native oyster from six of the eight remaining fisheries around Ireland.

Figure 5.3: CROMACH volunteers assisting with project restoration activities. Photos: Dan Renton/Craignish Restoration of Marine and Coastal Habitats (CROMACH).

EDUCATIONAL OUTREACH

Case study: Solent Oyster Restoration Project

Aim: Education aim: To improve ocean literacy and understanding of the local marine environment with an emphasis on the ecosystem service oysters can provide.

Through its education and outreach programme, the Blue Marine Foundation partnered with Wicor Primary School, Fareham, with the aim of inspiring future conservationists and increasing awareness of the Solent Oyster Restoration Project. The team conducted field visits to the oyster restoration sites in order to illustrate to Wicor's Year 5 students that oysters act as 'ecosystem engineers' and to give them first hand experience of the oyster's importance to native species within the Solent and the UK. Students were divided into two groups with the first observing the biodiversity found around the oyster cages and conducting species monitoring activities, while the second were taught scientific drawing skills and accurate measurement techniques using callipers (see Figure 5.4). To finish, students regrouped and were quizzed on lessons learnt.

The team also undertook a school visit to underpin key concepts of marine ecology and restoration. A verbal and interactive PowerPoint presentation covering the wider work of conservation charities was given to all year groups, followed by a two-hour oyster restoration project specific workshops with each of the Year 5 classes. The workshop was designed to integrate marine topics in a manner that covered various aspects of the curriculum through numerous interactive activities. For example, students were encouraged to engage with a marine food-web game devised to inspire teamwork. Additionally, a maths-based worksheet was provided to teach students how to calculate oyster mortality and highlight how this percentage changes over time. An oyster tank was kept in the classroom throughout the day, providing a visual demonstration of the water-filtering capabilities of native oysters.

The workshop concluded with an after school drop-in session for teachers, parents, guardians and siblings. This proved to be an extremely effective method for communicating the oyster restoration work to a wider audience in a single setting, with over 100 people attending the session with the children involved throughout the day passing on the information they had learnt to their parents and siblings.

INCREASING ACCESS TO NATURE

Case study: Essex Native Oyster Restoration Initiative (ENORI)

Aim: Essex estuaries having self-sustaining populations of native oysters that provide ecosystem services, increased biodiversity and sustainable fisheries whilst recognising their cultural importance.

Access to the natural environment can provide multiple benefits, particularly to those with special educational needs and disabilities (SEND) and those with behavioural issues. The Essex Native Oyster Restoration Initiative (ENORI) has developed a programme of outreach funded by the National Lottery Heritage Fund targeted at removing barriers to nature by providing specialist opportunities for these groups to experience and learn about the marine environment. Working with an outdoor educational specialist, children with SEND, along with pupils attending schools with very high 'pupil premium' (additional government financial support) and young people with behavioural issues or long-term illness including mental health issues will be invited on educational boat trips from Mersea Island out to the project site. The trips will be tailored to suit the passengers' needs to maximise learning and enjoyment and will include sensory activities such as touching and painting oyster shells.

Figure 5.4: Primary school outreach in the Solent, UK. Photos: Amy Munro/Blue Marine Foundation.

MONITORING THE SUCCESS OF OUTREACH

What is recorded, as part of a project's evaluation, all depends on what the project is trying to achieve, what its primary objectives are for the engagement and who the target audience is, so there are no hard and fast rules. The chosen method of evaluation will ultimately depend on what needs to be recorded. There are a number of resources that can enable projects to make decisions about all of these factors, from questionnaires to voting boxes, a few are detailed in Box 5.2.

By working closely with university students, and other volunteers, the Blue Marine Foundation has identified an opportunity to evaluate the outcomes and long-term impact through conducting electronic pre- and post-volunteer surveys. The surveys aim to measure changes in knowledge and awareness of the restoration project, its importance and other topics such as perceived threats to the marine environment. The close working relationship between the volunteers and staff also provides opportunities to conduct one-on-one interviews with volunteers to further understand the programme's value and how it could be improved. As much of the work is conducted in the field, having a digital form that can be completed in a short period of time on a tablet, mobile phone and/or app increases the likelihood of participation.

BOX 5.2: RESOURCES AND TOOLKITS FOR THE EVALUATION OF PUBLIC ENGAGEMENT

From the Science Festival Alliance lots of great toolkits and advice on evaluation:
https://sciencefestivals.org/toolkit/evaluation/

The NCCPE's guide to evaluating public engagement activities can be found here:
https://www.publicengagement.ac.uk/sites/default/files/publication/evaluating_your_public_engagement_work.pdf

Advice and evaluation method ideas from the University of Southampton here:
https://www.southampton.ac.uk/assets/imported/transforms/content-block/UsefulDownloads_Download/8D2521A89E504D70BF229953ED33A688/NCCPE-Beginners-guide-to-evaluating-PE-workbook.pdf

Tips: Using tablets or other mobile devices with preloaded questionnaire software or apps is a quick and easy way to record data and is likely to engage a wider range of demographics than a traditional pen and paper survey. This way data can be collated and analysed more efficiently, saving time and effort. Just remember to keep them charged!

FURTHER READING

Reef Resilience Network, communication planning process materials:
https://reefresilience.org/communication/communication-planning-process/

Figure 5.5: Native oyster shells painted at a music festival in Southsea. Photos: Luke Helmer.

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