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NORA 4
Reconnecting across Europe

4th Conference
23rd – 25th November 2021

ABSTRACTS

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Day 1 / Tuesday, November 23rd, 2021

10:00	**NORA Student Session**
12:00	**Registration and mingle in Gather.town**
13:00	**Opening and Welcome** Hein Sas
13:30	**Native Oyster Restoration Pilot Results Session** Chair: Alison Debney
	Stéphane Pouvreau **The flat oyster restoration in France – 10 years of research and future perspectives** *10*
	Emilie Reuchlin **Native oyster reefs in the Dutch North Sea: how much progress has been made in 5 years since discovery?** *11*
	Oliver Tully **Update on native oyster restoration projects in Ireland** *12*
	Luke Helmer **Solent Oyster Restoration Project update and a shift toward integrated restoration** *13*
14:15	**Questions & Comments**
14:30	Keynote speaker: Betsy Peabody of the Puget Sound Restoration Fund **Let me count the ways** *14*
15:00	**Questions & Comments** Chair: Boze Hancock
15:15	**Break and meet the keynote speaker in Gather.town**
15:50	**Site Selection Session** Chair: Bill Sanderson
	Bernadette Pogoda **The late Holocene demise of a sublittoral oyster bed in the North Sea** *15*
	Barbara Ondiviela **Historical ecology of flat oyster in the Atlantic coast of the Iberian Peninsula** *16*
	David Smyth **Twenty years observing natives settling in the wild; natural site selection and lessons for restoration** *17*
	Brecht Stechele **Modelling native oyster metabolism for aquaculture and restoration purposes** *18*
	Luca van Duren **Modelling tools to support successful offshore oyster restoration** *19*
16:40	**Questions & Comments**
17:00	**End of day one**

Day 2 / Wednesday November 24th, 2021

8:30	**Registration and mingle in Gather.town**
9:00	**Opening**
9:05	**Production Session** Chair: Pauline Kamermans & Bérenger Colosul
	Bérenger Colsoul **Helgoland Oyster Hatchery: Design, operation, first production results and observations** *20*
	Nicolas Araujo Piñeiro **Bonamia-free flat oyster (*Ostrea edulis*) spat-on- shell production: from small to large scale** *21*
	Pauline Kamermans **Hatchery production of Bonamia-free and -resistant flat oysters (*Ostrea edulis L.*)** *22*
	Matthew Johnston **Development of screening techniques for Bonamia to improve biosecurity and ensure disease free status for commercial shellfish hatcheries** *23*
	Camilla Bertolini **Introducing MAREA: Matchmaking restoration, ecology and aquaculture** *24*
10:00	**Questions & Comments**
10:20	**Break and Poster in Gather.town**
11:15	Edo Knegtering **Ensuring Bonamia-free introductions of *Ostrea edulis* for nature restoration purposes by implementing Regulation EU 2016/429 ('Animal Health Law') into national legislation of EU Member States**
11:30	**Management Session** Chair: Henning von Nordheim
	Tom van der Have **Shared risks of aquaculture and restoration projects: is there a need to integrate biosecurity license procedure?** *25*
	Remment ter Hofstede **The effect of human interventions at different scales within offshore wind farms to promote flat oyster (*Ostrea edulis*) reef development in the Southern North Sea** *26*
	David Donnan **Where, when, how much, how long? Reflections from Scotland on securing successful native oyster restoration** *27*
	Robert Whiteley **Native oyster restoration experiences from England´s Statutory Nature Conservation Body** *28*
12:15	**Questions & Comments**
12:30	**Lunch and Poster Session in Gather.town**

Day 2 / Wednesday November 24th, 2021

13:30	Philine zu Ermgassen **European Native Oyster Habitat Restoration Monitoring Handbook**	*29*
13:40	**Monitoring Session** Chair: David Donnan	
	Renate Olie **The status of offshore wind farm Borssele 3 as a new flat oyster habitat**	*30*
	Tom Cameron **Experimental estimation of efficiency for oyster survey ladder dredges over different seabed sediments**	*31*
	Oscar Bos **Oyster monitoring challenges in an offshore wind farm (ECOFRIEND project)**	*32*
	Andrew Hunt **British Sub Aqua Club´s Operation Oyster**	*33*
14:25	**Questions & Comments**	
14:40	**Break and Poster in Gather.town**	
15:25	**Working Group Session** Chair: Philine zu Ermgassen	
	Ruth Thurstan **Historical distribution of the native oyster (*Ostrea edulis*) in Europe**	*34*
	Anna Hughes **Determining the most important factors in site selection for European native oyster (*Ostrea edulis*) habitat restoration projects**	*35*
	Åsa Strand **Policy Brief and Information Sheets - the latest outputs from the NORA Production Working Group**	*36*
15:55	**Questions to NORA working group speakers**	
16:05	**NORA session with the Advisory Board**	
17:00	**Happy Hour in Gather.town**	

Day 3 / Thursday, November 25th, 2021

8:30	**Registration and mingle in Gather.town**	
9:00	**Opening**	
9:05	**Ecosystem Services Session** Chair: Joanne Preston and Luke Helmer	
	Joanne Preston **Habitat provisioning and nursery function of the European native oyster *Ostrea edulis* supported by the distinct and highly biodiverse community associated with native oyster habitat**	*37*
	Naomi Kennon **Understanding biodiversity restoration using sustainable, rotational fishery management**	*38*
	Marina Albentosa **Scope for growth of Mar Menor flat oysters under eutrophic conditions: Implications for future bioremediation actions**	*39*
	Hannah Lee **Balancing the equation: ´Blue carbon´ and the native European oyster (*Ostrea edulis*)**	*40*
9:50	**Questions & Comments**	
10:05	Keynote speaker: Chris Gillies, The Nature Conservancy's (Australia) Oceans Program Director **Seven years of oyster restoration in Australia. What's going on down there?**	*41*
10:30	**Questions & Comments** Chair: Boze Hancock	
10:45	**Break and meet the keynote speaker in Gather.town**	
11:15	**Genetics Session** Chair: Pierre Boudry	
	Paulino Martínez **Origin of the Mar Menor (SE Spain) flat oyster population: the end of a legend**	*42*
	Homère Alves Monteiro **How Many Parents Have You Got? Parental Contribution in a Flat Oyster Hatchery**	*43*
	Paulino Martínez **Validation and mapping of flat oyster genetic markers associated with the *Bonamia ostreae* status following a population genomics approach**	*44*
11:50	**Questions & Comments**	
12:00	**NORA session with the Advisory Board**	
12:45	**Closing Statement**	
13:00	**End of the conference**	

Poster Sessions

Poster Session - Native Oyster Restoration Pilot Results

Poster Session - Site Selection

Poster Session - Production

Poster Session - Management

Poster Sessions

Poster Session - Monitoring

Poster Session - Ecosystem Service

TALKS

The flat oyster restoration in France: 10 years of research and future perspectives

S. Pouvreau[1], H. Cochet[2], A. Fabien[3], N. Sebaibi[3], M. Perrot[4], I. Arzul[1], S. Lapègue[1], B. Salaun[5], N. Cozannet[5], P. Le Gal[6], M. Le Joubioux[7], A. Pibot[8], M. Remaud[8], A. Larzhillière[9], C. Carpentier[10], P. Boudry[1]

[1] Ifremer, Institut Français de Recherche pour l'Exploitation de la Mer, 29280 Plouzané, France, stephane.pouvreau@ifremer.fr
[2] COCHET Environnement - Bureau d'étude, 56550 Locoal Mendon, France
[3] COMUE Normandie Université, ESITC Caen, 14610 Épron, France
[4] SEABOOST, 34000 Montpellier, France
[5] CRC BN, Comité Régional Conchylicole de Bretagne Nord, 29600 Morlaix, France
[6] CRC BS, Comité Régional Conchylicole de Bretagne Sud, 56400 Auray, France
[7] SOBAIE, Syndicat Ostréicole de la Baie de Quiberon, 56740 Locmariaquer, France
[8] OFB, Office Français de la Biodiversité, 29200 Brest, France
[9] PNRA, Parc Naturel Régional d'Armorique, 29590 Le Faou, France
[10] CAPENA, 17480 Le Château d'Oléron

In recent years, the ecological restoration of the flat oyster has gained momentum in France, mainly on two workshop sites: the Brest bay and the Quiberon bay. More discreetly within the first two projects, PERLE from 2011 to 2014 and EVER from 2013 to 2015, this theme has really taken off within the framework of the FOREVER and the PERLE II projects from 2016 to 2020. This presentation provides a summary of the main results of these various French projects and outlines future prospects in the context of the decade for ecosystem restoration launched by the UN in 2021. Overall, these projects show a structured restoration ecology approach combining knowledge of the biology of the species and its living environment and including an ecological engineering component. In a simplistic way, the organisation of this approach could be summarised as follows: Why - Where - When and How to restore. But these past few years of research also show that there can be no restoration of the species without a localised socio-economic approach involving professionals from the sea, environmental managers, associations and also the education sector. Taking into account all of these keys should enable the flat oyster to be restored effectively in the years to come. Various new projects are already in gestation or at work. This emulation should also make it possible to gradually consider a renewed interest in this native species in scientific research in France and Europe. This virtuous circle could also be accompanied by the creation of a socio-economic network around coastal restoration in the forthcoming years in France. More generally, there is no doubt that shellfish restoration is a real Nature-based solution to make our coastal ecosystems more resilient to current and future crisis.

Key Words:
flat oyster restoration, nature based solutions, marine ecology, *ostrea edulis*

Native oyster reefs in the Dutch North Sea: how much progress has been made in 5 years since discovery?

E. Reuchlin[1], J.H. Bergsma [3], K. Didderen[3], P. Kamermans[5], W. Lengkeek[3], H. Sas[4], E. Shrijver[2], T.M. Van der Have[3], K. Van den Wijngaard[2]

[1] WWF Netherlands, Zeis, The Netherlands, ereuchlin@wwf.nl
[2] ARK Nature, Nijmegen, The Netherlands
[3] Bureau Waardenburg, Culemborg, The Netherlands
[4] Sas Consultancy, Amsterdam, The Netherlands
[5] Wageningen Marine Research, WUR, Yerseke, The Netherlands

The 2015 discovery of a native oyster reef in the Southern North Sea gave rise to and inspired numerous studies and pilots in this area. Efforts have been made on the description, protection and restoration of native oyster reefs in the Netherlands. Here we discuss the progress that has been made over the past five years in the Netherlands and Dutch North Sea in particular. We show the results of near-shore and off-shore restoration pilots and describe how evaluation of these results contributed to generating even more pilots. For the near-shore pilot, techniques that have been used over the past five years are evaluated in the context of future restoration efforts, including techniques for monitoring, substrate provisioning (including timing of deployment), active introduction and protection of native oysters. The off-shore pilots show multi-year survival and reproduction of native oysters and developments in biodiversity around the pilot. At the same time, knowledge gaps for long-term maintenance of the pilots and reefs are defined.

Update on native oyster restoration projects in Ireland

Oliver Tully[1], Diego Pereirra[1], Tomasz Dabrowski[1], Deborah Cheslett[1], Killian Coakley[1], Alex Blackwell[2], Patricia Daly[3], Mary Hannon[3], Diarmuid Kelly[4], Gerry O'Halloran[4], Alec Reid[4], Fiona Stapleton[5], Paul Bradley[5], Michael Conroy[6]

[1] Marine Institute, IRELAND, oliver.tully@marine.ie

[2] Clew Bay Oyster Co-operative, Mayo, IRELAND

[3] Bord Iascaigh Mhara, IRELAND

[4] Cuan Beo, Kinvara, Galway, IRELAND

[5] Lough Swilly Oyster Co-operative

[6] Comharcumann Sliogeisc Conamara, Kilkieran Bay, Galway

Oyster restoration projects in Ireland are currently being undertaken in Galway Bay, Kilkieran Bay, Clew Bay and Lough Swilly. Activities include biomass distribution and estimation, monitoring of *Bonamia*, deployment and monitoring of growth and survival of spatted cultch, deployment of cultch to enhance spat settlement and monitoring of spat settlement and habitat suitability assessment and experimental assessment of mortality rates in relation to temperature and salinity. Some historic oyster beds are no longer viable because of exposure to low salinities and habitat changes (Galway). Habitat suitability modelling is important for restoration in this case. Spat mortality in the first 2 years of life is high but varies spatially, Pacific oyster is now abundant on native oyster beds (L. Swilly), protected seagrass habitat has expanded into oyster beds that were previously fished (Kilkieran), spat settlement occurs in all areas but with strong inter-annual variability, *Bonamia* is present in all areas but prevalence varies in beds within the same area. The main constraints to restoration or rebuilding existing beds is inconsistent annual settlement in a background of high mortality which may be caused by Bonamia or other pressures. Fishing occurs in all areas other than Galway and areas are closed in Clew Bay and Kilkieran Bay for habitat protection.

Key Words:
biomass, spat, survival, cultch, *Bonamia*

Solent Oyster Restoration Project Update and a shift toward integrated restoration

Luke Helmer[1,2,3], Jacob Kean Hammerson[1], Morven Robertson[1], David Tudor[1],

[1] Blue Marine Foundation, London, UK, luke@bluemarinefoundation.com
[2] Institute of Marine Sciences, University of Portsmouth, Portsmouth, UK.
[3] School of Ocean and Earth Science, University of Southampton, Southampton UK

This year has seen some encouraging developments in the Solent for the restoration of key habitats. BLUE is gearing up to restore a hectare of oyster reef in Langstone Harbour and the River Hamble which will be one of the largest restoration efforts of its kind in Europe. In the River Hamble, the combined oyster and saltmarsh trial has progressed well, all structures have been placed to prevent saltmarsh erosion and promote oyster recovery. At the restoration hatchery, the first spawning event saw six million oyster larvae spawned with seven further tanks yet to spawn. BLUE has also progressed the vision for integrated restoration regionally, holding a large stakeholder workshop and sharing its findings as well as working with key partners to identify potential restoration sites around the Solent to trail integrated restoration. Next year will be an exciting time for this project. We will continue our oyster restoration programme and restore more areas of oyster reef across the Solent as well as ramping up oyster production in the hatchery. The first round of monitoring of the restored reefs will take place to assess the progress. We also hope to finalise, apply for licences, and begin integrated restoration trials in the Solent over the next year.

Key Words:
large-scale restoration, integrated restoration, ecosystem scale

Let me count the ways

Betsy Peabody[1]

[1] Exectuive Director, Puget Sound Restoration Fund, betsy@restorationfund.org

Olympia oysters (*Ostrea lurida*) are the quintessential gift that keeps on giving. There's the oyster itself, this still-living resource, nestled in nooks and crannies, somehow maintaining a foothold amid profound changes to the shore scape. No mean feat for a calcifier on the front lines of ocean acidification. Equally captivating are the people connected to the oyster - tribes, growers, scientists, historians, conservationists, gastronomes, to name a few. For a little oyster, slow to grow, not easily found on the tideflat, and not much to look at (objectively speaking), Olympia oysters have been big players on the west coast of North America. In times of old, dense aggregations cleansed surrounding waters and created living, organizing structures that supported life and diversity. At low tide, Olympia oysters became First Foods, sustaining people and communities for millennia. Today, restoration efforts add a new dimension to this age-old story of abundance and decline. Seeds produced in a hatchery to re-build populations in local waters help re-build our own connections to marine ecosystems. As a community-building organism, Olympia oysters provide a metaphor for the resilient and sustainable communities that we, too, are trying to create for ourselves, to support life and diversity. The story of this oyster contains within it countless seeds of engagement for powering restoration efforts into the future.

The late Holocene demise of a sublittoral oyster bed in the North Sea

Bernadette Pogoda[1,2], Lasse Sander[2], H. Christian Hass[2]†, Rune Michaelis[2,3], Christopher Groß[2], Tanja Hausen[2]

[1] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Biological Institute Helgoland, Germany

[2] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Wadden Sea Station Sylt, Germany

[3] Lower Saxon Wadden Sea National Park Authority, Wilhelmshaven, Germany

MA fossil oyster bed (*Ostrea edulis*) was recently encountered offshore Helgoland (German Bight). Oysters are important filter feeders in marine environments and their habitat structure supports a large associated biodiversity. The European flat oyster *Ostrea edulis* has historically occurred in vast populations in the North Sea, but declined massively in the early 20th century. The ecological restoration of Ostrea habitats is a current focal point in the North Sea. To better understand the mechanisms that caused the local collapse of the oyster population, this study investigated the size structure, weight, and age of the shells, along with the spatial dimensions, seafloor properties, and environmental context of the oyster bed. The results show that the demise of the population occurred around 700 CE, ruling out excessive harvest as a driver of decline. Synchronicity of increased geomorphological activity of rivers and concurrent major land use changes in early medieval Europe suggest that increased sedimentation was a viable stressor that reduced the performance of the oysters. The shells provided no indication of a demographically poor state of the oyster bed prior to its demise, but manifested evidence of the wide-spread occurrence of the boring sponge Cliona sp. Our study challenges the assumption of a stable preindustrial state of the European flat oyster in the North Sea, and we conclude that the long-term variability of environmental conditions needs to be addressed to benchmark success criteria for the restoration of *O. edulis*.

Key Words:
ostrea edulis, historical oyster ecology

Historical ecology of flat oyster in the Atlantic coast of the Iberian Peninsula

Bárbara Ondiviela[1], Inés Mazarrasa[1], José A. Juanes[1], María Recio[1] and Max Ricker[2]

[1] IHCantabria, Instituto de Hidráulica Ambiental de la Universidad de Cantabria, ondiviela@unican.es

[2] The Nature Conservancy, Germany

Oyster reefs once dominated numerous estuaries, playing a key role in the ecological integrity of the system and in the economy of coastal populations. However, centuries of intensive exploitation resulted in the destruction of more than 85 % of the world's oyster reef habitats (Beck et al, 2011). This process, especially intense in temperate biogenic reefs, has led to the loss of the European native species *Ostrea edulis*, along the Atlantic coast of the Iberian Peninsula in a relatively short period of time. To support the restoration of *O. edulis* grounds in the Iberian Peninsula, this study identified the location of historical oyster beds and explored the causes of loss by assessing the interactions between oyster grounds and human culture using a historical ecology approach.

Through the revision of scientific and grey literature and historical archives and the consultation to local stakeholders, the sites where the species was present in the past, the extractions techniques used throughout the history, the uses of the species, the national and international trade network and the landing prizes and regulations were documented. We obtained 134 citations, corresponding to 44 estuaries from Spain and Portugal, since the Mesolithic to the present time. The data from the historical records of *O. edulis* were combined with the current environmental quality conditions to identify on a first rough scale (i.e. Iberian Peninsula scale), the estuaries that could potentially host *O. edulis* and on a second finer scale, to model on a selection of estuaries the most suitable areas for restoration. This study is a contribution of the LIFE ADAPTABLUES project, that aims to enhance the implementation of climate change adaptation strategies in Europe through the management and restoration of estuarine ecosystems.

Key Words:
Ostrea edulis, iberian peninsula, historical ecology, site selection

Twenty years observing natives settling in the wild; natural site selection and lessons for restoration

David Smyth[1], Maria Hayden-Hughes[1], Louise Kregting[2]

[1] Shellfish Centre, Bangor University Wales, UK, d.smyth@bangor.ac.uk

[2] Portaferry Marine Laboratory, Queen's University Belfast, UK

The historically prolific native oyster was once a major habitat feature and fishery within Strangford Lough Northern Ireland. However, population dynamics followed the same trend as the rest of Europe with a complete collapse in the early 1900s. The native oyster was absent and considered functionally extinct from Strangford until the early 2000s. When an inadvertent spawning event from an aquaculture assemblage of 100,000 increased the wild population of < 5000 to > 1.4 million within four years. This unintentional re-establishment of *Ostrea edulis* has been closely monitored for more than 20 years with settlement patterns, larval dispersal, population dynamics, substrate types and habitat suitability all documented. As a result, a large data library has been collated over the period which can offer native oyster restoration participants an insight into what has proven best in the augmentation of *O. edulis* numbers in the wild. Research over the years has identified a number of key components and practices which should be applied and avoided in the reintroduction or expansion of native oyster populations. This presentation will outline and highlight some important findings over the decades of survey work which will be of value to many of the active restoration ventures currently underway in relation to site selection.

Key Words:
Ostrea edulis site suitability for reintroduction

Modelling native oyster metabolism for aquaculture and restoration purposes

Brecht Stechele[1], Dimitry Van der Zande[2], Leo Barbut[2], Geneviève Lacroix[2], Steven Degraer[2], Peter Bossier[1], Nancy Nevejan[1]

[1] Laboratorium voor Aquacultuur en Artemia Reference Center, Universiteit Gent (UGent-ARC), UGent BW13, Coupure Links 653, Blok F, 9000 Gent, Belgium, Brecht.Stechele@UGent.be

[2] Koninklijk Belgisch Instituut voor Natuurwetenschappen (IRScNB/KBIN), Vautierstraat 29, 1000 Brussel, Belgium

With the implementation of the Belgian Marine Spatial plan 2020-2026, new nearshore areas are now open for licensing commercial and industrial activities. These areas can host extractive aquaculture activities and commercial enterprises have already shown interest in large-scale shellfish aquaculture close to the harbor of Nieuwpoort. Besides areas for commercial and industrial activities, new multi-use areas are allocated offshore. Within these, a combination of renewable energy generation, extractive aquaculture, marine conservation, and passive fisheries is encouraged. Since these areas exclude bottom disturbing fisheries, and hard substrate is provided through scouring protection around wind turbines, they also show potential for flat oyster restoration and reintroduction projects.

The simulation of flat oyster metabolic parameters (growth, reproduction, and survival) and population traits is vital to aquaculture and restoration activities. The flat oyster Dynamic Energy Budget (Individual based model) forced with optimized remote sensing observations (Copernicus, Sentinel-3/OLCI) and the MIRO&CO biogeochemical model results is capable of assessing several aquaculture and restoration parameters such as inter-annual and individual growth variability, farm yields, harvesting time, mortality events, larval production, male/female and size distribution, condition index, etc. It offers the possibility to simulate restoration scenarios or estimate the state of (wild or aquaculture) stocks in real time or even in forecasting mode. The approach will be demonstrated in a case study in the Belgian Coastal Zone.

Key Words:
shellfish aquaculture, shellfish restoration, population modelling, dynamic energy budget

Modelling tools to support successful offshore oyster restoration

Luca A. van Duren[1], Greg Ballas[1,6], Tim Raaijmakers[1], Firmijn Zijl[1], Oscar G. Bos[2], Pauline Kamermans[2], Tom van der Have[3], Joost Bergsma[3], Hein Sas[4], Luuk Folkerts[5]

[1] Deltares, Deltares (www.deltares.nl), P.O. Box 177, 2600 MH Delft (NL), Luca.vanduren@deltares.nl

[2] Wageningen Marine Research, (www.wur.nl), PO Box 59, Den Helder (NL).

[3] Bureau Waardenburg Bureau Waardenburg (www.buwa.nl), Varkensmarkt 9, 4101 CK Culemborg (NL)

[4] Sas Consultancy Sas Consultancy (www.sasconsultancy.nl), Danie Theronstraat 22-D, 1091 XZ Amsterdam (NL)

[5] Gemini, Amstelveensweg 760 (2nd floor), 1081 JK Amsterdam (NL)

[6] Current work address: Van Oord, (https://www.vanoord.com/nl/) PO Box 8574, 3009 AN Rotterdam, The Netherlands

The success of any restoration depends on the choice of an environment that is suitable, not just for the adult species and reef structures but also for the transport and settlement conditions for larvae. Hydrodynamics is one of the fundamental primary driving forces for habitat suitability, defining the possibilities for transport and settlement of larvae, probabilities of dislodgement and the mobility of sediment. Furthermore, hydrodynamics is also a fundamental factor in the transport of heat, nutrients and phytoplankton through the water column, thereby influencing food availability, temperature regimes and other factors that determine habitat suitability and carrying capacity for shellfish and other species.

Deltares has developed a numerical model of the North Sea hydrodynamics. Within the ECOFRIEND project this model has been applied and validated with measurements collected at a restoration site in the GEMINI off shore wind farm. The model appears to perform very well in terms of predicting temperature regime and stratification, allowing to calculate parameters such as the “degree day” to predict timing of spawning and larval swarming.

Furthermore, hydrodynamic forces can also dislodge and transport material, including cages and other deployment structures for oyster restoration. At the Gemini pilot site some oyster cages were lost in 2018. The model, in combination with a basic stability and migration model for cages indicated that over the period the cages were deployed, storm conditions occurred that were strong enough to dislodge and subsequently transport the cages. Application of improved and validated models will prevent losses, but also prevent excessive costs due to over-specification and also make it easier to have wind farm operators accept such structures in the vicinity of turbines.

Such ecosystem models can give insights in many aspects relevant to restoration projects. The development of such models requires serious investment and interpreting the results is specialist work. However, such models have many other application fields for marine spatial planning, and if restoration project can make use of such developments for site selection and deployment methodology, risks of failure can be diminished.

Key words:
environmental hydrodynamics, modelling tools, site selection, method optimisation

Helgoland Oyster Hatchery: Design, operation, first production results & observations

Bérenger Colsoul[1]*, Lennard Klingforth[1], Clemens Kozian-Fleck[1], Corina Peter[1], Bernadette Pogoda[1,2]

[1] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Biological Institute Helgoland

[2] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI), Wadden Sea Station Sylt

* Am Handelshafen 12, 27570 Bremerhaven, berenger.colsoul@awi.de

The Helgoland Oyster Hatchery is an infrastructure at AWI Helgoland, funded and implemented via the PROCEED project. Main goals of the hatchery are to produce seed oysters for European flat oyster restoration in the North Sea and to address relevant research questions in the field. European flat oyster reintroduction and restoration measures are driven under the umbrella of national and international marine conservation measures, funded e.g. by the German Federal Agency for Nature Conservation (BfN). Against this background, the hatchery will meet the demand for seed oysters in required quality and quantity. The technical design and management of the Helgoland Oyster Hatchery is based on state-of-the-art knowledge on oyster conditioning and reproduction techniques with the defined goal to produce spat for mid- and large-scale restoration measures in the North Sea. This requires adaptation and optimization of commercial production techniques, which includes a number of applied research topics. Furthermore, the development and compliance of appropriate biosecurity measures for the imported and genetically diverse broodstock oysters as well as for the production of microalgae and seed oysters are important aspects of the work in the hatchery. The Helgoland Oyster Hatchery is the first and only shellfish hatchery in Germany, focusing on the production of oysters for restoration and research purposes. The research topics addressed within the hatchery are connected to important parameters for the survival, settlement success and growth of healthy seed oysters. Here, we present an overview of the different compartments of the Helgoland Oyster Hatchery as well as an overview of the production season 2021 with results of settlement success and lessons learned during the process.

Key Words:
spat-on-shell, seed oyster production, restoration, germany

Bonamia-free flat oyster (*Ostrea edulis*) spat-on-shell production: from small to large scale

Nicolas Araujo Piñeiro[1], Pascal Barreau[1], Pernille Nielsen[1], Camille Saurel[1],

[1] Danish Shellfish Centre, DTU Aqua, Øroddevej 80, 7900 Nykøbing Mors, Denmark, csau@aqua.dtu.dk

There are many challenges associated with European flat oyster (*Ostrea edulis*) restoration, in particular the supply of individuals (adults and/or spat) to unpopulated and disease-free habitats. Amongst them, biosecurity and genetic diversity issues are associated to the potential translocation of oysters, while settlement of spat on adapted substrate is important to secure anchoring of the oysters in the new environment. Some solutions include hatchery produced spat from disease-free broodstock with known effective population size and origin, and substrate attached spat such as spat-on-shell, a method widely used in the US for restoration programs of Eastern oysters (*Crassostrea virginica*).

For the past 15 years, flat oyster spat has been produced on grinded oyster shells as cultch at the Danish Shellfish Centre (DTU Aqua), with settlement rates around 50 %. In 2020, we initiated the development of a protocol for a cost-effective large-scale production of spat-on-shell. In a controlled experiment, we tested different substratum treatments to determine flat oyster settlement success on flat oyster shells, Pacific oyster (*Crassostrea gigas*) shells and grinded cultch on a single layer. We also measured the larvae attachment preferences to the shells side (inside vs outside) and valve, depending on the shell orientation. Between 29.000 and 32.000 larvae were used for each treatment. The results show successful settlement rates on both shell species with 16-22 % and 17-24 % on flat and Pacific oysters respectively with around 3.47 spat/cm² for both species. However, grinded cultch had higher settlement success of 38-53 %. Larvae preferred to settle on the outer side of valves irrespective of shell orientation and valve. In a second experiment, we tested a more cost-effective production with a thick volume of Pacific oyster shells placed in larger tanks. Results showed that despite high larvae mortalities (84-95 %), it was possible to produce spat-on-shell with 0.13 spat/cm² using a less controlled methodology with no water exchange and no continuous feeding during settlement.

The results show successful flat oyster settlement on both flat and Pacific oyster shells under controlled conditions in small scale and on Pacific oyster shells under less controlled and larger production scale. The latter being more cost-effective for restoration programmes.

Key Words:
spat-on-shell, hatchery, large scale production

Hatchery production of Bonamia-free and -resistant flat oysters (*Ostrea edulis* L.)

Pauline Kamermans[1,2], Ainhoa Blanco[1], Pim van Dalen[1], Nienke Bakker[3], Marc Engelsma[4], Pascalle Jacobs[5], Marco Dubbeldam[6], Manel Vera[7,8], Paulino Martinez[7,8]

[1] Wageningen Marine Research, Wageningen University and Research, P.O. Box 77, 4400 AB Yerseke, The Netherlands, pauline.kamermans@wur.nl

[2] Marine Animal Ecology Group, Wageningen University, P.O. Box 9101, 6700 HB Wageningen, The Netherlands

[3] Hatchery Roem van Yerseke, Groeninx van Zoelenstraat 35, 4401 KZ Yerseke, The Netherlands

[4] Wageningen Bioveterinary Research, P.O. Box 65, 8200 AB Lelystad, The Netherlands

[5] Royal Netherlands Institute of Sea Research, PO Box 59, 1790 AB Den Burg, The Netherlands

[6] Stichting Zeeschelp, Oosthavendijk 7, 4493 BK Kamperland, The Netherlands

[7] Department of Zoology, Genetics and Physical Anthropology, Faculty of Veterinary, University of Santiago de Compostela, 27002 Lugo, Spain

[8] Aquaculture Institute, University of Santiago de Compostela, 15705 Santiago de Compostela, Spain

When restoring flat oyster beds in areas where the oysters are absent it is unclear if pathogens such as Bonamia ostrea are present. In such cases it is advised to use Bonamia-free oysters. Adult oysters were collected in the Delta area of the South West Netherlands, a Bonamia infected area. With the aid of a non-destructive screening method Bonamia-free broodstock oysters were pre-selected. These oysters produced Bonamia-free larvae and spat. For comparison, broodstock oysters were collected in the Wadden Sea, an area free of Bonamia. These oysters also produced Bonamia-free larvae and spat. It is expected that the Delta area oysters have developed a degree of resistance to the disease, while the naive Wadden Sea oysters have not. To study this, samples of broodstock and spat were analysed for association of candidate genetic markers related to bonamiosis resistance. The pre-selected Bonamia-free oysters and spat showed a higher percentage of markers associated with resistance while the naive oyster spat showed a lower perentage, and in fact, the infection status (1: naïve and free; 2: free; 3: infected) showed a significant correlation with the percentage of resistant genotypes in the population (Spearman correlation: 0.949, P = 0.014). In addition, spat of both groups was challenged in Lake Grevelingen where Bonamia occurs. Survival of the pre-selected Bonamia-free oysters was higher than the naive group. When the tests show that the Bonamia-free spat from Lake Grevelingen is in possession of resistance variants and will be less likely to contract the disease when challenged, it indicates resistance to Bonamia. This is very useful for restoration projects since international regulations and national policies aim to prevent the transfer of diseases to new areas, but protection against disease is desired, in case it does appear in a newly established bed.

Key words:
flat oyster, *Ostrea edulis*, bonamia, resistance

Development of screening techniques for Bonamia to improve biosecurity and ensure disease free status for commercial shellfish hatcheries

Matthew Johnston[1], Forrest Petersen[1], Nikolas Sachlikidis[1]

[1] Orkney Shellfish Hatchery Ltd, The Lobster Ponds, Lamb Holm Quarry, Orkney, Scotland, KW17 2SF, info@orkneyshellfishhathcery.co.uk

Throughout much of the United Kingdom and Europe wild stocks of the native flat oyster, *Ostrea edulis*, are severely depleted because of overexploitation, pests, pollution, and disease. Despite these issues, market demand for native oysters remains high and, consequently, there is much interest in farming native oysters and restocking wild populations. Due to the presence of the parasitic disease, Bonamia ostrea, many farmers and restocking programs require disease-free oyster spat to cultivate and create reef structures in areas zoned or deemed Bonamia free. To meet this demand Orkney Shellfish Hatchery (OSH) has resourced, designed, and dedicated its hatchery to the production of native oysters. Its unique location in northern Scotland, bio-secure systems design and screening protocols have positioned the hatchery to provide a range of disease-free products to these different markets. The implementation of screening all broodstock that enters the hatchery using destructive histological techniques as well as additional PCR screening is one way that Orkney Shellfish Hatchery is staying one step ahead. OSH's broodstock screening program has now been extended to include environmental DNA (eDNA) testing. This approach is proving advantageous for commercial hatcheries because of its high degree of sensitivity, it does not involve the destructive testing of broodstock, and has the capacity to test every individual broodstock for the disease prior to introducing new stock to the hatchery. The results produced by Orkney Shellfish Hatchery and its commercial partner Xelect Ltd demonstrate how eDNA techniques could be used as a new tool for diagnostic laboratories for detecting Bonamia. Utilising the eDNA technique could be used to improve uptake of screening within hatcheries and assist with moving stock between locations, improving biosecurity for hatcheries, farmers, and wild restocking programs as well as profitability of commercial hatcheries.

Key Words:
native flat oysters, innovation, bonamia ostrea, recirculating aquaculture systems

Introducing MAREA: Matchmaking restoration, ecology and aquaculture

C. Bertolini[1], R. Pastres[1]

[1] Department of Environmental Sciences Informatics and Statistics, Ca' Foscari University of Venice, 30170 Venice, Italy, camilla.bertolini@unive.it

Habitat restoration management can be integrated within aquaculture practices to limit their negative impacts, bringing positive environmental changes while obtaining both economic and cultural returns. The project MAREA aims to reintroduce *Ostrea edulis* under mussels' culture sites, to ensure protection from dredging and harvesting of adults, and study its recruitment processes in order to both understand the possibility of harvesting the oyster spat recruiting on collectors in the farm area to start a local oyster farming chain and monitoring reef expansion on different substrata on the seabed area. Furthermore, the project aims to monitor the ecosystem services associated with the restoration action. This will be done combining modelling and experimental approaches with the installation of a pilot site where key environmental parameters, such as flow and temperature, will be monitored in order to gather mechanistic understanding allowing a potential scale up in space. To identify the long-term potential of this approach in a fast-warming area like the Mediterranean Sea, and in particular the Northern Adriatic, climate change scenarios will be incorporated in the temporal scale up of the results.

Key Words:
restorative aquaculture, recruitment

Shared risks of aquaculture and restoration projects: is there a need to integrate biosecurity license procedures?

T.M. van der Have[1]

[1] Bureau Waardenburg, Varkensmarkt 9, Culemborg, The Netherlands, t.m.van.der.have@buwa.nl

Translocation of oysters is frequently used in both restoration projects and aquaculture to acquire source populations for, respectively, initiating or enhancing natural, self-sustaining populations or production of oysters. And, therefore, there is an increasing demand for disease-free oysters produced in aquaculture. These translocations generally have two major biosecurity risks: the spread of infectious diseases and the introduction of new invasive alien species. Two separate EU Directives, the Habitat Directive (HD) and Aquaculture Directive (AD), are implemented in EU-member states to prevent the spread of marine invasive alien species (IAS) and notifiable infectious diseases, respectively. Ultimately, they aim to protect economical value (AD) or biodiversity (HD). However, the implementation of EU legislation and license procedures are complicated by the fact that oysters are often translocated (reintroduced) to areas without aquaculture (e.g., offshore) or flat oysters (due to extinction). In addition, new infectious diseases, often spread or facilitated by IAS, also impose threats to biodiversity, and vice versa, IAS can inflict substantial economical damage to aquaculture facilities. I discuss the license procedures in the Netherlands and propose to integrate a broader spectrum of biosecurity risks in the implementation of both EU Directives. The use of young sentinel oysters in aquaculture and areas without recent occurrences of oysters is proposed as a novel way to facilitate disease surveillance in both aquaculture and reintroduction projects.

Key words:
oyster restoration, nature conservation law, aquaculture directive

The effect of human interventions at different scales within offshore wind farms to promote flat oyster (*Ostrea edulis*) reef development in the Southern North Sea

Remment ter Hofstede[1,2], G. Williams[2], M. Van Koningsveld[1,2]

[1] Delft University of Technology, Civil Engineering and Geosciences, Stevinweg 1, 2628 CN Delft, The Netherlands, R.terHofstede@tudelft.nl

[2] Van Oord DMC, Schaardijk 211, 3068 NH Rotterdam, The Netherlands

Incorporation of ecology and ecosystem services into marine infrastructural developments has gained strong interest over the last decades. The ecological value in terms of biodiversity and biomass at and around marine infrastructure can be increased by making adjustments to the conventional engineering design and by including modified structures to enhance habitat complexity. Growing attention is given to combine the huge roll-out of offshore windfarm constructions in the North Sea with the reinstatement of hard substrate epibenthic communities, in particular of the once rich but nowadays nearly extinct European flat oyster (*Ostrea edulis*). Such actions could mitigate the ecological impact of the wind farm construction, facilitating the required permitting process and community acceptance.

Pilot studies are performed to determine best practices for enforcing oyster reef development in offshore wind farms. These studies provide knowledge on for example the type of substrate that is most likely to be successful in collecting oyster spat, and the design of broodstock structures to serve as larvae pumps in offshore wind farms. Despite the efforts, an overarching management approach is still lacking for the actual implementation of the research outcomes. This may be due to the lack of insight at which level to incorporate technical modifications of offshore wind farms, what the effect of these measures could be, and how much intervention is needed to be of significance for the surrounding environment. Therefore, a framework has been developed to enable the selection of appropriate measures for pro-actively facilitating flat oyster reef development in offshore windfarms. The framework addresses the historical and current situation of the physical system scale processes and social environment, and provides a quantitative assessment to estimate the effect of applying interventions at a range of scales, from micro-scale (materials used) to mega-scale (connectivity between wind farms). We present the application of this framework using results from previous and new research, and estimate quantitatively the effect of human interventions at different scales to facilitate and improve outcomes for inducing oyster reef development in offshore windfarms in the Southern North Sea. Our approach supports decision makers in restoration management for the successful reinstatement of flat oyster reefs.

Key Words:
offshore wind, oyster, restoration, management

Where, when, how much, how long? Reflections from Scotland on securing successful native oyster restoration

David W Donnan[1], Cass Bromley[1], Bernadette Moloughney[2], John Mouat[2]
[1] NatureScot, Battleby, Redgorton Perth PH1 3EW, david.donnan@nature.scot
[2] Marine Scotland, Scottish Government, Victoria Quay, Edinburgh EH6 6QQ

In Scotland, a number of oyster restoration projects are underway or in development. This presentation provides an overview of Scottish authorities' perspectives of the experience so far. Issues arising reflect the fact that the current projects are varied in location, scale and complexity and by their nature are relevant (and often novel) to a number of different consenting or regulatory mechanisms. In addition, there is a tendency for projects to arise in an ad hoc manner based on where funding and enthusiasm is available. Consequently, there are challenges in balancing the benefits of native oyster restoration with the inherent risks that come with the translocation of shellfish, and ensuring that restoration proposals are compatible with the conservation of the existing populations of native oyster on our west coast. There are practical and scientific challenges in developing a biosecure and genetically diverse supply of oysters for restoration purposes, and there is the perennial issue of short-term funding for work that requires a long-term commitment. Addressing these issues and challenges points to the benefits of taking a more structured approach to native oyster restoration in Scotland, and we present our thinking on what is needed and how that may be developed.

Key words:
biosecurity, consenting, conservation, policy

Native oyster restoration experiences from England's Statutory Nature Conservation Body

Rob Whiteley[1]
[1] robert.whiteley@naturalengland.org.uk

Native oyster restoration and designation work in England has brought us, Natural England, as Statutory Nature Conservation Body, some key issues and questions to consider:

1. What are realistic density targets and objectives for native oyster beds designated as an MPA feature, especially in a site with bonamia present? We reviewed the existing evidence and site condition against the established OSPAR definition of 5/m² and considered their application in the Blackwater MCZ.
2. Balancing native oyster restoration goals with other MPA objectives in the same site, especially in relation to designated SAC habitats. We reviewed the conflicts and opportunities, including using subtidal mixed sediment designations to help facilitate restoration works. The Solent Maritime SAC is presented as an example.
3. Deriving Favourable Conservation Status goals for native oyster. Natural England is applying FCS as a concept more widely to key species and habitats, and native oyster has presented some challenges in addressing this, including uncertainty around:
    a. What does a healthy self-sustaining population look like?
    b. Can FCS be achieved without continued ongoing anthropogenic intervention?
    c. What does supporting habitat look like and where does it occur naturally?
    d. How can it be applied across a complex variety of sites around the country with different biological conditions, including bonamia and the presence of competition from non-native species?

    Overall, how do we identify and separate the ideal from feasible outcome?
4. Can the conservation objectives of a SAC be altered to include the restoration of native oysters beds where there is proven historical presence? We have explored this key legislative question.

Key Words:
legislation, MPAs, recovery, SNCB, england

European Native Oyster Habitat Restoration Monitoring Handbook

Philine zu Ermgassen, Oscar Bos, Alison Debney, Celine Gamble, Azra Glover, Bernadette Pogoda, Stephane Pouvreau, William Sanderson, David Smyth, Joanne Preston on behalf of the NORA Monitoring Working Group

The Native Oyster Network UK and Ireland and the NORA Monitoring Working Group have worked together to develop Guidelines for European Native Oyster Habitat Restoration. Monitoring is critical for informing restoration practitioners whether a project is progressing as planned, as well as for building an evidence base regarding the benefits yielded by the restoration activity. This can be important for public outreach, stakeholder engagement, and for securing funding. As restoration ecology is a relatively new science, there is also value in monitoring because it can inform what works best and how restoration tools and designs can be improved. The standardisation of monitoring and the reporting of results is important in achieving this goal, as it will allow for powerful analyses across projects and enable learning opportunities that improve the implementation of future projects.

A brief introduction will be provided to the contents and structure of the guidelines, which includes recommendations for easy-to-score “universal” monitoring metrics which should be monitored in all restoration efforts, and “supplementary” monitoring metrics, which provided added value in some cases. Metrics and methods for assessing ecosystem service delivery and a chapter assisting practitioners with collecting and using the data to evaluate and report is also featured.

This handbook has been written for all those involved in native oyster habitat monitoring. This includes restoration project managers, restoration practitioners, community projects, governmental bodies, ‘citizen scientists’ and charitable organisations.

The status of offshore wind farm Borssele 3 as a new flat oyster habitat

Renate Olie[1], Edwin Verduin[2], Tim Schellekens[2], Michael Evans[3]

[1] De Rijke Noordzee, Arthur van Schendelstraat 600, 3511 MJ, Utrecht, The Netherlands, r.olie@derijkenoordzee.nl

[2] Eurofins AquaSense, H.J.E. Wenckebachweg 120, 1114 AD, Amsterdam, The Netherlands, edwinverduin@eurofins.com

[3] Blauwwind II CV, Weena 70, 3012 CM, Rotterdam, The Netherlands

The vision to include the potential for increased biodiversity in Offshore Wind Farm (OWF) construction is endorsed by windfarm developer Blauwwind and The Rich North Sea programme. Blauwwind is operating the Borssele III & IV wind park, that was delivered in 2020. The Rich North Sea investigates methods for nature enhancement within OWFs and is working on an open access toolbox for wind park operators that includes, among other things, best practices. Blauwwind and The Rich North Sea are conducting field experiments within the Borssele OWF area aimed at establishing native oyster reefs and increasing biodiversity. Monitoring of these experiments and of biodiversity developments are performed by Eurofins AquaSense.

Around four monopiles in the Borssele 3 wind farm, 2400 adult flat oysters were installed in cages on the scour protection in October 2020. In the same campaign, a T-0 measurement for the biodiversity analysis was carried out, consisting of an ROV photo and video survey and collection of water samples for environmental DNA analysis (eDNA). A reference site of four monopiles in Borssele 4 was also investigated for biodiversity.

In July 2021, a T-1 measurement was conducted in Borssele 3 and 4. Oyster survival was scored and part of the oysters were measured to obtain growth rates. Health of the oysters (Bonamia and reproduction status) were checked. To analyse if oyster larvae could be found in the close environment of the wind turbines, water samples were taken, filtered and analysed. The ROV survey and the eDNA sample collection was repeated.

During this presentation, results from the T-0 and T-1 monitoring works will be shared. Further monitoring of the biodiversity and flat oyster reef development will take place in 2023 and 2028.

Key Words:
flat oyster, offshore wind parks, nature enhancement, biodiversity

Experimental estimation of efficiency for oyster survey ladder dredges over different sea bed sediments

Tom C Cameron[1], Ross Wey[2], Jim Pullen[3], Alex Baker[4], Russell Smart[5]

[1] School of Life Sciences, University of Essex 1, tcameron@essex.ac.uk
[2] Tollesbury and Mersea Oyster Company
[3] JP Consultant, West Mersea, Essex
[4] Natural England
[5] School of Life Sciences, University of Essex

Single or paired ladder style dredges are used in most commercial native oyster fisheries and consist of a 1.2 metre or 4foot ladder that makes contact with the sea bed to size select shellfish, pushing those shellfish up and into a bad with a further size selective escae mesh or ring size. Catch data, specifically catch per unit effort can be used as an index of population trends for oysters of given size classes, but such data cannot determine the actual population size. If we know the catch efficiency of the dredge the population size can be estimated. As it stands different dredge efficiencies are being applied by different fishery consultants, IFCAs and research groups to data gathered from dredge surveys. A recent literature review conducted in the context of the Blackwater estuary (Essex) suggested the mean efficiency of ladder dredges to be 20 %, whereas published reports use values as low as 5 %. We undertook an experimental test of ladder dredge efficacy using an oyster dredger vessel, with a skipper experienced in fishing and surveys across a gradient of ground types and oyster densities. We discuss the importance of using realistic dredge efficiencies in reporting, knowledge gaps remaining and the consequences of these results for conservation and fisheries management.

Key Words:
oyster fisheries, utilitarian conservation, sedimentation, shellfish

Oyster monitoring challenges in an offshore windfarm (ECOFRIEND project)

Oscar G. Bos[1], Pauline Kamermans[1], Tom van der Have[2], Joost Bergsma[2], Tim Raaijmakers[3], Luca van Duren[3], Hein Sas[4], Luuk Folkerts[5]

[1] Wageningen Marine Research (www.wur.nl), PO Box 59, Den Helder (NL), oscar.bos@wur.nl

[2] Bureau Waardenburg (www.buwa.nl), Varkensmarkt 9, 4101 CK Culemborg (NL)

[3] Deltares (www.deltares.nl), P.O. Box 177, 2600 MH Delft (NL)

[4] Sas Consultancy (www.sasconsultancy.nl), Danie Theronstraat 22-D, 1091 XZ Amsterdam (NL)

[5] Gemini, Amstelveensweg 760 (2nd floor), 1081 JK, Amsterdam (NL)

The Dutch Government stimulates nature enhancement within offshore wind farms. Permit holders must take measures to increase the suitable habitat for species naturally occurring in the North Sea. European flat oysters are one of the focal species. In the ECOFRIEND project (2019-2023) we aim to monitor pilot oyster reefs, develop innovative monitoring methods, study abiotics and develop models, and provide advice.

The main study site is Gemini offshore windfarm, located in the historical distribution area of the European flat oyster, 60 km off the Wadden Sea coast. The existing pilot oyster restoration in the windfarm serves to test different monitoring techniques. The focus is on deployment of light instruments (<20 kg) that can be deployed by hand from a small vessel, as an alternative to using large costly offshore vessels and heavy equipment, as is done in other offshore wind farms. We used 1x1x1 m oyster cages, each with 20 oysters inside for monitoring of growth and survival, tested a drop cam, a bait cam and used eDNA analysis for the surrounding fish biodiversity, and took water samples from the seafloor at 30 m depth with a large pump to detect oyster larvae (qPCR and microscopical counts). Norwegian oysters in cages deployed in April 2019 and retrieved in August showed 90 % survival, growth, and remained free of Bonamia. Furthermore, results of eDNA analysis corresponded largely with bait cam footage, with fish species such as plaice, gobies, horse marckerel, and sandeel (not visible on camera). In July 2019, larvae were found, which shows hat oysters were reproducing. Based on the 2019 experiences, we are improving oyster cages, and eDNA sampling techniques, and we will test additional promising monitoring techniques such as the valve monitor and ROV.

Key words:
oyster pilot, offshore windfarm, monitoring, eDNA

British Sub Aqua Club's Operation Oyster

Andrew Hunt[1]

[1] andrew.hunt@bsac.com

The British Sub Aqua Club's (BSAC) Operation Oyster Project has its roots in a photography competition organised by the Zoological Society of London (ZSL) and BSAC in 2020. This raised awareness of the native flat oyster amongst the UK diving community with specimens being discovered on a range of dive sites frequented by sports divers, often on substrates where they were not expected to be found.

BSAC Operation Oyster is ultimately concerned with restoring the seabed, but the initial phases are concerned with setting up robust data gathering processes to collate data on the presence and distribution of *O. edulis* and invasive species across UK diving sites by the sport diving community.

This talk will present the approach being taken by the BSAC Team together with some initial findings, challenges and lessons learnt to date in the early stages of this project.

Historical distribution of the native oyster (*Ostrea edulis*) across Europe

Ruth H. Thurstan[1], Philine S.E. zu Ermgassen[2], NORA Historical Ecology Working Group[3]

[1] Centre for Ecology and Conservation, University of Exeter, UK, r.thurstan@exeter.ac.uk

[2] Native Oyster Restoration Alliance, Berlin, Germany

[3] Names and affiliations of individual co-authors will be included in the presentation

The exploitation of native oysters throughout Europe has an ancient history, but little is known about the original distribution and extent of past habitats, or the scale of benefits gained from their past use. Such information exists for a number of regions but is often highly fragmented, spanning multiple archival collections and data sources, and is thus difficult to identify and extract. This interdisciplinary project, conducted by members of the Historical Ecology Working Group of the Native Oyster Restoration Alliance, aims to close these gaps in our understanding. By examining sources from archival and material collections across Europe, we aim to collate descriptions of historical locations, extent, and past uses and significance of native oyster habitats across Europe. The information uncovered by this work will help to inform restoration and community engagement efforts by demonstrating the magnitude, timing and drivers of past change, as well as the benefits that native oyster habitats brought to local communities in the past.

Key Words:
historical ecology, shifting baselines

Determining the most important factors in site selection for European native oyster (*Ostrea edulis*) habitat restoration projects

Anna L. Hughes[1], Philine S. E. zu Ermgassen[2]

[1] School of GeoSciences, Grant Institute, Kings Buildings, University of Edinburgh, EH9 3FE, UK, s1619876@ed.ac.uk

[2] Native Oyster Restoration Alliance, Berlin

Identifying and creating appropriate sites for European native oyster habitat restoration projects is a fundamental pre-condition for long term project success. This study used the Delphi questionnaire technique to draw upon pan-European expertise in order to determine the most important factors in site selection for European native oyster habitat restoration projects. From this expert knowledge, comprehensive site selection guidelines are presented, encompassing abiotic, biotic, and socioeconomic factors, as well as considering the threats to native oysters and project logistics. No study to date has collectively assessed all facets of site selection, and there was hence a demand for a synthesis such as this. Through an iterative and anonymous analysis of expert opinion from across the NORA community, 65 factors reached consensus on being universally important to consider in site selection for European native oyster habitat restoration projects. Using a directed review of current literature, tolerance ranges and thresholds were assigned to these factors to enhance the utility of the guidance. Although this work aimed to generate consensus across the existing pool of knowledge, locational and contextual nuances are explored to allow the guidance to be tailored to individual restoration projects. It is hoped that this site selection guidance will be used by restoration practitioners across Europe to accelerate recovery of the valuable and threatened native oyster habitat.

Key words:
delphi, guidance, expert

Policy Brief and Information Sheets- the latest outputs from the NORA Production Working Group

Åsa Strand and Philine zu Ermgassen on behalf of the NORA Production Working Group

The NORA Production Working Group (WG) has run a series of workshops and meetings since its establishment in 2020. During this short time, the WG has worked together to share experiences of oyster production from across Europe, and to develop a series of short publications which we hope will be of use to the general NORA community and beyond. With an increasing number of native oyster habitat restoration projects seeking oysters for their activities, and with observed mismatches between production and restoration objectives, the first workshop in December 2020 was focussed on disseminating information related to both oyster seed production techniques and requirements in restoration practises, as well as discussing the barriers and opportunities in both practices.

During the workshop it was recognized that a key barrier to native oyster habitat restoration upscaling is sufficient production of oysters. There are many reasons behind this shortage of native oysters, some arising from the novel demands of restoration activities with regards to genetics and biosecurity and others arising from the mismatch in timeline between available funding for restoration and oyster production timelines. Therefore, as an outcome of the workshop, information sheets both for restoration practitioners seeking oysters, and for oyster producers exploring producing oysters for restoration has been developed, which would allow those new to restoration to learn from others' experience. The results are also being summarized in a policy brief, where recommendations and requirements for successful upscaling of restoration activities is discussed. The WG are pleased to launch the information sheets at the NORA 4 conference.

Habitat provisioning and nursery function of the European native oyster *Ostrea edulis* supported by the distinct and highly biodiverse community associated with native oyster habitat

Luke Helmer[1,2], Eric Harris-Scott[1], Fiona Woods[1], Ian Hendy[1,2], **Joanne Preston[1]**

[1] Institute of Marine Sciences, University of Portsmouth, Portsmouth, UK

[2] Blue Marine Foundation, London, UK

The European Native *Ostrea edulis* supports a distinct community with complex trophic structure and high biodiversity. Throughout the duration of this study, a total of 95 species, from 11 phyla, were recorded to be associated with *Ostrea edulis* and their respective restoration aquaculture cages across the Solent. The three-dimensional structure of high-density *O. edulis* populations within the cages provides a habitat and refugia for the critically endangered European eel Anguilla anguilla in Northern Europe. The variance in size, of elvers and yellow eels, suggests that a nursery function is also provided by the oyster cage structure, with an array of prey items present. The epibiont and macrofaunal community associated with *O. edulis* populations provides food provisioning services for numerous other fish species, including the commercially important European bass Dicentrarchus labrax, and protected long-snouted seahorse Hippocampus guttulatu,. The disparity between the species community associated with the biogenic *O. edulis* is driven by physio-chemical environmental factors that vary across relatively small geographic distances. However, the trophic structure and functional groups supported by *Ostrea edulis* appear to remain relatively constant both at local and wider European scales as shown by a meta-review of the biodiversity associated with native oyster habitat. The high biodiversity and distinct community composition is determined by the presence of live *Ostrea edulis* oyster, not by the physical complexity of the restoration structure or the presence of native oyster shells; the majority of macrofaunal biodiversity was associated with live oysters (55 %) vs microreef (25 %) or cage structure (18 %). Furthermore, the community associated with live oysters was significantly more diverse ($F4 = 2.19$, $p < 0.05$) and highly distinct (ANOSIM: Global R: 1, $p \leq 0.01$) from that associated with artificial habitat or shell. This data supports the native oyster as a biogenic ecosystem engineer that supports a highly diverse and distinct community, and that native oyster habitat or restoration aquaculture has the potential to support commercial finfish fisheries in addition to supporting general biodiversity enhancement.

Key Words:
biodiversity, biogenic, habitat provision, nursery function, essential fish habitat, *Ostrea edulis*, restoration aquaculture

Understanding biodiversity restoration using sustainable, rotational fishery management

Naomi A. Kennon[1], Alex Robertson-Jones[1], Sebastian Jemmett[1], Tristan Hugh-Jones[2], Michael Bell[3], William G. Sanderson[1]

[1] EGIS, School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University, UK, nak7@hw.ac.uk

[2] Loch Ryan Oyster Fishery Company LTD, Stranraer, UK.

[3] International Centre for Island Technology, School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University, UK

Oyster restoration has become a mainstream conservation practice within Europe. It is therefore important to establish the relationship between oyster reefs and their associated biotic community if the consequences of restoration activities are to be understood and justified.

The Loch Ryan oyster fishery, in Southwest Scotland, has operated since 1701 and uses a rotational harvest system where different areas of the fishery are harvested and then left for six years. In this study three treatment plots, having been commercially targeted one, two or six years earlier, were surveyed for macrofaunal biodiversity, oyster shell density and oyster shell percentage cover. The survey involved SCUBA and a combination of video transects and photo quadrats.

It was observed that the longer the time since fishing disturbance the greater the levels of shell density, shell percentage cover and macrofaunal biodiversity, indeed, in the six-year-old treatment plot Shannon-Wiener's diversity was found to be 40 % higher than the more recently fished treatments. Increased biodiversity is most likely due to the increase in structural complexity created by the matrix of live and dead oyster shell. The trend of biodiversity change in relation to time since disturbance suggests that it would likely take around ten years for full biodiversity recovery.

The findings from the present study show a unique example from a long-term dredge fishery that has enabled the survival of a rare oyster habitat and its diverse biotic community. Such an example could be used to gauge the progress of restoration projects both in terms of the increase in shell material and the implied simultaneous increase in biodiversity. This has provided a valuable insight into the recovery of biodiversity in the emerging field of European oyster habitat restoration.

Key Words:
biodiversity, structural complexity, bottom-towed fishing gear, reef recovery

Scope for growth of Mar Menor flat oysters under eutrophic conditions: Implications for future bioremediation actions

M.I. Akinyemi[1,2], F. da Costa[3], R. Filgueira[4], E. Galimany[5], I. Ibarrola[6], **M. Albentosa[1]**

[1] Instituto Español de Oceanografía (IEO, CSIC), Centro Oceanográfico de Murcia. C/Varadero 1, San Pedro del Pinatar 30740, Murcia, Spain, marina.albentosa@ieo.es

[2] Erasmus Mundus Joint Master Degree in Marine Environment and Resources-MER+EMJMD·

[3] Instituto Español de Oceanografía (IEO, CSIC), Centro Oceanográfico de Vigo, Subida a Radio Faro, 50-522, 36390 Vigo, Spain

[4] Marine Affairs Program, Dalhousie University, Halifax, Nova Scotia, B3H 4R2, Canada

[5] Institut de Ciències del Mar, ICM-CSIC, Passeig Marítim de la Barceloneta, 37-49,08003, Barcelona, Spain

[6] Departamento GAFFA (Fisiología Animal), Facultad de Ciencia y Tecnología, Universidad del País Vasco/ Euskal herriko Unibertsitatea, Apartado 644, 48080, Bilbao, Spain

The Mar Menor lagoon and its adjacent watershed are located in the Murcia region (SE Spain). It is one of the largest coastal lagoons in Europe, and one of the most important Spanish wetlands. Tourism and agricultural intensification released large amounts of nitrogen and phosphorus nutrients into the lagoon. This situation triggered a phytoplankton bloom in 2015 that turned the clear and transparent water turbid and greenish, and about 85 % of benthic macrophytes was completely lost. Since then, there have been a series of catastrophic events that have led to the eutrophication of the lagoon, one of them being a severe stormy meteorological phenomenon (DANA) that transformed the depths into an anoxic layer causing the death of all organisms in the deepest areas of the lagoon. Nutrient bioextraction by flat oysters has been proposed as a nature-based solution for remediation of these eutrophication events and recover water quality. The flat oyster colonized the lagoon from the adjacent Mediterranean and reached a population of 135 millions of individuals during the 80s and 90s as a consequence of the reduction of the lagoon salinity due to the increase of water exchange with the Mediterranean. This research aims to quantify the clearance potential of Mar Menor oysters and their scope for growth under the environmental scenarios observed during the phytoplankton blooms. For that, three particulate matter conditions (Low -1.3 mg L-1-, Medium -3.0 mg L-1- and High -5.5 mg L-1-) were replicated in the laboratory and the oyster feeding behaviour (clearance, ingestion rates and absorption efficiency) was studied using a flow-through system. Scope for growth (SFG) was estimated after integration of absorption and respiration rates into the energy balance equation. Results showed that oyster food ingestion increased with the increase of food concentration whereas absorption efficiency remains constant for all food conditions. As a consequence, SFG (2.1, 29.4 and 50.8 J g-1 h-1) increases at high food concentrations. Thus, the use of oysters for removal of phytoplankton during blooms in Mar Menor seems promising as the oysters have the potential for converting excess nutrients into energy which are used for growth.

Key words:
eutrophication, Nature-based-Solutions, nutrient removal, SFG

Balancing the equation: 'Blue carbon' and the native European oyster (*Ostrea edulis*)

Hannah Lee[1,2], Karen Diele[2], Ivan Davies[3], John Baxter[1], Alexander Robertson-Jones[1], William Sanderson[1]

[1] Centre for Marine Biodiversity and Biotechnology, ILES, EGIS, Heriot-Watt University, Edinburgh, UK 1, hzl1@hw.ac.uk

[2] School of Applied Sciences, Edinburgh Napier University, Edinburgh, UK

[3] Marine Scotland Science, Aberdeen, UK

'Blue carbon' is the carbon stored in the world's ocean. Research into blue carbon storage has gained momentum in the past decade, demonstrating the importance of carbon storage in habitats formed by primary producers, such as seagrasses, mangroves and saltmarshes. There is however a lack of knowledge of the role that non-vegetated habitats, such as bivalve beds, maerl beds and sediments in lochs or fjords play in the carbon cycle. Net carbon stabilization arises from the balance between carbon loss and carbon gain. In the case of bivalve habitats, carbon gain occurs through shell accretion, active deposition (biodeposition) and passive deposition (the influence of bed structure on deposition of particulate material from the water column), leading to material becoming integrated into the shellfish habitat. Meanwhile, the release of carbon occurs through respiration and, to some extent, during the process of calcification. These processes underpin a net carbon equation, allowing the real-time carbon cycling associated with the living bivalve to be estimated. Previously, we presented the first measures of the deposition of carbon associated with the feeding activities of *Ostrea edulis* (Lee et al., 2021). However, the balance between carbon deposition and carbon loss through respiration and calcification, was not considered. In the present study, work towards this more complete understanding of the real-time carbon budget of shellfish habitats is reported. The results are discussed within the context of valuing environmental restoration and the business models that support it.

Key Words:
blue carbon, ecosystem services, conservation management, climate change

Seven years of oyster restoration in Australia. What's going on down there?!

Chris Gillies

Oceans Program Director, The Nature Conservancy (Australia)

Australia is synonymous with sunshine, seafood and Shane Warne but until several years ago oysters weren't regarded as mainstream features of Australia's culture. Yet in 2014, a modest investment by The Nature Conservancy helped catalyze a shift from amnesia to action, cumulating in Australia's largest underwater restoration program, Reef Builder.

Please join Chris Gillies, Oceans Program Director from The Nature Conservancy, as he describes how through a multi-disciplinary approach, oyster reef ecosystems are rapidly infiltrating Australia's environmental psychic. Chris will discuss how the program was initiated, main elements of the strategy, including: research, reef-building, communication and policy and key lessons learnt along the way. Visually, you'll get to dive deep on a new reef and join the project team on one of the 13 oyster reefs currently being constructed as part of a nationwide Covid-19 economic recovery response. Chris will wrap up the discussion with a brief consideration of the future of oyster reef restoration in Australia.

Origin of the Mar Menor (SE Spain) flat oyster population: the end of a legend

P. Martínez[1], M. Vera[1], B.G. Pardo[1], M. Vázquez-Luis[2], A. Villalba[3], M. Albentosa[4]

[1] Departamento de Zoología, Genética y Antropología Física, Facultad de Veterinaria, Universidad de Santiago de Compostela, 27002, Lugo, Spain, paulino.martinez@usc.es

[2] Instituto Español de Oceanografía (IEO, CSIC), Centro Oceanográfico de Baleares, Muelle de Poniente s/n, 07015, Palma de Mallorca, Spain

[3] Centro de Investigacións Mariñas (CIMA), Consellería do Mar, Xunta de Galicia, 36620, Vilanova de Arousa, Spain

[4] Instituto Español de Oceanografía (IEO, CSIC), Centro Oceanográfico de Murcia, C/Varadero 1, San Pedro del Pinatar 30740, Murcia, Spain

The Mar Menor is a high ecological value hypersaline lagoon located in the south-east of Spain that it has been strongly affected by human activities (agriculture, tourism, mining) during decades. The anthropogenic pressure caused the collapse of the lagoon in 2015 due to successive episodes of eutrophication, in addition to an event of massive mortality due to anoxia after a DANA-type meteorological phenomenon occurred in 2019. The use of bivalves to restore Mar Menor has been proposed as one of the several management tools to improve water quality. During the 80s and 90s, an abundant population of flat oysters (*Ostrea edulis*) inhabited the lagoon, with an estimate of 135 million of individuals in 1992. A widespread belief explaining the rise of the flat oyster in the lagoon in those years was that it derived from the experimental translocation of oysters of Atlantic origin, namely from Galicia (NW Spain). In order to determine their origin, a genetic analysis has been carried out using hypervariable nuclear molecular markers (ie microsatellite loci) to compare oysters from the Mar Menor with both, oysters collected from the Mediterranean closest oyster bed (Santa Pola), and oysters from the Galician natural beds analyzed in the framework of the European project OYSTERECOVER. Analysis of genetic structure showed that Mar Menor oysters exhibited a similar genetic diversity to that detected in the other oysters beds analysed (Atlantic and Mediterranean origin). The population did not show significant deviations from the HW equilibrium, so it can considered as a panmictic population (random mating). Moreover, the Mar Menor oysters showed a close relationship with the Mediterranean bed from Santa Pola and no significant genetic differences were detected between them. However, both oyster beds showed a significant differentiation with the Galician populations, showing that most of the total genetic diversity detected is due to differences between the Atlantic and Mediterranean slopes. In conclusion, the flat oyster colonized the lagoon from the adjacent Mediterranean, as a consequence of the sharp decrease of its salinity due to the dredging of one of the main communication channels between the lagoon and the Mediterranean, the Estacio Channel.

Key Words:
genetic structure, origin, genetic diversity, bioremediation

How Many Parents Have You Got? Parental Contribution in a Flat Oyster Hatchery

Homère J. Alves Monteiro[1], Dorte Bekkevold[1], Camille Saurel[2], Jakob Hemmer-Hansen[1]

[1] National Institute of Aquatic Resources, Technical University of Denmark, Silkeborg, Denmark

[2] National Institute of Aquatic Resources, Technical University of Denmark, Danish Shellfish Centre, Øroddevej 80, DK-7900 Nykøbing Mors, Denmark, hmon@aqua.dtu.dk

A couple of years ago, the flat oyster (*Ostrea edulis*) population was thriving in the Limfjorden (Denmark), with a sustainably regulated fishery landing up to 320t/year. In late 2019, fishermen reported the first event of mass mortality in some fishing areas, probably due to the proliferation of parasitic pathogens.

Preserving and maximizing genetic diversity in putative conservation programs, including restocking, are therefore now of high importance. A new strategy was implemented in the sole flat oyster hatchery in Denmark for producing parasite-free spat and preserving high genetic diversity.

Hatchery procedures may affect the genetic variation among stocked spat in comparison with natural reproduction in the wild. We tested a cost-effective and easily applicable method to assess the genetic diversity in flat oyster production in the hatcheries. It consists in assigning parental contribution of broodstock to the offspring, reliably, in hatchery conditions.

To test our method, we studied the genetic composition at 17 microsatellite loci of hatchery-produced spat and compared it to that of the wild population, wild spat and adults from the broodstock source in the Limfjord. We found that swarming events were characterized by a single maternal and several paternal contributions, but also that only some potential parents contributed offspring per swarming event and that the number of successful parents varied between tanks in the hatchery. The work has provided a protocol that can give a robust estimation of the number of breeding pairs per swarming event (larval release) and it can provide input for potential conservation/restoration programs that utilize hatchery reared spat to support natural populations.

Key Words:
swarming, hatchery, conservation, population genetics

Validation and mapping of flat oyster genetic markers associated with the *Bonamia ostreae* status following a population genomics approach

I. Martínez, A. Chiclan, A. Blanco, M. Gundappa, T. Bean, D. Macqueen, R. Houston, A. Villalba, M. Vera, P. Kamermans, **P. Martínez**

The European flat oyster (*Ostrea edulis*) is severely affected by the disease bonamiosis, caused by the intracellular parasite Bonamia ostreae. Previous work has identified an area of the oyster genome, which may be associated with resilience to this disease. In this study, a medium-density SNP array was used to validate previous results by comparing further infected and naive populations.

A total of 134 wild and hatchery individuals from the North Sea, collected in both naïve and Bonamia affected areas were analysed. Overall, genetic diversity and differentiation between samples could be explained by neutral genetic markers, which revealed that populations group according to the origin of the samples (wild vs hatchery). However, when outlier loci were considered (i.e. those previously found to be associated with bonamiosis status of populations), two genetic clusters appeared intermingled in all samples at a frequency associated with their status. When both groups were compared, outlier datasets rendered high genetic divergence (FST > 0.25) unlike neutral loci (FST = 0). Moreover, the cluster associated with long-term bonamiosis-affected populations showed much higher genetic diversity and significant heterozygote excess with outlier loci, but not with neutral data, suggesting selective forces at play. Outliers were mostly clustered on chromosome 8 (C8), the same region where a quantitative trait locus related to the bonamiosis status of populations was reported, adding further weight to the hypothesis that this region is associated with disease resilience. Furthermore, differentially expressed genes (DEG) between naïve and long-term affected strains previously reported were mapped on the oyster genome and C8 showed the highest DEG density. Genes related to apoptosis and extracellular matrix were identified at C8, which is in accordance with previous hypothesis of how resistance to an intracellular parasite is mediated. Results suggest that marker assisted selection may be suitable for production of bonamiosis resistant strains, facilitating the management of oyster beds for production and ecosystem services recovery.

POSTERS

01
Accelerating native oyster reef creation using nature inclusive design & collaborative working

Tom Birbeck[1], Steve Wright [2], Sam Hickling[3]

[1] ARC Marine, tom@arcmarine.co.uk

[2] ARC Marine, steve.wright@arcmarine.co.uk

[3] ARC Marine, sam.hickling@arcmarine.co.uk

ARC Marine are accelerating *Ostrea edulis* restoration around offshore wind and aquaculture sites by incorporating juvenile oysters inside their patented reef unit "Reef Cubes®". Reef Cubes® are a precast building block for the ocean. They are free from plastics, toxic leachates or Portland cement and are made of 100 % recycled materials boasting a carbon saving of 90 % compared to other cementitious materials. A life cycle assessment is underway which will hopefully prove Reef Cubes® can last centuries whilst serving a foundation for reef building species. Research on *Ostrea edulis* restoration in Europe is scare, the project carried out in the North Sea will be the first of its kind in European waters and this species. Success from previous experiments involving shell materials will also be included in the pilot projects and will hopefully serve as a useful comparison for future restoration project. This presentation will share preliminary learnings from planning and executing pilot native oyster restoration projects in the North Sea and highlight the issues sourcing Bonamia free brood stock, transferring them into a new location using Reef Cube® structures as the deployment substrate seeding mechanism and quantifying the pre and post deployment eco-system impact and oyster survival rates.

Key Words:
accelerating, reef, creation, stewardship

02
Reef development: how to promote the development of bio-receptivity for micro-algae and native oyster?

A. Fabien[1], S. Pouvreau[2], N. Sebeibi[1]

[1] aurelie.fabien@esitc-caen.fr

[2] nassim.sebaibi@esitc-caen.fr

[3] stephane.pouvreau@ifremer.fr

Climate change, overfishing, predation, parasitic diseases and loss of natural habitats are driving many marine species to extinction. This is the case of the native oyster, *ostrea edulis*, which is an indigenous, engineering species with aquaculture interest. In order to restore these species, artificial reefs made from cementitious materials are being developed. But we know that each species has its preferences for the design of its habitat, the nature of its chemical composition and its geolocation. It is important to understand the phenomena of interactions between the reefs materials and the species targeted to settle there. Biofilm is usually the first phase of development on reefs. It comes to prepare the infrastructure for the fixation and development of other micro and macro-organisms. First, the study of the biofilm development is analyzed according to different chemical compositions of the material and different maturation conditions of the materials before immersion. Secondly, the influence of these same parameters will be studied on the native oyster fixation rate. The results highlighted the importance of parameters selection to increase the bio-receptivity of reef infrastructure: the formulation choice, the reef design as well as the maturation conditions before immersion.

Key Words:
species restoratio, concrete infrastructure, biofilm development, *ostrea edulis*

03
H2020 UNITED: Is scour protection suitable for flat oyster restoration in Belgium?

A.M. Declercq[1], T.R.H. Kerkhove[2], B. Stechele[1], A.B.K. Pribadi[3], B. Groenendaal[4], D. Vandercammen[5], E. Pinto da Silva[5], E. Lataire[3], E. Lemey[6], F. Maes[7], G.V. Fernandez[3], J. Vanaverbeke[2], J. Knoop[8], L. Pilgrim[9], O. De Clerck[8], S. Delerue-Ricard[6], S. Petit[6], S. Devriese[6], S.M. Dambalasa[9], S. Debels[4], S. Degraer[2], W. Voorend[9], W. Versluys[4], P. Bossier[1] and **N. Nevejan**[1]

[1] Laboratory of Aquaculture and Artemia Reference Center, Faculty of Bioscience Engineering, Ghent Universiteit, UGent BW13, Coupure Links 653, Blok F, 9000 Gent, Belgium, nancy.nevejan@ugent.be

[2] Marine Ecology and Management, Operational Directory Natural Environment, Royal Belgian Institute of Natural Sciences, Vautierstraat 29, 1000 Brussel, Belgium

[3] Maritime Technology Division, Faculty of Engineering and Architecture, Ghent University, Technologiepark Zwijnaarde 60, 9052 Zwijnaarde, Belgium

[4] Brevisco, Hendrik Baelskaai 38, 8400 Oostende, Belgium

[5] Parkwind, Esplanadestraat 10, 8400 Oostende, Belgium

[6] Jan De Nul NV, Tragel 60, 9308 Hofstade-Aalst, Belgium

[7] Department of European, Public and International Law, Faculty of Law and Criminology, Ghent University, Universiteitstraat 4, 9000 Gent, Belgium

[8] Department of Biology, Faculty of Sciences, Ghent University, Campus Sterre S8, Krijgslaan 281, , 9000 Gent, Belgium

[9] Colruyt Group, Edingensesteenweg 196, 1500 Halle, Belgium

Once a key habitat in the North Sea, European flat oyster (*Ostrea edulis*) reefs have completely disappeared in the Belgium part of the North Sea (BPNS) due to a combination of factors, including overexploitation, destruction by bottom trawling and diseases such as bonamiosis. Across Europe, a number of projects and initiatives are being deployed to bring back this iconic species and the associated ecosystem, but Belgium is trailing behind this wave of renewed interest in flat oyster restoration. However, with the UNITED project, a first and important initiative has started to restore flat oyster reefs in the BPNS.

UNITED (2020-2023) is a research project co-funded by the European Union's Horizon 2020 programme. The acronym UNITED stands for Multi-Use offshore platforms demoNstrators for boostIng cost-effecTive and Eco-friendly proDuction in sustainable marine activities. By installing specific test pilots at five different marine sites in five European countries, UNITED aims to assess the feasibility and added value of marine multi-use. The Belgian pilot focuses on a combination of flat oyster restoration and aquaculture, and sugar kelp (Saccharina latissima) aquaculture in an offshore wind farm. Belgian offshore wind farms might offer a unique environment for both flat oyster aquaculture and restoration. Bottom-disturbing activities such as trawling are forbidden here, while the scour protection around the wind turbine foundations might serve as a suitable substrate for oyster settlement. Recruitment from the aquaculture individuals can initiate and sustain natural oyster reef development on this scour protection, and as such restore a lost ecosystem in the BPNS.

An overview of the oyster restoration activities within UNITED will be presented, including the latest, promising results of the nearshore experiments and the successful offshore (within an offshore wind farm) installation of oyster restoration structures, which house broodstock animals. Before moving offshore, the nearshore experiments have tested and optimised the restoration structures and investigated the settlement of flat oyster spat on different materials as well as the survival, growth and reproduction of flat oysters in aquaculture systems.

Key Words:
multi-use, european flat oyster restoration, oyster and seaweed aquaculture, UNITED

04
Settlement success of flat oysters on different types of substrates

Linda Tonk[1], Remment ter Hofstede[2], Tony van der Hiele[3], Tjeerd Bouma[4], Edwin Kardinaal[5], Tom van der Have[5] and Pauline Kamermans[1]

[1] Wageningen Marine Research, Korringaweg 7, Yerseke, The Netherlands, linda.tonk@wur.nl.
[2] Van Oord DMC, Schaardijk 211, Rotterdam, The Netherlands.
[3] HZ university of applied sciences, Edisonweg 4, Vlissingen, The Netherlands
[4] NIOZ Netherlands Institute for Sea Research, Korringaweg 7, Yerseke, The Netherlands
[5] Bureau Waardenburg, Varkensmarkt 9, Culemborg, The Netherlands

Native European flat oysters (*Ostrea edulis*), important ecosystem engineers with several important ecosystem services, have near to disappeared from the Dutch North Sea. In order to reintroduce the flat oyster population in the North Sea, the availability of hard substrate for initial settlement is critical. Such substrate is offered in offshore wind farms where further anthropogenic disturbances of the seabed are restricted, making them a promising site for restoration efforts. The potential for offshore wind parks in the North Sea to contribute to nature-inclusive development and achieve biodiversity goals, restore ecosystem functions and enhance ecosystem services is gaining commitment through governmental policy aims.

For the success of a restoration project, selecting the right substrate is important. As part of the objective to test outplacements methods in the project plan Borssele V- EcoScour settlement success of oysters on 10 different types of substrates were compared, at three locations: the saltwater lake Grevelingen (Netherlands), an oyster spatting pond in New Quay (Ireland) and a Bonamia-free natural bay in Tralee, (Ireland). Overall settlement success was highest on mussel shells and granite. Settlement per surface area was highest on granite and marble. Per kg fresh mussel shells were the most successful substrate at all locations. Settlement of oyster spat per basket was most successful on fresh mussel shells in lake Grevelingen, while granite was most successful at both locations in Ireland.

Besides settlement success the final choice of substrate for application in wind farms also depends on cost-effectiveness and suitability for the offshore environment. In phase two spat on substrates will be outplaced and monitored at Borssele V. The knowledge gained with these experiments contributes to the return of oyster beds. Restoring self-sustaining populations of wild oysters to a significant level benefits the supply of wild oyster larvae.

Key Words:
Ostrea edulis, offshore wind, oyster spat, restoration

05
Oyster Restoration As Community Rehabilitation: Intersecting Social and Biological Ecologies in a Post-Industrial City?

Lilly Elberta Allen[1]

[1] University of Edinburgh, M.Sc. (expected 2021), lilly.e.allen@gmail.com

Oysters can indicate – and restore – not just the health of ecosystems, but of communities. As we face the intersecting threats of the 21st century, from climate change to wear on the social fabric, situating oyster restoration within both the scientific and urban planning literature affords opportunities to restore the social contexts that support viable ecologies, and vice versa. Taking Edinburgh's disadvantaged Granton neighbourhood as a case study, this paper combines multiple disciplines to demonstrate how oyster restoration projects can reimagine community resilience efforts, protect against climate change, and reorient social relationships in ways that mutually reinforce the urban fabric and local ecologies.Building upon an array of community interviews, historic studies, careful mapping of restoration sites, and detailed analysis of ways to tie together restoration efforts and community goals, this paper presents Granton as a replicable model system for the revitalization of coastal communities along with their marine biota, reconnecting and replenishing depleted landscapes above and below water. It offers ways to prepare for sea level rise that utilize nature-based solutions, including oyster reef restoration, to revitalize human/nature connections, while drawing broader lessons for similar landscapes.

Key Words:
nature-based solutions, urban planning, oyster restoration, community resilience

06
Historical and Ecological Assessment of the European Oyster (*Ostrea edulis*) in the Adriatic Sea

Anamarija Frankić[1], Ante Juricev-Martincev[1], Ante Siljeg[1] & Lovre Panda[1]

[1] University of Zadar, Croatia, afrankic@unizd.hr

The European oyster (*Ostrea edulis*) is an indigenous, native shellfish species, which used to thrive in marine systems throughout Europe. This bivalve has an oval shell with a rough and scaly surface, lives attached on a hard substrate, preferably on oyster shells in coastal, marine areas, establishing vast oyster reef habitats. As the keystone species, oysters have exceptional ecological value, and science has been acknowledging the ecological services and functions of oyster reefs, in coastal protection and their intertidal engineering connectivity between the land and the sea. The fact is that oyster habitats are the most degraded marine habitats globally, experiencing the loss between 85 and 95 percent. Oyster habitats have been degraded due to anthropogenic activities, including overfishing, pollution, and unsustainable use of marine and coastal resources. In Europe, the restoration efforts of *O. edulis* has been united through the Native Oyster Restoration Alliance (NORA). Along the Croatian coast, in the Adriatic Sea, suitable sites are providing favorable environmental conditions for *O. edulis*, including karst geology, embayment protected from waves, with low currents, and sufficient freshwater inflows (vrulje) and plankton production. Some of these locations have been used for oyster aquaculture like Limski canal in Istria, Novigrad Sea, Krka estuary, smaller bays around town of Split, Mali Ston Bay, and lakes on the Mljet island. The major goal of this paper is to provide the assessment of the historic distribution and ecological significance of European oyster (*O. edulis*) in the Adriatic Sea. Considering many environmentally suitable areas for oysters, as well as important historic oyster aquaculture activities, we are concluding that the native European oyster in the Adriatic Sea was much more naturally abundant and widespread in the past than known and acknowledged. Therefore, we are presenting the GIS map with present oyster habitats, including aquaculture sites, and potential historic distribution of this important species, to support oyster restoration efforts in the Adriatic Sea.

Key Words:
Ostrea edulis, adriatic sea, historic and ecological assessment

07
Are UK Water Quality parameters measured to a sufficient resolution?

Dominic Parry[1], Zoe Morrall[1], Eric Harris-Scott[1], Andrew van der Schatte Olivier[1] , Joanne Preston[1], John Aldridge[2], Sonia Amaaouch[3], Clothilde Berthelin[4], Phillippe Bryère[3], Elisa Capuzzo[2], Patricia Danican[4], Daniel Franklin[5], Graham Horton[6], Christele Kellner[4], Annesia Lamb[5], Stéphanie Lemesle[4], Mathilde Lemoine[7], Sophie Richer[8], Anthony Le Bris[8], Sébastien Bosc[8], Claire Hellio[9], Marilyne Fauchon[9], Rohan Smith[6] and Gordon Watson[1]

[1] Institute of Marine Science, University of Portsmouth, Ferry Rd, Southsea, Portsmouth PO4 9LY, Dominic.parry@port.ac.uk

[2] CEFAS - Centre for Environment, Fisheries and Aquaculture Science

[3] Argans Ltd, 260 Route du Pin Montard, BP 234, 06904 Sophia Antipolis, France

[4] Laboratoire de biologie des organismes et des écosystèmes aquatiques, MNHN, CNRS 8067, SU, IRD 207, UCN, UA, 43 rue Cuvier, CP 26, 75231 Paris Cedex 05, France

[5] Bournemouth University Christchurch House C208, Talbot Campus, Fern Barrow, Poole, BH12 5BB

[6] Natural England

[7] Aleor, 3 bis rue du Moulin a Mer, Lezardrieux, Brittany, 22740, France

[8] CEVA (Centre d'Etude et de Valorisation des Algues), 83 Rue de Pen Lan, 22610 Pleubian, France

[9] University of Brest, 3 Rue des Archives, 29238 Brest, France

Ostrea edulis population declines are primarily caused by over extraction, however, concurrent declines in environmental conditions, water quality and increases in pollution can be barriers to restoration. The environmental data used to identify suitable restoration locations is crucial in the ecological and physiological aspects of the decision-making process. However, often site data are extracted from long term data sets, which lack fine scale temporal and spatial resolution, have inconsistent sets of parameters that are measured or exclude key environmental variables. Site-specific differences between geographically close locations may, therefore, not be resolved leading to limited data for evidenced-based decisions. The RaNTrans project has deployed multi-parameter sondes at three sites on the south coast of England recording, nitrate, pH, temperature, salinity, chlorophyll-a, turbidity and dissolved oxygen levels, in order to record this data at a fine scale resolution (every 15 minutes). This has allowed the project to identify changes in these environmental data that are not obvious in the publically available datasets. This study highlights the need for more accurate water quality data for use in site selection, to maximise the successful restoration of *O. edulis* to our coastlines.

Key Words:
historical data, site selection, pollution, restorative aquaculture

08
Combining Local Knowledge and Data Collection with Ocean Modelling in Native Oyster Reef Restoration Site Selection

Alec Reid

Oyster Reef Restoration Officer, Cuan Beo, aleccharlesreid@gmail.com

The Galway Bay Native Oyster Restoration Project is a community, state and scientific institution led initiative that aims to restore the native oyster (*Ostrea edulis*) populations that once existed in huge quantities in Galway bay. Restoration activities to date include strategic cultch deployment to promote larval settlement, as well as identification of critical habitat for native oysters. In this poster we present how we conduct localised environmental monitoring, investigate oyster gonad development, and analyse the marine environment for settlement suitability. The results of these investigations are contributing to the EU wide FORCOAST project, which seeks to develop an ocean model that highlights areas that could be appropriate for oyster reef restoration.

Key Words:
oyster gonad monitoring, arval disbursement, native oyster spat production, salinty and temperature monitoring, ocean modelling mevelopment, seabed analysis, cultch deployment

09
Using an integral projection model (IPM) to focus restoration and estimate fishing impacts on a recovered population

A.E. Lown[1], L.A. Hepburn[1], R. Dyer[2] and T.C. Cameron[1]

[1] University of Essex, Wivenhoe Park, Colchester, Essex, CO4 3SQ, aelown@essex.ac.uk

[2] Kent and Essex Inshore Fisheries and Conservation Authority, The Sail Lost, Shipyard Estate, Brightlingsea, Colchester, Essex, CO7 0AR

Many restoration projects of the European native oyster use the translocation of adult stocks to boost population number. This may not always be the most effective method of restoration for some areas, particularly if there are existing adult stocks.

Integral Projection Models use individual and population based metrics to make predictions on current sensitivities of a population and where best to focus restoration efforts. In addition, these models can predict future states of population based on measured traits such as growth, survival and fecundity.

Moving forward from the model presented at NORA 2019, we show sensitivities of European native oysters within the Blackwater, Crouch, Roach and Colne Estuaries Marine Conservation Zone (BCRC.MCZ) in Essex, UK to change, and how sensitivity of the population shifts from being focused around reproduction success when recruitment is low, to be more balanced across all traits when recruitment is high. We then use this model to predict time to recovery (here, deemed as 800 tonnes within the BCRC.MCZ) and assess the long term impacts of various levels of harvesting on population rate of change.

Key Words:
population dynamics, fisheries, restoration, recovery

10
Specificities of oyster *Ostrea edulis* farming sites in Lim Bay and Mali Ston Bay, eastern Adriatic Sea, Croatia

Lorena Perić[1], Damir Kapetanović[1], Vedrana Nerlović[2], Anamarija Kolda[1], Irena Vardić-Smrzlić[1], Jakša Bolotin[3], Valter Kožul[3], Snježana Kazazić[1], Svjetlana Bobanović-Ćolić[3], Fran Barac[1]

[1] Ruđer Bošković Institute, 10000 Zagreb, Croatia, Lorena.Peric@irb.hr

[2] University Department of Marine Studies, University of Split, 21000 Split, Croatia

[3] Institute for Marine and Coastal Research, University of Dubrovnik, 20000 Dubrovnik, Croatia

Cultivation of European flat oyster *Ostrea edulis* (Linneaus, 1758) along the eastern Adriatic coast is traditionally carried out in situ, with the production success tightly linked to marine ecosystem quality. Sheltered bays and estuaries are preferred bivalve-farming areas, but have typically been subjected to natural and anthropogenic pressures. Besides, further aggravation of environmental conditions in the Adriatic, driven by climate changes, has also been forecasted. Therefore, the awareness of policy makers and overall public on the vulnerability of farming habitats is critical for future sustainability of the Adriatic *O. edulis* aquaculture.

Lim Bay and Mali Ston Bay are located in the northeast and southeast Adriatic, respectively. These two different and geographically distant marine reserve areas, are important as long-time oyster-farming zones. To assess the characteristics of two oyster-farming sites in Lim Bay and Mali Ston Bay, samples of seawater, sediment and adult oyster were collected bimonthly from July 2020 to May 2021. The research has been conducted within the framework of the ongoing project "Sensitivity of commercially important bivalves from eastern Adriatic aquaculture to variations in environmental conditions „Best Adria" (Croatian Science Foundation).

Seawater physico-chemical parameters displayed typical seasonal variations, while microbiological quality notably differed between the two oyster-farming sites. Faecal indicators in the seawater and sediment, namely, total coliforms, E.coli and enterococci, occasionally displayed slightly higher numbers at Lim Bay site. Total heterotrophic bacteria and Vibrio concentrations in the seawater and sediment were predominantly higher at Lim Bay site as well, where also a markedly higher total heterotrophic bacteria and Vibrio concentrations were recorded in *O. edulis* tissues over the whole investigation period. Some potentially pathogenic Vibrio species such as V. aestuarianus, V. alginolyticus and V. anguillarum were identified mostly, although not exclusively, also at Lim Bay site. The overall results reflect specificities of each farming area arising from differences in nutrients enrichment and hydrological conditions of Lim Bay and Mali Ston Bay. Some potential threats that might affect the safety and productivity of *O. edulis* aquaculture i.e. anthropogenic pressure and exotic species, were also observed during sampling campaigns.

Key Words:
Ostrea edulis, oyster, aquaculture, adriatic aea

11
Effects of different microalgal diets on *Ostrea edulis* (Linnaeus, 1758) broodstock conditioning and reproduction. Development of a non-destructive technique for the monitoring of oyster gametogenesis and sex differentiation

Monica Fabra[1], Tim Bean[2], Gordon Watson[1], Joanne Preston[1]

[1] Institute of Marine Sciences, University of Portsmouth, Portsmouth, UK, monica.fabra@port.ac.uk

[2] Roslin Institute, University of Edinburgh, Edinburgh, Scotland

The current distribution of the European flat oyster *Ostrea edulis* (Linnaeus, 1758) across the UK and Europe represents only a small fraction of the historic distribution. Seed oyster supply is currently one of the main limiting factors for most of the native oyster restoration projects. Although several hatcheries are being established across Europe to assist in restoring native oyster populations, *O. edulis* hatchery production is still prone to failure, with scarce capacity to produce large quantities of oyster seed. The knowledge gaps surrounding *O. edulis* biology and reproduction, and the factors responsible for the gametogenesis and sex differentiation, make it difficult to control the sex ratio, leading to disproportionate gametic contribution. This research investigated the effects of four single microalgal diets on *O. edulis* broodstock conditioning, assessing oyster survival, growth, filtration rate and absorption efficiency over four consecutive weeks. The results showed *Tetraselmis suecica* as not efficient for *O. edulis* broodstock conditioning due to its low ingestion and absorption, contrary to *Isochrysis galbana* and *Nannochloropsis oculata*. *Thalassiosira pseudonana* may be considered suitable for *O. edulis* conditioning, despite being characterised by lower ingestion. Given the importance of biochemical composition of diet for broodstock reproduction, with fatty acid-enriched diets expected to provide sufficient reserves for the development of ovogonia, future analysis of gonad samples will be performed to assess the allocation of fatty acids in the gonads of native oysters fed on the four different algal diets. This research also investigated the effects of two non-sacrificial techniques for the sampling of gonad tissue on oyster survival, growth and filtration rate over four consecutive weeks. The use of anaesthetic (magnesium chloride) did not result efficient for frequent sampling, causing high mortality rate (25% after only 3 weeks of sampling) and low filtration rate. Contrarily, the drilling of oyster shells caused 0% mortality and high filtration rate, likely associated to the production of new shell. This novel non-destructive approach, involving the shell drilling, may allow to monitor the effectiveness of broodstock conditioning protocols and the gametogenesis and sex differentiation of individual oysters throughout the whole reproductive season, without sacrificing large numbers of oysters.

12
Catalogue for designing nature-inclusive offshore wind farms

Oscar G. Bos[1], Annemiek Hermans[2], Ivana Prusina[2]

[1] Wageningen Marine Research (www.wur.nl), PO Box 59, Den Helder (NL), oscar.bos@wur.nl

[2] Witteveen+Bos, P.O. Box 85948, 2508 CP The Hague (NL)

The Dutch Government stimulates nature enhancement within offshore wind farms. Currently, permit holders must take measures to increase the suitable habitat for species naturally occurring in the North Sea. To support wind farm permit holders to design their wind farms in a nature-inclusive way, a catalogue of nature-inclusive design options has been developed by Witteveen+Bos and Wageningen Marine Research. This catalogue shows relevant nature-inclusive design options for target species, the expected construction costs, and possible suppliers and manufacturers.

The focus of the study was on native species that are under pressure, such as European oyster (*Ostrea edulis*) and cod (*Gadus morhua*). At the same time, many other species can also benefit from the measures. In addition, the catalogue focuses on a number of commercial species such as Edible crab (*Cancer pagurus*) and European lobster (*Homarus gammarus*) since there is also a lot of focus on co-using offshore wind farms for small scale fisheries. The catalogue was commissioned by the Dutch Ministry of Agriculture, Nature and Food Quality.

Key Words:
nature inclusive design, nature restoration, offshore windfarms

13
Active sea bed management for native oyster restoration in high sediment load estuaries

Tom C. Cameron[1], Graham Baker[2], Jim Pullen[3] and AliceLown[4]

[1] School of Life Sciences, University of Essex 1, tcameron@essex.ac.uk
[2] Tollesbury and Mersea Oyster Company
[3] JP Consultant, West Mersea, Essex
[4] School of Life Sciences, University of Essex

Several studies have been undertaken to determine the role of active interventions and bed management on the recruitment of bivalve spat to the seabed. Of these studies some have been inconclusive or undertaken at reduced spatial or temporal scale. The best of these previous studies has shown that bed interventions, or harrowing, has not improved oyster spat settlement. Here we present the analysis of a several order for the on bed mariculture on European oysters occupying 185 four hectare plots in the highly sedimented Blackwater estuary in Essex, UK. We determined significant and positive effects of on bed disturbance (effort in 2015-2018) on juvenile oyster recruitment by 2018, and this effect persists once spatial autocorrelation with adult abundance is taken into account. The contribution of effort in any one year to recruitment in 2018 is not uniform, suggesting that the intervention success may be influenced by environmental variation. We discuss these results in light of local ecological knowledge and conservation success as well as site specific decision on management in marine environments with high sediment loads.

Key Words:
oyster fisheries, utilitarian conservation, sedimentation, shellfish

14
Oyster beds in the Northern Adriatic - current state and restoration potential

Daria Ezgeta-Balić[1], Dražen Oraić[2], Željko Pavlinec[2], Ante Vujević[3], Nedo Vrgoč[1]

[1] Institute of Oceanography & Fisheries, Šetalište Ivana Meštrovića 63, 21000 Split, Croatia, ezgeta@izor.hr

[2] Croatian Veterinary Institute, Savska cesta 143, 10000 Zagreb, Croatia

[3] Ministry of Agriculture, Directorate of Fisheries, Alexandera von Humboldta 4b, 10000 Zagreb, Croatia

European flat oyster *Ostrea edulis* is one of the most commercially important species harvested in the Croatian part of the Adriatic Sea. Although it is present all along the eastern Adriatic coast, the main fishing ground for this species is the Northern Adriatic Sea. In that area, oysters are harvested by beam trawlers. The part of the Northern Adriatic where oyster beds are present is a relatively shallow offshore area with a depth up to around 35 m. According to official statistics harvesting of this species considerably increased after Croatia became a member of the EU due to an expansion of the market. Maximal landing of this species was around 513 tonnes in 2015 while afterwards decreased and the landing in 2019 was just 44 tonnes. This was also confirmed by scientific studies wherein 2013 recorded biomass indices were around 780 kg/km² while in 2017 biomass indices were lower than 100 kg/km². Although exploitation could be the main cause of *O. edulis* population decrease, other environmental factors that could cause natural mortality or a low recruitment rate cannot be excluded (e.g. increasing temperature, disease). Therefore, the aim of our ongoing study is to describe the current state of the oyster bed in the Northern Adriatic by analysing its reproductive cycle and the occurrence of the parasites. Our preliminary results bring us one good and one potentially bad news. The good news is that all analysed samples have negative PCR tests on parasites Bonamia ostreae, Bonamia exitiosa and Marteilia refringens. Potentially bad news was that a certain portion of adult specimens showed pre-spawning oocyte atresia that could affect the reproductive cycle. However, this phenomenon needs to be further investigated and our research is currently focused in that direction. The results of this study will serve as a scientific baseline for future spatial-temporal regulation of the fisheries in this area. Considering the great efforts that are invested in the restoration of *O. edulis* habitats across Europe, it is crucial to detect, protect and investigate the restoration potential of the oyster beds in the Northern Adriatic.

Key Words:
adriatic sea, oyster reproduction, parasites, beam trawl

15
Influence of translocation distance, stocking density and environmental conditions on the fecundity of the European flat oyster *Ostrea edulis*: implications for restoration

Luke Helmer[1,2,3], Jacob Kean Hammerson[1], Nicola Pratt[3], Eric Harris-Scott[2], Morven Robertson[1], Ian Hendy[2], Chris Hauton[3] and Joanne Preston[2]

[1] Blue Marine Foundation, London, UK, luke@bluemarinefoundation.com

[2] Institute of Marine Sciences, University of Portsmouth, Portsmouth, UK

[3] School of Ocean and Earth Science, University of Southampton, Southampton UK

The long-term goal of any native oyster restoration project is to achieve self-sustaining populations, whereby larvae produced by the adult population on a reef and other adult populations in proximity will allow for multiple year classes to establish and seed the future generations. Successful reproduction of *Ostrea edulis* relies upon several factors, including sufficient densities of broodstock to allow for a suitable sex ratio and internal fertilisation within those in a female state. With many populations now being functionally extinct any adults left in the remnant populations are likely to be dispersed, further reducing the likelihood of successful reproduction. A prime example of this has occurred within the Solent, an area that has seen such a dramatic decline since the late 1970s that the fishery, which once provided the table market with 15 million oysters a year, was closed in 2013. An opportunity to assess the impact of translocating oysters from dispersed seabed populations to suspended broodstock nurseries arose and was developed over several years. Determining the survival, reproductive capacity and spawning of the adult broodstock oysters used in this study was vital to not only understanding the likely number of larvae that would be produced in the intense stocking densities, but also in understanding the timing and duration of brooding at the surface of the water column. Across all locations and treatments, it was calculated that 958 of the initial 10,000 oysters were brooding and produced a total of 1,174,668,944 larvae during the 2017 season. The peak in brooding activity aligned with historic data from seabed populations and occurred during the last two weeks of June. No significant difference in the number of brooding adults was observed in the two trial densities, however, those stock at the lower of the two densities produced significantly more larvae (191,458, on average). The larval count also decreased with translocation distance from the source location, highlighting the local adaptations required for restoration, even on small spatial scales.

Key Words:
reproduction, source population, stocking density, local adaptations

16
Assessing the bioremediation potential of European flat oyster

Eric Harris-Scott[1], Andrew van der Schatte Olivier[1], Zoe Morrall[1] , Dominic Parry[1], Joanne Preston[1], John Aldridge[2], Sonia Amaaouch[3], Clothilde Berthelin[4], Phillippe Bryère[3], Elisa Capuzzo[2], Patricia Danican[4], Daniel Franklin[5], Graham Horton[6], Christele Kellner[4], Guillaume Riviere[4], Annesia Lamb[5], Stéphanie Lemesle[4], Mathilde Lemoine[7], Sophie Richer[8], Anthony Le Bris[8], Sébastien Bosc[8], Claire Hellio[9], Marilyne Fauchon[9], Luke Helmer[10], Rohan Smith[6] and Gordon Watson[1]

[1] Institute of Marine Science, University of Portsmouth, Ferry Rd, Southsea, Portsmouth PO4 9LY, eric.harris-scott@port.ac.uk

[2] CEFAS - Centre for Environment, Fisheries and Aquaculture Science

[3] Argans Ltd, 260 Route du Pin Montard, BP 234, 06904 Sophia Antipolis, FRANCE

[4] Laboratoire de biologie des organismes et des écosystèmes aquatiques, MNHN, CNRS 8067, SU, IRD 207, UCN, UA, 43 rue Cuvier, CP 26, 75231 Paris Cedex 05, France

[5] Bournemouth University Christchurch House C208, Talbot Campus, Fern Barrow, Poole, BH12 5BB

[6] Natural England

[7] Aleor, 3 bis rue du Moulin a Mer, Lezardrieux, Brittany, 22740, France

[8] CEVA (Centre d'Etude et de Valorisation des Algues), 83 Rue de Pen Lan, 22610 Pleubian, France

[9] University of Brest, 3 Rue des Archives, 29238 Brest, France

[10] Blue Marine Foundation, South Building, Somerset House, London WC2R 1LA, United Kingdom

Globally, nutrients from intensive agriculture and human waste lead to decreased water quality and the excessive growth of plants and algae. Bivalve culture has been discussed as a mechanism for helping to reduce the impact of eutrophication from terrestrial nutrient inputs in many locations through nutrient bioremediation. In Europe, significant efforts are under way to restore the native oyster, *Ostrea edulis*, with predicted natural capital benefits from the ecosystem services provided an important component in the wider discussion of native oyster restoration and culture. However, the impact of site location (intertidal/subtidal) and method of deployment have not been assessed. The RaNTrans project has deployed *Ostrea edulis* at three sites on the south coast of England, all of which have historically high nutrient loads. 3958 oysters were distributed across intertidal Ortacs (freely-swinging baskets supported on a metal frame 1m above the sediment), and cages (with a structured micro-reef to hold individual oysters placed 1-3 m subtidally) were deployed at each site. Regular sampling over an 18-month period for a suite of biomarkers and endpoints (e.g. survivorship, growth, reproductive state, condition and CHN), will be used to compare the effectiveness of the deployment methods across sites. Results from this study will maximise the impact of oyster restoration as a method of remediating nutrient pollution in coastal areas.

Key Words:
pollution, nitrogen, nature-based solution, aquaculture