Technical development of remote setting of European native oyster and parameterisation of survival during deployment

“Techniekontwikkeling voor REmote Setting en Parameterisatie van overleving bij plaatsing van Oestermateriaal” (TRESPO)

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1. Introduction

1.1. Remote setting and spat-on-substrate

Remote setting is a technique in which shellfish larvae are induced to settle on a hard substrate, which can subsequently be deployed in the field. The term “remote” refers to the fact that this settlement process occurs at a location geographically separate from the hatchery where the larvae are produced. A typical remote setting site might be a container located on a quay, where larvae are allowed to settle on substrate material. Once the process is complete, the substrate—now covered with juvenile shellfish—can be directly loaded onto a vessel for deployment at a restoration or aquaculture site. Thus, the remote setting technique means that the hatchery only has to produce the larvae which can then be transported in a very small package, and the introduction of larvae onto the substrate takes place in a convenient location considering requirements for space, logistics, and ability to load onto a vessel.

Originally developed for commercial shellfish aquaculture, this technique has been successfully developed and applied in Australia and the United States for oyster species such as *Ostrea angasi* and *Ostrea lurida*. In these countries, remote setting is used to re-establish large-scale oyster reefs[1,2]. The most common method involves setting larvae on shells (“spat-on-shell”), which are then deployed.

Ostrea angasi is closely related to *Ostrea edulis*, the native European flat oyster. In 2024, the setting of so-called “competent” (ready-to-settle) larvae of *Ostrea edulis* on shells was tested for the first time in the Netherlands. This pilot was successful: the setting technique, using shells as substrate, now also proved to be effective for the native European flat oyster, and simulation of the “remote” aspect by working outside was successful.

1.2. Spat-on-rock

Unlike the aforementioned international initiatives, the use of spat-on-shell techniques is generally considered unsuitable for reef development in the dynamic conditions of the North Sea. Both theoretical insights and practical experience indicate that shells—serving as hard substrate for oyster larvae—are prone to dispersal by wave action and tidal currents (both loose and when bundled).

In contrast, there is extensive experience in the North Sea with the design (mainly for stability and scouring) and placement of rock on the seabed, particularly in the context of (renewable) energy infrastructure projects and also coastal protection infrastructure. The setting of oyster larvae on rocks (“spat-on-rock”) is therefore considered a promising method for large-scale oyster deployment in the North Sea. This approach ensures that the substrate remains in place, allowing the oysters to develop into mature reef structures over time.

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[1] Bayraktarov E, Rullens V, Sandry B, Valesini F, Fitzsimons JA, Branigan S, Hamer P, Thomas A, Martinez-Baena F, Hancock B, Cleveland B, Gillies C, Reeves SE (no date) Assessing the ecological recovery of shellfish reefs following restoration in southern Australia. Restoration Ecology.

[2] Wasson K, Gossard DJ, Gardner L, Hain PR, Zabin CJ, Fork S, Ridlon AD, Bible JM, Deck AK, Hughes BB (2020) A scientific framework for conservation aquaculture: A case study of oyster restoration in central California. Biological Conservation 250:108745.

The necessary knowledge and technical capabilities for producing spat-on-rock are already available, and the existing logistics chain makes rock a relatively cost-efficient substrate. Moreover, unlike materials such as concrete, rock is a natural substrate, aligning well with ecological restoration principles.

There are three primary pathways through which spat-on-rock can be applied for large-scale oyster reef restoration in the North Sea:

a) Integration with offshore infrastructure projects

Rock is widely used in offshore infrastructure, particularly for seabed stabilization and foundation construction. Offshore wind energy projects are a prime example. Currently, Europe has approximately 37 GW of installed offshore wind capacity, with projections indicating growth to 158 GW by 2030[3]. A significant portion of this expansion will occur in the North Sea, presenting a major opportunity for integrating oyster reef restoration into these developments. Testing and refining the spat-on-rock technique is essential to capture this opportunity for nature-inclusive construction.

b) Stand-alone oyster reef restoration projects

The same technology and logistics can be applied to dedicated reef restoration initiatives, both nearshore and at suitable offshore locations. In areas with moderate to high seabed dynamics—which characterize much of the North Sea—rock is a logical choice due to its low cost and high stability. For these stand-alone projects, the development of spat-on-rock is equally critical to enable cost-effective scaling.

c) Integration with coastal (protection) infrastructure

Depending on local conditions and the competitive interaction landscape with other species such as the Pacific oyster *Crassostrea gigas*, remote setting could be applied to enrich coastal (protection) infrastructure with oyster reefs. Potentially this may be extended to Nature Based Solutions where the oyster reef takes on a role in the coastal protection function of the infrastructure.

1.3. Scaling up oyster reef restoration via remote setting

Large-scale remote setting of “spat-on-rock” for the purpose of offshore oyster reef restoration in the North Sea requires the development of dedicated and specialized technology. This technology encompasses the following key components:

1. Production of *Bonamia*-free and –tolerant larvae of the European flat oyster (*Ostrea edulis*);
2. Facilitating *O. edulis* larval settlement on rocks that are typically used in marine infrastructure projects and are also suitable for use in reef restoration;
3. Handling the weight and volume of the rock substrate in a practical and efficient manner;
4. Maintaining the viability of settled oysters on the rocks until the moment of deployment;
5. Enabling deployment of the spat-on-rock material from a working vessel at sea;
6. The availability of restoration sites free from seafloor disturbance; and
7. Follow-up monitoring to further optimise future restoration practices.

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[3] Based on data and forecast by WindEurope, Wind energy in Europe: 2024 Statistics and the outlook for 2025-2030, 27-02-2025

1.4. Project goals

The goal is to develop and test a scalable technique for remote setting of the European flat oyster (*Ostrea edulis*) on rock (“spat-on-rock”), with emphasis on the effect of mechanical handling of the spat-on-rock on the survival of the oyster spat after (mechanical) placement.

Two outplacement mechanisms will be tested and compared for practical applicability and loss rates incurred by handling and dropping of the spat-on-rock: tipping buckets, and a rock bag. The tipping bucket is an off-the-shelf bucket that can be tipped using a release on its mounting frame, normally applied for land-based bulk material handling. The rock bag is a special S-type (able to release the rocks, in contrast to regular rock bags) manufactured by Ridgeway, normally applied for offshore rock installations.

The foundation of the technique is a remote setting facility, i.e. a standard shipping 20ft container—readily available, easily transportable by truck, and compatible with a wide range of installation vessels. The objective is to design a simple, modular, container-based system that can be scaled up as needed.

1.5. Future outlook

This proposal supports and accelerates the development of the technological components required to establish a metapopulation of interconnected subpopulations of European flat oysters *(Ostrea edulis*) in the North Sea. This is to be achieved through the deployment of oyster spat on rock substrate—spat-on-rock. To date, oyster reef restoration efforts in the North Sea have primarily relied on the use of adult oysters. While these methods have shown some success, they are inherently limited in scalability and cost-effectiveness. For example, current approaches often involve manually attaching oysters to structures that are deployed individually—methods that are labour-intensive and not suited for large-scale application. Spat-on-rock overcomes these limitations. The technique enables the settlement of large numbers of oyster larvae on rock substrate, which can then be deployed efficiently. The use of rock as a settlement substrate during remote setting is both innovative and cost-effective, offering a sustainable alternative to manufactured materials. This allows for restoration efforts to be scaled up significantly. A critical knowledge gap is information about the survival rates of oyster spat once settled on rock during transportation and deployment. This project addresses that gap by providing the first quantitative assessment of survival during transportation and deployment, offering valuable insights into the viability of spat-on-rock as a restoration strategy.

2. Activities

The project was structured according to the following activities (Figure 2-1), which are described in order in this chapter:

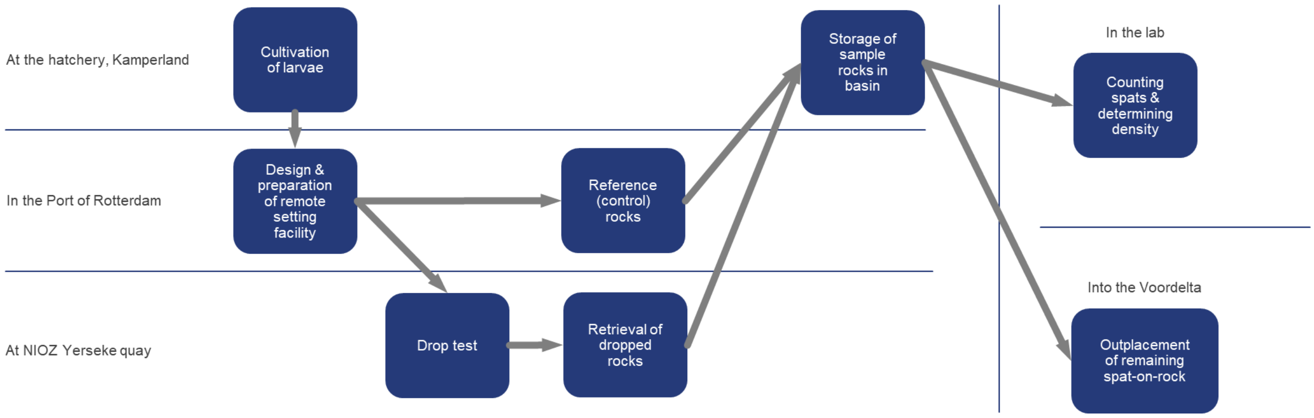

Figure 2-1. Schematic overview of activities.

2.1. Design & preparation of remote setting facility

The Port of Rotterdam provided a location (Figure 2-2) for the remote setting facility near the Futureland building (now superseded by Portlantis as the port's visitor center).

Figure 2-2. Satellite image showing the remote setting location in the Port of Rotterdam. Green arrow shows location of the Tweede Maasvlakte area in the Netherlands, of which the right panel shows a closer satellite view. Yellow arrow indicates the remote setting location.

The design consisted of the following main components:

1. Main pump supplying seawater from port
2. Water treatment unit: filtration & preheating
3. Air pump
4. Recirculating heat pump

5. Remote setting 20 ft half-height shipping container, air tube & ceramic heater, containing two outplacement solutions to be tested: four tipping buckets and one rock bag
6. Seawater return

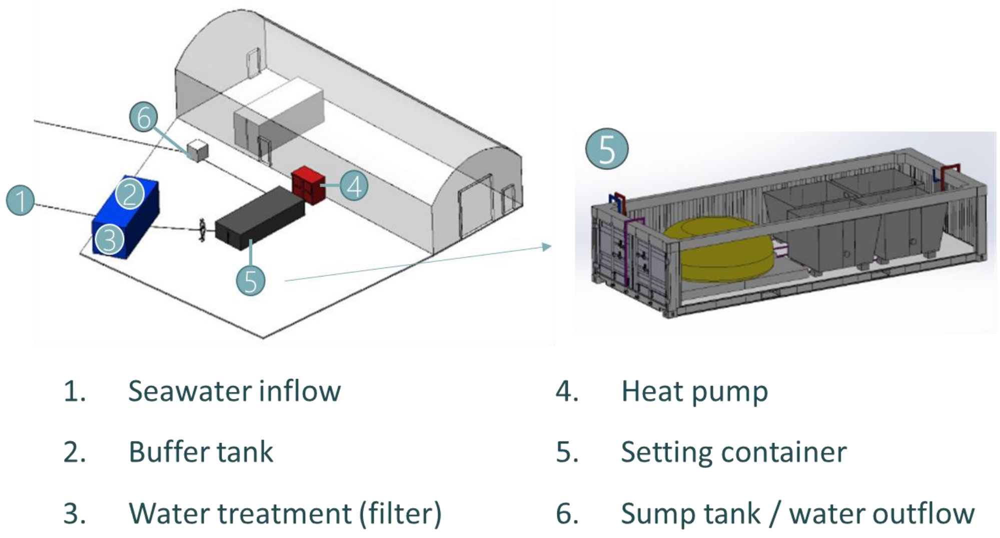

Figure 3. Schematic design of the TRESPO Remote Setting Facility (remote setting facility). (1) Seawater inflow facilitated by a pump, leading the water into a (2) buffer tank and through a (3) water treatment and filtration unit. The water then flows into the (5) setting container with receptacles for the setting substrates. (4) During the setting process, a heat pump array facilitates the warming of the water in the setting container. The throughflow system leads effluent water into the (6) sump tank, from where it is pumped back into the environment.

The system was prepared at the yard of Van Oord in Moerdijk before being transported to the remote setting location. A significant proportion of the materials needed were repurposed from Van Oord's ReefGuard system[5], a container-based facility previously used for the cultivation of coral larvae . This included water treatment including a shipping container, heating units, assorted piping, and various small materials.

The remote setting container of 20 ft was made watertight using rubber sheeting, upon which were placed a layer of protection, air supply piping, and finally the elements containing the rocks contained in four tipping buckets and one rock bag (Figure 2-3, Figure 2-4).

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[5] Van Koningsveld M, ter Hofstede R, Elzinga J, Smolders T, Schutter M, Osinga R (2017) ReefGuard: A Scientific Approach to Active Reef Rehabilitation. Terra et Aqua 147, 5-16.

Figure 2-3. View of the remote setting container before adding water. The rock bag is visible in the foreground, and the tipping containers in the background, all filled with rocks.

Figure 2-4. View of the remote setting facility. In the foreground the remote setting container with four tipping buckets. A small part of the rock bag is visible in the right-hand corner, the remainder of the rock bag is obscured from vision by the air bubbles. The water treatment container is visible on the right-hand side.

Four tipping buckets were filled with approximately 350 kg of limestone rocks each. One eight-tonne capacity rock bag was filled with one cubic meter of limestone rocks (i.e. 1.5 tons). In addition, a mimic rock bag was added containing a small amount of the same rock as a proxy for settlement rate of the larvae in the main rock bag, allowing for control samples to be collected before the drop test.

2.2. Cultivation of larvae

Approximately 5.2 million native European oyster larvae were produced from a broodstock taken from lake Veere (Veerse Meer) at Stichting Zeeschelp, following to their procedures for the generation of *Bonamia* parasite-free larvae. The broodstock was temperature-conditioned at the facility and induced to reproduce. The larvae were fed with a mixture of live algae produced at the hatchery (Figure 2-5) and cultivated until showing clear signs of competence to settle. At this point the larvae were collected onto a filter and transported under cooled conditions to the remote setting facility (Figure 2-5) in the Port of Rotterdam.

Figure 2-5. Collection of competent larvae at Stichting Zeeschelp for transportation to the remote setting facility. The conical basins contain the larvae.

2.3. Remote setting & growing period

The larvae were released into the preheated (approximately 26 ^{0}C) remote setting container at the remote setting facility in the Port of Rotterdam on June 4, 2025 (Figure 2-6). This was accompanied by a release of live algae mixture produced by Stichting Zeeschelp as food for the larvae.

Figure 2-6. Release of oyster larvae in the remote setting 20ft container at the facility in the Port of Rotterdam on June 4, 2025.

During the period of settlement at the rock material until the drop test, the oysters were supplied at regular intervals with a live algae mixture. The water was kept above 20 ^{0}C by the preheater on incoming water and the ceramic heater in the container during the first 7 days. The oyster spat grew well and became visible to the naked eye (Figure 2-7).

Regular visits to the remote setting facility were conducted to ensure the proper working order of the remote setting facility and its components. This allowed potential problems to be identified in time, and modifications to be made if needed, without impacting the living conditions for the oysters. As an example, a piece of tubing used for the main air supply showed a beginning rupture and was replaced before failing.

Figure 2-7. Oyster spat on June 16, 2025, 12 days after release

Figure 2-8 Close-up of spat after more than 3 weeks in the setting container (27 June 2025)

2.4. Reference samples

On June 30, the day before the drop test, reference sample rocks were collected from the tipping buckets and the mimic rock bag (Table 1). The purpose of these samples was to determine settlement rates (proportion of the larvae settled and growing on the rocks), and to provide a baseline for comparison to the samples taken after the drop test, in order to estimate the proportion lost as a result of handling and outplacement. The samples were placed in plastic crates with cloth on the bottom and between the rocks to protect the larvae from damage. To keep living conditions of the reference larvae similar to those undergoing the drop test, the crates were placed into the remote setting container in order to be transported to the drop test location and ultimately to Stichting Zeeschelp along with the dropped samples the next day, where all samples were kept until spat numbers on the sampled rocks were determined by visual counting. During the drop test day the samples were kept in a refrigerated climate cell provided by the Royal Netherlands Institute for Sea Research (NIOZ).

Table 1. Distribution of samples taken the day before outplacement.

Unit	Distribution	# rocks
Tipping bucket 1	5 from top, 5 from middle, 5 from bottom	15
Tipping bucket 2	5 from top, 5 from middle, 5 from bottom	15
Tipping bucket 3	5 from top, 5 from middle, 5 from bottom	15
Tipping bucket 4	5 from top, 5 from middle, 5 from bottom	15
Mimic rock bag	Not distinguishable between "layers”	15
	Total	**75**

2.5. Drop test

On July 1st 2025, the drop test was carried out at the NIOZ site in Yerseke (Figure 2-9). The location was selected because it allows access from a quay wall onto an intertidal flat. This provides a unique opportunity allowing the rocks to be dropped during high tide, simulating offshore outplacement, and subsequent recovery (of the rocks) for monitoring purposes during low tide.

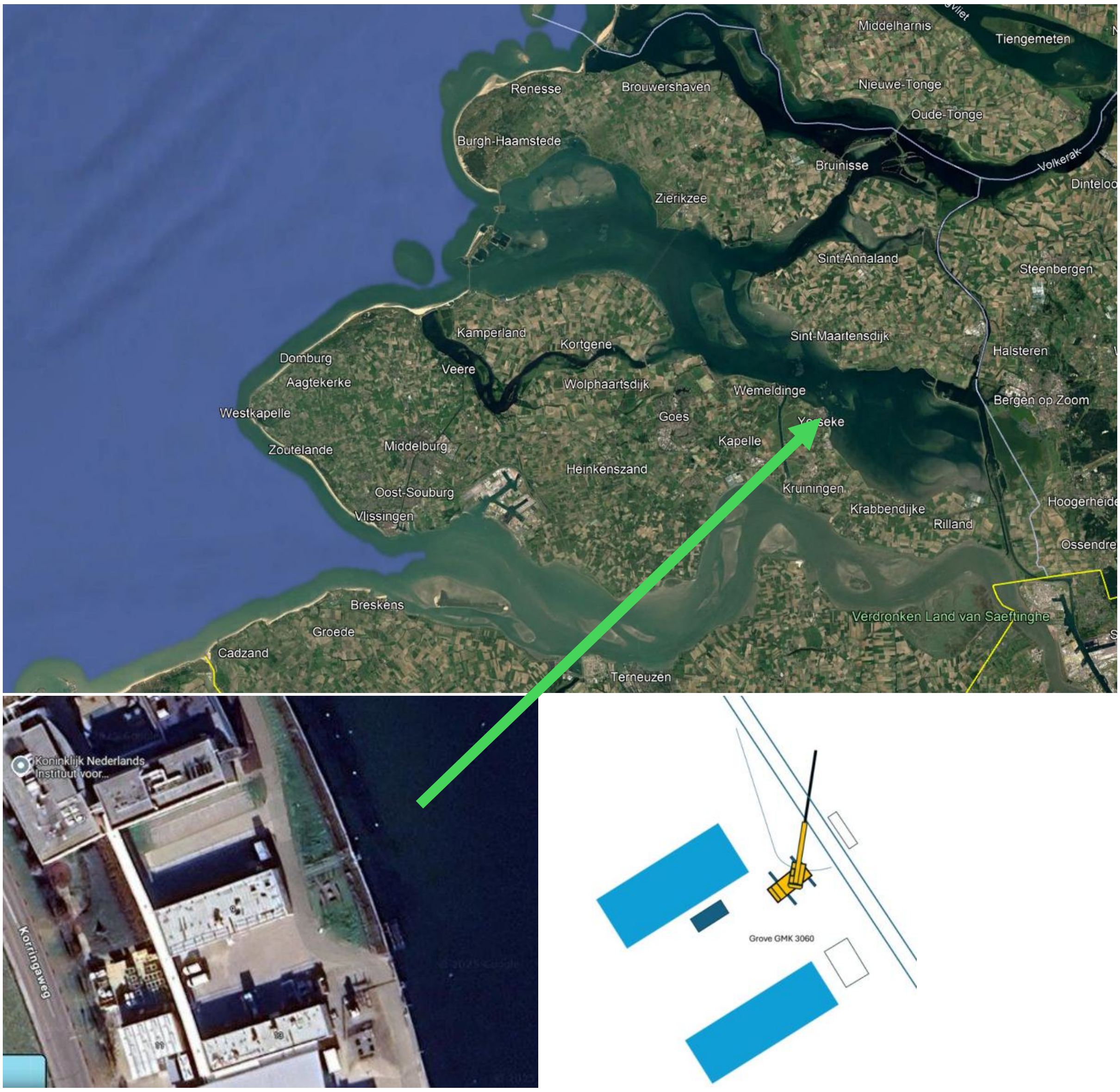

Figure 2-9. Drop test location at NIOZ Yerseke in the south-western delta region of the Netherlands. Bottom-left panel shows satellite view of the NIOZ site and bottom-right panel shows a schematic of the same view with approximate placement of crane with boom extended for the drop.

The remote setting container was drained of water around 18:00 on June 30th and covered for protection against sunlight and desiccation. On the morning of July 1st around 5:30, the drained container holding the tipping buckets, the rock bag, and the reference sample crates were loaded onto a truck and transported to the drop test location at the NIOZ in Yerseke.

On both days the weather was clear with high temperatures of around 26 ^{0}C on June 30th at the remote setting facility, and up to 36 ^{0}C in Yerseke in the afternoon during collection of the dropped rocks. To mitigate the impact of these high temperatures on the oyster spat, efforts were made to cover the rocks with cloth when not submerged in water, and keep them wet by pouring buckets of seawater over it.

The rocks were dropped from a height of approximately 2-3 m above the water surface during the morning high tide around 8:30 by a 80-tonne crane (Figure 2-10). Even though the setup allowed for dropping the rocks at or below the water surface , dropping from a height was chosen because it was considered to provide the most contact between the rocks during outplacement and therefore represent a worst-case scenario.

Figure 2-10. Crane in position with rock bag attached and being prepared for dropping.

The rock bag was deployed first (Figure 2-11), and subsequently each of the four tipping buckets was tipped to deploy the rocks into the water (-Figure 2-12), totalling five deployments. Marker buoys placed the day prior were used as a visual guide to assist in placement on the intertidal part of the seafloor and to avoid previous deployments and/or other structures present.

Figure 2-11. The moment of release of the rocks from the rock bag. Photo courtesy Gees van Hemert.

Figure 2-12. The moment of release of the rocks from the tipping bucket. Photo courtesy Gees van Hemert.

During the deployment, or drop test, the seafloor was not visible due to turbidity of the water column but as the tide went out distinct piles for each deployment were observed (Figure 2-13).

Two of the tipping buckets were dropped close together, where the perimeters of the piles overlapped.

Figure 2-13. Two piles produced by drops from two tipping buckets.

2.6. Sampling and retrieval of rocks

Samples were collected from each individual drop during the low tide directly following the drop, around 14:30 (Table 2). Rocks were collected in a haphazard manner, to approximate a random sample. To maximise random sampling, each deployment pile was treated as a circle, from which rocks were collected from each of their respective quarters, as well as from both top and bottom and both the central and outer parts of the circle / pile.

Table 2. Distribution of samples taken after the drop.

Unit	# rocks
Tipping bucket 1	15
Tipping bucket 2	15
Tipping bucket 3	15
Tipping bucket 4	15
Rock bag	15
Total	**75**

In the same way as the reference samples taken the day prior, the sampled rocks were placed in plastic crates with cloth to protect the larvae. After collection, the sampled rocks were kept in the same refrigerated climate cell provided by NIOZ as the reference samples. In the late afternoon all sampled rocks were transported in crates on pallets by truck to Stichting Zeeschelp, where all samples were kept in a seawater basin (Figure 2-15) to maintain the spat alive until spat numbers on the sampled rocks were determined by visual counting.

The remaining material not used in the experiments was dedicated to oyster reef restoration in the Voordelta (see Appendix in Chapter 7). After collection of the samples, the remaining rocks (approximately 3.4 tonnes) were collected manually and placed into crates (Figure 2-14). At the end of the day all the rocks were transported to Stichting Zeeschelp and placed into seawater basins, where they were kept until permanent outplacement at the Voordelta oyster reef.

Figure 2-14. Manual collection of all the rocks after collection of samples. The rocks were placed into crates on pallets for transportation. Photos courtesy Gees van Hemert.

Figure 2-15. Sampled rocks in seawater basin at Stichting Zeeschelp where they were kept until spat were counted. Oyster spat are visible on the rocks, with several examples indicated by arrows.

2.7. Counting spats and determining density

Spat was counted between July 8 and 11 i.e. 7 to 10 days after the drop test. On each rock, all spat was counted.

The density per unit surface area was calculated after converting the rock volume as measured by water displacement to surface area using a power relation based on the paper wrapping technique.

For the paper wrapping technique, a sample of the rocks was individually wrapped in paper as tightly as possible, after which the weight of the paper was determined. The weight to surface area relation of the paper was then used to calculate surface area of the rock. This was related to the volume of the rocks by measuring water displacement. The resulting power relation was:

$$a = 730{,}31\ V^{0{,}6556}$$

Were a = surface area (cm^2) and V = volume (L).

3. Results & discussion

3.1. Spat settlement

From the total 5.4 million larvae added at day 1, a total of 480.000 settled spat (8.9%) were estimated from the counting data around 27 days after introduction of larvae.

This included the counts of live plus dead specimens. Only dead spats of sufficient size could be observed (spat lost earlier are not detected, but were likely much higher in number). Dead spat completely disattached from the rocks were also not observable. Taking these factors in account means that this number cannot be interpreted as an initial settlement rate. The dead spat are assumed to have died shortly before counting, possibly as a result of sampling and handling. Therefore this number is reflective of spat density at the time of sampling i.e. 27 days after introduction of larvae.

3.2. Drop test

As expected, visual inspection of the rocks collected after dropping showed intact oyster spat on the rocks, as well as some that were damaged (Figure 3-1).

Figure 3-1. Rocks collected after the drop. Intact oyster spat is indicated by green arrows pointing rightward, damaged oyster spat are indicated by yellow arrows pointing leftward.

Comparing the densities (Table 3) of the controls with the dropped treatments for each container type produced a measure of loss of spat due to dropping and handling, plus non-experimental factors including the high outside temperature (see below). For the tipping container the loss was 24,5%, and for the rock bag 68,8%.

Table 3. Spat densities by container type and treatment.

Source	Treatment	Spat density (cm^{-2})	SE	Loss rate
Tipping container	Control	0,1757	0,014	24.5%
	Dropped	0,1327	0,010	
Rock bag	Control (mimic)	0,2136	0,025	68.8%
	Dropped	0,0667	0,010	

For the drop test as a whole and for both container types, loss of oysters may have been caused by the outside temperature. The drop test took place on probably the hottest day of the year with 36 ^{0}C air temperatures and strong direct sunlight. Dropped rocks were kept moist by pouring water from buckets, and once in sampling crates were placed in the shade and covered by cloth as much as possible, but significant loss due to heat and desiccation stress likely did occur as it was not possible to ensure constant wetting and shelter for the rocks. Contrary to the rocks that were dropped, the control rocks had been stored in a refrigerated climate cell and therefore were not exposed to the same stresses. This may have increased the difference in surviving spats between control and dropped rocks.

A possible explanation for estimated greater loss rates from the rock bag than the tipping container may be that the assumption that the settlement on rocks in the mimic rock bag from which the control rocks were taken was representative of settlement in the actual rock bag may not be valid. The mimic rock bag was much smaller than the tipping containers and the actual rock bag, which may have given larvae better access to the rocks contained within it. Indeed the spat density prior to dropping in the mimic rock bag was higher than that in the tipping container. Control rocks were taken from the mimic rock bag instead of the actual rock bag, to avoid opening the actual rock bag and causing additional abrasion of rocks.

The greater loss rate associated with the rock bag than the tipping container may also be attributed to the following factors:

1. In order to simulate a worst case approach, the drop took place from 3 m above the water. Judging from the deep rumbling sound heard during the drop, this resulted in a lot of tumbling and high energy contact between the rocks. Note, releasing below the water line could avoid this issue, as observed during a follow-up trial in the so-called RESO project, where release below the water line produced little to no audible effect. This suggested that release below the water line likely resulted in less abrasion than release from height.
2. The rock bag needed to be lifted out of the container and placed onto the quayside before the drop test, to release an auxiliary rope. This resulted in quite some rolling motion and contact between the rocks as the rock bag altered shape when setting down and lifting back up. The auxiliary rope was in place to ensure retention of the shape of the rock bag to fit in the container. This was necessary because the rock bag is designed to hold 8 tons of rocks whereas it was loaded with 2 tons. The manufacturer

will be introducing a 4 ton rock bag version shortly which could make the auxiliary rope unnecessary so that the damage from a quay placement can be avoided.

Both of the above issues can be avoided in future spat-on-rock deployments using rock bags, by releasing below the water line and by using smaller rock bags.

4. Lessons learned

Valuable lessons were learned from the project. These were already useful for the remote set of RESO, a TKI project taking place shortly after TRESPO.

- General:
    - The tested remote setting method, and deployment methods, have proven to be effective. Globally, the spat-on-rock technique is still in its infancy, and this project represents a first-of-its-kind initiative within Europe. The project delivered a proof of concept for spat-on-rock production as a viable method for large-scale oyster reef restoration.
- Remote setting facility operation:
    - The remote setting location requires adequate power supply and access to seawater (the closest the better)
    - Regular inspection especially during the first days after introduction of larvae is necessary to ensure the proper working order of the systems.
    - The air pump produced far too much heat to be housed in the water treatment unit and needed to be placed outside.
    - The water temperature dropped quickly upon disconnecting the recirculating heat pump when adding the larvae in order to prevent the larvae from being lost. This is probably due to the limited isolation of the 20 ft container
    - Tarpaulin needs to be kept on the remote setting 20 ft container in place to avoid algae growth and control the water temperature
    - Feeding of the growing spat-on-rocks represents a substantial amount of transports from the hatchery and man-hours
- Deployment:
    - The tipping buckets worked as intended but due to the large weight, releasing rocks required modifications to the original design to assist tipping. The system used is not rated for offshore application. Thus although the principle of the tipping bucket works it would require redesign to be suited to upscaling for offshore reef restoration.
    - The rock bags worked as intended, nevertheless the rock bags are currently oversized compare to the rocks accommodated in the 20ft container (size limitation on diameter)
    - The tipping buckets showed lower loss rates than the rock bag, although the rock bag associated mortality can likely be reduced by simple operational modifications (see under Recommendations, chapter 5)

5. Recommendations for large scale implementation

- The first lesson to be drawn from this project is regarding **complementarity of expertise that comes from a strong and broadly formed partnership**. In this project, the partners were truly complementary to each other, bringing each their own strong expertise. In this project we brought together expertise from larval rearing and care, facility and process design, oyster and algal biology, project management and quality control, HSE, procurement, transport, operations and communication.
- Offshore operability is a big factor in the scale-up potential of the chosen outplacement solution. The tipping buckets worked in principle, but would need to be adjusted, tested and certified for offshore use. Rock bags on the contrary, are already offshore approved and can be procured “off-the-shelf". Rock bags resulted in higher loss rates, but we expect that this will be mitigated fully or partly when avoiding an auxiliary rope and releasing below the water line. **Both outplacement approaches tested can be considered appropriate for further development**.
- In the limited scenario treated in this project, we explored the science, operations and logistics of remote setting, operating from a harbour on land. Running on limited budget and within the Port of Rotterdam industrial area, no or limited spare parts were anticipated and if needed available on short notice. While performing remote setting in a remote location, **appropriate spare parts should be accounted for**. If at all possible, it is highly recommended to bring spare pumps, tubing, tools and other parts and equipment to remote locations, to allow quick response during unforeseen issues.
- We foresee **realistic scenarios in which remote setting containers are lifted on board of a vessel**, sailing to the restoration location where the spat on rock is then deployed. It is recommended to explore ways of keeping the oyster spat alive while in transit and waiting for an installation window, likely requiring a water treatment unit to be brought on board alongside containers holding rock.
- One of the advantages of the remote setting method for oyster reef restoration is its scalability. This project was a pilot and therefore not very cost-efficient, which is expected to gradually improve during future iterations of the technique. Furthermore it is recommended to run **multiple remote setting containers in parallel to increase efficiency per unit rock**.
- During the post-settlement period, the operational steps that involved most logistics had to do with frequently providing algal feed to the juvenile oysters. Previous experiments indicated that the oyster spat tend to grow best on live algae, compared to algal paste which is widely available. Regarding the maintenance of the oyster spat post-settlement, it is recommended to **investigate (semi-) automated ways to optimise the delivery of algae**.
- Furthermore we recommend making **more use of sensor technology** to monitor the status of the remote setting facility (e.g. power status, water temperature, algal feed level, water flow rates) in order to optimise response time in case of technical issues as well as reduce the need for regular physical inspections on site.
- It is recommended to include **follow-up monitoring** to establish survival, growth, and reproduction rates of oysters outplaced in future endeavours via remote setting, in order to further optimise the methods.

- Finally thinking beyond the present project and ahead to upscaling oyster reef restoration via remote setting, the regulation around the parasite *Bonamia ostreae* is of importance. In this project, the spat on rock was deployed in water bodies that are already classified as *Bonamia* infected. Also, the hatchery at Stichting Zeeschelp has been able to produce *Bonamia*-free and –tolerant larvae for the past six years. Therefore, there was no concern for inadvertently introducing the disease in a water body without previous exposure to the disease. However, the open North Sea is considered free of *Bonamia*. If the policy is to enhance natural values in the North Sea by restoring ecosystem engineering species like *Ostrea edulis* forming reefs, it is important to have a **practical regulatory framework** in place to deal with avoidance of ***Bonamia*** introduction for future offshore deployments. This would allow for i) production of oyster larvae with a degree of tolerance for *Bonamia*, so that the restoration site is protected from future *Bonamia* infection, and ii) running the remote setting facility at locations nearest to the future restoration sites regardless of these being in a *Bonamia*-classified area or not.

6. Acknowledgements

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7. Appendix: deployment in the Voordelta

Beyond the scope of the experiments, for the permanent outplacement of the spat-on-rock, two things were needed: (1) a permit to deploy the spat-on-rock in the Voordelta, and (2) positive weather window. ARK Rewilding Nederland has been permit holder for a pilot location in the coastal lagoon located seaward of the Brouwersdam, colloquially known as the "Brouwersbaai". As the permit was scheduled for renewal, ARK opted to modify it, so that spat-on-rock could also be placed for the purpose of oyster reef restoration. In the meantime, the outplacement was planned between the partners, so that it could be realised on short notice.

During the first week of November, correspondence between ARK and the Dutch Water Management Board (Rijkswaterstaat) made it clear that the permit was almost certainly being issued. At the same time, a rather unusually calm weather period of ca. 10-12 days was predicted. Finally, on the morning of Tuesday, 11 November 2025, ARK received the official notification from Rijkswaterstaat of the permit having been issued. As most of the activities had already been planned, it was merely a matter of mobilisation of material and people.

On Thursday 13 November 2025, the staff of the North Sea Programme team of ARK Rewilding Nederland met with volunteers and staff from Stichting Zeeschelp and Van Oord at the Brouwersdam trailer ramp. The spat had grown considerably and were on average the size of a 2-euro coin. Several crates were observed to be almost without any spat. Such crates with few spat visible, were selected to be placed first, to function as a foundation layer for the other "spat-rich" rocks to be placed on top. Between to truck loads and ca. 8 sailing trips, the 3.4 tonnes of spat-on-rock were outplaced at the ARK pilot location "VD 05" (51°47'06"N 3°50'05"E).

At the VD05 pilot location, a marker buoy attached to an anchor stone was placed as orientation point for the spat-on-rock outplacement. Every sailing leg was performed with ca. 16 crates being loaded by hand, into the ca. 5 m boat equipped with a 40 HP outboard engine. Each sailing trip, the crates were emptied around the marker buoy, so as to create an aggregation of rocks, which is projected to grow into a small reef. By 15:00 all spat-on-rock had been outplaced and at 16:00 all equipment and people were demobilised and returned homeward.

Figure 77-1. The crates with spat-on-rock are placed on the trailer ramp at the Brouwersdam. The oysters have grown considerably since the summer. Photos courtesy Annika Mol, Stichting Zeeschelp.

Figure 77-2. Manual loading of the crates with spat-on-rock from the truck on the trailer ramp at the Brouwersdam, onto the boat. Photos courtesy Ernst Schrijver, ARK Rewilding Nederland.

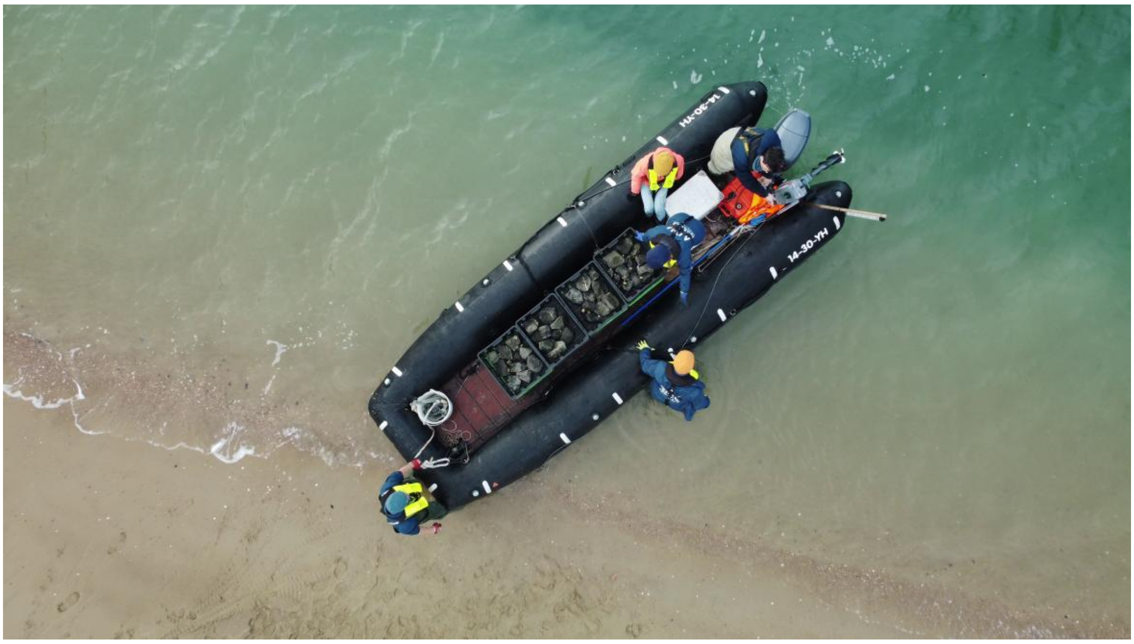

Figure 77-3. Top view of the boat loaded with 16 crates of spat-on-rock, ready to sail Photos courtesy Ernst Schrijver, ARK Rewilding Nederland.

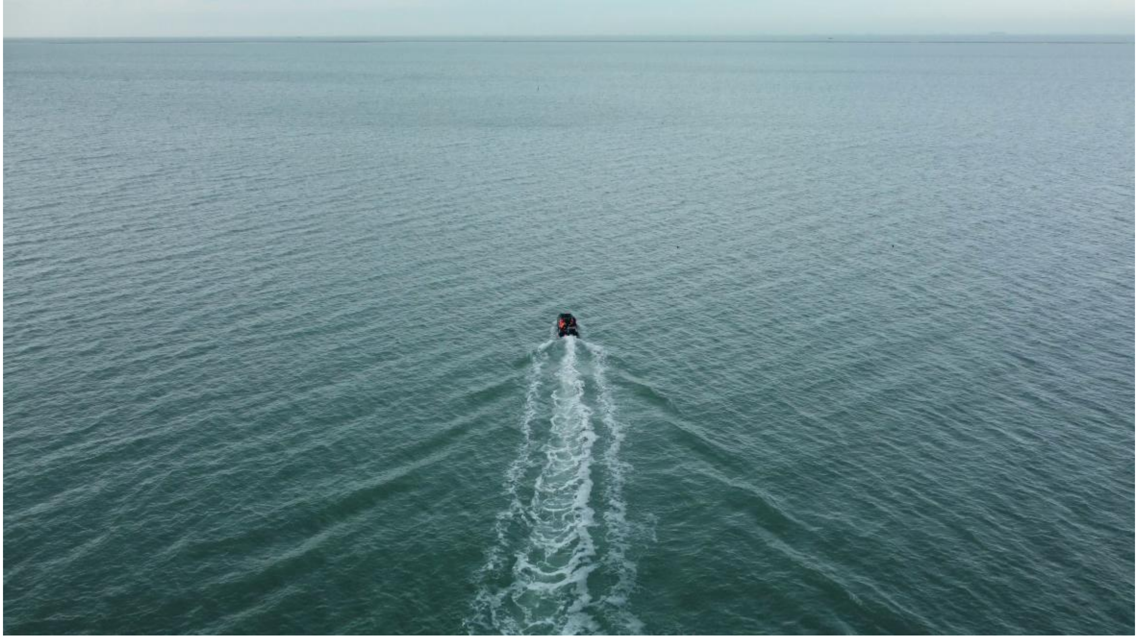

Figure 77-4. Birds' eye view of the boat sailing towards the VD05 pilot location. Photos courtesy Ernst Schrijver, ARK Rewilding Nederland.

Figure 77-5. Birds' eye view of the spat-on-rock being placed overboard from the boat, at the VD05 pilot location. The white marker buoy can be seen in the foreground. Photos courtesy Ernst Schrijver, ARK Rewilding Nederland.

Figure 211. Close-up of the spat-on-rock being placed overboard from the boat, at the VD05 pilot location. The white marker buoy can be seen on the left. Photo courtesy Annika Mol, Stichting Zeeschelp.