Habitat requirements for shellfish

This Building Solution focuses on the creation of shellfish (bivalve) reefs that change the near-bed flow and dissipate wave energy on intertidal flats, thereby influencing sediment transport, erosion and deposition. It describes the habitat requirements for shellfish reefs in soft sediment habitats, based on experience with the Pacific Oyster. The advantage of oysters compared to other shellfish such as mussels is that, due to its strong ‘cement-like’ coagulation, they stay attached to the substrate after dying and are therefore capable of forming stable and sustainable reefs. This guideline can be used to check whether a certain location is suitable or can be made suitable for the establishment of oyster reefs.

Required skills

This guideline can be used as a first-order assessment of the habitat requirements of reef forming bivalves, more specifically the Pacific Oyster. To fully assess the suitability for shellfish reefs one should have a thorough knowledge about the area of interest, as well as additional ecological expertise on the shellfish species considered and its ecosystem engineering capacity under different environmental conditions. Local hydrographic, sedimentologic, water quality and nutrient availability conditions, as well as historical data on reef occurrence and success, must be taken into account while selecting sites and developing restoration strategies.

BwN Interest

The added value of this tool within BwN-type projects is that it enables the creation of natural coastal barriers with reef-building ecosystem engineers. Ecosystem engineers are species that modify their own environment, to their own benefit and that of other species. Thus they can be key species in the formation and persistence of structurally complex habitats. Such habitats can be used to combine the intended function, for example, coastal protection and/or associated economic and social returns with habitat restoration/conservation, for example by enhancing biodiversity.

This Building Solution focuses on experiences using the Pacific Oyster (Crassostrea gigas) in temperate soft sediment habitats. Worldwide, the Pacific Oyster is one of the most widely cultured shellfish species. The preconditions for the use of - preferably indigenous- reef-forming oyster species in new habitats are best tested in the habitat concerned. This will help creating successful reefs (Mann and Powell, 2007).

Tip: In the figure below the light blue boxes show the advantages of using a shellfish reef. In the black box the main necessities for creating a shellfish reef is depicted. Clicking on the image will give you more in depth information about oyster reefs consisting of the Pacific Oyster.
Advantages

- Decreases shore erosion by dissipating wave-energy.
- Traps fine sediment and organic matter
- Provides a sustainable barrier hampering sediment transport from a protected area into the adjacent channels
- Can enhance biodiversity
- Provides shelter for other species
- Water quality improvement through filtering nutrients and contaminants
- Can keep up with a (certain) rate of relative sea level rise by sediment trapping.

Disadvantages

- Shellfish reefs only occur in temperate environments
- Contamination hampers shellfish establishment and growth
- Species that make up the shellfish reef can be an invasive species
- Can result in a shift of the benthic population
- Present (eco)system can be degraded

Habitat requirements for oyster reefs

Different oyster species have different habitat requirements. Temperate intertidal soft-sediment habitats are ideal for the Pacific Oyster, but other environmental characteristics may form bottlenecks for its survival.

The circular flowchart shows the complex interactions between the lifecycle of an oyster and the (a)biotic environmental conditions that determine the development of a natural oyster reef. The abiotic environmental conditions (white blocks: suitable substrate, wave action/flow velocity and inundation period) affect oyster performance (grey blocks: settlement, growth, survival, and reproduction) in different life stages (black blocks: larvae, spat and adults).

This Building Solution describes the critical habitat requirements for these oysters based on the 4 spheres approach, stating that all four spheres (biosphere, hydrosphere, lithosphere and
Circular flowchart of abiotic environmental conditions

A complete overview of the four spheres and the relevant parameters regarding oysters in these spheres is shown in the habitat requirement tree below. The background of all the parameters, including the limitations to each parameter can be found below.

Tip: select a 'sphere' in below diagram for more detailed information.

Habitat requirements of oyster reefs

How to Use
General

If an ecosystem engineer is considered to be included in a design for coastal protection or coastal rehabilitation, several questions need answering:

- Is it possible to create a suitable habitat for a specific ecosystem in the project area?
- What would be the envisaged services provided by this ecosystem?
- To what extent can the ecosystem contribute to the primary function of the design and how does this affect the design itself? For example, what dimensions of a shellfish reef are needed to reduce erosion or stabilize sediment? And what dimensions to act as an efficient wave reflector?
- What effects do the ecosystem engineers in this ecosystem have on the existing physical, ecological and socio-economical system?
- What are the costs, uncertainties and risks ensuing from including these ecosystem engineers in the design?

In this Building Solution, the focus lies on the habitat requirements for shellfish. The determination flowchart gives a first answer to the suitability of the project area as a habitat for shellfish. Other questions can be elaborated in subsequent or parallel steps.

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Determination flowchart

The determination flowchart is based on the habitat requirements described in the general introduction. The goal of the determination flowchart is to give an easy, accessible and low-cost first indication of whether a suitable habitat for shellfish exists or can be created. The flowchart can also be employed to determine if restoring or improving existing shellfish reefs is an option, as it helps finding the possible causes of shellfish degradation or development stagnation.

The potential ecosystem services of shellfish are:

- Coastal protection, e.g. by dissipating wave energy, thus reducing erosion of the protected area
- Water quality improvement by acting as a nutrient filter, by reducing turbidity via sediment trapping, etc.
- Providing a sustainable barrier hampering sediment transport from the protected area into the adjacent channels; this barrier is able to keep up with a certain rate of (relative) sea-level rise by trapping sediments

Other ecosystem services, such as provision, cultural and supporting services are not evaluated here.

The project Shellfish reefs of Building with Nature in the Eastern Scheldt gives further details on how to use shellfish reefs for protecting tidal flats against erosion.

Current Situation

Before employing the flowchart it is important to establish which (eco)system is present in the current situation and which function(s) it holds. Creating something new always comes at the cost of what presently exists. For every type of ecosystem, like a tidal flat, coral reef, seagrass meadow or saltmarsh, it is necessary to understand that system before being able to prevent or undo its degradation. Species communities may even support each other: a coral reef, for instance, can dissipate wave energy and create a sheltered area for seagrasses. The analysis of the current system should extend beyond the project site and consider adjacent systems. One reason is that
engineering works usually have a large influence on the sediment budget and hence on adjacent areas, another is that adjacent communities may produce seedlings for natural settling in the project area.

It is important to keep in mind that an existing (eco-)system may have other functions, such as cultural or supporting services, that may be lost by constructing something new. For example: creating a shellfish reef might be less attractive in a recreational area where people swim. If losing current functions is considered acceptable as long as a (new) shellfish reef providing the desired ecosystem services is created in return, the determination flowchart can be used.

The goal of the flowchart is to have a first answer to the following question:

“Does the intended project area have potential to (re-)establish a sustainable shellfish reef which provides the desired ecosystem services?”

The flowchart aims to indicate whether the important habitat requirements which enable the establishment and sustainable presence of shellfish are naturally present or can be engineered. The result can only be a first-order indication, as the dynamics involved are too complex to comprise in a generic tool. If and when more precise information is needed in later project stages, local shellfish expertise should be called in.

Interpretation

Before employing the flowchart, several issues have to be considered. Firstly, shellfish reefs only occur in temperate environments. Secondly, the history of the proposed site can give a good indication on the suitability for creating a shellfish reef. If a reef was present in the past, but lost e.g. due to human activities, this may indicate that the environmental conditions (salinity, wave exposure etc.) are in principle suitable for creating or restoring a shellfish reef. Other causes of disappearance can give insight into the habitat requirements that need to be adjusted or created. Finally, contaminated areas will hamper shellfish establishment and growth. The possibility to remediate the water and/or soil quality should be considered first, before going through the flowchart.

When going through the flowchart, note that comments are available to interpret the provided values. Keep in mind that every location is unique and has characteristic dynamics and shellfish ecosystems are characterized by complex interactions. This makes it challenging to give precise thresholds, which explains why many habitat requirements remain to be specified.

Practical Applications

This section describes the application of the Building Solution to a practical case. The study area for this application is the Eastern Scheldt (SW Netherlands). A separate Project Shellfish reefs page exists, which describes the phases in the design and construction process of the oyster reefs in the Eastern Scheldt. In the practical application described on this page, the flowchart is discussed by explaining and applying the text and values in the balloons.

>> Read more

Fill in determination flowchart

Following the determination flowchart, the aim is to determine the critical habitat requirements for oysters in the Eastern Scheldt. For each parameter in the chart, information on the specific project location is needed. The following sources of information can be considered to obtain site-specific values for these parameters:

- Current state of the ecosystem on site (occurrence of species/health of species present).
- Available literature.
- Computational Modelling.
Determination flowchart filled in

Data collection (measurements/field work).

The hierarchy above is based on the amount of effort it usually takes to obtain information from the specific source. However, the effort can differ significantly due to factors such as local knowledge, circumstances on site, availability of measuring equipment, etc. For the Eastern Scheldt case, information is abundant as basic data on salinity, waves and water levels are available on the internet (at government websites) and experience with the construction of artificial oyster reef substrates exists.

In the following section, the flowchart is discussed from top to bottom to give the rationale concerning each habitat requirement.

Salinity - Salinity in the Eastern Scheldt is suitable for the Pacific Oyster. Salinity is in the range of 25 and 35 ppt (Davis et al., 1962, Schellekens et al., 2011). In the Netherlands, this type of data is measured and made available through a national monitoring program (MWTL - Monitoring Waterstaatkundige Toestand des Lands).

Inundation time - Inundation periods vary along the slopes of the intertidal flats. The height of a flat is depending on the local hydrodynamics. Oyster reef substrate can be placed at such a level that the inundation time is optimal. In the case of the Eastern Scheldt an exposure time of less than 30% is optimal for the oysters, while exposure time above 60% is unsuitable (Schellekens et al., 2011). This implies that artificial reefs should not be placed outside this range.

Hydrodynamic energy - In the Eastern Scheldt oyster reefs are not observed at sites with current velocities larger than 50 cm/s (Schellekens et al., 2011). This implies that artificial reefs placed at more dynamic conditions need additional fixation of the substrate. Experiments with loose oyster shells at an exposed site (Dortsman) resulted in the complete loss of the shells during stormy conditions. Here the hydrodynamic energy (mainly waves) was too high to place shells without fixation. Therefore, the use of gabions filled with oyster shells was introduced. Attachment of oyster larvae is usually not limited by hydrodynamics, but dislodging of substrate can pose a significant problem. Storm events, may destroy initially successful settlement of oyster larvae, thus preventing sustainable reef creation.

Substrate available - In the Eastern Scheldt, oyster reefs nowadays occupy about 10% of the intertidal habitat (Smaal et al. 2009). Substrate (e.g. shells of cockles, oysters) is available throughout the Eastern Scheldt, but at exposed and eroding sites a more fixed substrate needs to be present to allow for an oyster reef to develop. Therefore, the use of gabions filled with oyster shells is required at these sites. Research has shown that dead oyster shells are the preferred substrate for settlement.

Sedimentation - Burial of oysters will lead to mortality and slow development or possible disappearance of the reef. Too high sedimentation rates are therefore limiting. The pilot in the Eastern Scheldt showed that this can be a problem, depending on location of the reefs and the meteorological circumstances (storm events).

Suspended sediment concentration - In the Eastern Scheldt suspended sediment concentrations are very low (on average < 25 mg/l), and therefore is not a limiting factor for oyster growth. However, in other systems too high SSC can clog the gills of oysters and result in mortality.

Sufficient food availability - Because of the high primary production in the Eastern Scheldt, the
area is an important shellfish culture area (mussels, oysters) (Smaal et al. 2013). A concern was raised that additional reefs for coastal protection purposes would affect the carrying capacity of the Eastern Scheldt for shellfish. In the case of the present experiments (Project Shellfish Reefs), calculation led to the conclusion that their effect on the carrying capacity in the Eastern Scheldt is marginal. However, when applied on a large scale, the possible influence on the carrying capacity must be considered.

Connectivity - Proximity to other shellfish reefs of the same species, in this case the Pacific Oyster, is important for the supply of larvae. Supply of larvae in the Eastern Scheldt is guaranteed by the presence of natural reefs and cultured oysters.

Disease in the vicinity - Until recently there were no diseases in the area, as far as known from experience of the oyster farmers in the region. However, in 2010 the oyster herpes virus was detected in the Eastern Scheldt. In addition, the predatory neogastropod the Japanese (Ocinebrellus inornatus) and American oyster drill (Urosalpinx cinerea) are found in the Eastern Scheldt.

Conclusion

Due to the experiments already conducted in the Eastern Scheldt a lot of information is available. It appears that location in combination with suitable hydrodynamic conditions is critical to the successful creation of sustainable oyster reefs there. In addition, appropriate substrate (preferably dead oyster shells) needs to be placed to allow settlement of larvae. Experiments have shown gabions are most suitable to keep the shellfish-substrate in place.

>> References

Literature

- Jackson, J. B. C., Kirby, M. X. et al. (2001). Historical Overfishing and the Recent Collapse


Internet

- http://ccrm.vims.edu/livingshoreslines/
- http://www.oyster-restoration.org/

Images

- Pacific oyster, photo: IMARES
- Established Pacific oyster reef in the Oosterschelde, photo: IMARES
- Installation artificial oyster reef in the Oosterschelde, photo: IMARES