Scaling up Building With Nature along the Danish Coast – the socio-economic rationale

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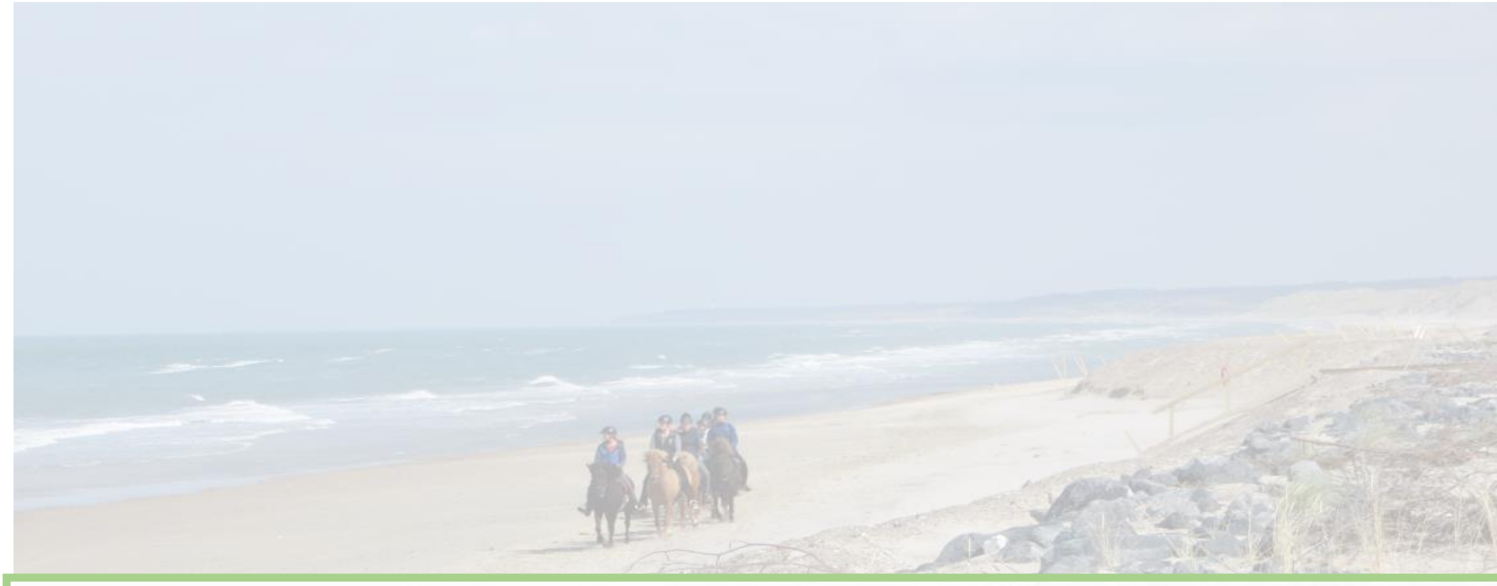

To the reader

Along the Danish coastline coastal protection via hard engineering solutions is still commonplace in many locations, despite its ineffectiveness in reducing chronic erosion, potential aggravation of erosion downdrift and higher costs in the long term. Building with Nature – e.g. through sand nourishment – can address these issues and additionally generate wider socio-economic and biodiversity benefits. The document discusses the socio-economic rationale for wide-scale adoption of a building-with nature (sand nourishment) coastal management strategy along the Danish coast, including an illustration from the benefits of decades of sand nourishment in the Ringkøbing area. This document is meant to inspire actors considering coastal management strategies in Denmark, such as municipalities or land owners.

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Content

1 Introduction

Denmark has a long coast line with in most areas a low level of habitation and development. Particularly along the Danish West coast there are various locations where chronic erosion is taking place. In most cases the erosion and related flood risk and consequent threats to properties is very local, but in some cases erosion leads to increased flood risk for the hinterland as well. In these locations, where coastal protection against flood risk and erosion is deemed of national importance, the Danish Coastal Authority (DCA) participates in a Joint Agreement with local authorities and supports and co-funds coastal protection (130 km). In other locations local private or public landowners are responsible for arranging and funding protection against coastal erosion and flooding (~6000 km). This fragmentation of responsibilities in coastal protection leads to a differentiation in coastal management strategies.

In locations with a Joint Agreement, large-scale sand nourishment strategies are adopted as coastal management strategy: aside from protection against flood risk and erosion, these bring additional benefits such as spatial quality, beach width and habitat provision. From a wider socio-economic perspective scaling up of the Building with Nature strategy along the entire Coast is attractive. However, in locations where local landowners are responsible, small-scale conventional infrastructure solutions such as groins and revetments are typically selected as people are more familiar with these and they require less cooperation: in the majority of these locations there is some kind of hard coastal protection in place.

The DCA aims to promote scaling up of Building with Nature strategies in regions where they have a supporting role rather than direct mandate for coastal management. In this white paper we discuss the economic rationale for scaling up Building with Nature along the Danish Coast based on literature and an illustrative case on the Ringkøbing coastal section.

1.1 Building with Nature – sand nourishment

Building with Nature for coastal protection is an approach where the natural system provides the starting point: natural processes such as current, wind and waves, and natural materials like sand and silt are used in the design (see also www.ecoshape.org; de Vriend et al 2014). If erosion occurs on sandy coastlines, sand nourishment can be used to compensate for this loss: dredging boats collect sand from the deep sea and deposit this on the beach or on the foreshore, where it is further distributed through natural processes. At the large-scale systemic level, Building with Nature is more (cost-)effective than conventional 'engineered' solutions such as groins or revetments in halting coastal erosion. Engineered solutions may halt erosion locally, but rather aggravate the erosion along the coastline as they do not address the root cause of erosion - the sediment deficit - and constrict the coastline further. Additionally, Building with Nature is a more sustainable strategy, easier to adapt with sea level rise in the future, and can create value for various stakeholders through increasing spatial quality and beach width (see also section 2).

1.2 Coastal management on the Danish Coast

The Danish North Sea Coast is a highly dynamic sandy coast dominated by a small tidal wave. There are large alongshore variations in the coastline with perturbations over time and erosion hotspots – local narrowing of the beach- migrating along with the mostly southbound sediment transport (Lassen et al., 2018).

Erosion protection needs

Particularly along the Danish West Coast there is severe chronic erosion (see left graph in Table 1.1). Although in many locations there is already some protection in place that may be effective, particularly along the west and north coast there is a need for further protection (right graph in Table 1.1). With sea level rise and increasing storm intensity due to climate change the severity of erosion is likely to increase. Additionally, since in 2014 tourism development regulations allow for more and easier tourism development along the coast (Andersen et al., 2018) exposure to erosion risk can be expected to increase as well: these trends combined indicate it is likely the demand for further protection will increase in the future.

Severity of chronic erosion trends (*without impact protective measures)*	Supply and demand for erosion protection until 2045

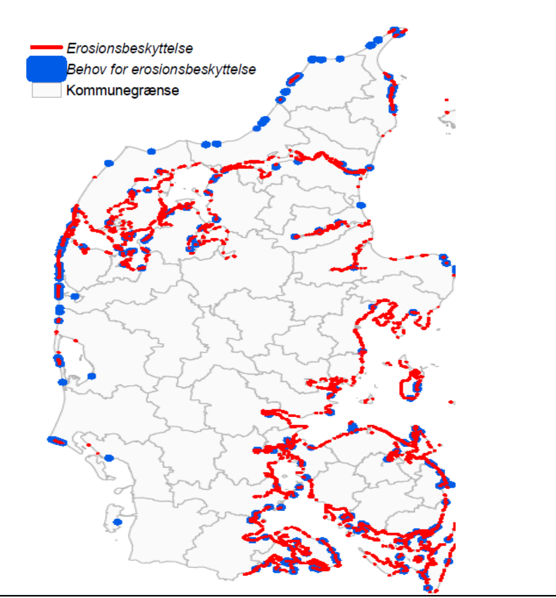

Table 1.1 The figure on the left shows current severity of chronic erosion. The figure on the right shows where erosion measures have been taken (red) and locations (blue) where there is further need to take erosion measures to prevent damage to infrastructure and property in the period 2020-2045.

Current coastal management practices

The current coastal management strategy consists predominantly of engineering solutions (Figure 1.1). Particularly in areas where local landowners are responsible, this is the preferred solution: it is deemed cheaper, and the effect is immediately visible. Long-term maintenance costs and the risk that e.g. revetments collapse over time due to high erosion rates are usually not taken into consideration red. Sand nourishment is applied only in a limited number of locations which fall under a Joint Agreement.

Figure 1.1 This figure shows what kind of coastal strategies are currently in place. The red lines in front of the coast show which sections fall under a Joint Agreement with the DKA: other areas are under responsibility of local landowners. This map can be viewed in more detail on [www.kyst.dk.](www.kyst.dk)

1.3 Potential for scaling up BwN

In various locations along the Danish coastline where the coastal authority has the mandate for coastal management, sand nourishment is used as the primary coastal defense strategy. There is a potential to scale up this strategy in:

1. Locations where an engineered protection is currently in place. These constructions require maintenance, and it may be attractive to combine or switch to sand nourishment at some point in the future, particularly when existing infrastructure needs large-scale maintenance or revision
2. Locations with protection needs, but currently no or limited protection in place yet

Technically, sand nourishment is feasible everywhere along the Danish coastline. Particularly in locations with predominantly on-shore winds the natural sedimentation process benefits from support by sand nourishment to provide protection. But also in locations with off-shore winds - due to the erratic orientation of the coastline this can occur everywhere - with often a quieter wave climate, a smaller erosion rate and no natural beach or dune formation, relatively little amounts of sand nourishment and active dune creation can still be a very valuable way to provide coastal protection.

2 The benefits of BwN versus hard coastal protection

How a choice is made between various coastal management strategies depends on the institutional context and regulations in a country. In some countries, societal cost-benefit analysis is used to inform decisions: the alternative with the most attractive benefit-cost ratio is selected. Soft values such as landscape and ecological quality may also be considered. In other locations, cost-effectiveness (the cheapest way to achieve a pre-defined goal) is the prescribed decision criterion. With increasing challenges from climate change, robustness of a strategy under a changing climate (e.g. sea-level rise) is also increasingly considered in decision making processes. In this section we highlight information from literature on the effectiveness and systemic impact of coastal strategies (2.1), cost-effectiveness (2.2) and added values of BwN (2.3).

2.1 Effectiveness and impact of coastal strategies

Along the North Sea coast the artificial stabilization of seafronts to prevent erosion or flooding, particularly in the UK and France, is increasingly limiting the number of sedimentary coastlines and cliffs: dynamic ecosystems are gradually disappearing due to a lack of sediment. In the long term, through disturbing coastal sedimentation processes, these structures lead to the degradation of the coastal landscape and the structure and functioning of coastal ecosystems on the local as well as the regional scale (Ospar, 2009). In the short term, hard structures partially hinder the recreational use of the beach as well: beach erosion may continue at the protected location, and due to interruption of sediment transport along the shore and ‘armoring’ of sediment supply itself they aggravate erosion ‘downdrift’ (Bralower, 2019).

Additionally, hard structures are designed to withstand pre-specified hazard conditions; if these conditions change (e.g. due to climate change) or the structure fails due to other reasons, they require modification and/ or maintenance. Building with Nature strategies such as sand nourishment are much more flexible under changing hazard conditions (e.g. sea level rise,) and require less maintenance (Gray et al., 2017).

<u>In short, both hard engineering as well as Building with Nature strategies can be effective in providing coastal protection or reducing flood risk locally on the short term, depending on local circumstances and required protection standards. However, hard engineering structures disturb coastal sedimentation processes which aggravates coastal erosion and loss of habitat in the long term on the regional scale, and they are less flexible under changing circumstances which may render them more expensive in the long term.</u>

2.2 Cost-effectiveness

Whether sand nourishment is more cost-effective than conventional engineering depends on the defined goal of the project and (local) circumstances that affect the costs. It may therefore differ from project to project and between locations which approach the most cost-effective.

One of the main difficulties in comparing sand nourishment against engineered solutions at the project level lies in defining the goal of the project: If the goal is to stop coastal retreat on a stretch of coast for a number of years, sand nourishment must be a part of the coastal protection scheme. However, in many cases along the Danish coast, project goals are defined with a local and short-term scope, despite regulation in the Coastal Act of 1988 which states the aim of coastal protection should not hinder or decrease the sediment budget. This definition of the aims of coastal protection strategy strongly affects which strategy is most cost-effective. At a short coastal stretch in the short term, an engineered solution is likely more cost-effective to stop coastal retreat. But in order to maintain the coastal profile and maintain or restore the sediment budget – as stipulated in the law – sand nourishment is the only way this can be achieved at all.

Aside from the definition of the projects goal', cost assessment of the alternative strategies may also prove difficult as the strategies are so different from each other. Costs of engineered solutions consist of initial construction costs, and periodic maintenance costs after that. Sand nourishment needs regular application. Although initial investment costs are likely lower compared to construction of engineered solutions, the costs of periodical application are higher. This is why it is recommended to use life-cycle cost analysis, in which the costs of both strategies for a long, fixed period of time (e.g. 100 years) is compared.

2.2.1 Life cycle costs of engineered structures and beach nourishment

Once the goal of a project is clearly defined, e.g. halting coastal retreat along a short or long coastal stretch for a determined period, strategies can be compared on cost-effectiveness. To be able to do this, a cost estimate is required for the different strategies. As beach nourishment and engineered structures have a very different cash flow over time, this should be done using life-cycle cost analysis. In this analysis the full range of costs of both strategies for a long, fixed period of time (e.g. 100 years) is compared, rather than looking only at initial construction costs.

Cost assessment

Some countries have official guidelines and standard numbers to be used in the costing of (coastal) infrastructure projects, but in most cases cost assessments of projects are done by engineering consultancies and/or public organizations: the amount of freely available data is limited and may be highly context (and country) specific. Hudson et al. (2015) describe an approach for costing engineered coastal protection structures and sand nourishment in the UK and include some standard numbers and cases from the UK. The range of reported costs is quite large as they are strongly affected by e.g. the size of the project and corresponding economies of scale. Chong and Tian (1996) compare costs for 30 coastal projects including both engineered and sand nourishment solutions used in Malaysia.

The range in construction costs of beach nourishment depends strongly on the price of a cubic meter of sand. This can vary depending on availability and transporting distance from source to application site, and availability of contractors to undertake the work (AVOID 1, 2010). Long-term costs depend on the required volume and the required frequency of replenishment[1].

Based on the reported cost figures from Chong and Tian (1996) and Hudson et al. (2015), their assumptions for average lifetime of structures and assuming 5% annual maintenance costs for engineered structures, **Table 2.1** shows the results of a quick-scan assessment of the range of lifecycle costs for each strategy over a time horizon of 100 years.

[1] Prices of sand for nourishment range from 4-6 €/m³ across Europe, with a high variability found in the UK 3,5-35 €/m³ and at times quite low costs in the Netherlands with 2-6 €/m³. Climate-Adapt (2015) also reports some figures per 100 m length of coastline from the UK: € 6,300-251,700. This does not include ongoing management, control structures and minor works.

	Hudson et al (UK)					Chong and Tian (Malaysia)				
	Construction costs per 100 meter coastal stretch		**Expected lifetime in years**	**LCC**		**Construction costs per 100 meter coastal stretch**		**Expected Lifetime in years**	**LCC**	
	Min	Max		Min	Max	Min	Max		Min	Max
Groynes	267	300	50	**869**	**977**	54	243	30	**199**	**896**
Revetments (rock)	156	2911	30-50	**737**	**10751**	75	291	30	**279**	**1075**
Breakwaters	175	220	50	**571**	**718**	-	-	-	**-**	**-**
Sand nourishment	193	295	10-30	**350**	**1259**	140	404	10-30	**254**	**1724**

Table 2.1 Range of construction costs in £*1000, price level 2015, adapted from Chong and Tian (1996); Hudson et al. (2015). Lifecycle costs are estimated assuming annual maintenance costs at 5% of construction costs and using a discount rate of 2,5%.

The key lesson from these studies is that there is no clear 'winner' in terms of lowest costs: which strategy has the lowest lifecycle costs strongly depends on local circumstances and elements such as the length of coastal stretch to be protected, proximity of material source and average lifetime (depending on e.g. local sediment dynamics and wave intensity). This cost-based comparison should not be confused with cost-effectiveness: a strategy can be very cheap, but not be effective in achieving the goal at all.

2.2.2 Evidence on cost-effectiveness from other countries

To analyze cost-effectiveness, the lifecycle costs of a strategy are weighed against the effect they achieve: e.g. reducing erosion by 5 meters along a 100 m stretch for 5 years costs $ 1 mln in Strategy A, and $ 1,3 mln in Strategy B. Cost-effectiveness analysis can only be done when there is one shared, pre-defined goal or metric against which to measure effectiveness of coastal protection. It is also good to note that cost-effectiveness analysis does not address adverse effects of a strategy regarding e.g. downdrift erosion or ecological disruption, nor address any added values a strategy may have beyond the pre-defined goal.

Although there are no large-scale studies that compare evidence from across the globe which strategy is more cost-effective for coastal protection, literature discusses various examples of cases where sand nourishment strategy indeed is more cost-effective.

For example in Stronkhorst et al., (2018) the authors assess the cost-effectiveness of sand nourishment along ~ 100 km long stretches of the Dutch coast and Portuguese coast in Aveiro, against two objectives 1) 'hold the line', in which coastline retreat along the entire stretch is directly restored with local sand nourishment and 2) 'sand balance', in which eroded high-value locations are restored every 5 years with sand nourishment. They find that particularly in the Aveiro region, where population density in flood-prone areas is limited and costs of sand are relatively high, a combination of sand nourishment in high value locations, engineered protection in others and managed retreat in low value areas is the most cost-effective strategy and helps avoid lock-in situations. Along the Dutch coast sand nourishment is a cost-effective strategy particularly in the long term to cope with SLR, as there are large sand resources available in the North sea and there is a high number of people benefiting from coastal protection (5,6 mln).

The design of the nourishment project itself also affects its cost-effectiveness. In a study for the UK, Brown et al. (2016) find that smaller nourishment interventions (55 ha) are more cost-effective on the short term (0-20 years), although large-scale (mega) nourishment (165-270 ha) become more cost-effective when considering a longer planning horizon (50-100 years).

2.3 Co-benefits of sand nourishment

Even if sand nourishment is not the most cost-effective solution to achieve a pre-defined goal, it may still be the most desirable alternative from a broader socio-economic perspective. Where hard engineering solutions often have negative side-effects such as aggravating downdrift erosion and loss of habitat, sand nourishment supports or increases co-benefits beyond coastal protection such as recreation, habitat provision, drinking water provision and landscape quality. The value of these co-benefits depends on local circumstances: is there a tourism industry nearby, are there settlements that profit from these services? Of course, biodiversity benefits may also be significant but are generally hard to quantify or monetize.

A study along the Dutch coast comparing benefits of sand nourishment for flood protection and recreation showed that in the province of Zeeland benefits generally were 2 to 4 times higher than investment costs, and in the provinces of Noord and Zuid-Holland 1,3 – 2 times higher. In the less populated WaddenSea area those benefits only covered about 45-90% of investment costs: however, the significant benefits for nature in this important Natura 2000 area – Europe's largest wetland - are not included in this analysis (Taal and Oeveren-Theeuwes, 2019).

Despite the attractiveness of these co-benefits, it is not always easy to include the wider socio-economic perspective into the decision- making process regarding investments in coastal management, as this often requires widening the scope of projects and cooperating with more (and unfamiliar) stakeholders. Appendix 1 discusses a method which could be applied for this purpose.

3 The benefits of three decades of sand nourishment in Ringkøbing coastal area

3.1 Case description

On the coastal stretch between Nymindegab and Søndervig in the municipalities of Ringkøbing and Holmsland, sand nourishment has already been applied for decades as a coastal protection strategy. With a flourishing tourism industry, a regionally important harbor at Hvide Sande and high value habitats for nature, the region has benefited significantly from this strategy, beyond protection from flood risk and erosion.

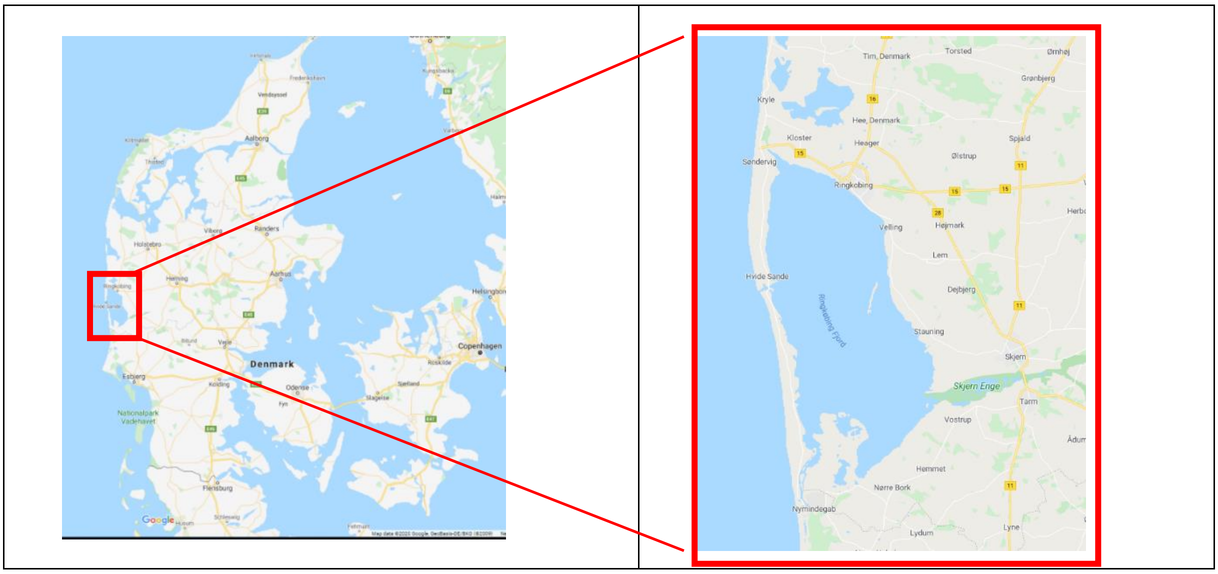

Table 3.1 Location of the coastal stretch in front of the Ringkøbing Fjord between Søndervig and Nymindegab

Flood and erosion risk between Nymindegab – Søndervig

The coastal stretch between Nymindegab and Søndervig is characterized by a beach and a narrow row of dunes between the North Sea and the low-lying hinterland. Along the shoreline the configuration of sand bars changes with weather conditions: in calm periods they are close to the beach, during storms they move away. In the entire stretch there is substantial natural coastal retreat and a relatively high-water level during storms. As the narrow dune belt does not provide significant protection (the required safety level is at the 1/100 year water level), there is quite a serious flooding hazard in the region: in case of dune penetration particularly vacation homes and nearby roads would be affected by flooding, and secondary also towns along the Ringkøbing fjord.

Institutional system and legislation

Since a storm event in 1981 the stretch between Lodbjerg and Nymindegab is protected with a Joint agreement. This means that the Danish government, represented by the coastal authority, and local municipalities agree on a coastal management strategy which is renegotiated every 5 years: the next five-year agreement expires in 2024. Large parts of the West coast fall under Natura 2000 legislation because of their great importance to migrating and nesting birds: in the project area the southern stretch below Hvide Sande is Natura 2000.

Socio-economic system

With approximately 3 million overnight stays, the entire area is an important and attractive area for inland and international tourism: the beach, attractive landscape and natural areas which provide recreation opportunities such as boat trips, hiking, bird watching and fishing, visiting towns and museums, lighthouses and wartime bunkers (Figure 3.1). Key overnight areas are campings (10) and mostly privately-owned vacation homes in small concentrations along the entire strip between Søndervig and Nymindegab (5000). A new park is currently being constructed in Søndervig: this will also have construction of private ownership and renting out tourists through an intermediate. Although the majority of residents of the area earn their income directly or indirectly from tourism, there are also some farmers who use the Ringkøbing lagoon coast as farmland for grazing of cows. In Hvide Sande there is a medium-large port with shipbuilding, fishing and catering to the offshore industry in the North Sea as its main activities. The port is also used for recreational trips and boat sports. In the village of Ringkøbing there is a small recreational harbor, and along the west coast of the Ringkøbing fjord a number of small privately-owned recreational harbors.

Figure 3.1 Socio-economic context of project area

Key stakeholders of coastal management in the area include property owners (representatives) along the coast and in the low-lying areas behind the coastline. flooding of dune valleys occurs mainly from pluvial (rain) flooding and saturation of ground – these actors are particularly interested in a broad beach to increase attractiveness of the area.

3.2 Coastal protection strategy

The goal set for the coastline is to protect against flooding at the 1:100 year event level. This includes a minimum requirement for the dune height and width, based on assessment of coastline retreat. Since 1990 the coastal protection has been based on sand nourishment. Before that time hard engineered constructions reduced the landward movement at this coastal stretch, but did not stop the erosion process. There is still a risk of flooding from the Ringkøbing Fjord due to the relatively low safety level: particularly in dune valleys, vacation homes occasionally may flood originating from high water levels in the Ringkøbing Fjord (Lassen et al., 2018). Along the coastal stretch between Nymindegab and Søndervig both shoreface and beach nourishment have been applied at intervals of 5-10 years.

Impact of coastal protection strategy on the landscape

The current strategy does not only bring a halt to chronic erosion, it also significantly increases the landscape quality, natural habitat provision and provides recreation opportunities. The pictures in Table 3.2 illustrate what the coast at various locations along the coastal stretch could be expected to look like if a conventional engineering strategy would be selected.

Søndervig current situation	Søndervig without BwN
	
Krogen current situation	*Krogen without BwN*
	
Hvide Sande current coastline	*Hvide Sande without BwN*
	

Table 3.2 Images of coastline in Søndervig, Krogen and Hvide sande in the current situation (with sand nourishment) and in the hypothetical case of a conventional engineered alternative to provide coastal protection.

3.3 Socio-economic value of sand nourishment in Ringkøbing-Skjern

The sand nourishment strategy does not only protect against flooding and chronic erosion: it promotes landscape quality by preserving dunes and beaches, and in doing so supports a range of ecosystem services such as recreation opportunities -(sun)bathing, walks along the beach, hiking in nature- and value of (holiday) properties. Tourism and recreation are the number one provider of income and job opportunities in the region: the sand nourishment strategy is a key condition that allows this sector to flourish.

It is difficult to quantify in economic terms to what extent the sand nourishment coastal management strategy has contributed to the development of this sector over the past decades and is still contributing to it today. But, as Ivan from the municipality of Ringkøbing puts it: '*We know that main reason people choose to visit our region is because of the sea, nature and the quiet. So* (if we would have a hard engineering coastal management strategy, red*) it may be expected this would keep some, but probably not all tourists away*.'

On another note, it was clear from the period before sand nourishment was applied in the area that a hard engineering strategy did not prevent chronic erosion along the coastal stretch between Ringkøbing and Nymindegab. Over time would have meant there was no or only a small beach and increasing threats to properties located close to the coast. This would have had a significant impact on property values and the attractiveness of investment in properties along the coast in general.

4 Scaling up BwN along the Danish Coast

4.1 What is scaling up?

Ultimate scaling up of innovative or new approaches such as BwN means the concept is applied in many areas and can be seen as 'common practice'. But scaling up also refers to more intermediate steps or developments that contribute to this end goal (Vreugdenhil et al 2012): for example, the inclusion of BwN in policies, programmes, policy documents, or pilot projects. Aside from the outcome (more applications of BwN strategy), the activities related to scaling up can be diverse: it can be the application of the concept of sand nourishment in a new location, or more specifically the application of specific knowledge about challenges in design, maintenance, monitoring or implementation arrangements in a new setting. This might also mean the formation of new actor coalitions – e.g. nature organizations, coastal authorities and local landowners.

The process of scaling up mostly goes through people as they take the knowledge and experience with them in new initiatives and contacts with others. Through their enthusiasm and knowledge, they stimulate consideration of a BwN approach in new projects. Ideally this process is supported by well documented and accessible knowledge that provides a reliable knowledge base, which can be further spread by education and courses for a wide-spread and long-term effect. A particularly effective way to transfer enthusiasm for the concept is through field visits of project locations.

4.2 Barriers in scaling up

Worldwide

Lessons learned from worldwide efforts to scale up BwN relate to the mismatch between the conditions for successful application of BwN and the institutional structure in a country. This is because the benefits are not necessarily for those with the largest influence in the process, uncertainties are often high, and institutions are not designed to work cross-sectoral and deal with integrated approaches (Janssen et al. 2020). Additionally, the integrative character of BwN – requiring input from various disciplines and providing a range of values - means that institutions must be capable of dealing with and valuing different benefits of BwN approach beyond erosion and flood risk protection, such as nature/biodiversity, recreation and quality of living. However, existing mandates and decision-making process on investments are often single-objective and not suited to take the wider range of benefits into consideration. For a successful scaling up of BwN the institutional and financial structure of coastal management might need re-aligned, including e.g. standard consideration of BwN in procedures and acceptation in contracting and licensing.

Barriers for scaling up BwN in Denmark

In the case of Denmark the institutional context presents an even higher challenge to scaling up BwN with in the majority of locations private owners responsible for coastal protection, supported by municipalities: in many other countries there is often some degree of public responsibility for coastal management. The initial response of many private land and property owners will be to limit costs as much as possible, use well-proven and familiar approaches and limit dependency and cooperation over a larger area. In some cases, there may even be a disincentive to invest in sand nourishment as this promotes widening of public beaches which in turn attracts more visitors in front of their property.

This local responsibility for coastal management also brings the problem of knowledge and capacity: coastal management is complex, and in most cases local stakeholders and municipalities will not have the knowledge to take long-term and downdrift impacts into consideration. Although the Danish coastal authority supports decision making in this context, it can be challenging with changing administrations and land owners to develop and maintain a basic knowledge level of coastal management strategies, and the need for continuous and sometimes volatile (e.g. after acute erosion events) investment.

If upscaling is considered to the East Coast and inner coasts (of lagoons) there is also a challenge of a more technical nature. Although sand nourishment is technically applicable everywhere along the Danish coast, the experiences with sand nourishment from the inner Danish coasts are few, and not widely known in the coastal communities.

4.3 Recommendations for scaling up

In general, looking further ahead into the needs and challenges of the future and building new coalitions is essential in scaling up innovations such as BwN. For an idea to be embraced, particularly an idea surrounded by uncertainties and potentially higher investments like BwN, it takes time before it is considered as an interesting alternative. Knowledge gaps need to be addressed, and exercises like societal costs benefit analyses can contribute to the decision-making process. While working on existing projects, new potential areas to apply sand nourishment can be identified and prioritized.

Along the Danish Coast, sand nourishment is theoretically applicable everywhere. However, evidence from other countries suggest that it is particularly worthwhile in locations with high erosion rates, tourism sector, high value for nature and/or medium to high density in populations. In these locations, active support in what the added value of applying BwN could be with local landowners and municipalities is valuable (see also Appendix 1), as well as developing a location – specific business case (improving the database for price estimations) or cost-benefit analysis. The stakeholders can also be invited for field visits to other areas with active sand nourishment as inspiration and to learn from locations where this approach has been applied before. Additionally, appointing local ambassadors in key organizations – land owners, tourism sector representatives, nature organizations, municipalities - that promote the concepts can be very valuable in spreading the idea and creating enthusiasm.

5 Conclusion

The Danish Coast is subject to chronic and acute erosion. In some locations (~120 km) where protection against flooding and erosion is important to protect key infrastructure or densely populated hinterland, the central government shares responsibility for coastal management with local municipalities via Joint Agreements. In these locations, sand nourishment has been applied successfully in the past decades as the coastal management strategy. However, in other locations local landowners bear responsibility for the protection of their property. In those locations, there is often a tradition of conventional 'hard' engineering solutions to protect the coast, such as groins or revetments: the fragmented ownership situation and private incentives (e.g. cost minimization) complicate a long-term and large-scale vision for coastal management.

Evidence from other countries suggests that in many cases there may be various benefits of sand nourishment over hard protection. Hard engineered protection aggravates erosion downdrift, may be more expensive on the long term and reduces landscape quality and habitats, whereas sand nourishment preserves and even promotes these aspects. Even when looking at cost-effectiveness at the local project level on the short-term, beach nourishment can be an attractive alternative, but particularly when addressing coastal retreat in case of disturbed sediment budgets in a longer spatial and temporal scale it is the only feasible alternative: possibly in combination with engineered alternatives. In Denmark, the coastal management strategy of the strip in the Ringkøbing-Skjern and Hvide Sande municipalities shows that decades of sand nourishment have achieved the safety and dynamic profile goals as well as contributed to a flourishing tourism industry of high economic value to the area.

To scale up this approach along the Danish Coast, finding the right arguments to convince local stakeholders is needed to support the required paradigm shift from a local, short-term perspective to a long-term, large scale perspective. These arguments may be found in developing cost-based business cases, but particularly require more open discussion with wider stakeholder constellations on the values derived from coastal protection and learning from other cases and locations where sand nourishment has been applied successfully, like in the Ringkøbing area.

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A1 Appendix: Added value of Cooperation in BwN

In 2019 Janssen et al. developed a participatory workshop approach to support cooperation between a range of stakeholders, particularly in the setting of promoting building with nature in the Netherlands. The approach consists of a participatory process that focuses on mapping out incentives and values that various stakeholders derive from cooperation and identify promising cooperation/ coalitions. The approach is based on social dilemma/ game theory and to identify situations in which cooperation could lead to greater added value for all but individual incentives may lead to a suboptimal outcome: as often the case with BwN. While originally designed as a series of workshops, a more light/ quick-scan approach could be used in the setting of coastal management along the Danish coast to identify the added value of different cooperative coastal management strategies for all stakeholders involved in a location, and to identify potential cooperation in implementing the most desirable strategy.

A1.1 Approach

The process will follow 5 steps to arrive at a concrete plan for cooperation in future, using the 'scan, focus, act model'[2] (*Figure 1*). The scanning phase is about diverging and assessing the possibilities. In this phase, knowledge and ideas are shared. Step 1 is about introduction and getting acquainted with each other and the subject. In step 2, coastal strategies and chances for cooperation are identified. The 'focus' phase is to elaborate on the results from the scanning phase. In step 3 the coastal strategies will be valued by the stakeholders, using their own criteria. Step 4 is the analysis step in which the results are translated into possibilities for cooperation and added value of the coastal strategies. The last phase, the 'act' phase, is about interpreting the results and (if applicable) making an action plan.

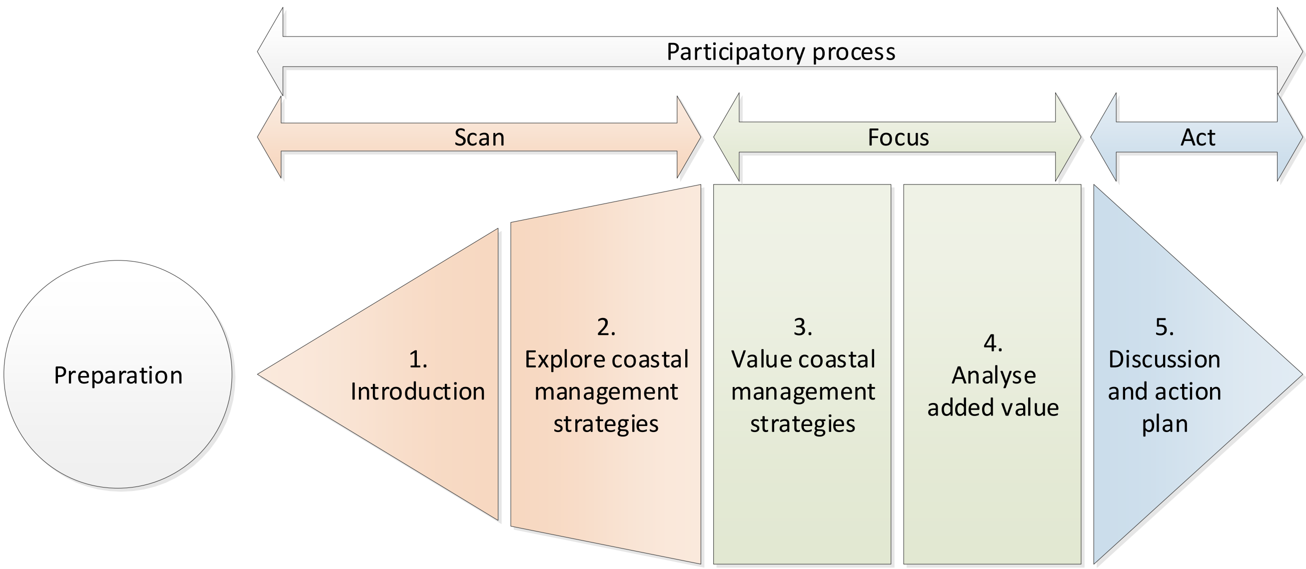

Figure 1 The scan, focus, act model and the 5 steps towards added value of coastal management and cooperation.

[2] http://legacy.mgtaylor.com/mgtaylor/glasbead/SFA.htm

A1.2 Introduction

Goal Getting acquainted with each other (if not already so), the context and creating a shared understanding of the problem (knowledge base).

Result Willingness and trust to work with each other in this activity, participants have knowledge about each other and a shared knowledge base.

Approach

1. General introduction round
2. Presentation of coastal plans/ current coastal management strategy
3. Presentation about Building with Nature approach/ alternative coastal management
4. Participants share their views on the local coastal system and how erosion affects them. This will differ for ach stakeholder and helps to create a shared understanding of the problem. A shared knowledge base prevents discussion about the characteristics of the problem later in the process.

A1.3 Explore coastal management strategies

Goal Identify coastal management strategies and the opportunities for cooperation.

Result List of coastal management strategies (such as individual rock revetments or a cooperative sand nourishment strategy) and the relevant stakeholders that should be involved in each strategy for successful implementation.

Approach

1. Make a list of coastal management strategies based on the coastal plan.
2. The participants are invited to add coastal strategies if they feel relevant alternatives are missing.
3. Together determine which stakeholders are involved in the implementation of each strategy, and what other stakeholders should/could be involved as well.

If possible, make the strategies visible by using drawings. These can be made beforehand, if other strategies are added we can add a drawing on the spot.

Figure 2 Stakeholder workshop to assess added value of cooperation at Wadden Sea coast (NL)[3]

A1.4 Value coastal management strategies

Goal Assess the value of the strategies by each stakeholder.

Result Valuation per stakeholder for each strategy in a multi-criteria analysis table (*Table 1*), based on their own criteria.

Approach

1. Stakeholders make a list of criteria which they find important to assess the strategies. The results will be shared to understand from each other, what the relevant criteria are.
2. Stakeholders fill in the multi-criteria analysis table, in which they value the strategies based on their own criteria.

Table 1. Example of multi-criteria table

Strategy → Criteria ↓	Weight criteria	Strategy 1 (values 0-5)	Strategy 2 (values 0-5)	Strategy 3 (values 0-5)
Criterium 1	1	1	0	2
Criterium 2	2	3	3	4
Criterium 3	1	2	5	2
Total score	4	=1*1+3*2+1*2 = 8	=0*1+3*2+5*1 = 11	=2*1+4*2+2*1 **= 12**
				Favourite!

A1.5 Analyse added value

Goal Conclude the valuation of strategies and added value of cooperation.

Result Insight in valuation of strategies by the stakeholders, and if the stakeholders think alike or not.

Approach

1. Calculates the results for each strategy and stakeholder.
2. Present the valuation of coastal strategies, and which ones are valued the most.

A1.6 Discussion and action plan

Goal Reflect upon results and define follow-up needed.

Result Discussion and (if applicable) follow-up actions.

Approach

1. Based on the analysis feasible strategies are identified (where stakeholders that are involved also value the strategy) and no-go strategies (where crucial stakeholders do not value the strategy).
2. Reflect on how to continue

[3] From Janssen 2019 (concept) *Handreiking meerwaarde van samenwerken.*