Samantha Tobias

# Vegaøyan: Impact and Management of Sea Level Rise and Flooding on World Heritage Sites

## Introduction

Rising sea levels and consequent coastal flooding pose an increasing threat to the island archipelago Vegaøyan off the western coast of Norway.

A short assessment of the situation regarding sea level rise due to climate change will be presented in the first section of this essay, leading to an introduction of Vegaøyan, the World Heritage Site in question: A cultural landscape renowned for the tradition of eider down harvesting, where cultural and natural heritage alike is at risk to be inundated.

Therefore, the second part of this essay will evaluate the risk rising sea levels and coastal flooding pose to the low-lying islands, especially to the archaeological sites, kelp forests, and birds. The implications for the local traditions and the people living there will be inferred, and the possible migration of the island inhabitants discussed.

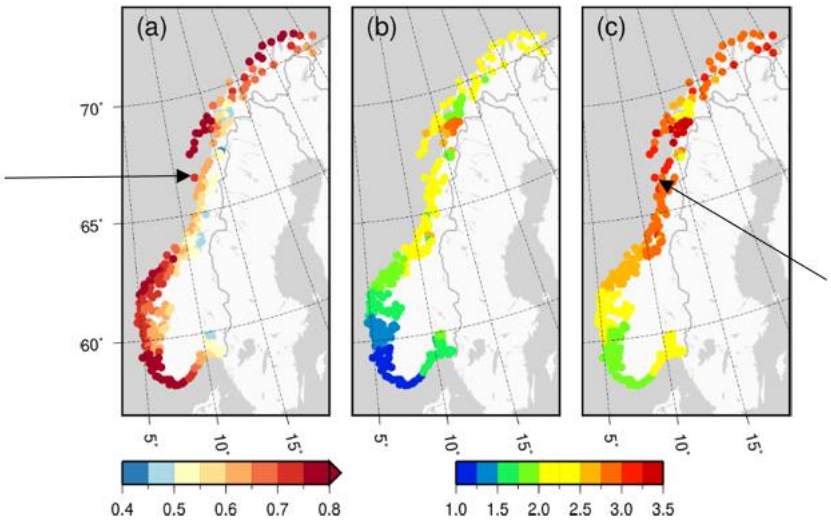
Finally, I will evaluate mitigation strategies and focus on relocation and coastal protection as viable options for Vegaøyan. The latter is an umbrella term as both man-made defences like breakwaters and nature-based protection such as kelp forests will be considered. Pointing out that there is a lot of research that needs to be done to assess the situation further, I will conclude that currently, the best strategy for Vegaøyan is the rehabilitation of the kelp forest and its associated ecosystem.

## Sea Level Rise and Vegaøyan

IPCC (2021:28) assessed in their climate change report that the risk for coastal flooding due to sea level events is increasing in many locations around the globe. It is but one of the symptoms of climate change in the group of flooding-related threats: Global warming leads to melting ice, intensifying precipitation, storm surges, and riverflow events that threaten cities, livelihoods, and heritage sites.

Coastal flooding and its associated dangers such as erosion are of particular concern to low-lying areas (IPCC 2021:33).

By taking tides, storm surges, wave setups, and regional relative sea level rise into consideration a 100-year projection revealed Norway as an area vulnerable to ‘future extreme sea levels’ (Kirezci 2020:6).




Projected relative sea level (RSL) change for the period 2081–2100 relative to 1986–2005 (a), 200-year storm surge return height above MHW (b), and the sum of these two (c). For all figures the values are given in meters.

*Figure 1 (Adapted from Breili 2020:676) Projected sea level rise and storm surge for Norway*

Within the country, Lawrence (2011:22) projected an increased flood magnitude for the region of Nordland; the vulnerability of the region is further reported by Breili (2020:676). Fig. 1 shows a traffic light system of 'inundation hot spots' with arrows pointing to a low-lying island archipelago that is indicated as red and therefore 'at risk': Vegaøyan.

Vegaøyan's flood risk has been assessed by Marzeion and Levermann (2014:6[supplements]): They state that global warming of 2.7±1.0K will lead to the site being at least partly submerged below the local mean sea level (Marzeion/Levermann 2014:5, see Fig. 2). The IPCC predicts that a change in temperature of 2K will be reached by 2060 and a change of 2.7K by 2100 according to their 'intermediate' global warming scenario (IPCC 2021:18), which means the inundation of Vegaøyan by 2100 is more likely than not.

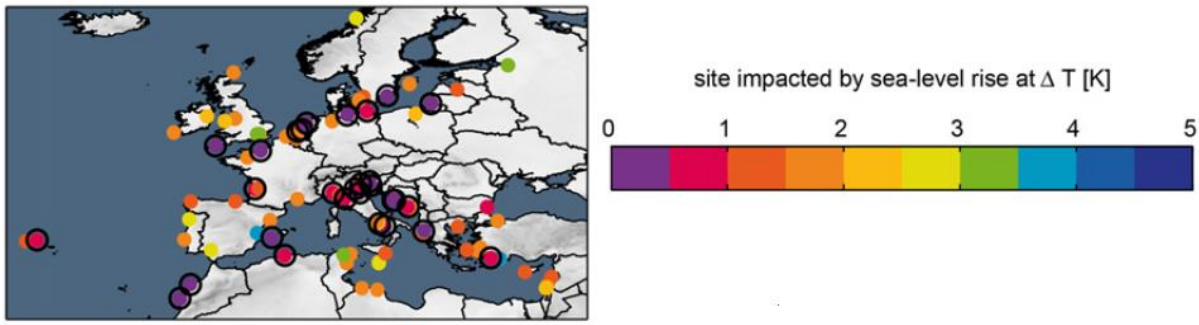



*Figure 2 (Adapted from Marzeion/Levermann 2014:5): World Heritage Sites impacted by sea level rise*

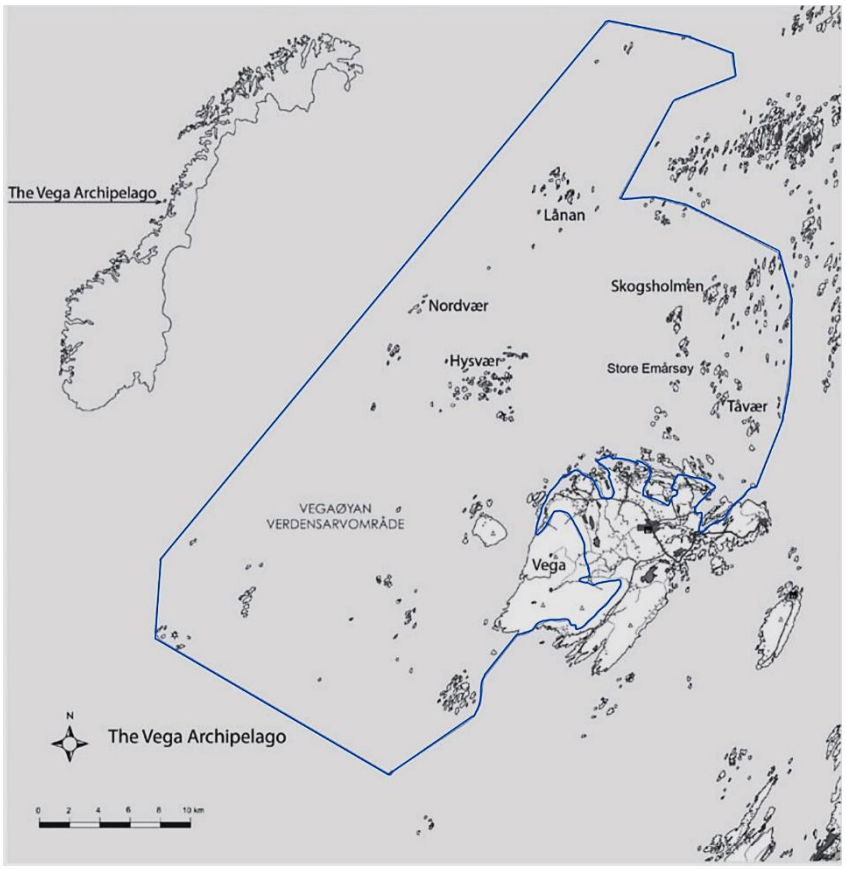



*Figure 3 (Adapted from Griggio 2016:114) Location of Vegaøya with WHS outlined in blue*

Located off the coast of Nordland (Fig. 3), Vegaøyan was inscribed as a cultural landscape World Heritage Site based on criterion (v) in 2004. The archipelago

> "*reflects the way generations of fishermen/farmers have, over the past 1,500 years, maintained a sustainable living in an inhospitable seascape near the Arctic Circle, based on the now unique practice of eider-down harvesting, and it also celebrates the contribution of women to the eider-down process."* (ICOMOS 2004:115)

The largest island, Vega, and its multitude of neighbouring islands have a rich history from Neolithic archaeological sites, fishing villages, and the farming landscapes to the traditional collection of eider down, the soft feathers of eider ducks (see Fig. 4). The ducks nest in 'eider houses', architecture specifically built for the birds to facilitate an easier harvest of the down from the empty nests when the ducklings leave them. The archipelago's eider tradition boomed in the 19$^{th}$ century but is reduced to 6 sites today. However, the wetlands and coastline provide a habitat for great biodiversity particularly for the Common Eider and Great Cormorant (breeding species) and the Barnacle Goose (a passing species), which lead to the inclusion in BirdLife International's (2021) selection of 'Important Bird and Biodiversity Areas'.

*Figure 4 (verdensarvvega 2021, photo by Cyril Russo) Women cleaning the eider down*

## Impacts of sea level rise on Vegaøyan

Sea water incursion, coastal erosion, and permanent submersion are the predominant consequences of rising sea levels (UNESCO 2007b:25), with the latter being the most extreme that would eradicate the existence of parts of the World Heritage Site and the Vega archipelago. Even a partial inundation would alter the amount of exposure of individual islands to the open sea and threaten the existence of sub-archipelagos. They are an element of biocultural importance, proven by the existence of a special Norwegian term for 'island group', øyvær (IUCN 2004:181).

Vegaøyan's archaeological heritage starts with preboreal sites (Glørstad 2013:76) and has the particularity that the in situ relation of sites to each other is of great importance: Climatic changes lead to a shore displacement of 3m per century, which means that people occupied sites at different elevations at different points in time (Bjerk 1990:5). Vega's oldest sites are 80m above today's sea level, late Bronze Age sites at 15-20m above sea level (Bjerk 1990:4). While a sea level rise to these heights within a plannable timeframe is improbable, changes in water-table levels, soil chemistry, and humidity cycles have an adverse impact on archaeological remains (UNESCO 2007a:52). Importantly for Vegaøyan, the stratification integrity can be affected as well due to cracking and heaving (UNESCO 2007a:52). This would classify as slow environmental deterioration.

There is additional risk to the Stone Age settlement site Åsgården on Vega, a 2300sqm area with 20 houses that date up to 9500BP (verdensarvvega 2021 citing Næss/Johansen), as it is located next to a river and may therefore be susceptible to fluvial floods.

The marine environment around Vegaøyan depends on strong east-west currents that exchange the water throughout the archipelago twice a day thanks to tides that range between 1.5-2m (verdensarvvega 2021, cited after Næss/Johansen). Sea level rise can alter currents (Lambeck 2002) and therefore impact the balance between tides, waves and the marine environment in the shallow waters around the islands. This ecosystem around Vegaøyan consists of kelp forests of *Laminaria hyperborea*, a macroalgae associated with great biodiversity because of the habitat it offers (Christie 2003).

In the 1970s the kelp forests around Vegaøyan started to decline because of sea urchin deforestation: With the disappearance of the kelp forests came significant ecological change, like decreasing fish populations (Norderhaug/Christie 2009:516). While the cause for this instance of sea urchin infestation is unknown (Norderhaug/Christie 2009), it may have been the rising sea temperature that stopped the sea urchin *Strongylocentrotus droebachiensis* from completely deforesting the macroalgae assemblage (Fagerli et al. 2013). However, with climate change associated rising temperatures also pose a problem for the heat-sensitive kelp (Steneck et al. 2002, Smale et al. 2013:4029).

Furthermore, a change in sea levels might impact the kelp forests due to a change in lighting conditions, as they rely on shallow depths and substrate and cannot grow on inundated hard rock. This has been proven for at least one other species of kelp (Graham 2007:72).

Further kelp deterioration poses a threat not only to the biodiversity in the immediate marine environment, but also to fishermen, whose struggle with the reduced fish populations would only worsen (Norderhaug/Christie 2009:523). Since fishing is part of Vegaøyan's cultural heritage, those traditions are indirectly threatened as well.

The loss of kelp forests will also impact birds like the eider duck that forage in kelp (Gundersen et al. 2017:50). With 222 bird species, 110 of which breed in the archipelago (UNESCO 2004:9), Vegaøan's avian biodiversity is an important part of its heritage. As increased flooding risks have been linked to reduced reproductive output in one species of bird in the Wadden Sea (van de Pol 2010:720), it is likely that rising sea levels will lead to habitat loss and a disturbance of roosting and breeding sites in the Vega archipelago as well.

*Figure 5 (verdensarvvega 2021, photo by Cyril Russo) Lånan's eider duck architecture*

The negative impact of climate change on the ecosystem will start a cumulative chain reaction: A decrease in eider duck populations will threaten the traditions around the down collection, and the changing ecosystem will limit fishing and farming opportunities. These are secondary and tertiary impacts of sea level rise.

It will impede the traditional local management of the landscape (Cave/Negussie 2017:222), possibly causing people to become more likely to migrate. A disruption of the community could lead to a breakdown of social interactions (UNESCO 2007b:25) and lead to depopulation: Because a lot of inhabitants left Vegaøyan in the 60s and 70s (ICOMOS 2004:113) there is precedent for this scenario, even though it was not related to a flooding risk then. A repetition of such resettlement would be detrimental to the cultural landscape. For instance, the previous decrease in population lead to buildings falling into disrepair, which may make them more susceptible to flood damage now.

All in all, the loss of traditions becomes an increasing threat, especially because the two largest eider duck sites on Lånan and Muddvær (verdensarvvega 2021, see Fig. 5) are located on particularly low lying øyvær, increasing their likelihood of at least partial submersion.

## Mitigation Strategies – a comparison

Even though Norway is not part of the EU, the EU Flood Directive (2007/60/EC:(14)) gives a good indication of the priorities within flood risk management: Prevention, protection, and preparedness.

Prevention would mean mitigation of climate change effects, for example by reaching the very low or low greenhouse emission scenarios with only minor or even decreasing global warming (IPCC 2021:18).

Inundations threats are uncompromising and can require extreme protection measures, such as the relocation of immovable heritage.

An example is the relocation of the Abu Simbel temple in Egypt as part of the Nubia campaign because the construction of the Aswan High Dam was going to cause the inundation of the temple (Hassan 2007). Herschel Island Territorial Park suffered a similar fate when a whaler's settlement was relocated further away from the rapidly eroding shoreline (UNESCO 2007a:58).

Considering it is a massive undertaking possibly detrimental to a site's authenticity, ICOMOS opposes relocation unless it is the last resort to save a heritage site from eradication (e.g. ICOMOS 2003:3.17). However, multiple further examples from non-World Heritage Sites in the UK and New Zealand (Bowcott 2008, Reimann 2018, Gregory 2008) show that relocation strategies are employed frequently. This practice blurs the line between natural change and a strict understanding of authenticity.

To apply the relocation strategy to Vegaøyan, buildings, piers, lighthouses, and the eider architecture could be moved to higher points on the islands or different islands altogether and would allow for adaptations like stilt houses. Since moving houses to the islands was a common practice during the 18$^{th}$ and 19$^{th}$ century (UNESCO 2004:10), relocation is not necessarily at odds with Vegaøyan's authenticity. However, it is unclear if drastic changes to the eider architecture would impact the eider ducks' breeding behaviour and how such relocations would be perceived by the community considering that privately owned buildings would have to be moved by their respective owners. This would tie into the depopulation threat and its associated loss of traditions.

A more feasible option are coastal protection strategies, which range from man-made defence structures to nature-based approaches.

The most famous mechanical defence against floods is the MOSE project in Venice, Italy. It consists of mobile barriers that lie submerged in the sea. They are raised for expected high tides above 110cm to close the entrances of the lagoon (UNESCO 2010:36). However, the system needs to be deployed in advance of the tides and is associated with high operating costs.

An example of a sea wall protecting a World Heritage Site is the Neolithic village Skara Brae on Orkney, UK, which is threatened by rising sea levels, storm surges, and the degradation of kelp forests (Day 2019:35). The sea wall was first constructed in the 1920s and undergoes close monitoring including biennial terrestrial laser scanning and extensive repairs and improvements (Day 2019:22).

While a mechanical defence like MOSE is probably financially unfeasible for Vegaøyan, there are already multiple breakwaters in use: The island Bremstein has two in 1921 completed breakwaters for its harbour, and Skjærvær (see Fig. 6) has two breakwaters built from 1930-36 (verdensarvvega 2021).

Building more structures to protect Vegaøyan's islands is a possible mitigation strategy to alleviate the threats rising sea levels pose to the archipelago, however, seawalls can have negative side effects like worsened erosion impact further down the coast (Miles 2020:36) and even lead to habitat loss for waterbirds (Fox 2015:199). Considering Vega's erosion resistance varies depending on the location (UNESCO 2004:18), this is a limitation of seawalls and breakwaters as a protection strategy.
Furthermore, the archipelago thrives off the regular exchange of its seawater so seawalls or a mechanical defence could inhibit the biodiversity and have adverse impacts on the ecosystem around the islands if the exchange of sea water were blocked.

*Figure 6 (verdensarvvega 2021, photo by Inge Ove Tysnes) Skjærvær with Vega and Søla in the background*

Around the world there are many different types of nature-based coastal protections, depending on the specific climate: By prioritising the restoration of the mangrove forests, Palau's Rock Islands Southern Lagoon World Heritage Site manages the mangrove ecosystem as coastal protection - this also benefits fishermen as fish stocks increase (Miles 2020). Similar efforts have been undertaken in Sundarbans in India and Bangladesh to conserve and rehabilitate mangrove forests to mitigate local sea level rise (UNESCO 2007a:36). The Great Barrier Reef, with a management plan that's considered the world's best practice, is equally looking to reduce stressors to improve the resilience of their corals to strengthen the ecosystem, which doubles as coastal protection (UNESCO 2007a:35).
While Vegaøyan is distinctly less tropical, the same principle can be applied: the naturally available coastal protection is kelp forest. The leafy biomass reduces the energy of oncoming waves, and its roots stabilise the sediment (Gundersen 2017:90). Breaking waves are reduced in velocity due to the altered water motion in and around the kelp (Smale 2013:4025) – the kelp endemic to the area around Vegaøyan reduces the swell energy of waves by as much as 60-75% (Mork 1996:324).

Therefore, a prioritisation of the kelp forest and reduction of anthropogenic stressors like overfishing is necessary to establish resilient kelp forests: A thriving ecosystem is more likely to effectively work as natural coastal protection. Realistically, this mitigation strategy can be implemented into the site's management plan and prioritised as a protection against the threat of rising sea levels.
To help the kelp forests rehabilitate from the sea urchin deforestation, methods from kelp aquaculture like transplantation could be considered and researched. To understand the impact climate change has on the kelp forest, a better understanding of its structure and functioning in different temperatures would be helpful (Smale 2013:4029) since the threat of climate change is multicausal and not only limited to rising sea levels and associated flooding.
Furthermore, there is evidence that oyster beds help to stabilise sediments and influence the tides and waves in the Netherlands (de Vriend/van Koningsveld 2012:18). A similar form of ecosystem engineering might be possible with blue mussels around Vegaøyan. This would tie in well with the ecosystem because they are the main diet of the eider duck (Gundersen 2017:66).

Finally, preparedness on the side of the community will need to be evaluated in direct communication with the people living on Vegaøyan: The lack of local opinions from people living and working on the Vega archipelago is a major weakness of this assessment. This is not only because the Outstanding Universal Value of Vegaøyan is directly related to their lifestyle and traditions (UNESCO 2004:112), but because their knowledge about this unique landscape is an important tool in the long-term management of the site, as they have managed it in their own ways long before it ever became a UNESCO cultural landscape.

Furthermore, the research around coastal flooding risks for the area is lacking: ICOMOS calls Vega an "exposed archipelago" (ICOMOS 2004:112) but neither flooding nor climate change are mentioned in their risk analysis. IUCN mentions Vegaøyan's exposure to ocean storms, but not in relation to rising sea levels or climate change (IUCN 2004:182).
In terms of flood risk assessment elaborate studies exist for World Heritage Sites in other parts of the world (e.g. Howard 2013 for all UK sites, Reimann 2018 for the Mediterranean) that need to be repeated for Norway. It is notable that even studies that do assess flood risk in Norway (Lawrence 2011, 2012, Breili 2020, Beldring 2008) or in Europe with mention of Norway (e.g. Madsen 2014) gloss over the heritage sites at risk. Specifically, a climate risk assessment like the report for Orkney (Day 2019) would be useful since other climate change drivers may also apply to Vegaøyan and need to be considered in a long-term management plan.

## Conclusion

Rising sea levels pose a mid- to long-term threat to Vegaøyan with serious consequences: Parts of the archipelago may become submerged. Additionally, the area must expect a negative impact on its biodiversity: The ecosystem will likely suffer from its kelp forests deteriorating due to altered lighting and temperature conditions; consequently fish stock and bird populations may decline. Since the ecosystem is tightly connected to the intangible heritage of the archipelago this poses a direct threat to the traditions of eider down collecting, fishing, and managing the landscape that has been assigned outstanding universal value. Furthermore, the increased flood risk may lead to depopulation of the already sparsely inhabited area.

Protection strategies like relocation of the buildings and the construction of seawalls need further consideration regarding their feasibility and possible negative consequences respectively. Instead, a focus on nature-based protection is recommended: By reducing anthropogenic stressors and with active rehabilitation measures, the kelp forest should be prioritised to mitigate the threat rising sea levels pose.

Furthermore, any management of the climate change threat should heavily involve the community as the local people have managed Vegaøyan for thousands of years and can share valuable knowledge. Global prevention efforts to climate change and further research for a better evaluation of the situation should tie into this local knowledge to conserve Vegaøyan's cultural landscape in the long term.

In summary, protection measures from other World Heritage Sites contain transferable knowledge that is applicable to Vegaøyan's situation. Noticeably, some of these strategies are aimed at cultural heritage sites only, like relocation. For natural heritage and cultural landscapes with intangible heritage, this drastically reduces viable options, which emphasises that we live in a constantly changing world. Ducks and traditions may have to adapt if their environment becomes irreversibly altered through partial submersion, but until that happens, coastal protection and especially the kelp forests are of the utmost importance to Vegaøyan.

3183 words

## Bibliography

Ammer, I. (2019): ‚Die Schutzmauern stehen'. *Donaukurier*, 22/05/2019. Last accessed at https://www.donaukurier.de/lokales/riedenburg/DKmobil-Die-Schutzmauern-stehen;art602,4192796 on 10/10/2021

Beldring, S., Engen-Skaugen, T., Førland, E. and Roald, L. (2008): Climate change impacts on hydrological processes in Norway based on two methods for transferring regional climate model results to meteorological station sites. *Tellus A – Dynam. Meteorol. Oceanograph.,* 60, 439-450.

BirdLife International (2021): *Important Bird Areas factsheet: Vega archipelago.* Last accessed at http://datazone.birdlife.org/site/factsheet/vega-archipelago-iba-norway on 06/10/2021

Bowcott, O. (2008): 'Stone by stone: rebuilt tower open to public'. *The Guardian*, 29/08/2008. Last accessed at https://www.theguardian.com/artanddesign/2008/aug/29/architecture.heritage on 09/10/2021

Breivik, H. M. (2014): Palaeo-oceanographic development and human adaptive strategies in the Pleistocene-Holocene transition: A study from the Norwegian coast. *The Holocene*, 24(11), 1478–1490.

Breili, K., Simpson, M.J.R., Klokkervold, E. and Roaldsdotter Ravndal, O. (2020): High-accuracy coastal flood mapping for Norway using lidar data*. Natural Hazards and Earth System Sciences*, 20(2), 673–694.

Cave, C. and Negussie, E. (2017): *World Heritage Conservation: The World Heritage Convention, Linking Culture and Nature for Sustainable Development.* London: Routledge.

Christie, H., Jørgensen, N.M., Norderhaug, K.M. and Waage-Nielsen, E. (2003): Species distribution and habitat exploitation of fauna associated with kelp (Laminaria hyperborea) along the Norwegian coast. *Journal of the Marine Biological Association of the United Kingdom*, 83(4), 687-699.

Church, J.A., Clark, P.U., Cazenave, A., Gregory, J.M., Jevrejeva, S., Levermann, A., Merrifield, M.A., Milne, G.A., Nerem, R.S, Nunn, P.D., Payne, A.J., Pfeffer, W.T., Stammer, D., and Unnikrishnan, A.S. (2013): Sea Level Change. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge/New York: Cambridge University Press.

Clausen, K.K., Stjernholm, M. and Clausen, P. (2013): Grazing management can counteract the impacts of climate change-induced sea level rise on salt marsh-dependent waterbirds. *Journal of Applied Ecology*, 50, 528–537.

Codino, R. (2021): 'Il Mose non si alza, la Basilica di San Marco va sott'acqua'. *Ansa*, 05/10/2021. Last accessed at https://www.ansa.it/sito/notizie/cronaca/2021/10/05/il-mose-non-si-alza-la-basilica-di-san-marco-va-sottacqua_4af929bb-b1fa-420d-abca-0a654490a7f1.html on 10/10/2021

Day, J.C., Heron, S.F., Markham, A., Downes, J., Gibson, J., Hyslop, E., Jones, R.H., Lyall, A. (2019): *Climate Risk Assessment for Heart of Neolithic Orkney World Heritage Property: An application of the Climate Vulnerability Index.* Historic Environment Scotland, Edinburgh.

De Vriend, H.J. and Van Koningsveld, M. (2012): *Building with Nature: Thinking, acting and interacting differently*. EcoShape, Building with Nature, Dordrecht, the Netherlands.

EU Directive 2007/60/EC (2007): EU Directive 2007/60/EC on the assessment and management of flood. *Official Journal of the European Union*, L 288/27.

Fagerli, C.W., Norderhaug, K.M., Christie, H.C. (2013): Lack of sea urchin settlement may explain kelp forest recovery in overgrazed areas in Norway. *Marine Ecology Progress Series*, 488, 119-132.

Fox, A.D., Jónsson, J.E., Aarvak, T., Bregnballe, T., Christensen, T.K., Clausen, K.K., Clausen, P., Dalby, L., Holm, T.E., Pavón-Jordan, D. and Laursen, K. (2015): Current and potential threats to Nordic duck populations—a horizon scanning exercise. *Annales Zoologici Fennici*, 52(4), 193-220.

Gundersen, H., Bryan, T., Chen, W., Moy, F.E., Sandman, A.N., Sundblad, G., Schneider, S., Andersen, J.H., Langaas, S. and Walday, M.G. (2017): *Ecosystem Services in the Coastal Zone of the Nordic Countries.* Nordic Council of Ministers.
Retrieved from https://norden.diva-portal.org/smash/get/diva2:1067839/FULLTEXT01.pdf on 06/10/2021

Glørstad, H. (2013): Where are the Missing Boats? The Pioneer Settlement of Norway as Long-Term History. *Norwegian Archaeological Review*, 46(1), 57-80.

Graham, M.H., Vasquez, J.A. and Buschmann, A.H. (2007): Global ecology of the giant kelp Macrocystis: from ecotypes to ecosystems. *Oceanography and Marine Biology*, 45, 39-88.

Gregory, J. (2008): Reconsidering Relocated Buildings: ICOMOS, Authenticity and Mass Relocation. *International Journal of Heritage Studies*, 14:2, 112-130.

Griggio, C. (2016): *The importance of grazing, haymaking and local heritage on the Vega Archipelago of Norway.* In: Island Landscapes. An Expression of European Culture [Gloria Pungetti (eds.)], London: Routledge.

Hassan, F.A. (2007): The Aswan High Dam and the International Rescue Nubia Campaign. *The African Archaeological Review*, 24(3/4), 73-94.

Howard, A.J. (2013): Managing global heritage in the face of future climate change: the importance of understanding geological and geomorphological processes and hazards. *International Journal of Heritage Studies*, 19:7, 632-658.

ICOMOS (2003): Icomos Charter- Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage.
Retrieved from https://www.icomos.org/charters/structures_e.pdf on 10/10/2021

ICOMOS (2004): Vegaøyan No1143 Evaluation.

Retrieved from https://whc.unesco.org/en/list/1143/documents/ on 03/10/2021

ICOMOS (2017): Vegaøyan No1143 Revised Evaluation.
Retrieved from https://whc.unesco.org/en/list/1143/documents/ on 03/10/2021

ICOMOS (2008): *Climate change and the effect on Norwegian World Heritage sites.* In: Heritage at Risk: ICOMOS World Report 2006/2007 on Monuments and Sites in Danger [M. Petzet and J. Ziesemer (eds)], Altenburg, Germany: E. Reinhold-Verlag.

IUCN (2004) Vegaøyan No1143 Evaluation.
From https://whc.unesco.org/en/list/1143/documents/ 03/10/2021

IPCC (2019): *Summary for Policymakers*. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

IPCC (2021): *Summary for Policymakers*. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press.

Kaltenborn, B.P., Thomassen, J., Wold, L.C., Linnell, J.D.C. and Skar, B. (2013): World Heritage status as a foundation for building local futures? A case study from Vega in Central Norway. *Journal of Sustainable Tourism*, 21(1), 99-116.

Lambeck, K., Esat, T.M. and Potter, E.K. (2002): Links between climate and sea levels for the past three million years. *Nature*, 419(6903), 199-206.

Lawrence D. and Hisdal, H. (2011): *Hydrological projections for floods in Norway under a future climate.* Norwegian Water Resources and Energy Directorate, Report no. 5 – 2011.
Retrieved from https://publikasjoner.nve.no/report/2011/report2011_05.pdf on 03/10/2021

Lawrence, D., Graham, L.P., den Besten, J. (2012): *Climate change impacts and uncertainties in flood risk management: Examples from the North Sea Region.* Norwegian Water Resources and Energy Directorate, Report no. 05 – 2012
Retrieved from https://www.osti.gov/etdeweb/servlets/purl/22017587 on 03/10/2021

JBA Consulting (2021): Case Studies – Coastal Engineering Design.
Retrieved from
https://www.jbaconsulting.ie/sites/www.jbaconsulting.ie/files/projects/Coastal%20Case%20studies_v2.pdf on 09/10/2021

Madsen, H., Lawrence, D., Lang, M., Martinkova, M., and Kjeldsen, T.R. (2014): Review of trend analysis and climate change projections of extreme precipitation and floods in Europe. *Journal of Hydrology*, 519, 3634–3650.

Marzeion, B. and Levermann, A. (2014): Loss of cultural world heritage and currently inhabited places to sea-level rise. *Environmental Research Letters*, 9, 034001.
Supplements retrieved from https://iopscience.iop.org/article/10.1088/1748-9326/9/3/034001/data on 04/10/2021

Miles, W., Grecni, Z., Matsutaro, E., Colin, P., Keener, V., Golbuu, Y. et al. (2020): *Climate Change in Palau: Indicators and Considerations for Key Sectors. Report for the Pacific Islands Regional Climate Assessment*. Honolulu, HI: East-West Center, https://www.eastwestcenter.org/PIRCA-Palau.

Van De Pol, M., Ens, B.J., Heg, D., Brouwer, L., Krol, J., Maier, M., Exo, K.M., Oosterbeek, K., Lok, T., Eising, C.M. and Koffijberg, K. (2010): Do changes in the frequency, magnitude and timing of extreme climatic events threaten the population viability of coastal birds? *Journal of Applied Ecology*, 47(4), 720–730.

Mork, M. (1996): The effect of kelp in wave damping. *Sarsia*, 80(4), 323-327.

Moy, F.E. and Christie, H. (2012): Large-scale shift from sugar kelp (Saccharina latissima) to ephemeral algae along the south and west coast of Norway. *Marine Biology Research*, 8(4), 309–321.

Norderhaug, K.M. and Christie, H. (2009): Sea urchin grazing and kelp re-vegetation in the NE Atlantic. *Marine Biology Research*, 5(6), 515-528.

Reimann, L., Vafeidis, A.T., Brown, S., Hinkel, J. and Tol, R.S.J. (2018): Mediterranean UNESCO World Heritage at risk from coastal flooding and erosion due to sea-level rise. *Nature Communications*, 9(1), 1-11.

Smale, D.A., Burrows, M.T., Moore, P., O'Connor, N. and Hawkins, S.J. (2013): Threats and knowledge gaps for ecosystem services provided by kelp forests: a northeast Atlantic perspective. *Ecology and Evolution*, 3(11), 4016-4038.

Steneck, R.S., Graham, M.H., Bourque, B.J., Corbett, D., Erlandson, J.M., Estes, J.A. and Tegner, M.J. (2002): Kelp forest ecosystems: biodiversity, stability, resilience and future. *Environmental conservation*, 29(4), 436-459.

Sundsvold, B. (2010): Stedets herligheter–amenities of place: eider down harvesting through changing times. *Acta Borealia*, 27(1), 91-115.

Tompkins, E.L., Nicholson-Cole, S.A., Boyd, E., Hurlston, L.A., Brooks Hodge, G., Clarke, J., Trotz, N., Gray, G. and Varlack, L. (2005): *Surviving climate change in small islands*: *A guidebook*. Tyndall Centre for Climate Change Research, UK.

UNESCO (2004): Vegaøyan -- The Vega Archipelago Nomination
Retrieved from https://whc.unesco.org/uploads/nominations/1143.pdf on 04/10/2021

UNESCO (2007a): Case Studies on Climate Change and World Heritage.
Retrieved from https://whc.unesco.org/en/activities/473/ on 02/10/2021

UNESCO (2007b): *Climate Change and World Heritage. Report on predicting and managing the impacts of climate change on World Heritage and Strategy to assist States Parties to implement appropriate management responses.* World Heritage Report Vol. 22.

UNESCO (2008): Development of Policy Document on Impacts of Climate Change and World Heritage. Document WHC-07/16.GA/10.
Retrieved from https://whc.unesco.org/en/CC-policy-document/ on 03/10/2021

UNESCO (2010): Managing Disaster Risks for World Heritage.
Retrieved from https://whc.unesco.org/en/managing-disaster-risks/ on 03/10/2021.

UNESCO (2014): *Climate Change Adaptation for Natural World Heritage Sites. A Practical Guide*. [Perry, J. and Falzon, C. (eds.)]. World Heritage Paper Series N°37.

UNESCO (2019): Operational Guidelines for the Implementation of the World Heritage Convention. WHC.19/01

van Wesenbeeck, B.K., van der Meulen, M.D., Pesch, C., de Vriend, H. and de Vries, M.B., 2016. Nature-based approaches in coastal flood risk management: Physical restrictions and engineering challenges. In *Ecosystem-Based Disaster Risk Reduction and Adaptation in Practice* (pp. 181-198). Springer, Cham.

verdensarvvega (2021): The Vega Archipelago World Heritage Area and Vega World Heritage Centre. Last accessed https://www.verdensarvvega.no/en/home on 09/10/2021

Kundzewicz, Z.W., Krysanova, V., Dankers, R., Hirabayashi, Y., Kanae, S., Hattermann, F.F., Huang, S., Milly, P.C., Stoffel, M., Driessen, P.P.J., Matczak, P., Quevauviller, P. and Schellnhuber, H.-J. (2017): Differences in flood hazard projections in Europe – their causes and consequences for decision making. *Hydrological Sciences Journal*, 62(1), 1-14.