



SCIENTIFIC FINAL REPORT

Two- and three-year projects and postdoctoral projects

Registration number, Östersjöstiftelsen: 55/17

Project manager: Elinor Andrén

Project title: Seaside - A multidisciplinary study of maritime environmental history

1. The three most important results of the project and what conclusions can be drawn from them

Shore displacement and human settlement in the Västervik region (Katrantsiotis et al., 2023; Katrantsiotis et al., in prep.; Palm et al., in prep). We have reconstructed the shore displacement the last 10,000 years in the Västervik-Gamlebyviken region on the southeastern coast of Sweden, an area that has been an important archaeological area since the Mesolithic. In this area shore displacement is characterised by regression caused by the isostatic rebound after the last deglaciation and superimposed on this the eustatic sea level changes are recorded. This results in a shore displacement which reflects a very changing environment with periods of coastline stability alternating with fast sea level changes. Our data indicate that the maximum sea level rise at ca. 8000 to 7500 years ago had a magnitude of about 4 m reaching an altitude of ca. 22 m above sea level. The results support evidence for an extended sea level highstand between 7400 and 4600 years ago which coincide with the Littorina Sea transgressions as recorded in southern Sweden. This Middle Holocene sea level highstand is attributed to a warmer climate and coincides with the final deglaciation of North America. Thereafter a fast regression is recorded with five meters in less than 500 years. This study shows the importance of actually conducting local shore displacement studies, and not relying solely on existing models, to construct accurate palaeogeographical maps of selected time windows and investigate the interplay between relative sea level change and the development of human settlements. The project's detailed results regarding environmental change and shore displacement in the analyzed area constitutes an important basis for a new knowledge and an expanded interpretation of archeological remains and settlement patterns in a local context.

Land use changes using different models (Vinogradova et al., submitted). Reconstructions of past land use and related land cover changes at local and regional scales are needed to evaluate the potential long-term impacts of land use on the coastal waters of the Baltic Sea. A pollen record from a small lake in our case study area on the Swedish east coast was analysed in high resolution together with available archaeological data to reconstruct local land use changes over the last 3000 years. Our results show that regional and local land cover changes are comparable over the last 1500 years (Late Iron Age to present), and that landscape openness was much larger locally than regionally (difference of ca. 20 – 40% cover over the last 500 years). This study shows that periods of largest potential impacts on the bay Gamlebyviken from regional and local land use are 200 – 950 CE (Late Iron Age) and 1450 CE– present, and of lowest potential impacts 950-1450 CE.

Long term changes in a coastal Baltic Sea setting (Andrén et al., in prep.). The aim was to scrutinize the impact of land use on the Baltic Sea coastal zone in a millennial perspective. Gamlebyviken was chosen as case study area due to its long history of archaeological documented agricultural activities, as well as its recent impact by and vulnerability to eutrophication. Further, the high-resolution soft sediments in Gamlebyviken form an excellent natural historic archive suitable for palaeoecological studies. The environmental status of the Baltic Sea coastal zone over the last 3000 years was studied by using siliceous



microfossils (mainly diatoms), stable nitrogen and carbon isotopes, organic carbon accumulation rates and lithological changes. Changes in land use and vegetation cover were modelled using pollen stratigraphical data (Vinogradova et al., submitted). The reconstructed regional vegetation cover shows that already 3000 years ago humans used the landscape with both cattle breeding (grasslands) and farming (cropland), but the impact on the Baltic coastal waters was minor. The diatom accumulation was quite high containing taxa indicative of high nutrients conditions/upwelling, and stable carbon isotopes show that the carbon was produced in the basin but did not result in elevated organic carbon accumulation. Less marine conditions in the Gamlebyviken from about 2500 years ago can be attributed to the ongoing shore displacement which resulted in a more enclosed embayment with only a narrow inlet area in Västervik today (Katrantsiotis et al., 2023; Katrantsiotis et al., in prep.). The medieval climate anomaly (950-1250 CE) is a time where extensive eutrophication is recorded in the open Baltic Sea (with cyanobacterial blooms and hypoxic bottoms), but in our case study area land use was not particularly intense and only minor environmental change is recorded in the coastal zone. The cold Little Ice Age (1400-1700 CE) which partly coincides with the Black Death, a pandemic when the Swedish population decreased by ca. 30% and many farms were abandoned, is recorded as a decrease in cropland and changes in the Baltic coastal zone visible as low carbon and diatom accumulation rates, increase in benthic diatom taxa (low turbidity), and high abundance in diatom taxa associated with sea ice (colder climate). The most spectacular changes in the Gamlebyviken occurred from about 1850 CE up to present times where maximum land cover (ca. 35%) in the region were covered by grassland and cropland on the expense of deciduous woodland and major changes indicative of a highly eutrophic environment was recorded in the coastal zone. These changes are visible as maximum in the stable nitrogen isotopes, maximum carbon and diatom accumulation rates, peak in planktonic diatom taxa (on the expense of benthic) and species indicative of high nutrient conditions. Variance partitioning show that more than 25% of the variance in the diatom assemblage is associated with land use changes. The variables grassland, cropland, and stable nitrogen isotopes are accordingly strong predictors of environmental change in the Baltic coastal zone as reflected by the diatoms.

2. The project's contribution to the international research frontline

This high-resolution study shows that coastal areas are very dynamic environments and has made it visible that both land use changes and climate change have impacted the coastal zone further back in time than previously thought. The interdisciplinary and multiproxy approach used in the SEASIDE-project, which combines knowledge of what has been going on in the terrestrial area (using various kinds of archaeological data, shore displacement, land use and land cover data) with records of historical environmental changes in the coastal zone, provides a powerful novel method to improve our understanding on long-term human impact and climate change.

The project has used the Landscape Reconstruction Algorithm (Sugita, 2007a, 2007b, doi.org/10.1177/0959683607075837; doi.org/10.1177/0959683607075838) to reconstruct changes in landscape openness in the study region using both published pollen stratigraphies and data produced within the project. This modelling approach provides a quantification of different land cover types that can be used as predictors of environmental change to statistically evaluate if long-term change in land use has been a nutrient source to coastal waters. This approach can be used in coastal areas worldwide.



3. The contribution of the research to the knowledge of the Baltic Sea Region and Eastern Europe

The Baltic Sea coastal zone is a dynamic environment due to the ongoing shore displacement and long-term paleoenvironmental reconstructions have therefore mainly been conducted in the open Baltic Sea. In the SEASIDE-project we used Gamlebyviken at the Swedish east coast as a case study area and show that it is possible to use coastal soft sediment as historical archive for high resolution studies. Awareness of the shore displacement, however, and how this has affected the paleogeography must be considered.

To improve our understanding of past sea level changes and its effects on coastal landscape dynamics and the development of human settlements there is a need to increase the spatial coverage of sea level records. Holocene shore displacement along the Baltic Sea coasts have exhibited temporal and spatial variability leading to large discrepancies regarding the timing and the number of transgressions between model results and available reconstructed sea level data. Our regional study of the shore displacement reveals the importance to perform such reconstructions since they differ from modelled data. Reconstruction of historical changes of shorelines are extremely important as we currently are experiencing climate change and a transgressive sea level which are affecting coastal areas worldwide at an accelerating rate. Our data have been included in the HOLSEA Baltic database constructed for relative shore-level data and contribute to fill a gap in Sweden (Rosentau et al. 2021, doi.org/10.1016/j.quascirev.2021.107071).

4. New research questions that the project has led to

- How general are our results on long-term environmental changes and the relationship between human impact (land use changes) and the environmental status of the Baltic Sea coastal zone? Can our results be extended to other coastal areas in the Baltic Sea and beyond?
- Humans living in our case study area has adapted to the changing sea level. How representative are these results in an international perspective and how flexible are our current society in this respect as a response to predicted future sea level rise?
- Determining the rate of sedimentation by dating the sediment in both isolated basins and in the sea provided new and unique knowledge about where to conduct archaeological investigations of cultural layers, artefacts and shipwreck under the seabed, and the possible future need for new methods and approaches.
- In our statistical analyses (PCA) the stable nitrogen isotope proved to be a very good proxy for land use, especially grassland. It would be very interesting to explore this result and study this correlation further in other coastal areas.
- Are there success stories where recent eutrophication has been effectively combated (e.g. through better implementation of coastal filters) or are the improvements achieved erased and counteracted by the effects of ongoing climate change?
- It would be interesting to study more pollen records from large lakes in the Baltic coastal area to confirm if the shifts between landscape openness and afforestation recorded in our data are regional or local events. This is also a very valuable archaeological source for interpreting the landscape development through time.
- The HOLSEA Baltic database shows that there is a gap of data from the Swedish east coast, especially between Blekinge and Bråviken (Rosentau et al. 2021). It would be good to fill this gap with more shore displacement studies, especially from the Bronze Age to present, since most studies concentrate on older development and the isostatic uplift varies in the area.



5. Dissemination of the results of the project within and outside the research community

Dissemination outside the research community (selected)

- We have ongoing been updating the community on the project by using the public channels provided by Environmental Science at Södertörn University, Västerviks Museum, and MARIS at Södertörn University, mainly Facebook (*Miljövetenskap vid Södertörns högskola; Västerviks Museum*).
- Students from Gamleby folkhögskola attended our first field work outside Gamleby, winter 2017 and made a movie.
- Kick-off of the SEASIDE project at Västerviks Museum January 2018 with invited guests and media. This resulted in an article in Västerviks-Posten, published January 30, 2018
- Interview with Elinor Andrén, Radio P4 Kalmar, broadcasted January 31, 2018
- Elinor Andrén and Thomas Andrén gave a presentation at "Arkeologiseminarium" in Blankaholm, February 2018 with the title "Tusentals år av miljöförändringar i Gamlebytrakten".
- Students in archeology from Södertörn University have carried out seminar excavations in connection with the SEASIDE project in spring 2018 and spring 2019.
- Västerviks Museum (Veronica Palm) invited the public and media to an "open house" at the research vessel Electra af Askö when we performed fieldwork in Gamlebyviken in collaboration with researchers from Stockholm University and the SEASIDE-project (Elinor Andrén, Thomas Andrén, Johan Rönnby). This resulted in an article published in Västerviks-Tidningen September 11, 2018. <https://vt.se/bli-prenumerant/artikel/r3154z2l/vt-bd-0kr-dpl>
<https://www.facebook.com/vasterviksmuseum/posts/10156718833538615/>
<https://www.havet.nu/manniskans-paverkan-sedan-stenaldern>
- Elinor Andrén, Thomas Andrén and Johan Rönnby participated in European Researchers' Night (*ForskarFredag*), Friday September 24 arranged by Veronica Palm at Västerviks Museum on the theme "Leva vid vatten – från forntid till nutid". <https://www.facebook.com/vasterviksmuseum/posts/10159890936358615/>

Dissemination within the research community

- Elinor Andrén and Thomas Andrén had a lunch-seminar at the Department for Environment, Development and Sustainability Studies, Södertörn University in February 2018, with the title "*SEASIDE – A multidisciplinary study of maritime environmental history*".
- Andrén, E., Holmlund, J., Rönnby, J., Palm, V., Vinogradova, O., Andrén, T. *SEASIDE - A multidisciplinary study of maritime environmental history*. 14th International Paleolimnology Symposium, Stockholm, 18-21 June 2018.
- Vinogradova, O., Palm, V., Andrén, E., Gaillard, M.-J. and Andrén, T. *The role of humans in past landscape change over the last 2000 years in southeastern Sweden*. International Paleolimnology Symposium, Stockholm, 18-21 June 2018.
- Vinogradova, O., Palm, V., Andrén, E., Gaillard, M.-J. and Andrén, T. *Anthropogenic landscape changes over the last 2000 years: A case study from southeastern Sweden*. 14th Baltic Sea Geologist Colloquium, Huddinge, 4-5 September 2018.
- Andrén, E., Holmlund, J., Rönnby, J., Palm, V., Vinogradova, O., Andrén, T. *SEASIDE - A multidisciplinary study of maritime environmental history*. Baltic Sea Geologist Colloquium, Huddinge, 4-5 September 2018.



- Vinogradova, O., Rönnby, J., Palm, V., Holmlund, J., Gaillard, M.-J., Andrén, E., Andrén, T. *Late Holocene land-use history in coastal areas: Palynological case study from south-eastern Sweden*. International Open Workshop 2019: Socio-Environmental Dynamics over the Last 12,000 Years: The Creation of Landscapes VI, Kiel, Germany, 11-16 March 2019.
- Andrén, E., Vinogradova, O., Rönnby, J., Holmlund, J., Palm, V., O'Regan, M., Jakobsson, M., Gaillard-Lemdal, M.-J., Andrén, T. *SEASIDE -A multidisciplinary study of maritime environmental history*. Nordic Diatomist Meeting, Tovetorp, Sweden. April 2019.
- Vinogradova, O., Rönnby, J., Palm, V., Gaillard, M.-J., Andrén, E., Andrén, T. *Late Holocene land-use history in the Baltic Sea Proper coastal area, southeastern Sweden*. Baltic Sea Science Congress, Stockholm, 19-23 August 2019.
- Christos Katrantsiotis held a seminar at the Department of Ecology and Environmental Science, Umeå University, in November 2020 with the title: "*Holocene climate and landscape changes in Southern Greece and Scandinavia using siliceous microfossils (diatoms) and geochemical (leaf wax biomarkers and isotopes) methods in sediment cores*".
- Vinogradova, O., Andrén, E., Gaillard, M.-J., Palm, V., Rönnby, J., Almgren, E., Karlsson, J., Nielsen, A.B., Åkesson, C., Andrén, T. *Late Holocene land-use dynamics in the coastal area of south-eastern Sweden*. 11th European Palaeobotany and Palynology Conference, 19-22 June 2022, Stockholm.
- Christos Katrantsiotis held a seminar in October 2022 at the Department of Historical, Philosophical and Religious studies; section Archaeology, Umeå University with the title: "*Holocene relative sea level changes in the southern Baltic Sea*"
- Elinor Andrén, Thomas Andrén, Johan Rönnby and Veronica Palm presented in the higher seminar series of Archaeology at Södertörn University October 2022, with the title "*SEASIDE - En tvärvetenskaplig studie av maritim miljöhistoria*".
- Veronica Palm and Christos Katrantsiotis held a seminar in January 2023 at the Department of Historical, Philosophical and Religious studies; section Archaeology, Umeå University presenting results from the SEASIDE-project.

List of publications

Peer reviewed articles

- Andrén, E, Vinogradova, O, Lönn, M, Belle, S., Dahl, M., Palm, V., Nielsen, A. B., Katrantsiotis, C., Jakobsson, M., Rönnby, J., Gaillard, M.-J., Andrén, T. Land use and climate as predictors explaining long-term changes in a coastal Baltic Sea setting. Manuscript in prep.
- Katrantsiotis, C, Vinogradova, O., Dahl, M, Palm, V., Rönnby, J, Andrén, T., Andrén, E. Shoreline reconstruction and pattern of human settlements based on an integrated paleoenvironmental- archaeological approach: A case study from the Västervik - Gamlebyviken region, SE coast of Sweden, Baltic Sea. Manuscript in prep.
- Katrantsiotis, C., Dahl, M., Palm, V., Rönnby, J., Andrén, T., Andrén, E. 2023. Holocene relative sea level changes in the Västervik-Gamlebyviken region on the southeast coast of Sweden, southern Baltic Sea. *Boreas* 52 (2), 206-222.
<https://doi.org/10.1111/bor.12605>
- Palm, V. et al. Environmental Change and Human Long-Term Strategies. A regional study at Västervik-Gamlebyviken region on the southeast coast of Sweden, southern Baltic Sea. Manuscript in prep.



Vinogradova, O., Gaillard, M.-J., Andrén, E., Palm, V., Rönby, J., Dahl, M., Almgren, E., Karlsson, J., Nielsen, A.B., Åkesson, C., Andrén, T. 3000 years of past regional and local land-use and land-cover change in the southeastern Swedish coastal area – a potential nutrient source to the Baltic Sea coastal waters? Submitted to *The Holocene*.

Forthcoming PhD thesis

Olena Vinogradova, preliminary title:

Land-use changes during the past 3000 years: Pollen analysis from the southwestern Baltic Sea onshore coastal zone

Organized conference and papers presented

We arranged a final SEASIDE conference with invited national and international guests at Västerviks Museum, November 9 – 10 2022, “People and the environment – humans and the Baltic Sea through time”.