Biophysical Modelling of *Lophelia pertusa* Larval Dispersal in the Skagerrak

An Area Isolated by Distance?

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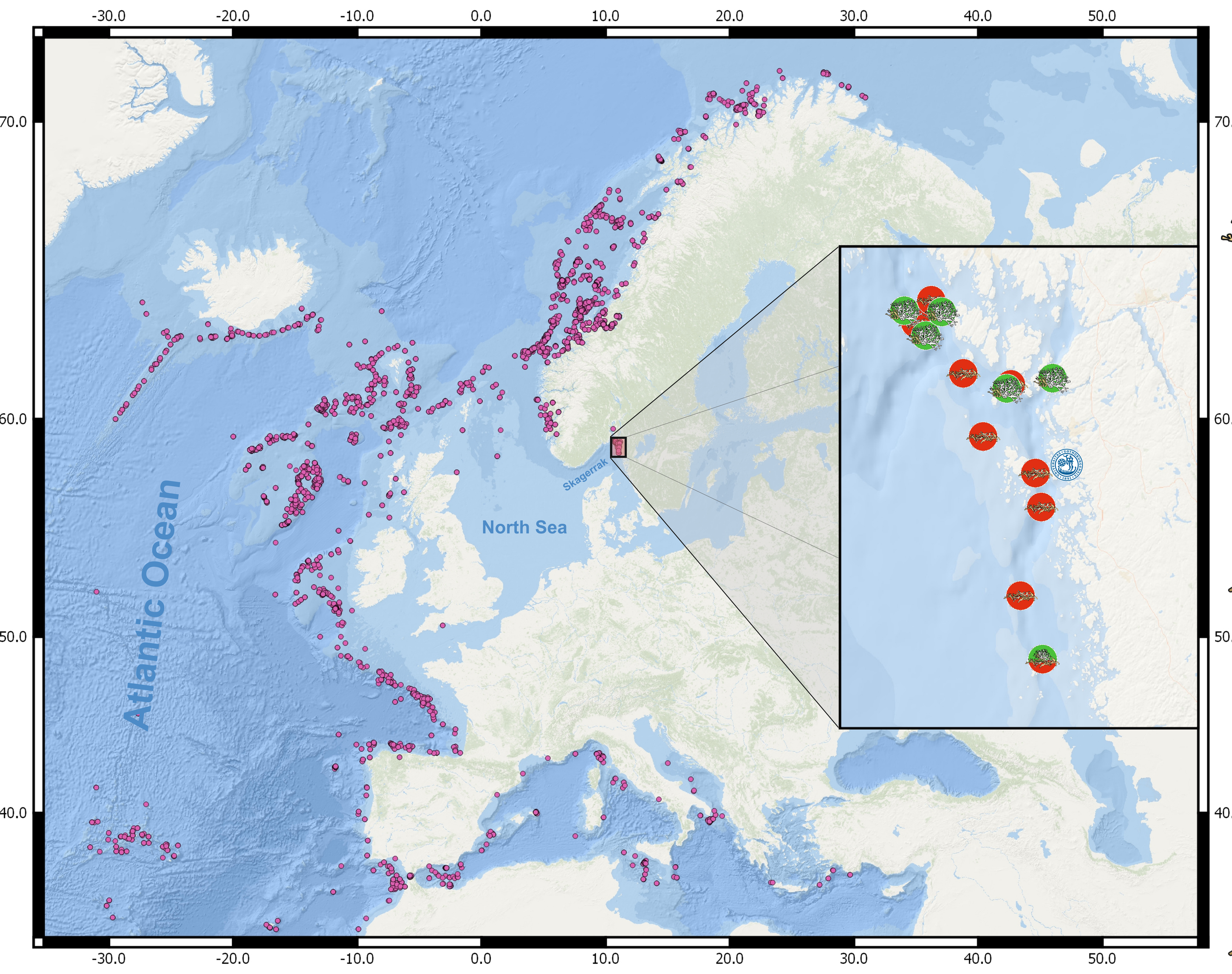
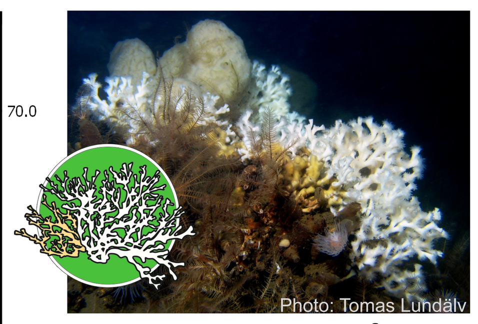


Map of the northeast Atlantic showing locations of historical *L. pertusa* observations (data from Freiwald et al. 2017). Inset shows the Hvaler-Koster area. Green and red symbols in inset mark the locations of living and extinct *L. pertusa* reef sites respectively. Two-colored symbol marks the location where re-colonization of a previously extinct reef was discovered in 2013. Location of the University of Gothenburg field station at Tjärnö is marked by the university logo.



Living *L. pertusa* reef.

Dead *L. pertusa* reef.

Young *L. pertusa* colonies growing on dead reef.

OBJECTIVE OF THE PROJECT

Biophysical modelling of planktonic larval transport will be used to investigate population connectivity of *Lophelia pertusa* cold-water corals found within the Skagerrak basin of the northeastern North Sea. Understanding about the level of larval exchange between coral sites is fundamental for management purposes and the biophysical modelling of this project is intended to constitute a useful complement to connectivity studies based on genetic structuring.

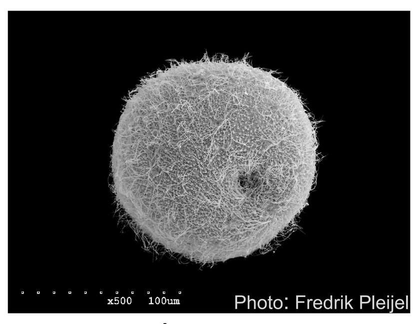
LOPHELIA PERTUSA IN THE SKAGERRAK

The Skagerrak basin constitutes an outpost in terms of the geographical distribution of *L. pertusa*, and here the species appears to occur exclusively in the Hvaler-Koster area located in the northeast corner of the basin. Within this area, living reefs are found at six localities while remains of extinct reefs have been found at a number of additional sites. Bottom trawling has historically constituted the main threat to the reefs and marine protected areas have been established to reduce further damage (e.g. Lundälv 2004).

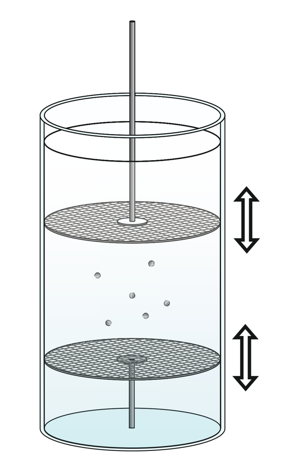
Previous studies indicate that the Skagerrak population of *L. pertusa* may be considerably isolated, likely due to a restricted exchange of larvae with other populations (e.g. Dahl et al. 2013, Fox et al. 2016). Genetics have also revealed a varying degree of isolation for individual reef sites within the Skagerrak (Dahl et al. 2012). Young *L. pertusa* colonies of unknown origin were recently discovered on the remains of a dead reef in the Koster area, demonstrating the possibility of re-colonization of extinct reef sites (Strömberg 2016).

LABORATORY STUDIES

L. pertusa polyp releasing eggs in lab.



L. pertusa larvae.

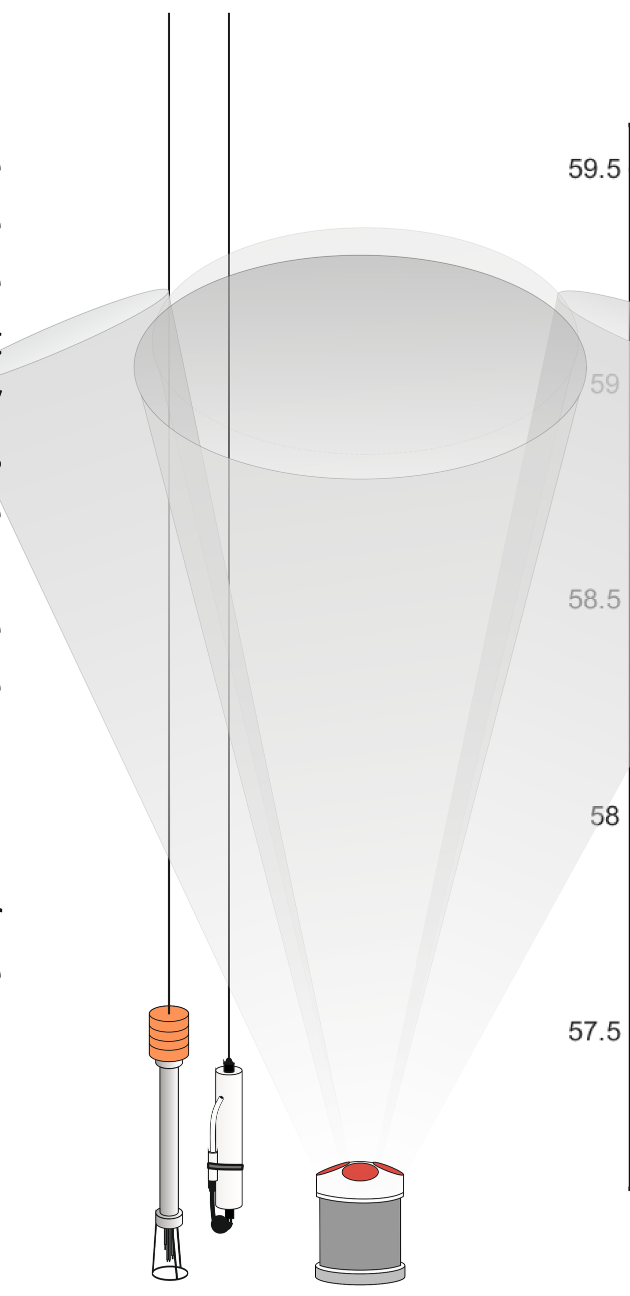


Grid-stirred turbulence tank.

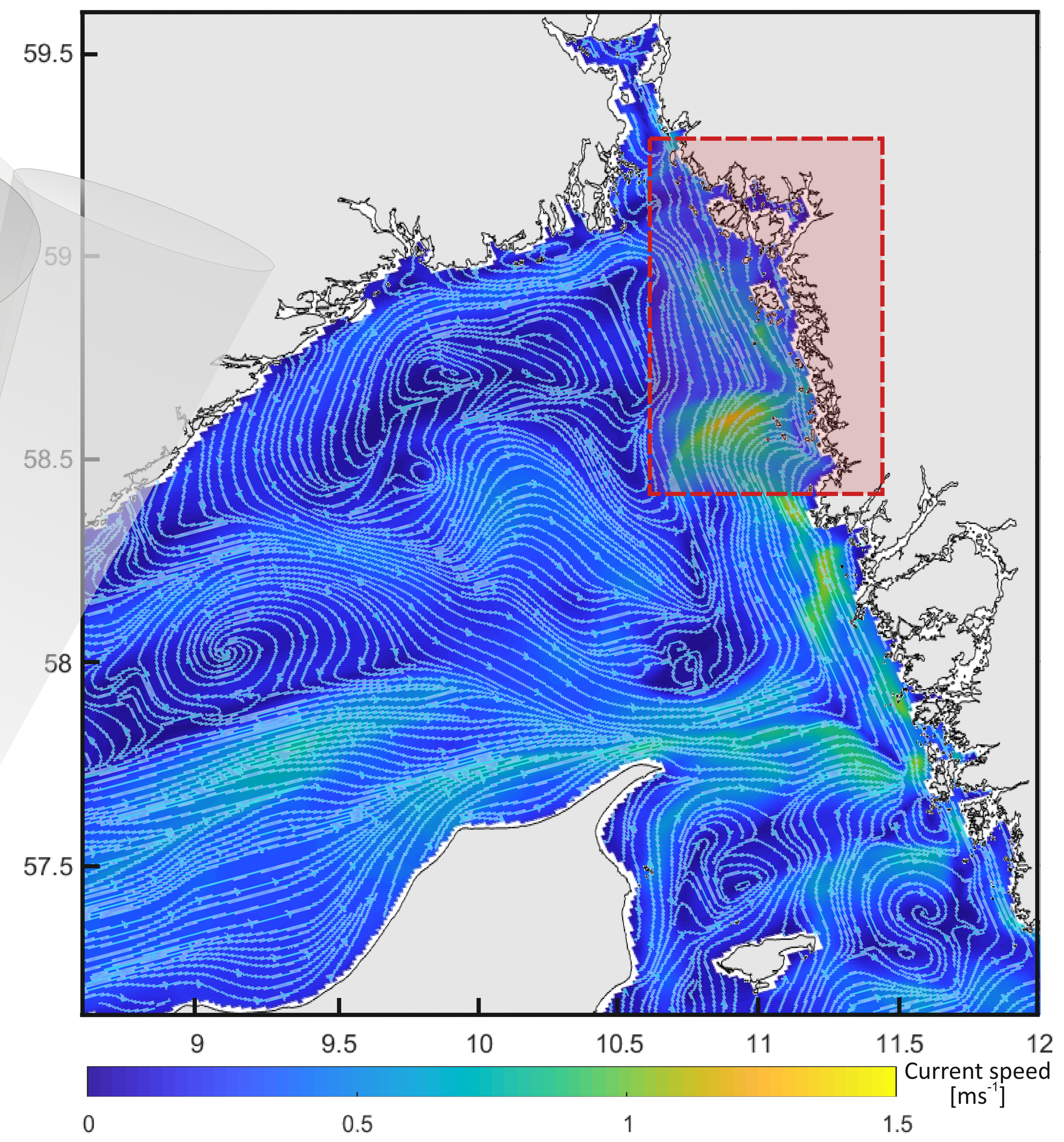
L. pertusa larvae have been seen to migrate vertically through the water column, possibly spending part of their planktonic stage near the ocean surface which is likely favorable for long distance dispersal (Strömberg and Larsson 2017). As part of the current project, new laboratory experiments will be carried out to study swimming behavior in waters influenced by turbulence. This is relevant since turbulence is an ever present factor that the larvae are exposed to in their natural environment. A grid-stirred turbulence tank will be used for the experiments which will be supplemented with field measurements of turbulence within the Hvaler-Koster area.

OCEAN CIRCULATION MODEL

The Skagerrak basin is hydrographically complex, with water properties and circulation patterns varying substantially in space and time (e.g. Gustafsson and Stigebrandt 1996). Combined with a complex local topography, this implies that a high spatial and temporal resolution is required to successfully model the local water movements. A high-resolution regional 3D ocean circulation model (ROMS), covering the Hvaler-Koster area, will therefore be set up to generate the 3D current velocity fields required for the larval dispersal modelling. Model performance will be evaluated by comparing the model output to in-situ measurement data collected as part of the project.



Data from field measurements will be used to evaluate the circulation model and to improve the larval drift model.



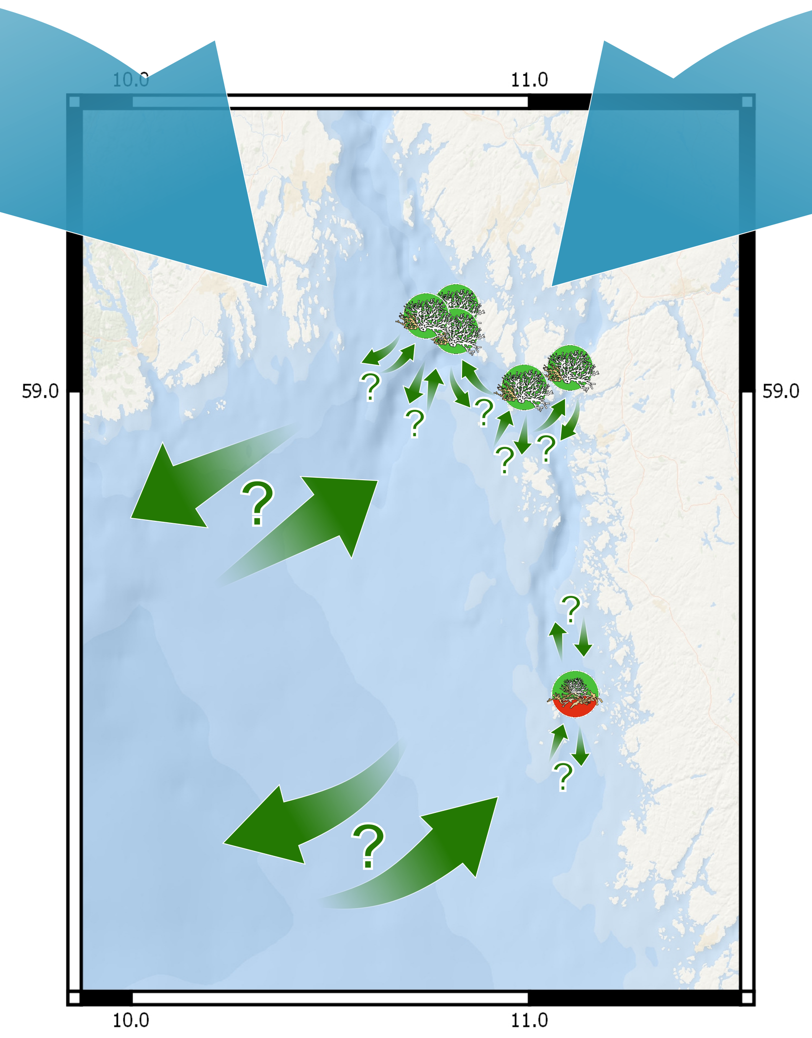
Example of modelled surface current velocities in the Skagerrak for February 20, 2015. A high-resolution circulation model will be set up for the Hvaler-Koster area outlined in red. For details on the model see Christensen et al. (2018).

TRANSPORT MODELLING

The 3D current velocity fields from the high-resolution circulation model will be used to drive a Lagrangian drift model that simulates the transport of *L. pertusa* larvae within the Hvaler-Koster area. Current velocity data from an existing, coarser circulation model with larger geographical extent will be used to model possible larval exchange with populations outside of the region.

Biological traits such as planktonic larval duration and vertical migration patterns of *L. pertusa* larvae, observed during previous and planned laboratory experiments, will be incorporated into the drift model to increase the reliability of the dispersal simulations.

The simulation results will provide information about the movements of individual larvae which allows for further analysis of possible dispersal pathways.



A Lagrangian drift model will be used to simulate the transport of larvae. Results from the simulations will serve as a basis for analysis of *L. pertusa* population connectivity.

CONNECTIVITY STUDIES

By applying connectivity analysis methods on the results from the Lagrangian drift model, interpretations can be made regarding the level of exchange of larvae between geographically separated sites as well as the degree of larval retention in certain areas. Knowledge gained from these analyses may be of great importance when further developing interventions to protect and restore *L. pertusa* reef sites within the Skagerrak basin.

REFERENCES

- Christensen, K. H., Sperrevik, A., K., and Broström, G. (2018). On the Variability in the Onset of the Norwegian Coastal Current. *J. Phys. Oceanogr.* 48 (3), 723-738.
- Dahl, M. P., Pereyra, R. T., Lundälv, T., and André, C. (2012). Fine-scale spatial genetic structure and clonal distribution of the cold-water coral *Lophelia pertusa*. *Coral Reefs* 31, 1135–1148. doi: 10.1007/s00338-012-0937-5
- Dahl, M.P., Pereyra, R. T., Lundälv, T., Järnegren, J., Arnaud-Haond, S., and André, C. (2013). Genetic structure and the postglacial colonization process in East Atlantic Ocean populations of the cold-water coral *Lophelia pertusa*. *Manuscript in: Conservation Genetics of Lophelia pertusa,* Dissertation Thesis, University of Gothenburg.
- Fox, A. D., Henry, L. A., Corne, D. W., and Roberts, J. M. (2016). Sensitivity of marine protected area network connectivity to atmospheric variability. *R. Soc. Open Sci*. 3:160494. doi:10.1098/rsos.160494
- Freiwald, A., Rogers, A., Hall-Spencer, J., Guinotte, J. M. , Davies, A. J., Yesson, C., Martin, C., S., and Weatherdon, L., V., (2017). Global distribution of cold-water corals (version 4.0). Third update to the dataset in Freiwald et al. (2004) by UNEP-WCMC, in collaboration with Andre Freiwald and John Guinotte. Cambridge (UK): UN Environment World Conservation Monitoring Centre. URL: http://data.unep-wcmc.org/datasets/
- Gustafsson, B., and Stigebrandt, A. (1996). Dynamics of the freshwater-influenced surface layers in the Skagerrak. *J. Sea Res.* 35(1-3), 39-53.
- Lundälv, T. (2004). Kartläggning av marina habitat i Yttre Hvalerområdet, nordöstra Skagerrak. *En pilotstudie. Kartlegging av Marine Naturtyper. En Nordisk Pilotstudie*. Nordic Council of Ministers, Copenhagen 2004, TemaNord (2004:523). doi: 10.6027/tn2004-523
- Strömberg, S. M. (2016). *Early Life History of the Cold-Water Coral Lophelia pertusa - With Implications for Dispersal*, Dissertation Thesis, University of Gothenburg.
- Strömberg, S. M., and Larsson A. I. (2017). Larval Behavior and Longevity in the Cold-Water Coral *Lophelia pertusa* Indicate Potential for Long Distance Dispersal. *Front. Mar. Sci.* 4, 411. doi: 10.3389/fmars.2017.00411