Box 4: Restoration of *Lophelia pertusa* reef habitats in Skagerrak: enhancement of larval settling

The Kosterfjord-Väderöfjord in the NE Skagerrak off the Swedish west coast is an area with a complex bathymetry including deep troughs, that connect an inshore marine environment with the deep Atlantic via the Norwegian Trench (Wisshak et al., 2005). Just off the coast there are relatively stable oceanic conditions that allows deep-sea biota to thrive shallower than their normal depths. The deep-sea scleractinian *L.pertusa* can here be found at around 85-90 m together with many of its associated species. The mouth of these troughs is situated in the neighboring Norwegian waters, in the Ytre Hvaler area. Through this passage, with its sills and constrictions, the currents are sped up, creating optimal conditions for *L. pertusa*. The four reefs present on the Norwegian side are reproductively active, and the genetic population structure is fairly well understood (Dahl et al., 2012).

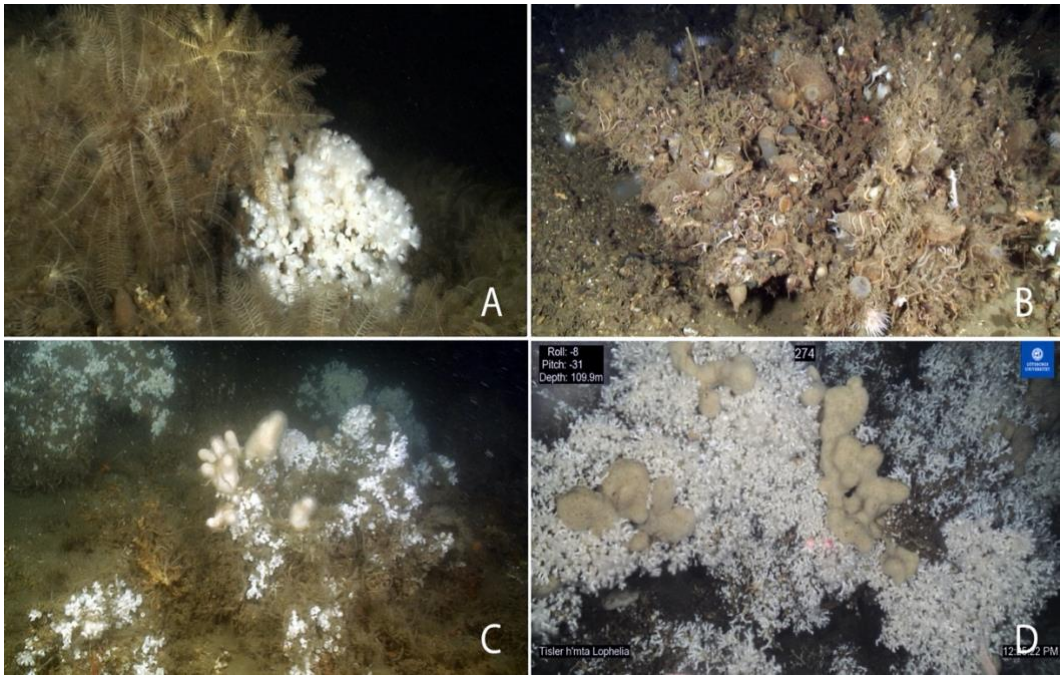
The Skagerrak reefs are now all protected but have historically been decimated by bottom-trawling. The Tisler reef has shrunk from the original estimated two kilometers to 1200 meters and altogether the Norwegian reefs in Ytre Hvaler is estimated to have been reduced by more than 50% (Lundälv, 2004). On the Swedish side, there are two small reefs with live corals, while four other known reef sites only consist of dead coral rubble. The two sites with live corals are at the opposite ends of the Kosterfjord-Väderöfjord (Box 5 Fig. 1). The most northern site, Säcken, is situated on a sill in the strait between the Swedish mainland and a Norwegian island. It consists of a few colonies, with mostly dead skeletal structures and a few still live parts. Field experiments with transplantation of coral colonies from the nearby Tisler reef to Säcken have shown good survival and growth (Dahl, 2013; Jonsson et al., 2015).

Most Swedish reef sites have been protected since 2001 as a Natura 2000 designated area with additional trawling restrictions for certain areas, while a site discovered later achieved protected status in 2015. In 2009, a large part of the Kosterfjord-Väderöfjord area was also designated a Marine National Park. With protection in place, active restoration of the *Lophelia* reef habitats is now possible. In 2019, the project LIFE LOPHELIA started with the aim of developing artificial reef objects that facilitate

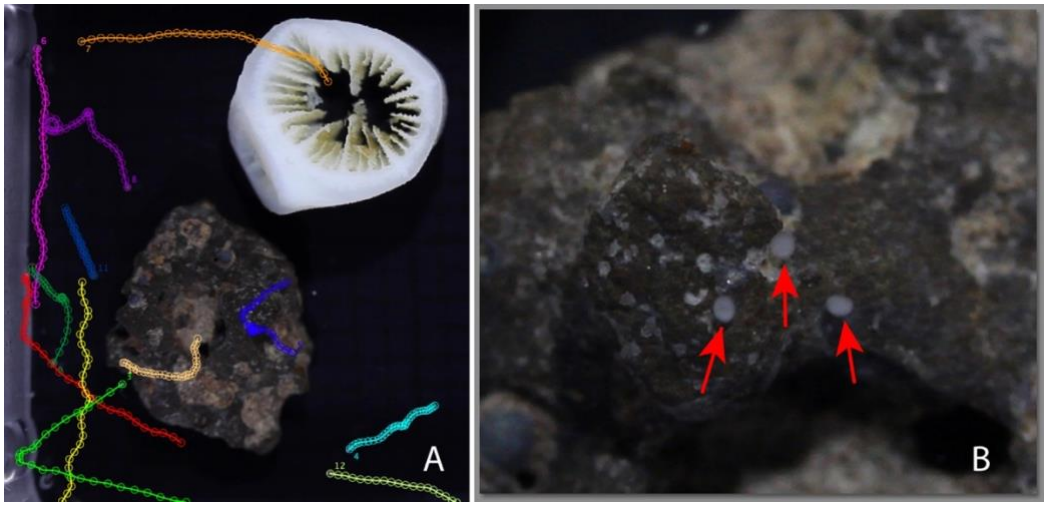
recruitment of naturally occurring larvae and to restore *L. pertusa* populations in the Kosterfjord-Väderöfjord area.

Understanding both the needs of the adult corals and the prerequisites for successful settling and recruitment of their larvae is crucial when designing artificial reefs and settling substrates. Larvae of *L. pertusa* use cnidocysts with sticky tubules for temporary anchoring to a protruding object, and once in contact with a substrate, they seem to prefer to squeeze into small crevices (Strömberg et al., 2019). *Lophelia pertusa* thrives in areas with fast currents, and to enhance the ability of larvae to attach the substrates need to break up the current into small eddies and offer low-flow micro environments, which will increase the probability of contact and attachment. Through a series of planned experiments, the larvae's ability and propensity to attach under different flow regimes and the substratum's composition and surface complexity will be studied in the laboratory. With input from environmental measurements of reef sites to be restored, artificial reef objects will be designed to optimize conditions for *L. pertusa* settlement. The design/concept should also be possible to transfer and reproduce to other reef areas in need of active restoration.

An inexpensive and readily available material that could be a suitable substrate for *L. pertusa* larvae, is metallurgical slag, a residual product from industrial metal production. The slag has a complex surface structure with different sized holes and crevices, and is tested to be non-toxic under neutral to alkaline conditions (Fisher and Barron, 2019). In our preliminary tests the *L. pertusa* larvae have been exploring the slag, swimming in and out of crevices, contacting the slag more frequently than coral skeleton, and attaching temporarily to the surface (Box 5 Fig. 2). The work will continue by testing attachment depending on flow conditions and to investigate if flow promotes larvae to settle permanently and fully recruit to the substrates.



Box 5 Figure 1 The *Lophelia pertusa* habitats in Kosterfjord-Väderöfjord (Sweden, A-C) and Ytre Hvaler (Norway, D). **(A)** A small colony of live corals at Säcken. **(B)** Dead coral lump with a rich epifauna at Säcken. **(C)** Live colonies at Väderöarn**a. (D)** Large healthy colonies at Tisler Reef. Images are screen dumps from ROV videos picked by Susanna Strömberg. ROV pilot: Roger Johansson.



Box 5 Figure 2 (A) Movements of *Lophelia pertusa* larvae in relation to substrata. Two substrates were used in this trial, coral skeleton (cut through mid-calyx with skeletal lamellae intact), and metallurgical slag. Larvae were often seen exploring the surface of

the slag. Tracking was done in Fiji/ImageJ, with the MTrackJ plug-in. **(B)** Three larvae resting on the surface of the slag, temporarily attached. Photos: Susanna Strömberg.