

(Projects funded under the Call 2014 onwards must use this format)



LIFE Project Number

<LIFE18 NAT/SE/000959>

Mid-term Report

Covering the project activities from 01/09/2019¹ to 30/04/2022

Reporting Date²

<01/07/2022>

LIFE PROJECT NAME or Acronym

<LIFE LOPHELIA>

Data Project

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¹ Project start date

² Include the reporting date as foreseen in part C2 of Annex II of the Grant Agreement

Package completeness and correctness check	
Obligatory elements	✓ or N/A
Technical report	
The correct latest template for the type of project (e.g. traditional) has been followed and all sections have been filled in, in English <i>In electronic version only</i>	✓
Index of deliverables with short description annexed, in English <i>In electronic version only</i>	✓
<u>Mid-term report</u> : Deliverables due in the reporting period (from project start) annexed <u>Final report</u> : Deliverables not already submitted with the MTR annexed including the Layman's report and after-LIFE plan Deliverables in language(s) other than English include a summary in English <i>In electronic version only</i>	✓
Financial report	
The reporting period in the financial report (consolidated financial statement and financial statement of each Individual Beneficiary) is the same as in the technical report with the exception of any terminated beneficiary for which the end period should be the date of the termination.	✓
Consolidated Financial Statement with all 5 forms duly filled in and signed and dated <i>Electronically Q-signed or if paper submission signed and dated originals* and in electronic version (pdfs of signed sheets + full Excel file)</i>	✓
Financial Statement(s) of the Coordinating Beneficiary, of each Associated Beneficiary and of each affiliate (if involved), with all forms duly filled in (signed and dated). The Financial Statement(s) of Beneficiaries with affiliate(s) include the total cost of each affiliate in 1 line per cost category. <i>In electronic version (pdfs of signed sheets + full Excel files) + in the case of the Final report the overall summary forms of each beneficiary electronically Q-signed or if paper submission, signed and dated originals*</i>	✓
Amounts, names and other data (e.g. bank account) are correct and consistent with the Grant Agreement / across the different forms (e.g. figures from the individual statements are the same as those reported in the consolidated statement)	✓
Mid-term report (for all projects except IPs): the threshold for the second pre-financing payment has been reached	✓
Beneficiary's certificate for Durable Goods included (if required, i.e. beneficiaries claiming 100% cost for durable goods) <i>Electronically Q-signed or if paper submission signed and dated originals* and in electronic version (pdfs of signed sheets)</i>	✓
Certificate on financial statements (if required, i.e. for beneficiaries with EU contribution ≥750,000 € in the budget) <i>Electronically Q-signed or if paper submission signed original and in electronic version (pdf)</i>	✓
Other checks	
Additional information / clarifications and supporting documents requested in previous letters from the Agency (unless already submitted or not yet due) <i>In electronic version only</i>	N/A
This table, page 2 of the Mid-term, is completed - each tick box is filled in <i>In electronic version only</i>	✓

**signature by a legal or statutory representative of the beneficiary / affiliate concerned*

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2. List of key-words and abbreviations

Key-words

Cold-water coral	
Coral reef	
<i>Lophelia pertusa</i>	synonym <i>Desmophyllum pertusum</i>
<i>Desmophyllum pertusum</i>	
scleractinian	
Artificial reef	
Biodiversity	

Abbreviations

AR	Artificial Reef
AUV	Automated Underwater Vehicle
ROV	Remotely Operated Vehicle
CWC	Cold-Water Coral
CAD	Computer Aided Design
GGBS	Ground Granulated Blast furnace Slag (cementitious additive to concrete)
PLA	PolyLactic Acid (plastic material made from starch)
CABO	County Administrative Board of Västra Götaland
UGOT	University of Gothenburg
SLU	Swedish University of Agricultural Science
SwAM	Swedish Agency for Marine and Water Management

3. Executive Summary

The main objective for the project is to develop an efficient and cost-effective method to restore reef habitats of the scleractinian Cold-Water Coral (CWC) *Lophelia pertusa* (syn. *Desmophyllum pertusum*) with artificial reefs (ARs). This method will then be implemented in the Natura 2000 Kosterfjord-Väderöfjord area along the Swedish west coast with the goal to restore ecosystem services and provide blue infrastructure. The area harbours all six known *Lophelia* reef sites in Sweden whereof today only two sites harbour live coral in small parts of their previous range. With successful outcome of this project, we will transfer the results to other stakeholders within the European union. The method developed will build on studies of larval behaviour and preferences at settlement, and will thereby be applicable to other regions. Another objective is to test if metallurgical slag can be used in the production of ARs. This slag is a by-product from manufacturing of metal products which is rich in CaCO₃, non-toxic and has high surface complexity likely promoting coral larvae recruitment.

The key deliverables and outputs from the project will be:

- Artificial reefs with optimal shape and surface structure to maximize the settlement and recruitment rate of *Lophelia pertusa* larvae.
- The restoration method applied to six reef sites in Natura 2000 Kosterfjorden-Väderöfjorden.
- A published Technical Handbook describing the developed method and how it should be implemented.
- Increased awareness of the existence of cold-water coral reefs and the ecosystem services they provide, and the restoration efforts performed during this project.

The plan for the preparation actions in A1 is to study larval behaviour and attachment rates with several surface materials including the assessment of metallurgical slag. Different models of AR are designed and tested in a laboratory flow channel regarding their hydrodynamic performance. The objective is to find the most optimal design and material of AR structures and their placement relative to each other to maximise the contact rate and attachment rate of *Lophelia pertusa* (*Lp*) larvae.

During these first two and a half years we have conducted experiments in both laboratory and in the field, to evaluate different substrate compositions and textures using both natural substrates, metallurgic slag, and 3D printed complex substrates of different designs. We have established what substrate composition and level of complexity that attracts *Lp* larvae. The long-term quantitative laboratory studies on larval recruitment have been compromised by the presence of parasites that led to 100% mortality over time, and these studies have thus not given the anticipated results. Thus, only short-term experiments on larvae behavior have been successful so far. We have tried different measures to minimize the damage and will continue with different measures.

To measure settlement and recruitment rates of *Lophelia* larvae we have deployed settlement panels with different surface structures in the field, to verify laboratory studies, to get estimate of larval availability at different sites and to be able to monitor recruitment. The first of the two sets of panels will be retrieved and analyzed beginning in September 2022. Another set of settlement panels were deployed during early spring 2022 and will be retrieved after one year to assess the effect of material composition for enhanced recruitment, and longevity and compressive strength of the concrete in the marine environment. To compensate for the lack of successful settling studies in the laboratory, we have deployed

several other sets of panels focusing on the role of surface structure, the first of which will be retrieved for analysis in September 2022. In parallel with the laboratory and field experiments, we have continuously been working on designing and testing AR models and had several at hand to work with when we initiated the dialogue with the interested companies during the procurement process in the spring 2022 for action C2. We decided (in June 2022) to postpone the manufacturing and deployment of the first reefs to 2023. Deployment was planned to take place in the autumn of 2022 with a few AR (30-60) and most reefs (approx. 400) in autumn of 2023. Now all reefs will be deployed in 2023.

In action A2 the goal was to ban all type of fishing gear in the restoration areas before the deployment of the artificial reefs. Since 2015 all six restoration areas have had a trawling ban but fishing with anglers and cages was allowed. This action was necessary to ensure that both the ARs and the coral reefs are protected from negative impacts from fishing gear. The fishing ban came into effect in October 2021, well before the deployment of the ARs. The action A2 is thus completed.

The conservation actions in C1 include detailed mapping of environmental conditions, total geographical distribution, bottom topography, live parts of each reef area and associated biodiversity. Environmental data have been gathered continuously during the first years of the project and will continue until quarter two of 2023 to discern possible seasonal/annual variability. One Acoustic Doppler Current Profiler (ADCP) was flooded and corrupted during a 5-month deployment at one of the restoration sites, leading to delays in data collection as well as extra expenses related to the purchase of a new instrument. A detailed survey of bottom topography with sonar and biodiversity with drop camera at the sites have been conducted to establish a baseline. The resolution of the sonar mosaic images was not as high as desirable, but if we combine these data with multibeam and backscatter we believe that there will be enough information about bottom complexity to guide our decisions on where to place the ARs. The costs for this sonar survey were unfortunately underestimated in the project budget. The County Board is prepared to cover the additional costs by increasing their own funding if required. A follow-up is planned after AR deployments are done, and CABO have secured a recurring biodiversity survey in collaboration with SwAM that will be performed every three years from 2021 and beyond the end of the current project time.

The action E1 aims at communicating the results in a broad sense and at networking. All deliverables are met so far, with networking and kick-off at the University of Azores, website published and notice-boards printed and posted at six sites. The Communication plan is also completed and video production for the public started in April 2022. We are networking with other projects through both collaborations and dialogs/knowledge exchange. No participation, however, in international conferences so far due to the covid pandemic.

We have requested postponement of the following deliverables 1) *Preliminary results of laboratory studies* to be able to add more data from a fourth experimental season; 2) *Final blueprints of ARs ready (accepted)* to be able to adjust the design in response to the preliminary results as we do the first evaluation of the settling panels; 3) *Report on the initial habitat complexity and biodiversity* with three months due to delayed data delivery; 4) *Leaflet printed* and 5) *Public video produced*, to be able to incorporate information about the ARs; 6) *Summary of scientific workshop (accepted)* to be able to have more results from experiments to present on the workshop that will be held in October 2023.

4. Introduction

Background, problems and objectives

The cold-water coral *Lophelia pertusa* (syn. *Desmophyllum pertusum*) is one of the major habitat building species in the deep sea. It is widely spread in the NE Atlantic and the Mediterranean, and the biodiversity of *Lophelia* reefs are equal to tropical coral reefs. *Lophelia* reefs are rich feeding grounds providing important ecosystem services, sustaining the fisheries. Fishermen have long targeted reef areas since fishing has been more successful there. In Scandinavia, it has been estimated that 30–50% of the reef areas are damaged by bottom trawling.

Lophelia reefs are biogenic reefs and subtype to the marine habitat 1170 in the Habitat Directive and was reported by Sweden having unfavourable condition in the Skagerrak both 2007, 2013 and 2019. Both area extent and quality of the subtype has diminished, and the prospects was assessed as bad. *Lophelia* is listed in the OSPAR List of Threatened and/or Declining Species and Habitats (2008-6). Within the Natura 2000 Kosterfjorden-Väderöfjorden, four of six known reef areas are dead, and recovery with new recruitment has only occurred at one site that still has erect dead coral skeletons left. *Lophelia* is therefore listed as Critically Endangered (CR) in the national Red List of Sweden.

Lophelia is a slow growing species with a growth rate at 4–26 mm per year depending on conditions. Full recovery to a state where colonies form a habitat and provide ecosystem services for other species thus takes centuries. Besides the vegetative growth, they reproduce sexually in annual spawning events where gametes are released into the free water mass, and fertilization takes place externally. Coral larvae are depending on elevated hard substrates to settle. If reefs are reduced to rubble recovery is hampered, or completely inhibited. Adding elevated substrates would allow natural recovery to take place through larval settlement. Constructing artificial reefs (ARs) with a complexity similar to natural reefs could provide a substitute for the reef-associated fauna until the settled corals has grown out to form a reef.

The project objectives are:

1. To develop an efficient and cost-effective method to restore *Lophelia pertusa* reefs

The objective is to find the most optimal design of artificial reef structures and their placement relative to each other to maximise the contact rate and attachment rate of *Lophelia* larvae. Therefore, studies of larval behaviour and attachment are performed in the lab.

2. To implement the developed method to restore all reefs in the Natura 2000 Kosterfjorden-Väderöfjorden with the goal to restore ecosystem services and provide blue infrastructure

This area harbor all six known *Lophelia* reef sites in Sweden whereof today only two sites have live coral in small parts of their previous range. Five reef sites are protected from trawling since 2001 and one site since 2015.

3. To transfer the results of the project to other stakeholders within the European union

With successful outcome of this project, we expect the methods to be transferable to other disturbed reef areas. The method developed will build on studies of larval behaviour at settlement, and thereby applicable to other regions.

4. To assess the use of the industrial by-product metallurgical slag in cold-water coral restoration efforts

Metallurgical slag is a by-product formed during manufacturing of metal products and is typically rich in CaCO₃, which is also a component of coral skeleton. The slag is non-toxic and has high surface complexity. These characteristics together with the high availability and low cost make the product very interesting to use in coral restoration efforts.

Preparatory and conservation actions

Both larval behaviour and attachment rates are studied. Several surface materials are investigated with special interest in assessment of metallurgical slag. Different models of ARs are designed and tested in a laboratory flow channel regarding their hydrodynamic performance. Settlement and recruitment rates of *Lophelia* larvae in the field are measured by deploying settlement panels with different surface structures to verify laboratory studies, get estimate of larval availability at different sites and to be able to monitor recruitment.

Six reef sites in the Natura 2000 Kosterfjorden-Väderöfjorden will be subjected to restoration actions. The conservation actions include detailed mapping of total geographical distribution, bottom topography, biodiversity and live parts of each reef area. The purpose is to assess where to place the ARs and to get a before and after deployment value of habitat complexity and diversity. By measuring environmental conditions (ambient flow velocities, temperature, salinity, sediment exposure) at each reef site, the deployment of ARs can be adapted to the local situation. The plan is to deploy AR prototypes on a total area of approx. 25 ha.

Expected longer term results

After the completion of this project, we aim to have:

1. developed a cost-efficient method for restoring *Lophelia pertusa* (*Lp*) reef habitats with artificial reefs (ARs). The ARs have optimal shape and surface structure and their placement relative to each other have been tried out to maximize the settlement and recruitment rate of *Lp* larvae. The industrial by-product metallurgical slag has been tested out for use in production of ARs.

2. reintroduced *Lp* to all known reef sites within the Natura 2000 Kosterfjorden-Väderöfjorden and that the ARs have increased the habitat complexity and number of available substrates for larval settling. The ARs initially also themselves have served to increase the complexity, providing shelter for other species. With growing coral coverage, the complexity will attract an increasing number of associated species. The long-term result is a network of viable reproductive reef sites with the possibility of larval exchange. The reef sites are sustaining a high biodiversity and function as refuge and feeding grounds for a variety of species, including commercially important fish species. The national Red List status of *Lp* in Sweden can be changed from Critically Endangered (CR) to Endangered (EN) or better.

3. made the restoration method available to the European community. Other sites in need of restoration are identified. A Technical Handbook is published describing the developed method and how it should be implemented. In addition, this handbook will have an analytical toolkit of how to implement/adjust the method to other deep-sea coral species such as *Madrepora oculata* and *Solenosmilia variabilis*.

4. made the public increasingly aware of the existence of cold-water coral reefs and the ecosystem services they provide, the threats they face, and the restoration efforts performed

during this project. Through continuous cooperation between the partners also after the end of the project, public cruises are arranged as part of the public activities of the Kosterhavet National Park and Tjärnö Marine Laboratory public outreach program.

5. Administrative part

The LIFE *Lophelia* project started in Sept 2019 with, among other things, arrangement of a kick-off and in connection with this a study visit to the University of Azores in Oct 2019 with the aim of networking for future collaborations (see chapter 6.1 Action E1.5 Networking for further details). We also presented the project at the kick-off meeting in Brussels in Nov 2019.

Initially, UGOT hired a research engineer and a project assistant for the project. The signed agreement between the coordinating beneficiary (CABO) and the associated beneficiary (UGOT) on the technical and financial participation in the project was finalized in June 2020.

The Nomination of the Steering Committee was finalized in December 2019 and we have decided to have two meetings each year, and if necessary extra meetings online (for details see chapter 6.1 Action F1 Management).

We have monthly meetings between partners to inform each other about the progress, if there are any problems that we need to deal with jointly and what results we see from the project. At these meetings we also deal with financial issues. In several actions we also work closely together. We have a web-platform, where we easily can share documents and photos between partners. This facilitates collaboration as many documents and photos are large files. The project is small in terms of number of partners, and it makes it easy to have a close collaboration, which we see benefits the project. The collaboration with our partner UGOT works very well.

Each year in February we report, both financial and technical, to our co-financer the Swedish Agency for Marine and Water Management (SwAM), and in connection with this we also make an extra control of the finances of the project.

There have been three meetings with the EASME project monitor Sonja Jaari, in February and November (digital) 2020 and in August/Sept 2021. Prior to these meetings, the monitor asks for samples of time reporting and invoices and the financial files for both of us partners. At the meetings, we review the project both technically and financially. We appreciate these meeting as we also can ask questions and discuss how we can best solve various financial and technical issues.

We have received e-mails from the Project Advisor Mr. Zableckis after the monitor's visit about issues that our monitor has drawn attention to during her visits. We have also had e-mail correspondence with and acceptance from Mr. Zableckis concerning the need to postpone some deliverables and milestones (LIFE18 NAT SE 000959 MISMC3LET 210922 SZ Project visit). We also had a question and acceptance about altering the procurement procedure for the biodiversity assessment (Ares(2021)2584997 - RE: LIFE LOPHELIA, LIFE18 NAT/SE/000959 - question on agreement between state authorities, e-mail 210416). Mr Zableckis also gave us some extra time for finalizing this Mid-term report (e-mail 220629, Mid-term Report LIFE18 NAT/SE/000959 LIFE Lophelia). The correspondence with the PA has worked very well.

We have not had to make any major changes from the project plan therefore no amendment has been needed, but the changes we now need are to postpone some of the deliverables and milestones, see below under the actual actions and under 6.2.

6. Technical part

6.1. Technical progress, per Action

The project is going well and largely according to plan, which means that the project's objectives are still achievable. At the following pages we describe the progress action by action.

Action A.1 Development of restoration method (UGOT)

Foreseen start date: 09/2019 Actual start date: 10/2019

Foreseen end date: 09/2023 Actual end date:

<i>Deliverable</i>	<i>Deadline</i>	<i>Changed</i>	<i>Delivered</i>
Preliminary results from field settling studies	30/06/2023		
Preliminary results of laboratory studies	15/09/2022	15/09/2023?	
		Here we wish to change deadline to 09/2023	

<i>Milestone</i>	<i>Deadline</i>	<i>Changed</i>	<i>Delivered</i>
Cites permits (valid 6 months) for export/import of corals 2019–2020	31/10/2019		27/11/2019
Permits to collect corals and to do scientific work in Norwegian waters for 2020	31/12/2019		19/12/2019
Cites permits (valid 6 months) for export/import of corals 2020–2021	31/10/2020		04/09/2020
Cites permits (valid 6 months) for export/import of corals 2021–2022	31/10/2021		16/09/2021
Permits to collect corals and to do scientific work in Norwegian waters for 2021	31/12/2020		02/02/2021
Permits to collect corals and to do scientific work in Norwegian waters for 2022	31/12/2021		18/01/2022
Reaching decision on preliminary artificial reef design	31/01/2022	31/01/2023?	
		Here we wish to change deadline to 31/01/2023	

The objective of this action is to find the most optimal design of artificial reef (AR) structures and their placement relative to each other to maximise the contact rate and attachment of *Lophelia pertusa* (*Lp*) larvae. Laboratory studies of larval behaviour and substrate attachment, and hydrodynamic evaluations of the produced AR models and surface textures have been performed to evaluate the surface structure and overall shape of ARs.

Parental colonies of *Lp* have been collected in Norwegian waters (Tisler reef, Ytre Hvaler national park) to obtain larvae for the laboratory experiments. All permits necessary for collecting parental colonies of *Lophelia pertusa* (syn. *Desmophyllum pertusum*) in Norwegian waters have been obtained in time, in all years (2019, 2020, and 2021). Coral

collections were done in January 2020, November 2020, December 2021, and January 2022. Successful larval breeding was achieved during all spawning seasons (January-February 2020, 2021, 2022), although long-term viability of larvae was compromised by the presence of parasites, as explained below.

A 3D-printer was purchased in 2020 to be able to produce substrates with different textures and complexity for both the laboratory and field settling experiments. The 3D-printer has also been used to produce models of the ARs during the design phase, to test the hydrodynamic effects of different designs in a large laboratory flow channel equipped with instrumentation to measure flow speed and details of flow patterns and turbulence around the ARs.

A1.1. Prerequisites for successful larval attachment depending on flow conditions, sediment load and the structure and composition of AR surfaces

During the 2020 spawning season, pilot trials were performed in a small race-track flume in different flow velocities but no larvae attached to the experimental surfaces. The 2021 and 2022 spawning seasons did not produce any larvae that reached competency to settle, thus only short-term experiments have been successful so far. During 2022, experiments on embryo development and survival and pre-competent larval survival depending on exposure to suspended benthic sediment were performed. Results indicate sediment exposure arrested the development in early embryos and decreased survival in later stages of embryos with increased effects with increasing sediment load (0–25 mg/l). The fully developed larvae survived the sediment exposure with no detectable effects. Experiments were ended before the larvae reached competency for settling (attachment) and metamorphosis.

For the spawning season 2021, we developed complex substrates for a substrate choice experiment in a Computer Aided Design (CAD) program (Blender 2.8, 3.1) that was then 3D printed in different materials, i.e., black and white PLA (non-toxic made from corn and potato starch) and LayBrick Sandstone (fine-milled calcium carbonate mineral and PLA, white). Three different surface structures were tested: ridges, pillars, and Voronoi spheres (see fig. 1 substrate imgs). Observations were made on nine occasions when larvae were between 46 and 59 days old (c. 7–8 weeks), after which the larvae were in too poor condition to be active due to parasite infections, and the experiment was ended. Three replicate cups with 120 larvae in each was used for every round of observations. Only a few larvae were actively swimming on each occasion.

Larvae were observed interacting with the substrates and were found to be more interested in exploring the LayBrick substrates compared to the PLA (see fig.2). 68% of larvae preferred LayBrick. Retention time was longer on LayBrick, and they entered cryptic spaces and would remain there for longer periods, in contrast to the brief explorations on the PLA substrates. LayBrick is thus a very promising material for creating complex larval substrates that can enrich the surface of the ARs and facilitate larval recruitment.



Fig. 1. Examples of surface structures of 3D printed substrates (here only LayBrick) and pieces of metallurgic slag. From top left: pillars, flat (low relief) Voronoi, ridges, slag, high Voronoi.

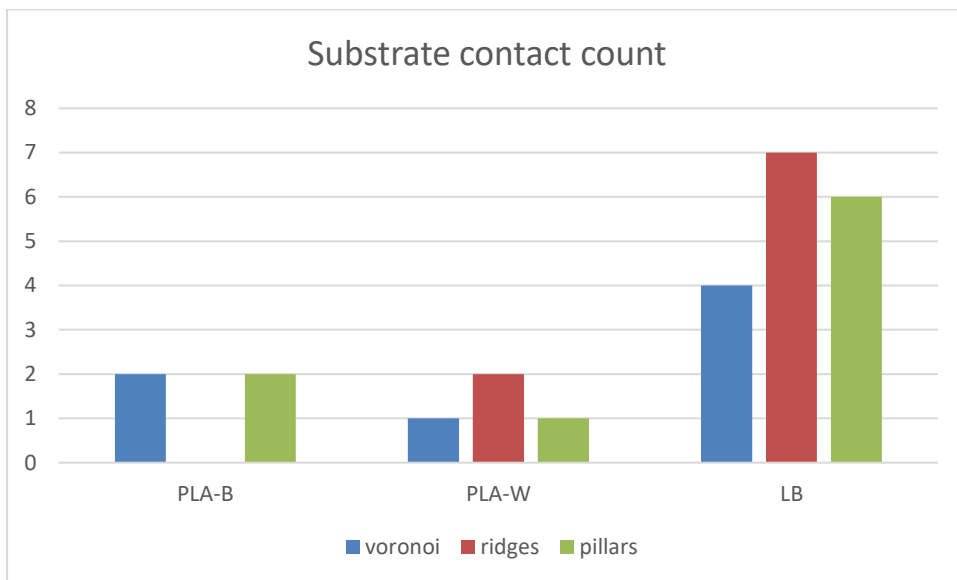


Fig. 2. Larval contact frequency on the different substrates. PLA-B = black PLA; PLA-W= white PLA; LB = LayBrick; Voronoi, ridges and pillars were the different surface structures.

During spawning seasons 2021 and 2022 we expanded our experiments on substrate choice and tested larval settling in moving water in two different custom-made set-ups. However, during both years there were problems with parasites in the larval cultures that ended in 100% mortality in these long-term experiments, and no results have been achieved. We have tried different measures to minimize the damage and are getting help sequencing the DNA of the parasites to be able to identify it and take more efficient measures to protect the health of the larvae for the next spawning season.

Because of the problems with laboratory reared larvae, we have expanded our field trials with both different materials and surface structures. The LayBrick substrates aimed for the lab experiments have instead been deployed in the field (03/2022). Other 3-D printed settlement surfaces with surface structure of different scales were deployed 04/2021, for more details see A1.4 below.

A1.2. Assessment of the industrial by-product metallurgical slag in cold-water coral restoration

During the first spawning season (Jan-Feb 2020) we tested how the larvae reacted to metallurgic slag (Petrit E from Höganäs AB) compared to natural substrates (coral skeleton). The larvae explored the slag and attached temporarily. The holes and crevices on the slag was not small enough for larvae to enter to seek protection, instead they attached on flat surfaces. On pieces of coral skeleton, however, the larvae entered cryptic spaces (spaces on the scale of the larvae). The slag has also been tested in the race-track flume and in the other set-ups with moving water, but no results could be derived from those tests. Pieces of slag is also deployed in the field trials, both small and larger more complex pieces.

In a second set-up during spawning season 2021 the metallurgic slag was compared to 3D printed LayBrick substrates, with the same three surface structures as described in section A1.1 above (see fig. 1). Observations were carried out on eight occasions from when larvae were 48 days old to 59 days old, with two replicate cups with 140 larvae in each. The larvae were observed interacting mostly with the pillars and ridges (see fig. 3), and less with the slag and Voronoi spheres. The Voronoi spheres are a very complex substrate with cryptic spaces where larvae can hide. Larvae were observed to swim into holes and remain inside, not visible for the eye. The count of larvae interacting with that particular substrate may thus be underestimated. All larvae on the other substrates were fully visible and possible to count.

The metallurgic slag is further tested using field deployments (see section A1.4. below). The results from these experiments will be examined during the fall of 2022.

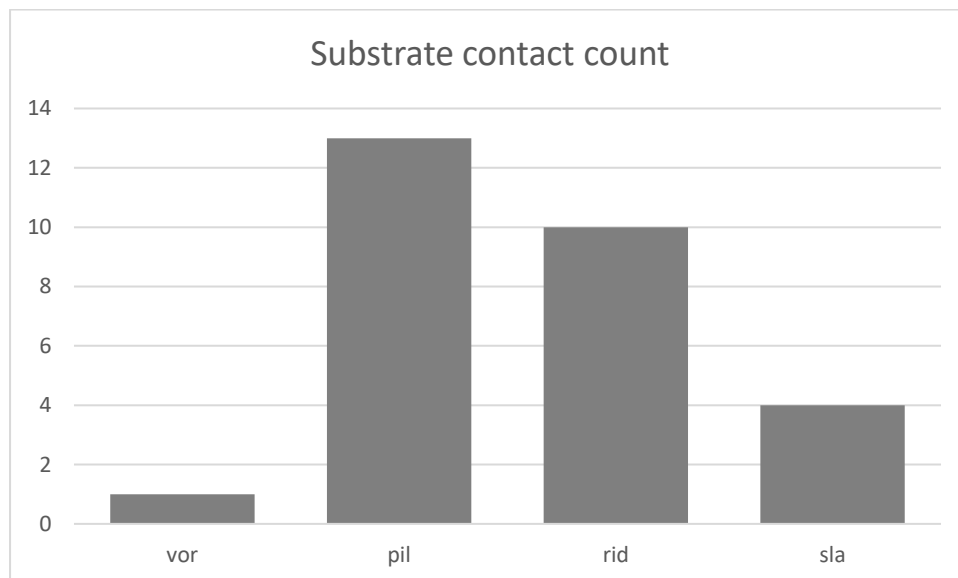


Fig. 3. Larval contact frequency on different substrate structures (LayBrick only) compared with slag. From left to right: vor = Voronoi spheres; pil = pillars; rid = ridges; sla = slag.

A1.3. Design and hydrodynamic assessment of artificial reef structures:

Twenty models of ARs have been designed in the CAD program. In a first screening of AR performance in a small circular flume, six of these models have been tested to evaluate the effect of design on the hydrodynamics, so that we can choose the most promising designs for further analysis in the large flow channel equipped with a PIVsystem (Particle Image Velocimetry) for detailed measurements of flow patterns and turbulence around the ARs.

A Mississippi type paddle in the middle of the circular tank put the water in motion, and two different velocities were tested, one low (c.10 rpm), and one higher (c. 20 rpm). Particles of similar size as larvae were used to visualize the water movements (see fig. 4 below). Both still images and 20-second video sequences were taken, with three replicates each.

Complex 3D printed substrates have also been designed and screened in the small circular flume under the same conditions as the above tests, to see if we can find a design that will enhance larval contact rate with the surface. Sixteen different designs were tested, and the screenings have revealed that the design of some of the substrates have created the kind of micro-eddies that potentially can allow larvae to attach to the surfaces. These complex substrates could enhance recruitment and act as primary recruitment points on the ARs. In the tests we used black PLA substrates for better visualization, while in the larval experiments we use the white LayBrick substrates, but with the same design.



Figure 4. Examples of two of the six tested AR models (left) and three of the sixteen complex substrates (right) designed to enhance coral larval recruitment. The traces are particle movements over the substrates, achieved by long exposure time. Two velocities were used, 10 and 20 rpm. Images are taken in the small circular flume for the purpose of initial screening of AR models and substrates. The most promising ones will be further analyzed in the large flow channel equipped with a PIV system.

The assessment of the hydrodynamic performance on AR models in the large flow channel using PIV has been delayed due to high demand from other projects using the flume and because of malfunctioning of the laser needed to perform PIV. A repairman representing the deliverer has tried to repair the laser on site but unfortunately the laser had to be sent for reparation in France where it will soon be reviewed and hopefully repaired. The delay in

hydrodynamic assessment of ARs is very unfortunate and one of the reasons we decided to postpone the deployment of the first round of ARs on our restoration sites which was originally planned for the autumn of 2022 (see also C2).

Due to this delay and the above-mentioned problems with parasites in larval cultures, we wish to change the deliverable “*Preliminary results of laboratory studies*” from 09/2022 to 09/2023 to be able to include results also from the next spawning season. Hence we intend to do laboratory work with larvae also in early spring 2023 and the hydrodynamic assessment of ARs in the flow channel will be conducted during autumn of 2022. Since we have postponed the first deployment of ARs until spring 2023 and the majority of ARs will be deployed in the autumn of 2023 (which also was originally planned), the delay will not affect the project in large.

A1.4. Measurement of settlement and recruitment rates of Lophelia pertusa on field deployed settling panels

Testing larval availability at different sites

To test for larval availability at all sites, settling racks and substrates for field settling experiments were constructed. Star-shaped settling panels were designed, and the final panels were cast in concrete in latex molds made from the original 3D printed models. The panels were mounted on 1 m long poles held together by a scaffold structure. Three by three panels at three different heights above seafloor (30–60–90 cm) was added. A total of 504 panels were mounted, half of them had metallurgic slag added on the surface, the other half without slag (fig. 5). Slag has been delivered by Höganäs Sweden AB, a metal processing company, and we have been in continuous contact with Björn Haase who is in charge of the company's efforts to find ways of using their rest products from the metal production.

Fourteen racks were constructed, with two racks placed at each of the six sites: Säcken, Grisbådarna, Björn's rev, Ulvillarna, SO Spiran, and Väderöarna. Two additional racks were deployed at our reference site Tisler, in Ytre Hvaler, Norway. The settling racks were deployed during February to April 2021, and recovery will commence in September 2022, c. one year and a half after deployment. We will analyze recruitment on the panels during fall 2022. The second round of racks is planned to be retrieved in the early autumn of 2023. Anticipated information to gain from this set-up is availability of *Lp* larvae and larvae of other reef associated fauna, preferred settling height above seafloor to guide us on how high the artificial reefs need to be, and if added slag on the concrete surface will increase recruitment. Other calcifying organisms will be used as indicators of the suitability of the substrate for coral larvae if no *Lp* larvae are found, since all calcifying organisms are benefiting from substrates rich in calcium carbonate and larvae of many species prefer cryptic spaces for settlement.

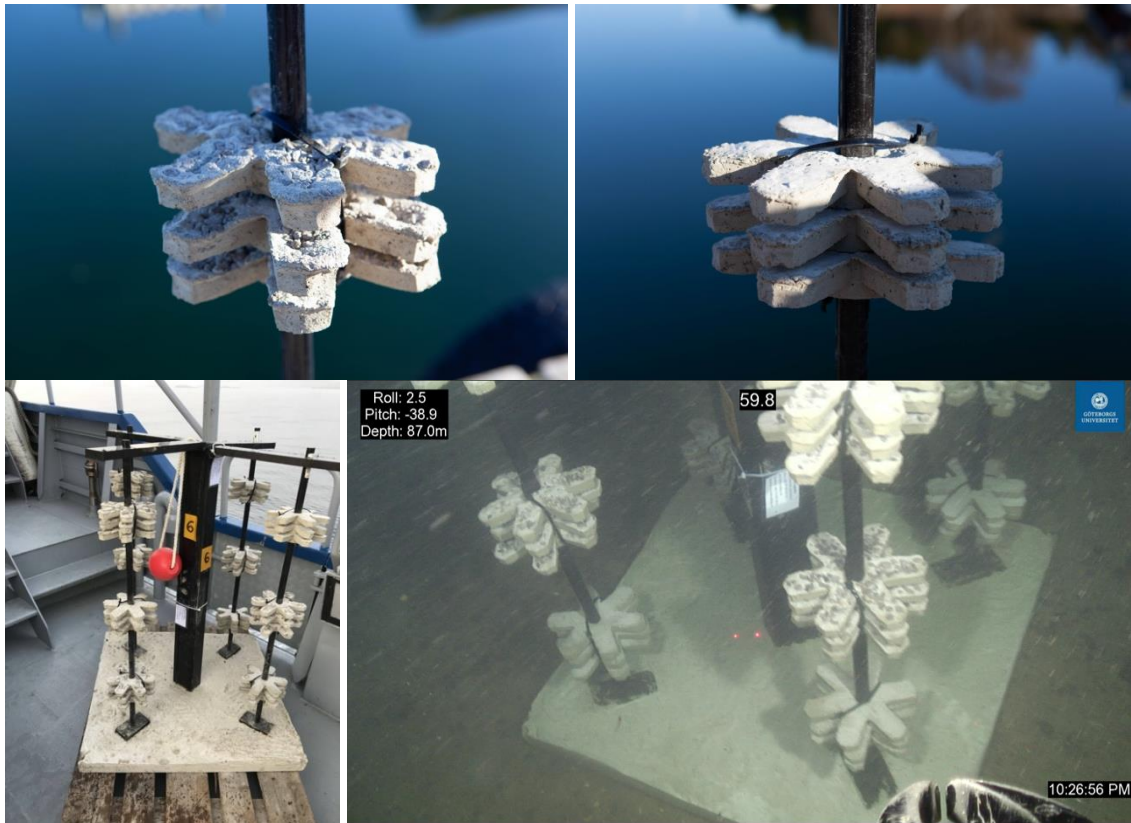


Fig. 5. Settling racks with star-shaped panels, with and without metallurgic slag, for the larval availability tests.

In addition to these settling racks, two racks of the same design were dedicated for more complex substrates. Mounted on the poles were cylinders of two kinds: concrete cylinders with slag covering the surface, and more complex 3D printed cylinders in LayBrick (fig. 6). Using other available surfaces on the racks, concrete bricks with larger pieces of slag on, and complex 3D printed LayBrick substrates were mounted on the top. On the mid-piece we attached 3D printed panels. The panels were printed in PLA and LayBrick and had grooves of 2 different dimensions, and flat controls. The grooved panels had either only macro structure (4 mm), microstructure (0.4 mm), or a combination of the two. The aim is to test the role of a combination of surface roughness on resulting recruitment of sessile fauna since a roughness scale close to larval size likely will be more important for settlement while roughness on the mm scale likely will benefit the survival of young recruits. One of these settling racks were deployed at Tisler, and the other at Väderöarna, in March 2021. The panels will be retrieved and evaluated in September–October 2022 to inform on choice of surface structure on the final ARs.

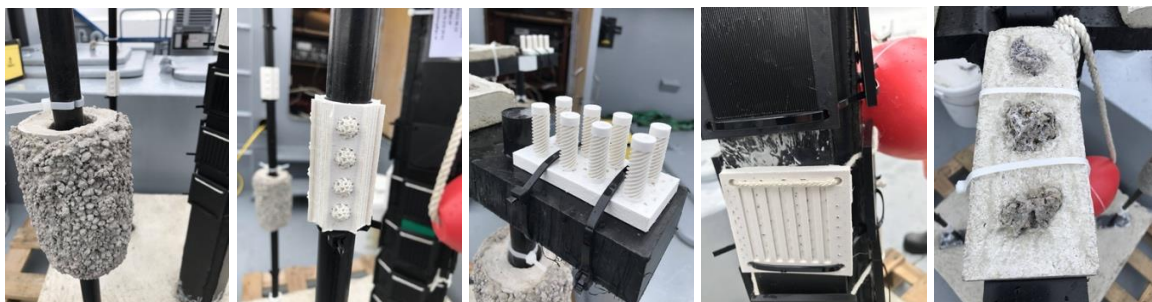


Fig. 6. Complex substrates: concrete cylinder with slag (8 per rack); 3D printed cylinder with grooves and Voronoi spheres (4 per rack); complex LayBrick substrate with protruding cylinders (4 per rack); panels with grooves (12 per rack) black = PLA, and white = LayBrick); and large pieces of slag casted onto a concrete brick (4 sets per rack).

Testing the effect of surface texture on recruitment

Two sets of settling panels focused on testing different surface textures was made in January and March 2022. The first set had 45 panels with three different surface textures produced by adding small stones, porous slag, and non-porous slag. This study was designed to try to discern the effect of the composition of the slag material from the effect of porosity, i.e., surface structure. (fig. 7). A standard concrete mixture was used: 1 part Portland Cement, and 2 parts sand (0.4–0.8 mm grain size), plus the added material on the surface. The panels were deployed at Väderöarna in February 2022. The second set consisted of 30 panels with two types of surface texture to test the effect of microscopic pores on the surface of the panels. The pores were rendered by adding an air-entraining admixture to the concrete. Half the panels had the additive, the other half was regular concrete mixture with 1 part Portland Cement, 1 part sand (0.4–0.8 mm grain size), and 4% air-entraining solution. The smaller amount of sand in this second set of panels was due to that the sand interfered with the air-entraining solution reducing the pores produced. This rack was deployed in April 2022.



Fig. 7. Panels with added small stones, smooth slag, and porous slag, to test for the effect of chemical composition and porosity of the added material.

The effect of concrete composition on recruitment and compressive strength

The composition of the concrete mixture can affect recruitment as well as the long-term stability of the ARs. By adding Ground Granulated Blast Furnace Slag (GGBS), silica oxide, and aluminum oxide to a cement mixture, the pH of the concrete becomes lower (pH 10–11, instead of pH 13–14 for standard Portland cement). This will increase compressive strength over time, and the lower pH has also been found to speed up recruitment for some organisms in previous studies. Two sets of panels were deployed: a first set with 18 panels mounted on one metal frame was deployed at an experimental jetty outside the Tjärnö Marine Laboratory at a shallow depth of 0.75–1.90 cm (deployed 16/07/2020; retrieved 11/08/2020), and a second set with 18 panels divided over three smaller racks were deployed at Tisler at a depth of 115–132 m (deployed 29/09/2020; retrieved 31/08/2021). This was a pilot study to test different cement mixtures with different pH to see if it is possible to enhance recruitment also in deep-sea temperate environments. The results were ambiguous, and surface texture seemed to be more important than pH or concrete composition. It is plausible that the faster recruitment seen in previous studies with cement of lower pH (10–11) is only observed during the first few weeks, until pH has reached equilibrium with the ambient seawater. With deployment periods over a year, this initial enhancement is probably negligible. Especially in a deep-sea setting where the recruitment process is substantially slower than in the shallows.

In October 2021 we started a new, full-scale, experiment with different cement mixtures with the help of a cement laboratory, C-Lab (Thomas Cement). Now with the focus of finding a cement mixture that will increase the longevity and compressive strength of the ARs in the marine environment. The preliminary results show that by mixing in GGBS and Silica oxide, the compressive strength increases over time beyond that of regular Portland cement (fig. 8). The in-mixing of GGBS will also reduce the carbon footprint of the concrete used for the ARs, another important goal of the chosen concrete composition. New panels (a total of 224), with controls (standard Portland cement, ref. CEM I 42,5 N SR3 MH/LA) and three different mixtures, were casted in January-February of 2022, and deployed in April at Väderöarna (fig. 9). See table X for the composition of the different mixtures. Besides the different cement mixtures, we also tested two different surface textures to produce panels with high surface complexity: slag mixed with wet cement of the same mix as the panel, and jute soaked in wet cement. These are cheap and simple ways of adding surface complexity on the ARs. A total of 224 panels were casted divided over the four cement mixtures and two surface textures, giving 28 replicates per texture*mix. These panels will be retrieved and analyzed after one year, so that we will get the results in time to adjust the concrete mixture of the major part of the ARs to be deployed if necessary.

Together with the concrete panels, some LayBrick substrates were also added to the racks when deployed. These were the LayBrick substrates that was aimed for the long-term larval laboratory experiments with substrate choice in moving water that could not be run due to parasites (see section A1.1).

Table 1. The cement mixtures and water content tested. PC = Portland Cement; GGBS = Ground Granulated Blast Furnace Slag; MFS = MicroFil Silica (silica oxide). A plasticizer (Master Glenium 5118) was used since this additive will be used for the final cement mixtures for the ARs. The increasing amount of Glenium with increased fraction of silica oxide was to counter the reduced workability with increased silica content. Sand with standardized grain size was also added to the mixtures.

MIX	DRY CONTENT	WATER CONTENT (L)	MASTER GLENIUM	DATE CAST
C1	100% PC	2.097	20 g	13 jan
M1	50:50 PC:GGBS	2.097	20 g	17 feb
M2	40:40:20 PC:GGBS:MFS	2.0961	25 g	22 feb
M3	30:40:30 PC:GGBS:MFS	2.095	30g	13 feb

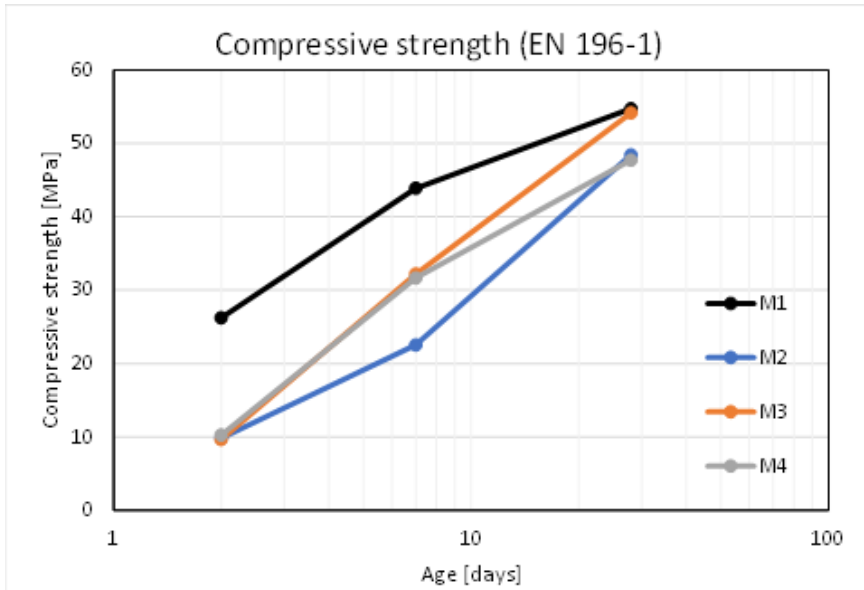


Figure 8: Preliminary results: Compressive strength of the four different cement mixtures tested at day 2, 7, and 28. The compressive strength starts lower in the mixtures, but will surpass the strength of standard Portland Cement over time. Further results from tests at 90 days and beyond will be added.

M1 = standard Portland Cement, PC (CEM I 42,5 N SR3 MH/LA); **M2** = 50:50 PC:GGBS; **M3** = 40:40:20 PC:GGBS:SF; **M4** = 30:40:30 PC:GGBS:SF

PC = Portland Cement

GGBS = Ground Granulated Blast furnace Slag

SF = Silica Fume (silica oxide).

Note that our control (C1) here is called M1, and all names of the mixtures has been shifted to M1–M4 instead of C1, M1–M3 as in the table above.



Figure 9: Settling panels with different cement mixtures, two surface structures (slag mixed with cement, and jute soaked in wet cement), and 3D printed complex substrates. Day of deployment, April 11, 2022.

Action A2 Expanded fishery restrictions (CABO)

The purpose of this action was to ban all type of fishing gear in the restoration areas before the deployment of the artificial reefs.

Foreseen start date: Oct 2019

Actual start date: Oct 2019

Foreseen end date: 03/2021

Actual end date: 15/10/2021

<i>Deliverable</i>	<i>Deadline</i>	<i>Delivered</i>
Proposed increase (extension) in fishing ban reported	17/12/2020	08/01/2021
		Annex 1_Deliv A2_LIFE Lophelia_fishing ban.pdf

In the autumn of 2021, new fishing rules were introduced and since 15/10/2021 all six restoration areas are now non-fishing zones, no fishing gear are allowed.

Since 2015 all six restoration areas have had a trawling ban but it was allowed to fish with anglers and cages. Although anglers and cages are much less destructive compared to trawling there is still a possibility that these gears can cause damage to the corals and the artificial reefs (ARs). This action is necessary to ensure that both the ARs and the coral reefs are protected from negative impacts from fishing gear.

The question was raised with the authority that regulate fishing in Sweden, the Swedish Agency for Marine and Water Management (SwAM) and with local fishermen in early 2019. The action included meetings between CABO, SwAM and the fishermen using the areas. Together with SwAM the Project manager (CABO) had meetings with local fishermen in October 2019 and May 2020. After that SwAM sent out a referral in January 2021 on proposals for new fishing regulations in these areas, but also other areas in Sweden. The referral (proposal) from SwAM to the fishermen's organisations and to other authorities was delayed a month, however the regulations in the restoration sites entered into force on 15/10/2021. This means that the expanded fishing rules are in place well before the deployment of the artificial reefs (action C2).

Action C.1 Environmental mapping of reef sites to be restored (CABO, UGOT)

This action aims to thoroughly map the sea floor, the environmental conditions and biodiversity at each reef site before deployments of the artificial reefs (AR).

CI.1: Detailed mapping of total geographical distribution, bottom topography and living parts of each reef area. (CABO)

Foreseen start date: 04/2020

Actual start date: 02/2020

Foreseen end date: 09/2021

Actual end date:

Here we wish to change foreseen end date to 12/2022.

<i>Deliverable</i>	<i>Deadline</i>	<i>Changed</i>	<i>Delivered</i>
Report on the initial habitat complexity and biodiversity.	30/09/2022	31/12/2022?	
		Here we wish to change deadline to 31/12/2022	

<i>Milestone</i>	<i>Deadline</i>	<i>Changed</i>	<i>Delivered</i>
The baseline of <i>Lophelia pertusa</i> cover and biodiversity measures is established.	30/09/2022	31/12/2022?	
		Here we wish to change deadline to 31/12/2022	

This action has been implemented, what remains is a report on biodiversity and living parts of the reefs. This report will be finalized to 31/12/2022, the three months delay in reporting will not affect any other actions.

Sonar survey

Using an Automated Underwater Vehicle (AUV) equipped with high-resolution sonar (SSS 900 kHz) the bottom complexity of the targeted sites was mapped during 2020-21. The purpose was to assess where exactly to place the ARs, to measure the bottom complexity before deployment and possibly find new corals. The company that carried out the study, Clinton AB, was contracted after the usual procurement procedure.

The costs for this underwater mapping were unfortunately underestimated in the project budget. The County Board is prepared to cover the additional costs by increasing their own funding if required by approximately 195,034 euros (2,000,000 Swedish krona) to cover this extra cost. We have communicated this with our Project Advisor *Mr ZABLECKIS Sarunas (CINEA)*, who has approved this change” if it will not interfere with your ability to abide with the 2% rule as stated in the General Conditions Article II.19.2.a”. Reference e-mail: LIFE18 NAT/SE/000959 - LIFE LOPHELIA - Project visit 26 - 27 November 2020.

The investigation started in November 2020 but had to be stopped shortly afterwards due to technical problems with two of the used AUVs. During the current pandemic, repairs were delayed. The survey was resumed in April 2021 and all field work was completed in August 2021. Results from the data processing and the final report were received on 03/05/2022.

The resolution of the sonar mosaic images was not as high as desirable. The complex topography in the survey areas affected the quality of the data and made it difficult to interpret. Coral reef presence could only be identified in flat areas with large reefs directly in the sonar images. By the combined analysis of sonar, multibeam and backscatter data from the restoration sites, we will still get good information about the bottom complexity and whether there is current swept seafloor or soft sediments to guide our decisions on where to place the ARs.

Biodiversity investigation

The Swedish University of Agricultural Sciences (SLU) was commissioned by CABO (by government agreement) to conduct a survey in September 2021 of the biological biodiversity surrounding the remaining coral reefs in the restoration sites. During the survey, video transects were filmed with a drop camera from the ship R/V SVEA. SLU also undertakes to analyse the filmed material and measure area with living coral and area with dead coral (coral rubble) and the presence of various species in these areas. Both benthic and mobile fauna shall be documented. Collected transects will be analysed based on 30 samples per area. Each sample consists of 90 seconds of video. These 90 seconds are randomized from the entire collected video per site. Biodiversity (Shannon-Wiener's diversity index and number of species) is used to monitor the associated fauna in areas with both living and dead coral, respectively. The analysis is ongoing, and a report will be delivered 31/12/2022.

There was some correspondence with our Project Advisor *Mr ZABLECKIS Sarunas (CINEA)* in April 2021 (2021/04/15-19) concerning the procurement of this biodiversity investigation. We asked if it was possible to change from procurement to agreement between government authorities and make an agreement with SLU for this survey since it would benefit the project both in terms of finances, quality and continuity for future monitoring. *Mr ZABLECKIS* accepted this and judged that no amendment was needed, since it follows the procurement rules that apply to authorities in Sweden. Reference: Ares (2021)2584997 - RE: LIFE LOPHELIA, LIFE18 NAT/SE/000959 - question on agreement between state authorities.

C1.2: Measurements of environmental conditions on each reef site (UGOT)

Foreseen start date: Apr 2020 Actual start date: Feb 2020
 Foreseen end date: Mar 2022 Actual end date: Jun 2023

<i>Milestone</i>	<i>Deadline</i>	<i>Delivered</i>
Permits for temporary objects (instrument and settlement panels) for deployment from autumn 2020 to throughout the year of 2022		08/2020

Measurements of environmental conditions on each reef site have been conducted since February 2020. Measurements were initiated a few months before expected start date (quarter 2 2020, Gantt chart in proposal erroneously marked 3 quarters too early) Foreseen end date for the collection of environmental data was in the first quarter of 2022, but we plan to continue to collect data until quarter 2 of 2023 to complete our datasets and to discern possible seasonal/annual variability. One Acoustic Doppler Current Profiler (ADCP) was flooded and corrupted during a 5-month deployment at one of the restoration sites, leading to delays in data collection as well as extra expenses related to the purchase of a new instrument. Delays with the procurement process of the sediment traps retarded our progress

larval dispersal in the Skagerrak and the Norwegian project EcoPulse (funded by the Research Council of Norway), which studies the effect of internal waves on cold-water coral occurrence and ecology. Through these collaborations, we will also attain modelled oceanographic data for longer time series, complementing our sporadic measurements.

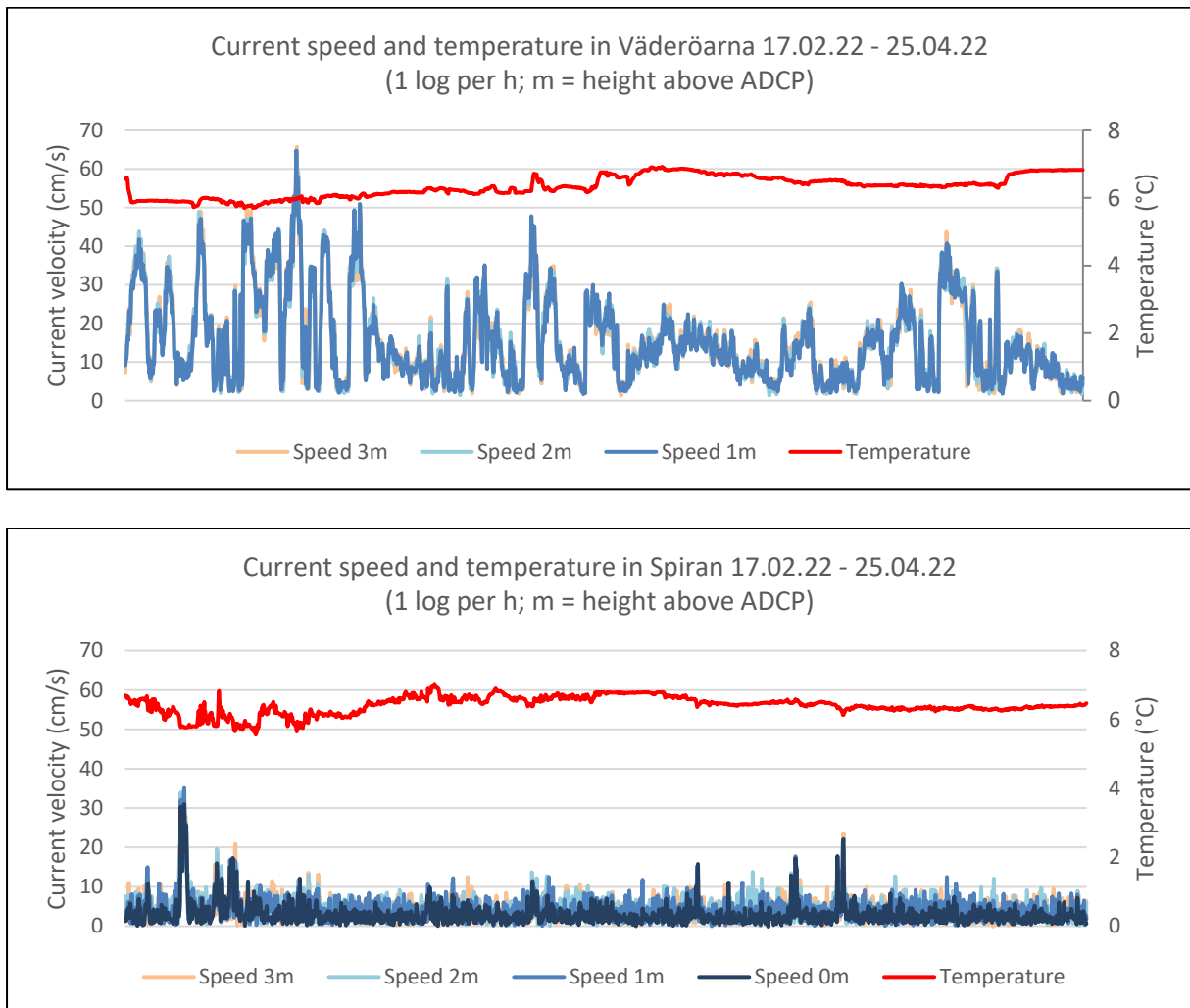


Figure 10. Examples of current velocity and temperature data collected from two different restoration sites over the same 2-month period.

Action C.2 Manufacturing and deployment of artificial reef objects (CABO)

In this action, we implement the method developed in A1 with the attempt to restore *Lophelia pertusa* reef habitats in the project area. This action is also dependent on information gathered in C1.

C2.1: Manufacturing of artificial reef objects

Foreseen start date: 01/03/2021

Actual start date: 02/2022

Foreseen end date: 30/11/2023

Actual end date:

<i>Deliverable</i>	<i>Deadline</i>	<i>Changed</i>	<i>Delivered</i>
Final blueprints of artificial reefs ready	30/06/2022	30/06/2023	
		Accepted change 01/10/2021, Letter from PA, reference: LIFE18 NAT/SE/000959 - LIFE LOPHELIA - Project visit 31 Aug - 1 Sept 2021.	

<i>Milestone</i>	<i>Deadline</i>	<i>Changed</i>	<i>Delivered</i>
Contract signed with manufacturer of artificial reefs	31/03/2022	31/03/2023?	
Here we ask to change deadline to 31/03/2023			

Manufacturing was planned to take place in Aug-Sept 2022 by a contracted manufacturing company. The procurement procedure was prepared in February 2022 and was announced on 30/03/2022. We have in this procedure had dialogue with several manufacturing companies about what is possible to manufacture. After these dialogues we decided (in June 2022) to postpone the manufacturing and deployment of the first reefs to 2023. The reason why we are postponing manufacturing and deployment is that we need more results from our studies (action A1 and C1) to be able to specify material and design for the artificial reefs and to minimize the need of changes for the second round. This will delay the time for first evaluations of the ARs, but we think the data achieved from the field trials with settling panels (in autumn 2022) will make it possible to make better decisions about the design of the ARs and surface texture. The plan is to deploy ARs from spring-summer 2023 and to Oct-Nov 2023, all ARs will be deployed in 2023. The production of casting molds is costly, and the more we know about the optimal form and surface texture beforehand, the less adjustments of the molds or new builds will be needed. This will potentially lead to a reduction in price for manufacturing.

C2.2: Deployment of artificial reef objects

Foreseen start date: 15/09/2022

Actual start date:

Foreseen end date: 31/10/2023

Actual end date:

<i>Milestone</i>	<i>Deadline</i>	<i>Changed</i>	<i>Delivered</i>
Permits for stationary objects (artificial reefs) for 2022–2023	30/09/2021		17/12/2021
Final reef design decided together with the contracted company	29/04/2022	30/06/2023	
		Accepted change 01/10/2021, Letter from PA, reference: LIFE18 NAT/SE/000959 - LIFE LOPHELIA - Project visit 31 Aug - 1 Sept 2021	
First round of artificial reef deployments finished	31/03/2023	31/10/2023?	
		Here we wish to change deadline to 31/10/2023	

Deployment was planned to take place in the autumn of 2022 with a few artificial reefs (30-60) and most reefs (approx. 400) in autumn of 2023. Now all AR will be deployed in 2023. Deployments was planned to be made using the UGOT research vessel Nereus. However, we have included the deployment in the procurement for the manufacturing of the AR. This means that the company we contract will be responsible for manufacturing, transport and deployment. The reason is partly that the question of responsibility becomes clearer if something should go wrong and one or more reefs are damaged during transport and deployment, and partly that there are too many reefs to be deployed with R/V Nereus, that has limited deck space and weight capacity on the A-frame onboard. The financial consequences of this will be that more money will go to the contracted company. As previously planned, the costs of deployment would end up on UGOT for their research vessels. All costs (manufacturing and deployment) will now end up in the category External costs and on CABO, as CABO will be responsible for the procurement of production and deployment. Costs for UGOT for deployment were divided into several categories; external assistance, consumables and other direct costs (see 8.1 for further details).

Action D. Monitoring of the impact of the project actions (CABO, UGOT)

Monitoring of conservation status has taken place during 2021 under C1 before the first deployment and then there will be monitoring after the second deployment of artificial reef objects. The monitoring made under C1 will be used for extraction of data needed to assess the conservation status before restoration actions are implemented.

Foreseen start date: 09/2019

Actual start date: 09/2019

Foreseen end date: 12/2025

Actual end date:

D.1: Monitoring of conservation status and public outreach (CABO)

<i>Deliverable</i>	<i>Deadline</i>	<i>Delivered</i>
Report of achieved increase of habitat complexity, biodiversity and ecosystem services	12/2025	
Report of public outreach success	03/2026	

For the public outreach we gather statistics regarding the number of individuals reached through our channels of communication; visitors to the Visitor Centres, web sites, lectures, etc. for details see action E1.

D.2: Evaluation of the restoration method and actual replication and transfer (UGOT)

<i>Deliverable</i>	<i>Deadline</i>	<i>Delivered</i>
Report of the evaluation of the restoration method and actual replication and transfer	03/2026	

The work in this action is concentrated to the end of the project (start quarter 1 2025) since it is only by then we have indication of how well the restoration method is working, and how well we have succeeded with replication and transfer of the project.

D.3 Monitoring of LIFE Key Project Indicators (CABO)

<i>Deliverable</i>	<i>Deadline</i>	<i>Delivered</i>
KPI Webtool and analysis of results	02/2021	11/02/2021
		Annex 2_Deliv D3_LIFE Lophelia_KPI_revised.pdf

<i>Milestone</i>	<i>Deadline</i>	<i>Delivered</i>
Up-date of KPI Webtool and analysis of results	12/02/2021	11/02/2021
Up-date of KPI Webtool and analysis of results	27/03/2026	

The KPI web tool has been completed and data has been verified.

- Establishing the exact baseline for *Lophelia pertusa* reef habitats is ongoing under actions C1. Special focus for the associated biodiversity will be on the red listed species, *Macandrevia cranium*, *Munidopsis serricornis* and the spiny dogfish *Squalus acanthias*.

- Population data of fish and crustaceans as well as fish catch (cod, shrimp) is monitored by the Swedish Agency for Marine and Water Management every year- and we will use their statistics to evaluate the effect of the deployed ARs.
- CABO monitor the visitors to the National Park area every year.
- For the dissemination/awareness we gather statistics regarding the number of individuals reached through our channels of communication; visitors to the Visitor Centres, web sites, exhibitions, cruises with boat that visits the ARs.

Any results on the targeted species in the KPI are not expected until the final evaluation of the follow-up on the biodiversity surveys, and the monitoring of recruitment on the deployed ARs. We are convinced that we will be able to report all indicators.

Action E. Public awareness and dissemination of results (CABO, UGOT)

Foreseen start date: 01/10/2019

Actual start date: 01/10/2019

Foreseen end date: 31/12/2025

Actual end date:

E.1 General communication and dissemination (CABO)

This action aims at communicating the results in a broad sense and at networking.

Information from mostly A1, C1 and C2 is and will be communicated here. The action is divided into 5 sub actions:

<i>Deliverable</i>	<i>Deadline</i>	<i>Changed</i>	<i>Delivered</i>
Noticeboards printed	12/2019		09/2020
			Annex 4_Deliv E1_LIFE Lophelia_Notice boards.pdf
Communication plan completed	12/2019		30/09/2020
			Annex 3_Deliv E1_LIFE Lophelia_Commun.plan.pdf
Web site published	02/2020		28/02/2020
			Annex 5_Deliv E1_LIFE Lophelia_webpage.pdf
Leaflet printed	06/2022	30/11/2023?	
		Here we wish to change deadline to 30/11/2023	
Public video produced	11/2022	11/2023?	
		Here we wish to change deadline to 11/2023	
Scientific video produced	03/2025		
Layman's report printed	03/2026		
After LIFE plan	03/2026		

<i>Milestone</i>	<i>Deadline</i>	<i>Delivered</i>
Web site published	02/2020	28/02/2020

We here ask to change deadline for the Deliverable *Leaflet printed* to 30/11/2023 and *Public video produced* to 11/2023 to be able to incorporate information and pictures on the artificial reefs, because the ARs are central to the project and manufacturing of ARs will start in spring 2023.

E1.1. Dissemination/Communication Plan (CABO)

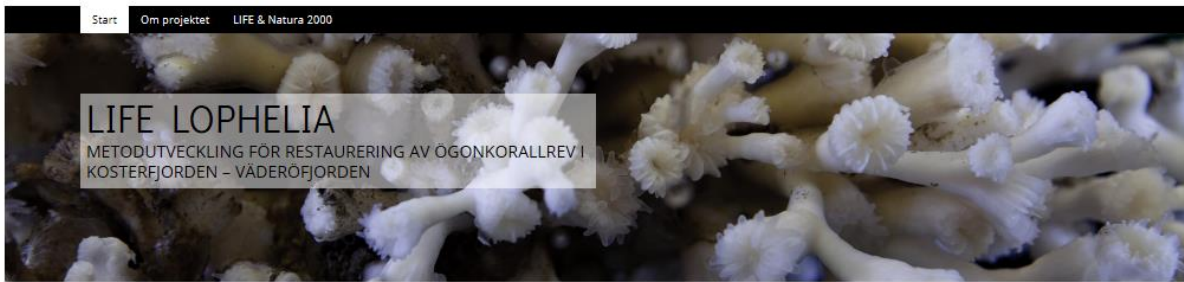
The communication plan was completed by CABO and approved by the Steering Committee in September 2020. The overall communication goals are to spread knowledge about the LIFE *Lophelia* project, the coral, the habitat it forms and about Natura 2000, as well as the EU LIFE fund. The primary focus, however, is to spread knowledge about the project and its results. But also, general knowledge about the coral and about the biodiversity that a living reef creates. This plan, written in Swedish, include all general aspects of the information package of the project; project logotype, directives regarding the use of the EU-logotype, content and time plan for updating of the project website, media contacts, production of roll-up, leaflets and notice boards etc.

Internal target groups are all employees at the County Administrative Board's Department of Nature and Water, as well as researchers, doctoral students and students at the Department of Marine Sciences, University of Gothenburg.

External target groups are the public, school children, the local population in Tanum and Strömstad municipalities, local tourist offices, local professional and recreational fishermen, authorities in Sweden (Swedish Maritime Administration, Swedish Environmental Protection Agency, coastal County Administrative Boards, coastal municipalities), interest groups (WWF, SNF, Greenpeace, STF, etc.), Swedish LIFE network, other LIFE programs in the EU, European Commission, authorities in other countries in need of coral restoration (will be identified within the project). Researchers in Sweden and internationally (with a focus on the EU).

E1.2: Noticeboards, website, Layman's report (CABO)

A project website is up and running since Feb 2020 www.lifelophelia.se (fig. 11). The website has had in total 1934 visitors from the start to 30/04/2020. We have basic information on the web about the project including a five-minute video in English that we were asked to produce to a digital Nordic-Baltic LIFE meeting in April 2021 (this was not in the proposal/GA). We publish news on the web regularly on what happens in the project.



LIFE Lophelia ska skapa förutsättningar för fler rev med ögonkorall

Idag finns bara två små levande korallrev i Sverige. Det fanns fler korallrev förr, både i Sverige och inom övriga Europa.

Ögonkorallen, *Lophelia pertusa*, är en revbyggande kallvattenkorall som bildar spektakulära ekosystem. Drygt 1 300 olika arter har observerats vid rev av ögonkorall. Det är en precis lika imponerande artrikedom som vid tropiska korallrev.

Vi ska tillverka och placera ut konstgjorda revstrukturer i havet. Då får korallernas larver något att sätta sig på. De behöver hårda ytor som sticker upp från havsbotten för att trivas. På så sätt ska vi restaurera tidigare kända områden med död och levande ögonkorall i Kosterfjorden/Väderöfjordens Natura 2000-område.

Method development for cold-water coral reef habitat restoration with implementation in Kosterfjord-Väderöfjord, Sweden

LIFE *Lophelia* will create the conditions for more coral reefs. Today there are only two small living coral reefs in Sweden. There were more coral reefs in the past, both in Sweden and in the rest of Europe. The coral, *Lophelia pertusa*, is a reef-building cold water coral that forms spectacular ecosystems. More than 1,300 different species have been observed in these coral reefs. It is just as impressive species richness as in tropical coral reefs.

We will design, produce and place artificial reef structures in the sea. Then the coral larvae get something to settle on. They need hard surfaces that protrude from the seabed to thrive. In this way, we will restore previously known areas with dead and living corals in the Natura 2000 area of Kosterfjord-Väderöfjord.

Aktuellt



Fig 11. Web site www.lifelophelia.se

Seven notice boards are produced and currently posted at six locations; the Kosterhavet Visitor Centre, the Tjärnö Marine Laboratory (fig. 12), at the National Park Entrances at Saltö, Rossö and Strömstad Tourist Centre, and at Väderöarna guest harbor (Tanum municipality). The National Park entrance at Resö is under construction (and delayed) and a notice board will be placed there during spring 2023, when the building is finalized. In the proposal we planned for five notice boards and two smaller signs. A disclaimer "The responsibility for the contents lies with County Board and does not reflect the official position of the EU" is put on all signs after a reminder from our monitor and Project Advisor, reference: e-mail LIFE18 NAT/SE/000959 - LIFE LOPHELIA - Project visit 26 - 27 November 2020.



Fig 12. Slide show and notice board at Tjärnö Marine Laboratory, both with disclaimer.

E1.3. Implementation of the dissemination pack (CABO)

We have information about the project in a short slide show (from June 2020) in the National Park visitor centre and at the aquarium at Tjärnö Marine Laboratory (fig 12). This was not planned for in the proposal, but we thought that it was valuable since a lot of people visit the centre each year. A total of 85441 people has visited the centre from June 2020 to the end of April 2022 (despite the pandemic years) and the aquarium at Tjärnö had 4200 visits during summer 2020 and 2021, which was much less due to the pandemic.

We were asked to produce a five-minute overview video in English about the project to a digital Nordic-Baltic LIFE meeting in April 2021. This video was not in our plans in GA but has been valuable to have and is still available at our web and at YouTube (<https://youtu.be/U2FQA0OzfdA>). The video was also shown at the ENCORE conference in September 2021, a conference that the chairman of our steering committee participated in.

The plan is to send press releases when we have interesting information and when necessary (decided in the communication plan). After the first press release in June 2020 there has been great interest from journalists. With interview in regional radio (P4-Väst) and an article on the International Day for Biological Diversity at www.havet.nu (a web jointly run by several universities). We were also interviewed by Dagens Industri, a daily newspaper in trade and industry, resulting in articles following in many smaller newspapers and an interest in the project by a large industrial company specializing in underwater technology. Articles in the government research council Formas' online magazine Extrakt, and in the major daily newspaper Göteborgs-Posten. There have also been articles in local media (Trossen, Strömstad tidning, Allihopa), as well as in our social media.

A second press release from the University's communication department in February 2021 on coral-larvae release in the laboratory resulted in great interest from the national media, our largest news programs on television (Rapport, TV4 Nyheterna) and both national (Sveriges radio) and local radio (P4-Väst) and the major daily newspaper Dagens Nyheter. There is also a film about corals and the project on [UR Samtiden - Naturum Kosterhavet: Koraller i kalla hav | UR Play](#), a national television channel for education and a film in an online magazine Deep Sea Reporter [Svenska korallrev ska räddas - Deep Sea Reporter](#). We have also been part of a nature program on national radio (P1) in February 2022 (fig. 13).

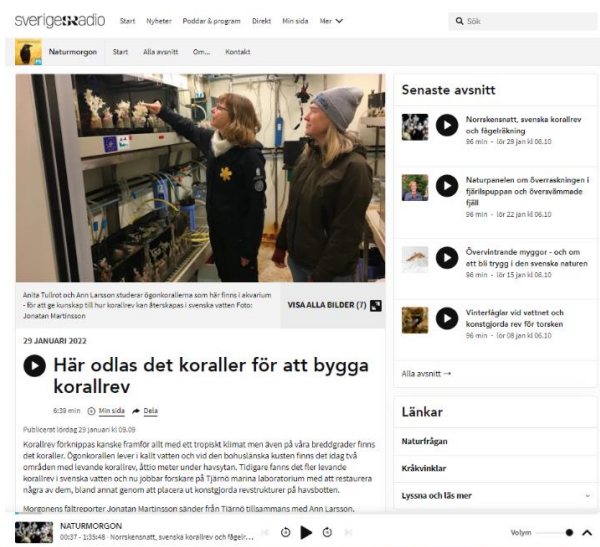


Fig 13. From Naturmorgon web page on Swedish national radio (P1) in February 2022.

Both the company that supplies us with the metallurgic slag (Höganäs AB), and the cement laboratory (C-Lab) that helped us with the different cement mixes and tests, have published articles online at their web sites about the project and our collaborations.

We have received a lot of attention even without press releases. The different media (newspapers, radio, TV) have inspired each other, and we have received good publicity via the social media, but also from the two press releases that were sent out. Cold-water corals are charismatic organisms, and most people are not aware of that we have them in Sweden. This fact helps making the impact of articles and interviews so great.

Video/film

In the proposal/GA we planned for two professional videos, one for the public and one to support the technical handbook. The video aimed to the public to inform about the *Lophelia pertusa* habitat and the restoration project is being produced under 2022. A company called Gullers has been commissioned by CABO to produce this film. They have started with interviews and filming, but this will continue in September 2022. This video will be in Swedish, with subtitles in English. It will be released on the project website and on YouTube. It will also be shown at Kosterhavet Visitor Centre and at Tjärnö Marine Laboratory for students and for the public.

For the technical video, we will be able to use parts of the filmed material for the public video, but here we need to add more details so that it can support the technical handbook. The technical video will be produced by an employed filmmaker at CABO who can follow the project for a longer time period. This has become possible because we have used less money for staff than we budgeted for (see explanation 8.1)

Student's visits

Our project has attracted attention from thirteen students so far, probably as a result of the attention from media. A student from Malmö University interviewed us on cold-water corals and the effect of climate change, for a seminar project. Another student, from Västsvenska gymnasiet (high school) visited us for an interview on effects of climate change on cold-water corals as part of her high school work. We have also had a weeklong visit from four high school students from Uppsala who did work on corals and sustainable development. We have also attracted three art students that wanted to raise awareness of deep-sea corals, through their art projects. A student in journalism, media, and communication wanted to include LIFE *Lophelia* in a series of articles on climate change for a Bachelor thesis.

A number of University students (a total of 29 during the reporting period) have contacted us and asked about the possibilities of doing an internship or a bachelor's or master's project within the project, of which a bachelor's degree and a master's degree have been completed. We have also had two University students for internship during spring 2022 who have helped us with various practical things.

We did not plan for any students in the proposal/GA but have been able to help those who have reached out with questions as time permits and where there have been suitable tasks within our project for a degree student. We think that this as a good way to spread information about the project.

Lectures

We have held several lectures about the project both online and in person for groups of students at the University of Gothenburg, and other universities or high schools and also for persons from different authorities. In total we have had an audience of 763 people on 29 occasions. For example, an online lecture for students at the International School of Gothenburg, called Ocean Blues – turning eco-anxiety into eco-action. A popular science talk for the public was held at Tjärnö Marine Laboratory in July 2021 (fig. 14).



Fig 14. Dr. Susanna Strömberg giving a popular science talk to the public, July 2021.

E1.4: After-LIFE plan (CABO)

This will be produced in the end of the project.

E1.5: Networking with LIFE and non-LIFE projects (UGOT)

During the kick-off and study visit in October 2019 at the University of Azores in Portugal we exchanged experiences and presented our projects for each other. In the Azores, restoration experiments are being carried out for several species of corals and they are participating in several large research projects (Horizon 2020: MERCES, ATLAS, iAtlantic). We agreed to cooperate in the future, and this resulted in a visit from the Azores by a supervisor and her PhD student in February 2022, who performed experiments at the Tjärnö laboratory during the stay. Further collaboration is planned with a new PhD student visit in Sep 2022.

Within this project we are networking and have been networking with other projects through both collaborations and dialogs/knowledge exchange. The projects are listed below:

MERCES	Marine Ecosystem Restoration in Changing European Seas
EU-ATLAS	A trans-Atlantic assessment and deep-water ecosystem based spatial management plan for Europe
iAtlantic	Integrated Assessment of Atlantic Marine Ecosystems in Space and Time
LIFE ECOREST	Restoration of deep-sea habitats with the active collaboration of fishing industry stakeholders
RESTORESEAS	Marine Forests of animals, plants and algae: nature-based tools to protect and restore biodiversity

EcoPulse	Ecosystem structuring by pulses of internal wave breaking
UGOT PhD-project	Biophysical Modelling of <i>Lophelia pertusa</i> Larval Dispersal in the Skagerrak

E2. Dissemination of scientific results (UGOT)

<i>Deliverable</i>	<i>Deadline</i>	<i>Changed</i>	<i>Delivered</i>
Summary of scientific workshop	30/09/2022	15/12/2023	
		Accepted change 01/10/2021, Letter from PA, reference: LIFE18 NAT/SE/000959 - LIFE LOPHELIA - Project visit 31 Aug - 1 Sept 2021	
Technical handbook published	19/12/2025		

<i>Milestone</i>	<i>Deadline</i>	<i>Changed</i>	<i>Delivered</i>
First networking workshop arranged within the project, accepted to 08/2023	31/08/2022	08/2023 (accepted) 10/2023?	
		Accepted change 01/10/2021, Letter from PA, reference: LIFE18 NAT/SE/000959 - LIFE LOPHELIA - Project visit 31 Aug - 1 Sept 2021	
		Here we wish to change deadline from 08/2023 to 31/10/2023	

We want to move the workshop forward to September-Oktober 2023 to be able to have more results from experiments to present on the workshop and not to collide with the International Symposium on Deep-Sea Corals in Edinburgh that has been postponed to the end of May 2023. We asked earlier to postpone it to August 2023 and got acceptance for this from our PA on 01/10/2021, see the table above.

E3. Sustainability and replication of project – CABO & GU

<i>Deliverable</i>	<i>Deadline</i>	<i>Delivered</i>
Summary from arranged seminar	16/06/2023	

<i>Milestone</i>	<i>Deadline</i>	<i>Delivered</i>
Final conference	18/06/2025	

A seminar will be arranged in April/Maj 2023 targeting the public, authorities, fishermen, tourist entrepreneurs and other stakeholder of the Natura 2000 area and deep-sea coral habitats. At this seminar we will present the results so far and also present the artificial reefs.

The process of replication and transfer has already started since we were approached by a H2020-proposal consortium, iMERCES, which in one of the WPs aimed to restore populations of *L. pertusa* in Scottish and Irish waters. In this proposed project, we were supposed to deliver knowledge on larval biology and settlement substrate selection by *L. pertusa* and hydrodynamic performance of reef structures to inform restoration unit design. The proposal was submitted in Jan 2021 but was not funded. This shows however that the knowledge and techniques being developed in this project is in high demand with high possibilities of replication and transfer.

We were invited to join a BiodivERsA call with the acronym RESTORESEAS headed by Professor Ester Serrao from Portugal. The project was accepted for funding and started April 2022. RESTORESEAS is focused on restoration of marine forests of both animals, plants, and algae, in shallow and deep marine areas. There are participants from eleven countries, both within and outside the EU. The funding received within this project will finance a post-doc working at UGOT. This post-doc will look at the role of microbial films for settlement of *L. pertusa* larvae and if micro-fragmentation of adults could be a feasible restoration technique. Hence this work will not overlap with our work in the LIFE *Lophelia* project but information gained may be useful also for us.

We have also been contacted by an EU-LIFE project consortium (LIFE ECOREST) which aims to restore Gorgonian cold-water corals in the Mediterranean. This LIFE-project was granted in 2021 and will continue to 2026, this project will be part of our networking efforts.

The financial officers among the Swedish LIFE programs exchange information and help each other, but so far only online due to the pandemic. A first meeting will be held in September 2022. We hope that networking will start again also for the Swedish project leaders, a planned meeting in 2020 was postponed due to the pandemic.

Action F1. Project management (CABO)

Foreseen start date: 01/09/2019

Actual start date: 01/09/2019

Foreseen end date: 27/03/2026

Actual end date:

<i>Deliverable</i>	<i>Deadline</i>	<i>Delivered</i>
Audit Report Midterm 07/2022. Set up in proposal, but not required for traditional projects and LIFE18 projects		
Audit Report Final	26/03/2026	

<i>Milestone</i>	<i>Deadline</i>	<i>Delivered</i>
Project Kick-off 11/2019	11/2019	10/2019
Nomination of the Steering Committee	10/2019	12/2019

The County Board of Västra Götaland (CABO) is legally and financially responsible to the Commission for the full implementation of the project measures to achieve the project objectives and for the dissemination of the project results. The CABO has appointed a Project Manager at 50%, a Financial Advisor on 20% and a Communicator on 5% of full time to the project, these persons belong to the ordinary staff and have all good experiences in their fields. An agreement between the County Administrative Board and the University of Gothenburg on their technical and financial participation in the project is in place since May 2020. This agreement follows the LIFE template for agreements between partners.

The Project Manager (CABO) and the Senior Researcher at Gothenburg University (UGOT) constitute the Project Management Team together with support from the financial officer (CABO). The Senior Researcher (appointed at 30% belongs to the ordinary staff) is responsible for the technical team at Gothenburg University, which constitute of a Research Technician on full time and an Assistant on full time (during part of the project time). Initially, UGOT hired the research technician in Oct. 2019 and a project assistant in Jan 2020 for the project.

The project group constitute of the project manager, financial officer, senior researcher, research technician and the assistant. We have monthly meetings to inform each other about the progress. At these meetings we also deal with financial issues. In several actions we also work closely together. We have a web-platform, where we easily can share documents and photos between partners. The project is small in terms of number of partners, and it makes it easy to have a close collaboration, which we see benefits the project.

Financial reconciliation takes place at regular intervals internally and between partners. Since this is a LIFE18 project provision of the auditor's details is not required with the mid-term report. However, our audit has reviewed all documents for this reporting period.

The Project Manager together with the Senior Researcher at Gothenburg University (UGOT) arranged a study visit in October 2019 at the University of Azores in Portugal and in connection with this visit we also had a kick-off for the project (for details see action E1.5).

The Project manager and the financial officer also participated and presented the project at the LIFE kick-off meeting in Brussels in Nov 2019 and at the Nordic Baltic LIFE online meeting in April 2021.

The Nomination of the Steering Committee was finalized in December 2019. The committee includes representatives of the Swedish authorities (The County Board of Västra Götaland, Gothenburg University and Swedish Agency for Marine and Water Management (SwAM)). In the proposal/GA we planned also to have representatives from the municipalities of Strömstad and Tanum as well as from Ytre Hvaler national park, which borders Kosterhavet National Park. The reason why we changed this is that the members we have now chosen can ensure that we get the resources we need, as they represent both participants and funders. The municipalities and the Norwegian national park receive continuous information about the project through the meetings that take place in the management of the national park where our project manager always participates.

The members meet twice a year and are informed about the project by the Project Manager between meetings. We have had five Steering committee meetings, in 23/01/2020, 30/09/2020, 9/4 2021, 30/09/2021, and 20/04/2022. The next is planned to 22/09/2022. At these meetings we present what has happened and what is going on in the project, as well as any problems. The steering committee has, for example, taken a position on the communication plan and the need for time changes for deliverables and milestones.

There have been three meetings with the external project monitor Ms Sonja Jaari, in February and November 2020, the latter digitally and in August/September 2021. During the visit in 2021 we also arranged a field trip on the sea collecting experiment equipment. All the meetings have been held at Tjärnö Marine Laboratory where we have been able to show corals in the aquarium, equipment and part of ongoing method development. These meetings have been arranged by the project manager in collaboration with the senior researcher.

Each year in mid-February we report to our co-financer SwAM both a technical and economic report, in total so far three reports, February 2020, 2021 and 2022. The first reporting to EU/EASME was a Progress report in February 2021 together with update of the KPI webtool. The project manager is responsible for these reports.

6.2. Main deviations, problems and corrective actions implemented

Action A.1 Development of restoration method (UGOT)

Alteration: Postponement of Deliverable: *Preliminary results of laboratory studies* (15/09/2022) until 15/09/2023.

Reason for change: During spawning seasons 2021 and 2022 there were problems with parasites in the larval cultures that ended in 100% mortality in the long-term laboratory experiment on larval settling and recruitment, and only results from short-term observational studies have been achieved. We have tried different measures to minimize the damage and we will take more efficient measures to protect the health of the larvae for the next spawning season (see also part 6.1 action A1.1.)

Even if we would not manage to get the parasites under control in the laboratory experiments, the results from the field experiments are potentially enough to get the results we need to evaluate the different substrates produced either by recruitment of *L. pertusa* larvae directly, or by recruitment of other organisms with similar life-history traits as indicators of suitability for *L. pertusa*.

Action C.1 Environmental mapping of reef sites to be restored (CABO, UGOT)

The costs for the underwater mapping with AUV and sonar were underestimated in the project budget. CABO is prepared to cover the additional costs by increasing their own funding if required by approximately 195,034 euros (2,000,000 Swedish krona) to cover this extra cost. There were also problems with the AUV that broke down and during the current pandemic it took time to repair. The survey was therefore delayed, and all field work was completed in August 2021. The large variation of topography in the areas affected the quality of the data and the resolution of the sonar mosaic images was not as high as desirable as described in 6.1 action C1. Together with multibeam and backscatter data from the restoration sites, we will still get good information about the bottom complexity to guide our decisions on where to place the ARs.

One Acoustic Doppler Current Profiler (ADCP) was flooded and corrupted during a 5-month deployment at one of the restoration sites, leading to delays in data collection as well as extra expenses related to the purchase of a new instrument. Delays with the procurement process of the sediment traps retarded our progress with measuring sediment load on the reefs. These delays will be recovered if we can extend duration of the sub action as asked for in 6.1. There are no deliverables or milestones affected by this extension. Also, no other actions are affected since enough data of flow velocities are already collected to mimic field conditions in the flow aquaria studies in action A1. The other data collected is needed firstly to determine AR distribution within and among sites in action C2 during autumn 2023. In addition, the environmental conditions will be correlated to observed restoration success at the very end of the project (action E3).

Action C.2 Manufacturing and deployment of artificial reef objects (CABO)

1. Alteration: Postponement of Deliverable *Final blueprints of artificial reefs ready* (30/06/2022) until 30/06/2023. Accepted change on 01/10/2021, Letter from PA, reference: LIFE18 NAT/SE/000959 - LIFE LOPHELIA - Project visit 31 Aug - 1 Sept 2021.
2. Alteration: Postponement of Milestone *Final reef design decided together with the contracted company* (29/04/2022) until 30/06/2023. Accepted change on 01/10/2021, Letter from PA, reference: LIFE18 NAT/SE/000959 - LIFE LOPHELIA - Project visit 31 Aug - 1 Sept 2021.
3. Alteration: Postponement of Milestone *Contract signed with manufacturer of artificial reefs* (31/03/2022) until 31/03/2023.

Reason for change: We need more results from our studies (action A1 and C1) to be able to specify material and design for the artificial reefs, this helps us stay within budget. The procurement started in March 2022 but had to be paused until Oct 2022 pending more results (see also part 6.1 action C2).

4. Alteration: Postponement of Milestone *First round of artificial reef deployments finished* (31/03/2023) until 31/10/2023.

Reason for change: We decided (in June 2022) to postpone the manufacturing and deployment of the first reefs to 2023. Deployment was planned to take place in the autumn of 2022 with a few artificial reefs (30-60) and most reefs (approx. 400) in autumn of 2023. Now all reefs will be deployed in 2023. The reason for postponing is that we need more results from our studies (action A1 and C1) to be able to specify material and form for the artificial reefs and to minimize the need of changes for the second round. This will mean a lower price since the contractors do not have to include extra costs for major changes, this helps us stay within budget.

Action E. Public awareness and dissemination of results (CABO, UGOT)

We will not be able to attend the same number of meetings and international conferences as planned for the remaining duration of the project due to the covid-19 pandemic which meant cancelled and moved conferences. The senior researcher and the research engineer at UGOT planned for a total of 6 scientific conferences each during the project period. The project manager planned for 2 conferences in the proposal/GA. We anticipate that there is still time for attending 4-5 conferences each for the SR and the RE and the 2 planned conferences for the PM. In addition, the SR and the RE planned 3 travels each to network with appropriate European projects. This goal may still be achievable especially if one or two of the travels can be done by the project assistant instead (not planned for in the GA). The project manager (PM) and the financial advisor (FA) had planned 6 travels each to network in Sweden and within EU, among other things to participate in Nordic-Baltic Network arrangements. We anticipate that there is still time for 5-6 networking travels for both PM and FA.

Another result of the pandemic is that travelling costs (flights) have increased perhaps not allowing all originally planned travels to be realised due to budget reasons.

See section 9 for planned network and conference travels.

6.3 Evaluation of Project Implementation

Methodology applied

It proved not so easy to detect and map coral with the AUV and the sonar equipment (900 kHz) used in action C1 as described under 6.1 and 6.2. With a highly heterogeneous bottom, this became a challenge that the contracted company could not meet with its equipment. Here we believe that a small AUV equipped with a more advanced sonar (SAS, Synthetic Aperture Sonar) would have given a better result. Such a sonar survey is significantly more expensive and since we had underestimated this underwater mapping in the budget (see 8.1) we would have had to reduce the surveyed area significantly. Prior to the application and budget calculation, we made inquiries with another company, which apparently underestimated the cost of this type of survey. With the results in hand, we should of course have asked more companies. The company we hired (the only one that bid) had no experience looking for corals or other biogenic structures but was experienced in other types of bottom surveys in the deep sea. Despite this, we believe that we should be able to interpret the sonar images with the help of multibeam and backscatter from the same areas to guide our decisions on where to place the artificial reefs.

Successful larval breeding was achieved during all spawning seasons according to previously successful procedures at Tjärnö Marine Laboratory. Unfortunately, there were problems with parasites and difficulties of keeping the larval cultures healthy for longer periods (see action A1.1). This has so far hindered any results from the long-term laboratory experiments. This is a huge challenge for the project, and we will prepare with several mitigating measures (e.g., clean the water lines, treatment with UV light) for next spawning season and experimental period that hopefully will reduce the impact of the parasites. Because of the problems with the laboratory reared larvae, we have expanded our field trials with both different materials and surface structures. And we are positive that we can achieve the anticipated results despite problems with parasites with the combination of laboratory and field settling experiments.

The use of the CAD program and 3D printing in action A.1 to design and develop ARs, and substrates have been very useful. It is quick to build a model or adjust one already made to achieve the desirable micro-eddies, that will allow larvae to attach to the substrate. Small 3D printed complex substrates are quick to print out in larger quantities for use in laboratory experiments for hydrodynamic testing of AR models and complex substrates.

The hydrodynamic assessment of ARs in the large flow channel with PIV system is delayed as described in action A1.3. This is very unfortunate and one of the reasons we decided to postpone the manufacturing and deployment of the first round of ARs. To help during the design phase we started with the easy set-up screenings in a smaller tank to visualize the hydrodynamics over the AR models and complex substrates. PIV is very data heavy, and it is good to have a simpler way of screening the effect to choose what models to run in the large flume. The PIV will be used for final analyses as soon as the laser is repaired.

The total fishing ban (action A2) in our restoration sites came into force in October 2021. There is a long history of cooperation between the national park managers at CABO and the local fishermen, with a good dialogue and trust between them, which made this possible well in advance of the deployment of the ARs. Having a dialogue with the fishermen affected by the restrictions and being prepared to compromise result in that understanding is achieved and that the rules are complied with to a higher degree.

Objectives and results achieved

Action	Foreseen in the revised proposal	Achieved	Evaluation
A1	<p>Objectives: To develop a restoration method that meets the prerequisites for <i>Lp</i> recruitment</p> <p>Expected results: Successful recruitment of <i>Lp</i> larvae on substrates, both in laboratory and in the field, and an AR design tested out and ready for manufacturing in Action C2</p> <p>Decision on preliminary AR design due 31/01/2022</p> <p>Preliminary results from laboratory studies are due 15/09/2022</p> <p>Preliminary results from field studies are due 06/2023</p>	<p>Complex substrates have been tested in short-term <i>in vivo</i> observational studies and the preliminary hydrodynamic screenings</p> <p>AR models have been designed and tested in preliminary screenings</p> <p>Not yet achieved: Long-term trials with an endpoint of settling and metamorphosis has not yet succeeded due to parasites</p> <p>Hydrodynamic evaluation of AR models using Particle Image velocimetry.</p>	<p>We are well on our way with the development of complex substrates and AR design. Some of the complex substrates has produced the micro-eddies necessary for larval attachment. The AR models have also shown promising hydrodynamic properties in the preliminary screenings</p> <p>Additional larval experiments will be performed during period I-II of 2023</p> <p>We ask to postpone the deliverables one year on Decision on preliminary AR design to 31/01/2023 and on Preliminary results from laboratory studies to 15/09/2023</p>
C1	<p>Objectives: Mapping of bottom topography, biodiversity, and environmental conditions at all six restoration sites before AR deployments</p> <p>Expected results: Initial habitat complexity and biodiversity before AR deployment is known and we have a baseline for out Before</p>	<p>Sonar survey was completed and final report delivered 03/05/2022.</p> <p>Biodiversity survey is completed, and date for biodiversity report will be 31/12/2022</p>	<p>The sonar data together with multibeam and backscatter are being analyzed, and during the fall of 2022 we aim to decide on where AR deployments can be done based on the analyses</p>

	<p>& After analysis (BACI design)</p> <p>Report on the initial habitat complexity and biodiversity due 09/2022</p>	<p>Environmental data collection is ongoing, and estimated date for completion is in second quarter 2023</p>	<p>Report on the initial habitat complexity and biodiversity is asked to be postponed to 31/12/2022 because late data delivery from SLU.</p>
D1	<p>Objectives: Assessing effects of restoration efforts on live coral distribution, environmental status, and ecosystem services, and monitoring the effect of public outreach and dissemination</p> <p>Expected results: Increased live coral cover and reef associated species, fish included</p> <p>Report of achieved increase of habitat complexity, biodiversity, and ecosystem services 12/2025</p> <p>Report of public outreach success 03/2026</p>	<p>Monitoring of public outreach and dissemination is ongoing.</p> <p>Assessing effects of restoration efforts will be initiated in the fall of 2024, after ARs have been deployed and been in place for a year</p>	<p>We already see through the many contacts from journalists and students the effect of the number of talks and articles in the media, as more and more people know about the <i>Lp</i> and the project</p> <p>This action will be part of the final evaluation of the project during 2024–2025</p>
D2	<p>Objectives: Evaluation of restoration method and it's replicability</p> <p>Expected results: Adoption of method for deep-sea scleractinian reef habitat restoration in other areas within or outside EU Report of the evaluation of the restoration method and actual replication and transfer 03/2026</p>	<p>This action is to be initiated during quarters I–III 2025</p>	
D3	<p>Objectives: Monitoring of LIFE KPI, fisheries catch data, public awareness</p>	<p>The KPI web tool has been completed and data has been verified 11/02/2021</p>	<p>The final evaluation of KPI will be done in III-IV 2025 as the final analyses of biodiversity after AR</p>

	<p>Expected results: An increase in rare reef associated fauna, reef associated fish, and increased public awareness of cold-water coral reef habitats</p> <p>KPI web tool and analysis of results 02/2021, Up-date of KPI Webtool and analysis of results 03/2026</p>	<p>Fisheries catch data are gathered each year by SwAM.</p> <p>Monitoring of public outreach and dissemination is ongoing</p>	<p>deployments and recruitment on the ARs are done, and all public outreach and dissemination is finished</p>
E1	<p>Objectives: General communication and dissemination, networking, reaching the public and raising awareness</p> <p>Expected results: We have increased the awareness of CWC reef habitats and their ecological importance, and presented the results of our restoration efforts, reaching both the public, fishermen, scientists, and authorities</p> <p>Notice-boards printed 12/2019 Website published 28/12/2019 Communication plan 12/2019 Leaflet printed 06/2022 Public video produced 11/2022 Scientific video produced 03/2025 Layman's report printed 03/2026 After LIFE Plan 03/2026</p>	<p>Networking and kick-off at the University of Azores, Portugal 10/2019</p> <p>Website published 28/02/2020 and are continuously updated</p> <p>Notice-boards printed 08/2020, posted at 6 sites</p> <p>Communication plan completed 09/2020</p> <p>Video production for the public started in April 2022.</p> <p>Production of scientific video will start in 2023</p>	<p>Data collection of number of people reached through all activities and channels will be ongoing during the project time span.</p> <p>We ask for postponement of the leaflet printing one year to 30/11/2023, since we think it is important to include pictures of deployment of the ARs</p>
E2	<p>Objectives: Dissemination of scientific results</p> <p>Expected results: 6–7 publications in peer reviewed journals, participation on several international conferences/symposia,</p>	<p>No participation in international conferences so far due to the covid pandemic</p> <p>We will sign up for the 8th International</p>	<p>Compilation of results, and analyses of experiments are ongoing</p> <p><i>The first networking workshop accepted to be postponed until 08/2023, to have more results to</i></p>

	<p>participation in and arranging workshops with collaborating projects</p> <p>First networking workshop arranged 08/2022</p> <p>A summary of the scientific workshop 09/2022</p>	<p>Symposium on Deep-Sea Corals 29/05–02/06/2023 in Edinburgh, Scotland,</p> <p>and the 17th Deep-Sea Biology Symposium in Hong-Kong 2024</p> <p>Also available are: International Conference on Marine Ecosystems and Rehabilitation, and the UN Ocean Conference</p>	<p>present during the workshop</p> <p><i>"Summary of scientific workshop"</i> is accepted to be postponed until 12/2023.</p>
E3	<p>Objectives: Half-way seminar and final conference directed at stakeholders and the scientific community to convey the results of the restoration method</p> <p>Expected results: Increased interest and collaboration from stakeholders to support the restoration efforts.</p> <p>Summary from arranged seminar 06/2023 Technical handbook published 12/2025 Final conference 06/2025</p>		<p>At the seminar we will present the results so far and also present the artificial reefs, and inform about the deployment of them.</p> <p>Evaluation in final report 03/2026</p>
F1	<p>Objectives: Contracted staff for the project and the project plan implemented as planned</p> <p>Expected results: A well-executed project where the goals and objectives have been achieved both technically and financially</p>	<p>Contracted from 01/09/2019, 01/10/2019 and 01/01/2020</p> <p>Arrangement of study visit and project kick-off 10/2019</p>	<p>Evaluation in final report 03/2026</p>

	Project Kick-off 11/2019	Contract established between parties 05/2020	
	Nomination of the Steering Committee 10/2019		
	Progress report 12/02/2021 Midterm report 01/07/2022	Nomination of the Steering Committee 09/2020	
	Progress report 30/09/2024		
	Final report 27/03/2026	Progress report 02/2021	
	Audit Report Final 03/2026	Mid-term report 31/07/2022 with some changes in the timing of deliverables and milestones	

Project results visible

The *Expanded fishery restrictions* (Action A2) resulted in total fishing ban in all restoration sites and was achieved on time. Control of compliance with the new rules is carried out by SwAM in their regular assignment. The longer-term result on the corals and associated fauna of this expanded ban will only be visible over time, but we have secured that the ARs and natural coral reefs will be protected against these historical anthropogenic stressors.

Amendment

There has been no amendment of the project so far.

Results of the replication efforts

Replication and transfer of results is still in its infancy, but several contacts have been taken and collaborations initiated with other researchers and new projects, iMERCES, RESTORESEAS and LIFE ECOREST as described in section 6.1. under E3 and also in section 6.4. It is too soon to evaluate the results; it will not be visible until the final evaluation during 2024–2025.

Effectiveness of the dissemination activities

When it comes to the dissemination to the public (action E1), we have received much interest from media which has resulted in at least 14 publications in written media, 5 interviews in national and regional radio and 4 interviews on national television. At least 89 641 visitors to the Kosterhavet National Park Visitor Centre and to the Tjärnö Aquarium have been informed about the project through notice boards and the project slide show. In addition, 763 students and persons in authorities have been reached through lectures and talks. Public awareness of the existence of coral reef in Sweden and of this LIFE restoration project has increased through these activities at a relatively small cost.

The covid pandemic, however, has delayed the scientific dissemination (action E2) via international conferences. Through our networking activities we have still reached a significant number of colleagues in the European and global scientific community. When our data collection has reached a critical mass that makes it worthwhile starting to produce papers for publication, we will start delivering on the anticipated scientific papers planned for the project and presenting this data on International conferences.

Policy impact

The project outcomes, a restoration method for the coral *L. pertusa*, have potential to become broadly implemented in other EU waters since *L. pertusa* is widely spread in the OSPAR region. The extent of reefs is in overall decline in all OSPAR areas where they occur, due to mechanical damage by demersal fishing gear. Bottom trawling gears can level coral reefs, leaving only unconsolidated coral rubble with no chance of recovery. Concern about this habitat has led to that protective legislation in many European waters is put in place soon after reefs are discovered. In this project, we have also introduced total fishing bans, so-called No fishing zones, to protect the corals from negative impacts from all fishing, not just trawling.

This project has also potential to contribute to the development and implementation of the Habitat Directive 92/43/EEC on the conservation of natural habitats and wild fauna. *Lophelia pertusa* reefs are biogenic reefs and subtype to the marine habitat 1170 in the Habitat Directive. The project has also potential to contribute to achieving good environmental status for biological diversity according to the Marine Framework Directive (2008/56/EG). It will have potential to positive impact on the goals of "Coastal and seawater have a good environmental status regarding physical, chemical and biological conditions in accordance with the Marine Environment Ordinance (2010:1341). As in "The important ecosystem services of the coasts and oceans are maintained". Good environmental status of the integrity of the seabed is characterized by (HVMFS 2012:18, appendix 2) that "The benthic community's ecological functions, species diversity and occurrence of species are maintained", which this project also have the potential to contribute to. There is also a connection to the new EU Biodiversity strategy 2030 as is included as a central part of the European Green Deal. The strategy will contribute to the work within the Convention on Biological Diversity (CBD) and a global framework with new goals for the period after 2020, with an overall ambition to ensure before 2050 a situation where all the world's ecosystems have been restored, are resilient and adequately protected. In the ICES Advice 2010, Book 1, it is recommended that reefs should be restored by means of artificial substrates in areas where they have been "smashed to such an extent that no stable substrate remains".

Both the County Administrative Board (CABO) and the University of Gothenburg (UGOT) has decided guidelines about sustainable procurement. For environmental requirements the tenderer must report routines for systematic environmental work in the implementation of the assignment and verify this with ISO 14001, EMAS or other environmental management standards. Procurement in this LIFE project also follow the handbook on green public procurement, published by the European Commission. For all procurement in the project, we have and will set environmental requirements. The tenderer must always report routines for systematic environmental work in the implementation of the assignment.

6.4 Analysis of benefits

Environmental benefits

Within this project we have secured 458,6 ha of *No fishing zones* (action A2) in Natura 2000 Kosterfjorden-Väderöfjorden (406,2 ha of this are the restoration areas in this project). These *No fishing zones* will contribute to recovery from anthropogenic stressors of those areas. These areas, which already had trawl bans since 2001 and 2015, have a high biodiversity and with the introduction of non-fishing zones they will recover further from human impact. With the ARs that the project will place in these areas in 2023 to restore the corals, we will hopefully also get living coral reefs back and that will increase the biodiversity even more.

A warming ocean is a result of global climate change, and this threat is more difficult to address. Increased ocean temperatures will force species to shift their distribution. The temperature span of *L. pertusa* is 4–12°C, and while it can tolerate shorter periods of higher temperatures, it will be negatively affected when temperatures stay at the higher end of the span for longer periods. Reducing all other stress factors can help *L. pertusa* cope with rising temperatures. During this project we will increase the public awareness about these ecosystems and their susceptibility to the stresses of climate change and other anthropogenic stressors, to increase the willingness of the public to accept policy changes that could favour the continued prosperity of these ecosystems.

The surveys we are doing within the project show that the live parts of the reef in Säcken are decreasing further, while the recovered reef at Väderöarna is growing and flourishing. We don't know for sure why it is like this yet, but our environmental measurements of e.g., currents and sedimentation rates at the restoration sites and at the healthy reference reef Tisler will probably give us an answer to this. This will also guide us where to prioritize putting most of the ARs. The restoration method we are developing within the project will be available for restoration of deep-sea corals in other areas.

The Natura 2000 area is managed and will be managed by CABO also after the end of the project. Monitoring of development of corals and associated fauna on the ARs and restoration areas will be performed every third year in collaboration with SwAM and SLU with national funding.

Economic benefits

Thanks to the LIFE project, two people have been given full-time jobs at UGOT. Students have had the opportunity to do internships and theses. We have hired a marine survey company that employs several people including skippers, measurement technicians and analysis staff. Film production is underway which provides jobs for a media company and instruments and materials are purchased which contribute to jobs at manufacturing companies.

Social benefits

So far, our project has contributed to increased knowledge about the existence of deep-sea corals in Sweden and that there is an ongoing LIFE project that will develop methods to restore these coral reefs. The increased knowledge is spread via our website and social media, but also largely through all the articles in the media that many interviews with us have resulted in. We also spread knowledge through lectures.

Replicability, transferability, cooperation

The work with cooperation with other projects and replication and transfer of the project outcomes are going according to plan. This projects likeliness for replication is considered as high. There are many cold-water coral areas in European waters and elsewhere that are heavily impacted by e.g., intrusive fishing methods and in need of restoration. For example, are 30–50% of the Swedish and Norwegian reefs severely impacted. There is a large interest among scientists to involve in projects that aim to develop methods for coral restoration and perform actual restoration. Some examples within EU are the ongoing projects RESTORESEAS and LIFE ECOREST and the initiative iMERCES (see section 6.1, actions E1.5 and E3). The initiative iMERCES, aimed to restore populations of *L. pertusa* in Scottish and Irish waters. In that proposed project, we were supposed to deliver knowledge on larval biology and settlement substrate selection by *L. pertusa* and hydrodynamic performance of reef structures to inform restoration unit design. The proposal was submitted in Jan 2021 but was not funded (see also part 6.1 action E1.5. Networking). This shows however, that the knowledge and techniques being developed in this project is in high demand with high possibilities of replication and transfer. In the project RESTORESEAS that UGOT is involved in, the role of microbial films for settlement of *L. pertusa* larvae and if micro-fragmentation of adults could be a feasible restoration technique is studied further demonstrating the urge to restore this coral.

Scientists involved in this line of work are typically in close cooperation with policy makers. Replication of this project on larger scales is likely mostly policy dependent. For the restoration measures to work in the long run, the areas must be protected from further physical damage. Through our continuous networking with other stakeholders within the EU involved in management and restoration of deep-water corals, other possible sites suitable for restoration will be identified and further mapped. Within this project, existing environmental data and information on historical distribution of corals on the sites will be compiled. Should the by-product metallurgical slag Petrit E produced by Höganäs Sweden AB prove to be an efficient substrate enhancing coral settlement and recruitment, other steelworks in the EU producing corresponding type of slag will also be identified. This will facilitate replication of the method in other parts of the EU and reduce transport emissions when local products can be used. The work with replication and transfer of the project with intensify towards the end of the project period but through our involvement in other ongoing deep-sea and restoration projects (iAtlantic and RESTORESEAS) and networking with additionally more projects we consider the goals set up in the proposal to be achievable.

Innovation and demonstration value

Within this project, we are developing a method to restore the cold-water coral *Lophelia pertusa* by facilitating recruitment of naturally occurring larvae. We do this by constructing artificial reefs that maximize settlement and recruitment rates of *L. pertusa* larvae. The technique is developed through extensive studies of larval behaviour and hydrodynamic assessment of models of ARs in the laboratory. Further complementing studies are done in the field by testing effects on settlement by different materials and surface structures. The approach is unique and innovative and by complementing with studies of larvae of other deep-sea corals, the method can be adjusted for other targeted species. We will produce a "Technical handbook" where the developed method and how it should be implemented will be thoroughly described. The handbook will include e.g. drawings of the artificial reef design and the moulds used so that any construction company should be able to copy the design and construct the ARs. Also included will be an analytical toolkit of how to implement/adjust the method to different environmental conditions and to other deep-sea coral species. Although

problems with performing long term studies of larvae in the laboratory so far, we are optimistic about reaching the goals set up in our proposal. We have performed successful short term larval behavioural studies in the lab, and preliminary studies of hydrodynamic performance of models of ARs. We are doing complementary field studies which were not originally planned to fill in the gaps of preferred settling substrates for larvae. Further hydrodynamic assessment of AR design with full scale flow analysis using Particle Image Velocimetry (PIV) will be performed before final AR design is determined.

There is a long history of collaboration between the national park managers at CABO and the local fishermen, resulting in a good dialogue and trust between them. This stakeholder involvement was valuable when the No fishing zones was established (action A2).

Policy implication

Through action A2, we have introduced small areas with a total fishing ban in the Natura 2000 area Kosterfjord-Väderöfjord. This will contribute to the Biodiversity goal for 2030 of 10% strict protection of the sea.

7. Key Project-level Indicators

There are no anticipated significant deviations yet from the targets set initially. We will be able to report on all the indicators.

8. Comments on the financial report

a. Summary of Costs Incurred

PROJECT COSTS INCURRED			
Cost category	Budget according to the grant agreement in €*	Costs incurred within the reporting period in €	%**
1. Personnel	1,234,076	459,295	37,22
2. Travel and subsistence	92,145	10,612	11,52
3. External assistance	1,084,442	479,457	44,21
4. Durables goods: total <u>non-depreciated</u> cost			
- <i>Infrastructure sub-tot.</i>	0	0	0
- <i>Equipment sub-tot.</i>	256,036	74,578	29,13
- <i>Prototype sub-tot.</i>	106,000	0	0
5. Consumables	62,252	43,614	70,06
6. Other costs	94,820	60,078	63,36
7. Overheads	196,756	78,933	40,11
TOTAL	3,126,528	1,206,570	38,59

Tabell 3. *) If the Agency has officially approved a budget modification through an amendment, indicate the breakdown of the revised budget. Otherwise, this should be the budget in the original grant agreement.

***) Calculate the percentages by budget lines: e.g., the % of the budgeted personnel costs that were actually incurred

Comments on cost categories

Personnel

For both CABO and UGOT the personnel costs are somewhat lower than expected for the reporting period. One explanation is that the exchange rate (SEK/EUR) has remained higher during all the reporting period than the exchange rate used for budget calculation. The second explanation for the lower costs than budgeted is due to the SARS-CoV-2 pandemic which has prevented personal meetings and travels to conferences, workshops, fellow LIFE-projects etc. Another explanation is lower than expected salary costs for the employed project assistant at UGOT due to high sick leave (after an accident) during autumn 2021 and spring 2022. If possible, the project assistant's contract will be prolonged accordingly to compensate for the loss of work hours in the project.

The personnel costs are calculated using a monthly exchange rate (SEK/EUR) and is further specified in excel-sheets for each of the years 2019–2022 (Personnel 20XX exchange rating). For 2019 personnel costs for the months Sep–Dec are specified (project started in Sept 2019) and for 2022 Jan–Apr (end of report period). The Research engineer and the Project assistant are employed 100% in the project and for them a yearly productive work time of 1720 h are used. The Senior researcher works on average 30% in the project and uses Time Sheets to

keep track of time allocated to the LIFE project and to other duties. UGOT does not use any time registration system for the employees. Because of this the Senior researcher does not know her true total amount of working hours for the year 2019, hence 1720 h are used for the calculation. The same is true for year 2022 since only Jan–Apr goes into this report period and 1720 h are calculated with. If instead the total working time for these specific months should have been used, the total productive hours would be unproportionally high since a great majority of the vacation days are taken during the summer months (Jun–Aug).

Travel and subsistence

For UGOT this cost category is much lower than budgeted for the reporting period. Also for CABO the costs are lower than budgeted. The large discrepancy is due to the SARS-CoV-2 pandemic which has prevented personal meetings and travels to conferences, workshops, fellow LIFE-projects etc. The big expenses we had here are for our study trip and kick-off to the University of Azores. Where we could visit researchers who work with restoration of deep-sea corals. This was just before the pandemic and a successful visit with valuable information exchange and networking that resulted in collaboration between us and the researchers in the Azores.

In the financial reporting excel document for UGOT, the verifications for posts 11 (invoice 3.536.412.392), 12 (invoice 3.558.857.909) and 15 (invoice 6.556.560.622) are missing the social costs that are triggered for subsistence within Sweden. These are SEK 124.68, 119.48 and 129.42 for the three posts respectively.

External assistance

For UGOT the external assistance costs are associated with the use of the UGOT ship Nereus and the Remotely Operated Vehicle (ROV) with pilot for coral collection (A1) and instrument deployment/retrievement (C1). For CABO the costs here are associated with the mapping of restoration sites with AUV/sonar (C1) and some costs also for the biodiversity assessment (C1). This mapping of restoration sites has been underestimated in the project budget. CABO is prepared to cover the additional costs by increasing their own funding if required by approximately 195,034 euros (2,000,000 Swedish krona), this is approved by Mr. Zableckis (LIFE18 NAT SE 000959 MISMC2LET 201217 SZ Project visit 26 - 27 November 2020).

For the coming reporting period there will be a change as described in chapter 6.1 for action C2. The financial consequences of this change will be that the budget for UGOT for deployment of AR will instead go to the contracted company for both manufacturing and deployment, because it becomes clearer with responsibility for the entire chain of manufacturing, transport and deployment. In the budget we had divided the costs and responsibility for manufacturing and deployment between CABO and UGOT. CABO will now be responsible for the procurement of both production and deployment, and the costs will end up in the category external costs to a total budget of 159,778 € (construction and transport 106,000 €, deployment 53,778 €). Costs for UGOT was for using the research vessel Nereus for deployment and were divided into several categories; external assistance, consumables and other costs, and the budget was summing up to 53,778 €. The change will not affect the total budget for the action.

Equipment

For UGOT there is a large discrepancy in the costs for equipment which is much lower than the budgeted. This is due to changed directives from EASME regarding eligible costs for use

of the UGOT ship Nereus and the Remotely Operated Vehicle (ROV) for coral collection and instrument deployment/retrievement. In our submitted step 2 proposal, the total costs for Nereus and ROV respectively were placed under other costs based on internal rent charges. However, during the revision process of the step 2 proposal, it was made clear to us that the actual costs for our part of the use of the ship and the ROV should be calculated (on a yearly basis) and broken down and entered respective cost categories. We were then given the information that new equipment for the ship and the ROV that was procured during the project time was eligible costs (depreciation costs for them) but not salaries for the skippers and ROV-pilot that are necessary for using this infrastructure. During further discussions and meetings with our monitor, 26–27 November 2020, we raised the question again about eligible costs since it is impossible for us to use the infrastructures ship and ROV without skippers and ROV-pilots. The answer coming back from EASME and the Project advisor Mr. Zableckis (LIFE18 NAT SE 000959 MISMC2LET 201217 SZ Project visit 26 - 27 November 2020) was then that eligible costs are personal costs but not depreciation costs. Therefore, we have chosen not to include any costs for equipment for the ship Nereus or ROV. Hence in the end the total costs for equipment will deviate (be lower) than in the accepted proposal.

Other discrepancies compared to the budget are that an ADCP (acoustic doppler current profiler) was purchased to replace one that got broken during use in the project. In our project, three ADCPs are used at the same time to compare current velocities among restoration sites. We also decided to purchase 4 single sediment traps instead of 2 multi sediment traps that were specified in the budget. This to be able to compare sedimentation rates among more restoration sites at the same time. Total costs for the ADCP and the 4 single sediment traps (EUR 63 319) were less than the budgeted for the 2 multi sediment traps (EUR 74 000). This the issue was raised on the monitoring visit.

Because of delayed delivery of a new ROV to the infrastructure of UGOT, the cost for the specific control of the robotic arm for coral collection does not as expected fall within this reporting period. Other small discrepancies include personal computers and screens which costs were not as customary for UGOT merged and posted as equipment (UGOT limit for equipment SEK 30 000). These costs are posted under consumables instead (seq no 116–119), a total of 3 598 EUR. The personal computers are for the research engineer and project assistant who are 100% employed by the LIFE *Lophelia* project. At UGOT, computers for these categories of staff are not covered by the OH.

Consumables

For UGOT the costs for consumables are somewhat higher than calculated for in the budget for the reporting period. This is partly due to computers and accessories posted in this category instead (seq no 116–119), a total of 3,598 EUR but also due to some purchases that was not thought about when the budget was specified (e.g., 3-D printer, seq no 34 and accessories to it). The 3-D printer is frequently used in action A1 (development of restoration method) where different designs of larval settling substrates are tested both in lab and field trials. The 3-D printer is further used in A1 to make models of artificial reef structures of various design to hydrodynamically test those in the flow aquarium. Overall, most consumables needed for the project are for the A1 and C1 actions for which the work is concentrated to the first half of the project. We do not see it as a problem that 70% of the budget for consumables are used up. If necessary, some funds in the cost category Travel or Equipment can be reallocated for consumables.

Other direct costs

The UGOT budget for other direct costs in the accepted proposal is EUR 61,720. Because of the changed directives for eligible costs for use of the ship Nereus and ROV (see under *Equipment*), the costs for salaries for skippers and ROV-pilot are posted here under other direct costs and sums up to EUR 53,896 of the total of EUR 59,857 incurred other direct costs for the reporting period. This category of costs will in the end deviate far from the budgeted costs because of these changed directives for eligible ship and ROV costs.

b. Accounting system

b.1. Financial accounting systems and internal routines at the County Board of Västra Götaland (CABO)

Accounting system

The accounting systems used by the County Administrative Board are Unit4 Business World, UBW (former Agresso) and Visma Proceedo. UBW is used for time registration, travels, vacation etc. For e-commerce including supplier invoice management, the Visma Proceedo system is used.

The time is registered daily. All worked time and absence is reported per project. All employees are required to report their time at least once a week. When this is done the employee mark the week as ready. Then the closest manager certifies the registered time, but only the absence and overtime. If you do not register your time, you will get an automatic reminder by e-mail.

Personnel costs

- Actual salary (account 4011+4012)
- +Employer's contribution (arbetsgivaravgift) (account 4511) *Statutory cost*
- +Contractual insurance (avtalsförsäkring) (account 4611) *State-run compulsory cost*
- +Pension for government employees (Kåpan and Iåpen) and specific income tax (account 4531+ 4631) *State-run compulsory cost for pension and statutory cost of 21,46% specific income tax relates to the pension costs*
- +Development Council (Utvecklingsrådet) (account 4661) *State-run collective agreements*
- +Competence actions (Kompetensåtgärder) (account 4831) *State-run collective agreement*

	Konto	Konto(T)	Belopp
1	4011	Löner o arvoden, anställd personal	499 196,07
2	4012	Bruttolöneavdrag, anställd personal	-2 448,00
3	4511	Arbetsgivaravgifter Löner anställda	156 387,37
4	4531	Särskild löneskatt, premiebestämd pension	5 422,55
5	4611	Betalda premier, pensioner, PSA, TGL-S och omställningsavtal	41 055,70
6	4631	Betalda premier, premiebestämd pension	22 352,00
7	4661	Avgift Utvecklingsrådet/Trygghetsstiftelsen	1 766,99
8	4831	Kompetensåtgärder	1 493,25
Σ			725 225,93

Tabell 4. An example for one person from the accounting system: Annual personnel cost = 725 225,93 SEK

Approving costs

Every employee can make a purchase, but it must be approved by the manager at the operative department. When the invoice is registered in the accounting system the person who made the order gets an e-mail from the system that says they have a new invoice to handle. They then register the right account, project code etc. in the system. When this is

done the invoice goes to the manager for attestation. After the attestation the invoice is recorded in the accounting system and then paid.

Reference to the LIFE project on invoices

We encourage all suppliers to refer to the project name or project code on the invoices. For agreements and orders, we ensure that references to the project are written into these documents.

Procurement/ selection procedure

The Public Procurement Act is regulating procurement at the County Administrative Board. All County Boards do also have their own procurement policy. There are some differences between the County Administrative Boards regarding when they must report the purchases to the procurement coordinator. In the County Board of Västra Götaland it must be reported when a purchase already exceeds SEK 100,000.

Time registration

The system used for time registration is the electronic system Unit4 Business World, UBW (former Agresso). In our version of this system, only absence and holidays are attested. Even if the employee has made electronic attestations of both absence and worked time in the time registration system, we print out their time sheets and then the employee and the manager manually sign them in the beginning of the following month.

The time is registered daily in the time unit hours. Every employee must report their time at least once a week. Then it goes to the manager for attestation. All time is registered; actual time worked, sick leave, holiday etc. Time reporting is conducted monthly, in the same month that the salary is paid. The actual accounting is carried out a few days into the following month. The project codes that each employee enters for the time reports are debited with the salary costs, including hours.

Project codes in the accounting system

Find below the project codes in Table 5:

P 4159X LIFE LOPHELIA
(finansiering 55/23/22% EU/NV/HaV)

P 41591*	LIFE LOPHELIA (EU)
P 415910	LIFE LOPHELIA (EU) - A1 - Development of restoration method
P 415911	LIFE LOPHELIA (EU) - A2 - Expanding fishery restrictions
P 415912	LIFE LOPHELIA (EU) - C1 - Environmental mapping of reef sites to be r
P 415913	LIFE LOPHELIA (EU) - C2 - Manufacturing and deployment of artificial
P 415914	LIFE LOPHELIA (EU) - D1 - Monitoring of conservation status and publ
P 415915	LIFE LOPHELIA (EU) - D2 - Evaluation of the restoration method and
P 415916	LIFE LOPHELIA (EU) - E1 - General communication and dissemination
P 415917	LIFE LOPHELIA (EU) - E2 - Dissemination of scientific results
P 415918	LIFE LOPHELIA (EU) - E3 - Sustainability and replication of project
P 415919	LIFE LOPHELIA (EU) - F1 - Project management

Agresso:

b.2. Financial accounting systems and internal routines at the University of Gothenburg (UGOT)

Accounting system

The accounting systems used by University of Gothenburg are Unit4 Business World, UBW (former Agresso) as accounting system and Visma Proceedo for procurements. UBW is used for all accounting and invoice payments. For procurements and e-commerce, the Visma Proceedo system is used.

In the accounting system we have different codes that correspond with the title of the employees. The ones most used in the EU LIFE Lophelia project are:

4015 – Senior Lecturer – sv. Universitetslektor

4024 – Other research staff – sv. Annan forskande personal

4032 – Administrative staff – sv. Administrativ personal

The salary costs that are reported on the project include social fees.

We have also costs related to salaries:

4081 – vacations debt

4091 – interim account for the salary increase the salary year is between October to September

43* – travel costs

4311	Skattefria kostnadsersättninga	F
4321	Skattefria traktamenten, sveri	F
4322	Skattepliktiga traktamenten, s	F
4323	Skattefria traktamenten, utlan	F
4324	Skattepliktiga traktamenten, u	F
4331	Bilersättningar, skattefria	F

4011	Lön professor	R
4012	Lön adjungerad professor	R
4013	Lön forskarassistent	R
4014	Lön forskare, projektledare m ansvar	R
4015	Lön universitetslektor	R
4016	Lön universitetsadjunkt	R
4017	Lön gästforskare, gästprofessor	R
4018	Lön annan undervisande personal	R
4019	Lön övertid/mertid lärare	R
4021	Lön doktorand	R
4023	Lön amanuens/assistent	R
4024	Lön annan forskande personal	R

Table 6. Accounting system with the different codes for CABO.

Project coding in the accounting system:

Firstly, our department's identification is deputy 3150.

Then Ann Larsson's PI project leader code is: 30884.

From her PI code we derive the project code for EU LIFE Lophelia: 253088408

As part of the PI's salary cost is in kind, we report this on a separate coding: 31501005

	Konto	Konto(T)
Σ2	253088408	Larsson, Ann Life Lophelia
Σ1	3150	Inst f marina vetenskaper
Σ		

	Konto	Konto(T)
Σ1	31501005	Life Lophelia, Ann Larsson del i projektet

Table 7. Project coding for UGOT.

Approving costs

Every employee can make a purchase, but it must be approved by the manager at the operative department. When the invoice is registered in the accounting system UBW, the person who made the order gets an e-mail from the system that says they have a new invoice to handle. They then register the right project code and a cost description. When this is done the invoice goes to the financial officer for coding in the book-keeping codes and then to the manager for payment attest. After the payment attest the invoice is recorded in the accounting system and then paid.

Reference to the LIFE project on invoices

UGOT tries to ensure that invoices contain a clear reference to the LIFE Lophelia project by asking (when the product is ordered) for the reference LIFE-18 NAT/SE/000959 to be added on each invoice. Although this is asked for, the reference does not always appear on the invoice. For purchases made through our internal purchase system, there is no way of adding a reference on the invoice but by always naming each purchase “LIFE Lophelia, LIFE-18 NAT/SE/000959” the reference appears anyhow. Another way of ensuring a reference to the project is that all invoices are charged on the same internal account (253088408) where only costs within the LIFE Lophelia project are charged.

Procurement/selection procedure

The University of Gothenburg (the university) is a procuring public authority which is under an obligation to follow public procurement legislation when purchasing goods and services. In this connection, the relevant regulatory framework is provided by Sweden’s Public Procurement Act (2016:1145), and Act on Procurement of Concessions (2016:1147). The acronyms for these are, respectively, LOU and LUK.

The direct procurement limit is SEK 700,000 from and including 1 February 2022. The threshold value is calculated in Euros and adjusted every other year by law. It is generally permissible under the Public Procurement Act (2016:1145) to directly procure all goods/services that are not included in framework agreements as long as the contract value is less than SEK 700,000.

Documents from direct procurement where the value of the contract / order is less than SEK 100,000 can be scanned in and attached to the invoice in the financial system, or alternatively kept in a systematic order in a folder at the department. Calculation of value is always done excluding VAT.

If the value of the contract / order exceeds SEK 100,000, the documents must be preserved and recorded in ventral registry. Inquiries, tenders / quotes, decisions and agreements are the documents that must be recorded. Indicate that it is a direct procurement and whether it is a

product or service. These registered direct procurements must be reported once a year to the finance unit.

Time registration system

UGOT does not use any time registration system for the employees. Only employees involved in projects where the funder requests time registration do register their time. In this LIFE project, UGOT uses manually completed time sheets which are monthly reviewed, approved and manually signed by the line manager. The signed time sheets are saved both in paper format and scanned to be saved electronically.

c. Partnership arrangements

The financial reporting has been reviewed at several meetings together with project managers and economists from both CABO and UGOT where structure and requirements for layout have been made and reconciled to meet the reporting requirements for the project costs (time reporting, marking of invoices, certificates etc.). There is a code structure for the project where each action has its own code. Interim reports have been made on an ongoing basis for both time and other costs. We have a review with our partner before we make the consolidated file, which is a compilation of the financial files from both parties. The internal auditor has already been involved in this Mid-term reporting, see below.

Requisition of funds has been made on a basis where the percent distribution according to the partnership agreement is stated. All funds come to CABO as coordinating beneficiary from both the EU and SwAM. Thereafter, UGOT requisitions funds from CABO corresponding to its percentage of the budget.

d. Certificate on the financial statement

The project is a LIFE18 project and therefore provision of the auditor's details is not required with the mid-term report. However, the project's auditor has reviewed the financial files both for Gothenburg University and for the County Board of Västra Götaland and looked at the documentation for the accounting. Number of hours for the two full-time employees at the University is calculated at 1720 hours per year. Despite this, they have reported their hours worked to get an estimate of the distribution of working hours per action. This, the auditor points out, entails a smaller difference. The auditor has no other comments.

e. Estimation of person-days used per action

Action type	Budgeted person-days	Estimated % of person-days spent
All projects when applicable Action A: Preparatory actions	1335	64,63
NAT projects Action C – Concrete conservation actions	332	71,00
NAT and CLIMA projects Action D: Monitoring and impact assessment	165	0,11
NAT and CLIMA projects Action E: Communication and Dissemination of results	901	18,85
NAT and CLIMA projects Action F: Project management (and progress)	632	33,55
TOTAL	3365	44,00

Table 8. Person days per action for the project.

Comments to person days used per action

UGOT has used up 60–70 % of the allocated person days in action A (development of restoration method) and C (C1 environmental mapping of reef sites to be restored) which is according to plan since these actions are primarily taken place in the first half of the project. CABO has used more time for action C1 according to plan. The procurement of the sonar survey had to be done twice because we did not receive any tenders at the first opportunity. In addition, the company that was contracted had problems with the equipment, which is why the entire investigation and analysis was greatly delayed. This has meant a lot of dialogue with the company.

Action D2, evaluation of the restoration method and actual replication and transfer which UGOT is responsible for is taking place only at the end of the project. In action E, quite a lot of general communication and dissemination (E1) has taken part but less of dissemination of scientific results (E2) due to the SARS-CoV-2 pandemic. The pandemic also meant that planned trips and networking for CABO were cancelled which results in lower than anticipated person days in E as a total for this reporting period. E3, sustainability and replication of project is mainly taking place at the end of the project. Regarding project management (F1), UGOT has spent more time than allocated in the proposal mainly because of chores falling within this action that were not thought about. CABO, on the other hand, has spent slightly less time on F1.

Despite these minor deviations in person days compared to allocated in the proposal, we assess that there is enough time to be able to carry out the entire project according to the Grant Agreement.

9. Envisaged progress until next report

Project plan 2019-2025		Year:	19	20				21				22				23				24				25			
		Quart	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Reports								Prog						Mid													Prog
A1 Development of restoration method	Proposed																										
	Realised/planned																										
A2 Expanded fishery restriction	Proposed																										
	Realised/planned																										
C1 Environmental mapping of reef sites to be restored	Proposed																										
	Realised/planned																										
C2 Manufacturing and deployment of artificial reef	Proposed																										
	Realised/planned																										
D1 Monitoring of conservation status	Proposed																										
	Realised/planned																										
D2 Evaluation of the restoration method and its	Proposed																										
	Realised/planned																										
D3 Monitoring of LIFE Key Project Indicators	Proposed																										
	Realised/planned																										
E1 General communication and dissemination	Proposed																										
	Realised/planned																										
E2 Dissemination of scientific results	Proposed																										
	Realised/planned																										
E3 Sustainability and replication of project	Proposed																										
	Realised/planned																										
F1 Project management	Proposed																										
	Realised/planned																										

Table 9. Gantt chart with planned action to next report.

The next progress report is in September 2024 and envisaged progress action for action is as follows:

A1 Development of restoration method

The work with developing the restoration method will continue until the second quarter of 2023. In the original proposal, laboratory work on larvae was not planned for spring 2023 but because of severe parasitic outbreaks in the larval cultures both during the spawning season of 2021 and 2022, many planned experiments could not yet be carried through. Deployment of most reef structures (action C2) will take place during quarter 3 and 4 of 2023 and the various experiments and field studies of settlement specified for this action will go on until then. The milestone of reaching decision on preliminary artificial reef design (01/2022 in proposal) has only partly been met and is now envisioned for 11/2022 with fine adjustments possible to be made before the final design is set in quarter 2 2023.

A2 Expended fishery restriction

This action is completed.

C1 Environmental mapping of reef sites to be restored

The Sonar survey is completed, and the biodiversity investigation will be reported in 12/2022 (milestone).

Foreseen end date for the collection of environmental data on each reef site (C1.2) was in the first quarter of 2022, but the work with these measurements will continue until the second quarter of 2023 to complete our datasets and to discern possible seasonal/annual variability. This action will be completed within the next reporting period.

C2 Manufacturing and deployment of artificial reef objects

Within the next reporting period, all ARs will be manufactured and deployed. The procurement procedure for a manufacturing company is ongoing and a contract will be signed before 31/01/2023 (milestone). To test the production and deployment methods, deployments of ARs

with a preliminary design will start in spring 2023 with final blueprints of artificial reefs ready 30/06/2023 (deliverable). If everything goes according to plan, manufacturing and deployment of all ARs will be finished before the end of 2023.

D1 Monitoring of conservation status and public outreach

In quarter 3 2024 there will be a new biodiversity investigation, after the deployment of the AR in quarter 3 and 4 2023. The first biodiversity investigation was performed under C1 in quarter 3 2021.

We will continue to gather statistics of the reached audience and visitors to the public outreach. We track the number of individuals reached through all our channels of communication: e.g., visitors to the websites, lectures, exhibitions, cruises with the R/V Nereus that visits the ARs, etc.

D2 Evaluation of the restoration method and its replicability

This action will not start (quarter 1 2025) until after the next progress report.

D3 Monitoring of LIFE Key Project indicators

- Monitoring of *Lophelia pertusa* reef habitats as well as the red listed species; *Macandrevia cranium*, *Munidopsis serricornis* and *Squalus acanthias* is done in C1 quarter 3 2021, will be done in D1 quarter 3 2024.
- Monitoring of fish and crustaceans is done every third year by SwAM and will be compiled for the project years by the project manager.
- Monitoring of visitors to the National Park area is done every year by the project manager.
- Statistics of fish catch (cod, shrimp) in N2000 area is gathered by SwAM every year and will be compiled for the project years by the project manager.
- We will continue to gather statistic over the people reach though our different communications.
- Monitoring of visitors to the project website will be developed.

E1 General communication and dissemination

- We will continue to update the information on the project website.
- Leaflets will be produced and printed when the first AR is manufactured, quarter 3 2023.
- We will also continue to inform the public and students about the project. Other public awareness activities include finalizing the production of the project video/film and boat trips using ROV to visit restored reef sites.
- A second video/film will be produced aimed at the scientific community to supplement the technical manual. This more technical video will be produced in house of CABO with a permanent filmmaker.
- We will contract an artist to illustrate artificial reefs with corals and associated biodiversity.
- Arrangement of a seminar and final conference to directly communicate the results to the identified stakeholders

We will further continue our outreach activities and will be available for interviews and reportages in press and other media. We are invited to present the project for the general public in the Ytre Hvaler National Park. The date is yet to be decided but planned for the fourth quarter of 2022. The senior researcher at UGOT will represent the project at the

iAtlantic General Assembly 2022 which takes place in Florianópolis, Brazil on 10-14 October. We also plan a visit to network with the recently started *LIFE ECOREST* project in Spain. This project aims to restore cold-water coral gardens in the Mediterranean.

E2 Dissemination of scientific results

We hope to participate at international conferences during the years to come, since this has been affected by the pandemic so far. UGOT plan to present results from the project at the 8th International Symposium on Deep Sea Corals 29 May–2 June 2023 in Edinburgh Scotland and at the 17th Deep-Sea Biology Symposium in Hong-Kong 2024. The work with dissemination of results in scientific articles will also intensify and quite a lot of time will be allocated to this sub-action until the next progress report. We will also arrange the workshop targeting scientists involved in deep-sea coral restoration and management. Arrangement of this workshop is a milestone and is planned to the third quarter of 2023.

E3 Sustainability and replication of project

The work within action E3.1 with identification of other sites and their respective stakeholders within the EU where the developed method can be applied will start seriously in the coming reporting period and will be further intensified towards the end of the project. The seminar in E3.2 targeting the public, authorities, fishermen, tourist entrepreneurs and other stakeholder of the Natura 2000 area and deep-sea coral habitats will be arranged after the deployment of artificial reefs in autumn 2023, and before the next progress report in Sep 2024. The work with the “Technical Handbook” describing the developed method and how it should be implemented will start in the later part of the coming report period but a majority of the work with it will be done towards the end of the full project period.
