Deliverable No D7.4: Ice and Wind Resistance Test for Aquacosms

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Main Authors: Henrik Larsson
### Abstract
In order to test and develop two Aquacosm mesocosm prototypes they were exposed to rough wind and wave conditions and was frozen in sea ice for two winters at a sub-Arctic site in the northern Baltic Sea. The results from the tests enabled successive refinements of the prototypes that have led to an Aquacosm design that is expected to sustain use in ice and under otherwise harsh weather conditions over many years.

### Keywords
Ice, wind, waves, mooring, metal frame, roof, bag, floating units, experimental water enclosures.
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1. Executive summary

The conducted tests refer to Task 7.6: “Testing of the AQUACOSMS under near Arctic conditions, including two winters” and replace tests originally planned Task 7.6: “Testing of the AQUACOSMS under Arctic conditions in NyÅlesund”, according to amendment AMD-731065-31.

As most pelagic mesocosms (or water enclosures) are neither standardised nor do withstand strong wind or ice conditions, one of the main Joint Research Activities in the AQUACOSM project is to develop a standardised pelagic mesocosm that withstands at least moderate wave and ice conditions. In order to develop such mesocosms two prototypes were subjected to tests under winter conditions during two periods; Dec 2017 to May 2018 and October 2018 to April 2019. The tests were done in sub-Arctic conditions in the Gulf of Bothnia 800 m off Umeå Marine Sciences Center, test-site latitude: 63.563354, longitude: 19.848572. The test site was a relatively shallow semi-sheltered area of the Bothnian Sea, waves can be up to 1 m high with a relatively short wave to wave distance as compared to oceanic conditions. The ice-thickness was a few dm at its maximum during the two winters. The Aquacosm prototypes were subjected to strong winds both in open water and while frozen into an ice-sheet. A free-floating design concept was adopted in WP 7.1 and the construction was successively refined after each winter within Task 7.3. The successive refinement of Aquacosm design and mooring resulted in a construction that can handle ice and rough weather over several years.

This report specifically describes how the different parts of the Aquacosms coped with rough weather and ice, and how successive refinements resulted in a final ice resistant construction.
2. Aquacosms in rough weather and ice

2.1 Description of tests and test conditions

The first two Aquacosm prototypes were launched into the sea in late November 2017. During their deployment they handled average winds of up to 17 m/s during early December. The sea froze in early January and the prototypes experienced average winds of up to 18 m/s during mid-January. The prototypes where retrieved for inspections and further development in early-May 2018.

After some refinements in the constructions (detailed below), the prototypes where relaunched in mid-November 2018. The prototypes experienced average winds up to 20 m/s before the sea froze, and over 15 m/s in ice during this second winter. The prototypes were picked up and inspected in late April 2019, relaunched a week later and finally picked up in early August 2019.

2.2 Mooring of the Aquacosms

One of the lessons learned during the first winter is that free-floating Aquacosms that sit in an ice-sheet will be dragged downwards if the ice sheet starts to move while the moorings extends down to weight anchors. The mooring of the Aquacosm during the second winter was therefore done with the aid of ball fenders. These fenders where attached to the Aquacosms with ropes that extended horizontally at the water surface, while the mooring was done using ropes between the ball-fenders and the weight anchors. This arrangement proved to effectively reduce the displacement of the mesocosms downwards, due to ice movements.

2.3 The Aluminium frames

The structural integrity of the Aquacosms depends on the metal frame and all parts are attached to it. The metal frames were essentially the same during both test periods. No breakage of any part of the frames could be observed after two winters, despite rough weather and pressure from moving ice. However, while all Aluminium parts of the first prototypes of marine quality showed no noticeable corrosion, parts made from...
standard Aluminium corroded heavily. Further, a one-meter high Aluminium cylinder was employed in one of the prototypes to protect the mesocosm bag from wear and tear by the ice, this arrangement turned out to be unnecessary. The tests proved that the metal frame displayed in Figure 1 is sound for use in ice and rough weather, provided that all parts are made from Aluminium of marine quality.

### 2.4 The bags

The absolute structural integrity of the bags are the most important feature of the mesocosms, as the bags separate the experimental water from the surrounding water, and even very small leaks would jeopardize the manipulation of the water within the bag.

The bags used under the tests were 4.23 m high, 2 meters wide and made from 1 mm thick Polyurethane. Both bags proved to be intact after the first winter as no leaks could be detected. However, inspection after the second winter revealed some ruptures along diagonal welding’s of the Polyurethane material. We concluded that (1) the bag should be protected from outside water pressure after launching before filling, (2) the number of vertical welding’s of the Polyurethane material should be minimized, and (3) reinforced polyurethane should be used at the position of the ice. The construction of the new mesocosm bags for the final Aquacosms have now been upgraded in response to all these points, and are expected to perform better than even the first year when no leaks were detected even after many months in ice. The light conditions within the Aquacosm was also further improved by choosing a new clear transparent Polyurethane material for the Aquacosm bags in place of the earlier more yellowish variant.

### 2.5 The roofs

The roof protects the enclosed water in the bag from unwanted intrusion by rain and bird faeces.

A flat roof design was abandoned after the first winter since it did not withstand the harsh conditions and allowed for snow and ice to gather on top, causing unwanted changes of the light conditions. This construction was replaced by a dome shaped roof using a clear and low-cost EVA-5 material for the tarpaulin. This latter construction is displayed in Figure 2. This roof construction worked well initially but was eventually captured by bird claws and/or beaks. Another dome shaped roof was based on 1 mm thick clear polyurethane for the tarpaulin and was used for two winters without any damage. This roof design was therefore chosen for the construction of the final Aquacosm model.

### 2.6 The floating units

The floating units allow Aquacosms to float in a specific vertical position in the water. Two different types of floating units were evaluated during the two winters, one of which employed fenders and the other sealed HDPE tubes, the latter shown in Figure 1. The fender construction was inferior to the HDPE tubes in several ways. The fenders were less fixed to the frame, resulting in less stable positioning of the mesocosm in the water. The fender system also showed more wear and tear of the attachment lines, and uneven air volumes in the different fenders over time. Thus, the construction with fenders was abandoned. In contrast, the concept with sealed black HDPE tubes proved to function perfectly for two winters and was therefore chosen for construction of the final Aquacosms.

### 2.7 General behaviour in rough weather and ice

Even in the highest observed waves up to 1-meter high, the Aquacosms did not show much vertical movement. The vertical alignment of the floating units places much of the lifting power below the waves, and the weight octagon constitutes a relatively large area with sharp edges creating drag that further resists vertical movements. Visibly the waves tended to go through the Aquacosms rather than lifting them up or pushing them down.
The Aquocosms kept their vertical position in the water and the water surface remained at the same position relative the aluminium frame during the winter experienced. Although, the behaviour may vary with site and weather conditions during winter and cannot be generalized from this individual case, we conclude that the final Aquacosm model is able to successfully endure these weather conditions over many months, and thus is well adapted to become widely used throughout Europe and beyond.
3. **Dissemination activities related to D7.4**

- The progress of the work has been reported in general assembly meetings and steering group meetings during the Aquacosm project.
- One article with title *Constructing mesocosm for arctic conditions* have been finalized but has yet to be published on https://www.aquacosm.eu/.
- The work done has also been a part of a running presentation at the university of Umeå in November 2018 and November 2019, estimated audience about 300 researchers and students on each occasion.
- The design and availability of the Aquacosms will be widely disseminated during the follow up project AQUACOSM-plus, where the aim is to support construction of these mesocosms as at many sites as possible, as well as open for collaborative projects using the already constructed Aquacosms.