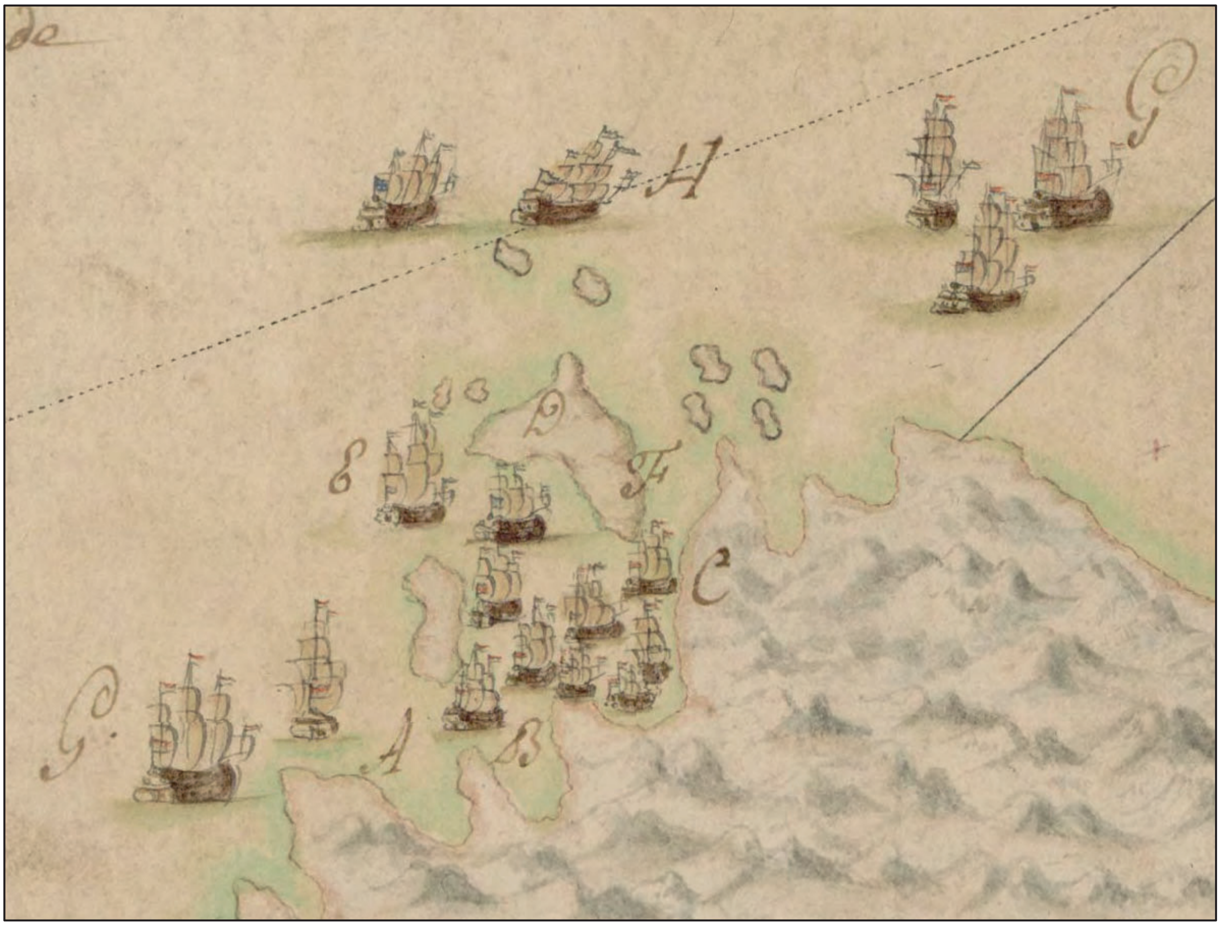
Smeerenburgfjorden Marine Archaeological Survey



Report from the 2019 Smeerenburgfjorden Marine Archaeological Survey
A project supported by the Svalbard Environmental Protection Fund and
NTNU AMOS

SVALBARD ENVIRONMENTAL
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Operations and Systems

THE ARCTIC UNIVERSITY OF NORWAY
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Innhold

Figure 1: European Arctic with inset of Northwestern region of Svalbard

Introduction

In 1693, a small fleet of four French warships under the command of M. de La Varenne was ordered by King Louis XIV to "destroy the Enemy's vessels going out to whale in Greenland [Spitsbergen]. […] His Majesty wants that he burns or sinks, without any exception, all the ships which fly the British, Dutch or Hamburg flags and, as far as those which sail under the Danish flag, the captain will make sure that they are really Danish." This was during the Nine-year war in Europe, and the motive was to hurt the Dutch economy by hitting the prosperous whaling enterprise in the Arctic. The campaign was a success. Twenty-eight Dutch whaling ships were captured, of which 17 were sunk near Smeerenburg on the northwestern edge of Spitsbergen (Henrat, 1984).

The wrecks of these ships, and an estimated 1000 other historical shipwrecks around Svalbard, constitutes an important but largely unexplored part of our Arctic cultural heritage. Apart from an expedition of sports divers in collaboration with the Norwegian Maritime Museum and the Polar Institute in 1966 (Molaug & Olsen, 1966), only a few official efforts have been made to survey underwater cultural heritage in the waters surrounding Svalbard. Logistical and safety requirements for diver-based operations to survey unknown seabed areas in harsh environments are considerable, and management and research on maritime cultural heritage in Svalbard have mainly been limited to sites on land.

With recent developments in portable underwater robotics and sensor technology, operational constraints for conducting marine archaeological surveys are being mitigated. The current project aimed to do detailed seabed mapping with side scan sonar and video to discover and investigate any potential shipwrecks in the Smeerenburgfjord area, using safe and efficient methods that do not require diving operations. In addition, environmental and biological data were acquired for assessment of conditions for preservation of underwater cultural heritage in the area.

Areas of interest

The survey areas were selected based on historical texts and maps describing anchorages, sailing routes and wreckings around the old Dutch settlement in Smeerenburg. A detailed report to King Louis XIV, including a map showing encounters between French and Dutch vessels, was the main source of information in the planning of this survey.

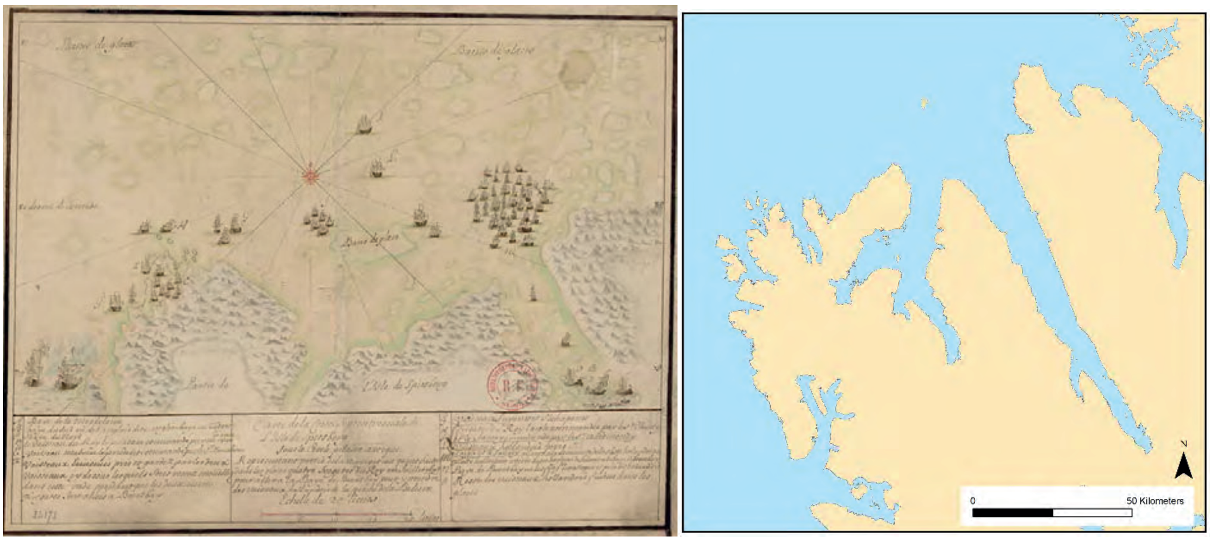

Figure 2: To the left: drawn map presented to Louis XIV with report in 1693, to the right: same area in modern map.

However, there seem to be some geographical inaccuracies in this map, and the written account in the report and the map sometimes to do not align well. Historical sources describing activities in the region during the whaling period were used to locate preferred anchoring areas. Additional information was gathered from more recent Arctic pilots (British and Norwegian), and also bathymetric charts were analysed, to select survey areas. The exact positions for where the Dutch vessels were sunk are unknown, but based on available sources we believe we were able to identify the most probable areas.

Sørgattet

(Be. Anglaise, Feer-haven, Beere bay, Bjørnbaisundet, Bocca della Baia, Engelse baay, Englischer Hafen, Passe du Sud, Zuid baaij, Suijer Gadt, Suyder Gat, Süd Gat, Zuyder Gadt, Zuyder Gat of Engelse bay)

Figure 3: Sørgattet with Moseøya seen from the east

In the southern entrance to Smeerenburgfjorden, between Danskeøya and Spitsbergen (Albert I land), is a narrow strait called Sørgattet. In the French map (1693) this area is called "Englis-baye ou Zudgat". According to the text in the report to the King, this is where all the Dutch ships were gathered, and 17 ultimately sunk.

In several old maps, a harbour is marked close to land between Moseøya and Danskeneset.

In the 1934 version of the Arctic Pilot (Pilot, 1934) we can read the following about anchoring in Sørgattet:

"The tidal stream runs with great strength through the narrows. Sørgat seems to have been frequently used as an anchorage since its discovery by Jonas Poole in 1610.

Anchorage may be obtained northward of the fairway in a bight, on the southern coast of Danskøya, between Moss island and the western end of the shoal south-westward of Danes ness. The anchorage is about 2 cables offshore, in a depth of about 10 fathoms, between half a mile and three quarters of a mile north-eastward of Moss island. HMS Trent anchored in this bight in 1818, and Lieutenant Beechey describes the anchorage as being completely landlocked and as secure a port as a vessel under ordinary circumstances could require."

According to the Norwegian Pilot (den Norske Los), an additional anchorage can be had in the outlet of *Scheibukta* at 12 m. depth ("The Norwegian Pilot," 2018).

All of Sørgattet (approximately 20 km^2), from Moseøya to Scheibukta, was an area of interest for this survey. Priority areas were the two anchorages mentioned above, and the deeper (70 m) trench in the middle of the strait. The 1966 diving expedition focused on this area (Molaug & Olsen, 1966).

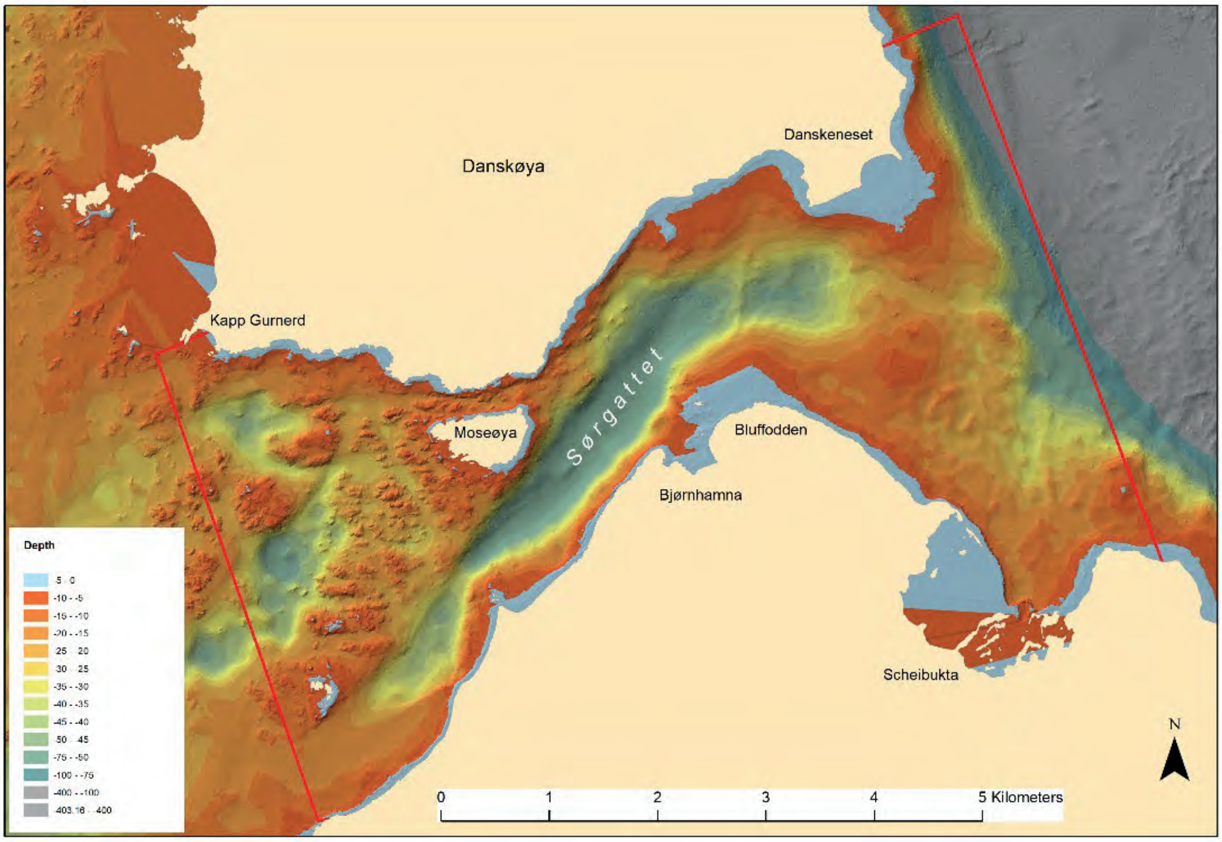

Figure 4: Bathymetry in Sørgattet (data from the Norwegian Mapping Authority).

Kobbefjorden

(B. Danoise, Baies des Phoques, Baye de Richelieu dict le port de S:Pierre, Deens-Bay, Deensche-baay, Dänischer Bay, D¨nischer Hafen, Kjøbenhavnsbay, Kobbebay, Kobbebugt, P :st Pierre apelle par les danois copen haure baies, Par les holandois apelle Robesbaies, Robbe Bay, Robbe Gat, S :tus Petrus, Seehunds-Bai)

Figure 5: Kobbefjorden

This bay on the western side of Danskøya was used as a Danish whaling station at least since 1625, after they were evicted from Smeerenburg and Amsterdam Island by the Dutch. Nordenskiöld described the bay as:

"This harbour of all the harbours of Spitsbergen is the first free from ice, and on the shore of the inner bay there is a fresh-water lake that never freezes to the bottom, and therefore always supplies good water."

A bar of sand and stones (3,7-5,5 m depth) stretches across the entrance to the bay, making it difficult to enter for larger vessels. The sheltered inner part of the bay is 18,3-23,8 m deep.

In the 1966 diving expedition, diving was attempted on the southern shore of the inner bay. A whale skeleton was found at a few meters depth. At 15 meters, the divers encountered a white layer with zero visibility. This layer seemingly went on for at least several meters, and prevented further investigations of the seabed.

Other information tells that a small boat got its anchor stuck in "something" in this bay, and had to cut the cable to get loose.

The inner part of the bay (deep areas - approximately 0.5 km^2) was an area of interest for SSS mapping.

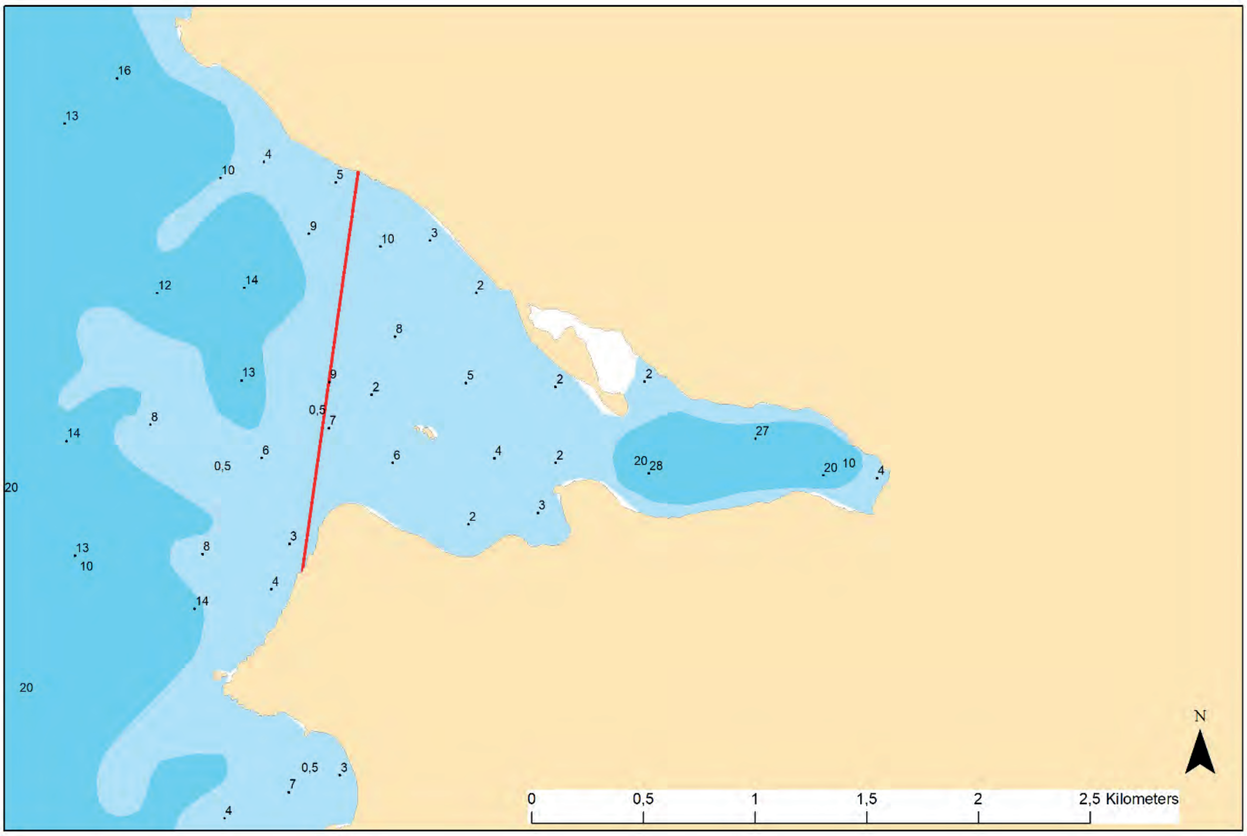

Figure 6: Kobbefjorden - Robbe bay

Danskegattet

(Danes Gat, Danskesundet, De West-Bahy, Dänenthor, Dänische Bay, Havre du Sud, Middel Gat, Middelgat of Zuyder Bay, Porto del Sud, Zuyd Bay, South Bay, Stretto dei Danesi, Suydt Bay, Südhafen, Südlicher Hafen, West Bay)

Figure 7: Danskegattet and Virgohamna with Smeerenburgodden (photo:Asgeir Sørensen)

The strait that separates Danskeøya and Amsterdamøya has several shallow areas in both the western and eastern entrances that can make navigation hazardous for anyone not familiar with the area. In the middle of the strait is Likholmen (Deadmans Island), used as a burial ground for whalers. The Norwegian Pilot says that there is good anchorage with sand and mud in Danskegattet, but it is deep in the middle, west of Likholmen. The best anchorage in Danskegattet is *Virgohamna (Houcker Bay, Danes Bay, Pike's bay),* a bay on the northern shore of Danskeøya. In 1634, the cookery of Harlingen was set up here, as there was no more room at Smeerenburg. It has a stream of fresh water and is partly sheltered by Ekholmpynten and Æøya. Best anchorage may be obtained between Virgohamna and Likholmen.

Friedrich Martens wrote about his travels with a whaling ship in this area in 1671. He visited "South-harbour" or "South-haven" several times, and tells of ships that were at anchor there:

"In the South or North Haven or Bay, ride commonly the most ships; I told several times ten, twenty, nay thirty ships that lay at anchor." (White, Martens, La Peyrère, & Pellham, 1855).

In older maps a shallow area in the eastern entrance to Danskegattet is called *Eyl. daer't Schip de Oliphant op vast geseten heft* – The rock that *the Elephant* hit.

A likely interpretation of the descriptions and annotations on the map in the French 1693 report is that the Dutch vessels could have been gathered in Danskegattet just as likely as in Sørgattet. The strait can be controlled by a frigate in each entrance, making it a seemingly better choice for controlling a fleet of captured vessels than Sørgattet. The names South bay, South gat and South haven seems to have been used inconsistently in maps through the 17th and 18th centuries. Confusion of these place names in the 1693 report was very likely, and Danskegattet was considered a highly probable location for the sunk vessels.

In 2016, during the Polar Night Research Cruise, an area in the middle of Danskegattet was surveyed with AUV (SSS). No apparent wrecks were found, but several possible objects of interest were marked for later inspection, among them what appeared to be an admiralty anchor.

All of Danskegattet (approximately 12 km^2), was included as an area of interest for the project.

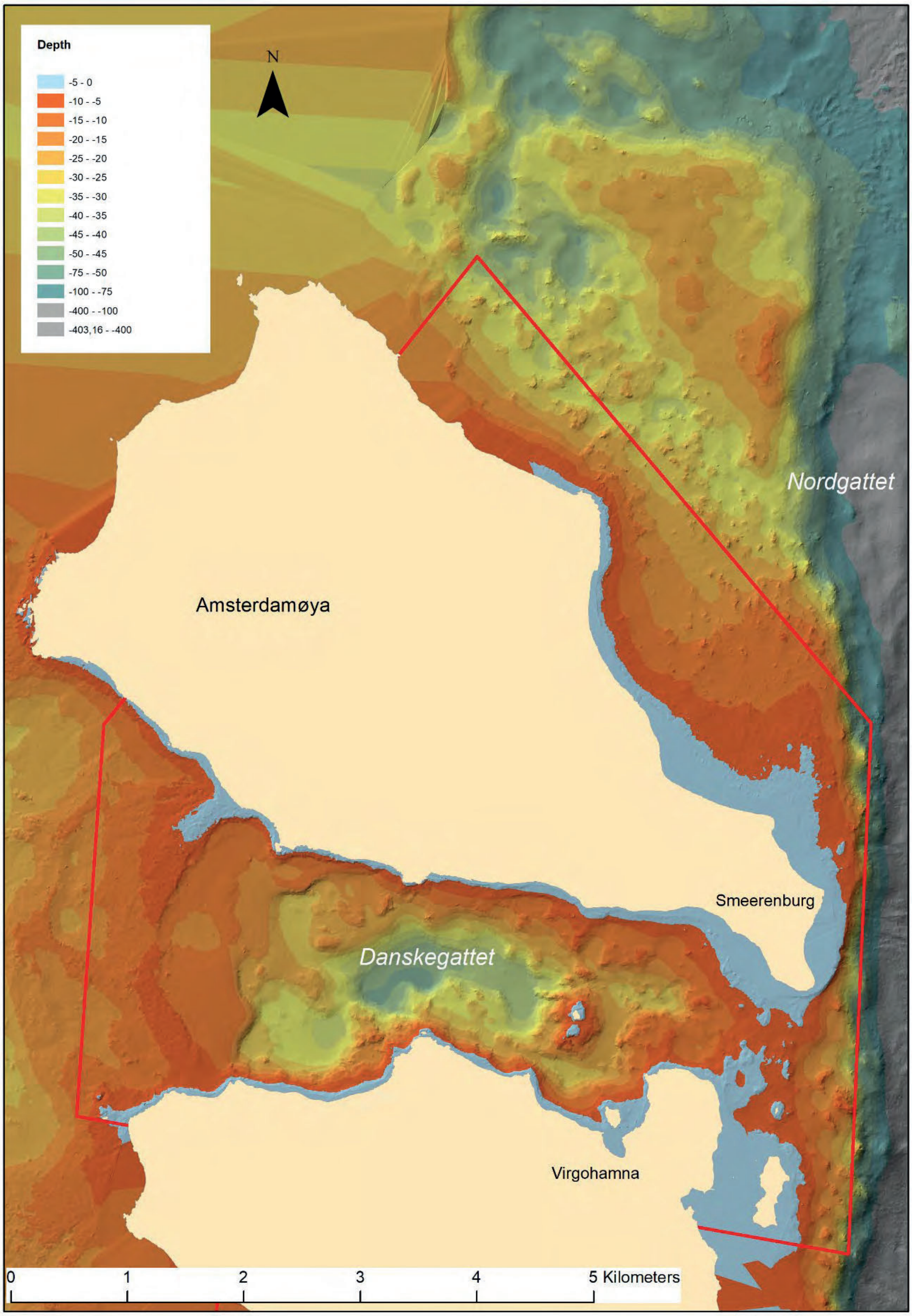

Figure 8: Danskegattet and Nordgattet (data from the Norwegian Mapping Authority).

Nordgattet

(Baye du Nord, Noord Bay, Noorder Gat, Nordlicher Hafen)

Nordgattet is the wide northern entrance to Smeerenburgfjorden. As noted by Martens, the South and North bays were the most common anchorages for many ships. Conway (1906) mentions that in 1675: *"[…] no less than 13 Dutch ships were destroyed and 72 men killed by one icefloe near Smeerenburg."* It is likely that these ships were anchored on the northern side of Smeerenburg, in Smeerenbukta.

The Norwegian Pilot says:

"Smeerenbukta, on the north side of Smeerenburgodden, is otherwise the best anchorage along this stretch. Vessels can anchor in suitable depths, 5-10 m, but beware of the 6 m shoal that lies furthest outermost edge of the danger line, about 8 cables northeast of the wide point in the middle of the bay."

In addition to the 1675 incident, Nordgattet is an area of interest due to it being frequently trafficked, and therefore believed to have a general high potential for wreckings.

A scallop trawler in the 1980s allegedly caught ceramics and wooden ship beams in its trawl somewhere north of Amsterdamøya. The exact position is not known, but the report indicates that the trawl has run over or through a historical shipwreck site. (The Icelandic scallop is typically found to habitat at 20-60 m depth (Pedersen, 1994).)

The shallow areas northeast of Amsterdamøya were considered to be of general interest (approximately 7 km^2), and a priority area was Smeerenbukta.

2019 Survey

The Smeerenburgfjorden Marine Archaeological Survey project took place 12-30. June 2019, with operational phase 15-22. June. In addition, some data sets were acquired in January 2016, as part of the Polar Night Research Cruise.

Date	Area	MS Farm	Zodiac I	Zodiac II
15.06.2019	LYB transit			
16.06.2019	Sørgattet	AZFP	Fridtjof	ROV/towfish
17.06.2019	Sørgattet	AZFP	Fridtjof	ROV/towfish
18.06.2019	Danskegattet		Fridtjof	ROV/towfish
19.06.2019	Danskegattet	AZFP	Fridtjof	ROV/towfish
20.06.2019	Danskegattet/Kobbefjorden	AZFP	Fridtjof	ROV/towfish
21.06.2019	Sørgattet		Fridtjof	ROV/towfish
22.06.2019	Sørgattet/ return to LYB		Fridtjof	ROV/towfish

The chartered boat *MS Farm* had sleeping berths for all participants. In addition we had disposal of cabins in Bjørnhamna (4 beds) and Sallyhamna (3-4 beds). Access to Sallyhamna was not possible during the project period due to ice. A polar bear appeared near Bjørnhamna the first night, and as a safety measure we decided to stay on board MS Farm for the duration of the project.

Participants in the 2019 survey were:

Stig Henningsen	Captain MS Farm		
Øyvind Ødegård (ØØ)	Cruise manager	12.06.2019	30.06.2019
Martin Ludvigsen (ML)	AUV/ROV	13.06.2019	30.06.2019
Asgeir Sørensen (AJS)	AUV/ROV/Media	13.06.2019	30.06.2019
Geir Johnsen (GJ)	AZFP/Biology	12.06.2019	30.06.2019
Maxime Geoffroy (MG)	AZFP/Biology	12.06.2019	29.06.2019
Øystein Sture (ØS)	AUV/GIS	13.06.2019	25.06.2019
Tore Mo-Bjørkelund (TMB)	AUV/Positioning system	13.06.2019	25.06.2019

All participants attended a mandatory safety course at UNIS, followed by a project safety briefing with UNIS HSE manager. All field operations were conducted according to UNIS HSE regulations and routines.

Operations

Due to much ice drifting in from the north, it was not possible to do surveying in Nordgattet during the project. Also in Danskegattet and Sørgattet, operations had to be adjusted due to ice-floes that prevented safe navigation and retrieval of AUV.

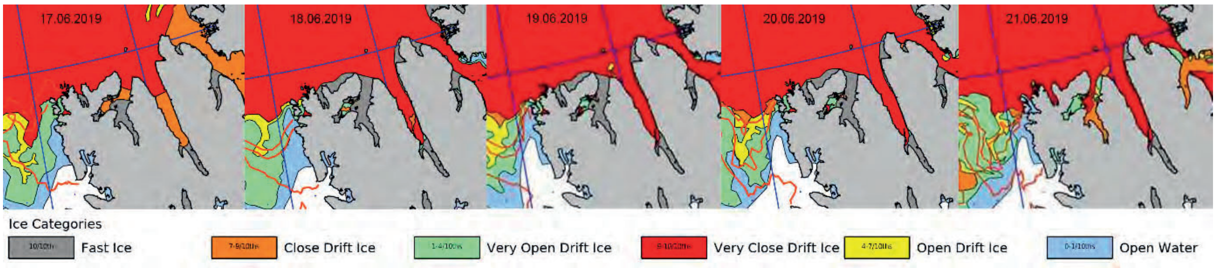

Figure 9: Ice conditions during project period. Source: cryo.met.no

16.06.2019

Established station in Bjørnhamna. Some ice in Sørgattet.

LAUV Fridtjof mission in area between Danskerevet and Moseøya

Towfish mission, one survey line in the middle of the deep area between Bjørnhamna and Moseøya.

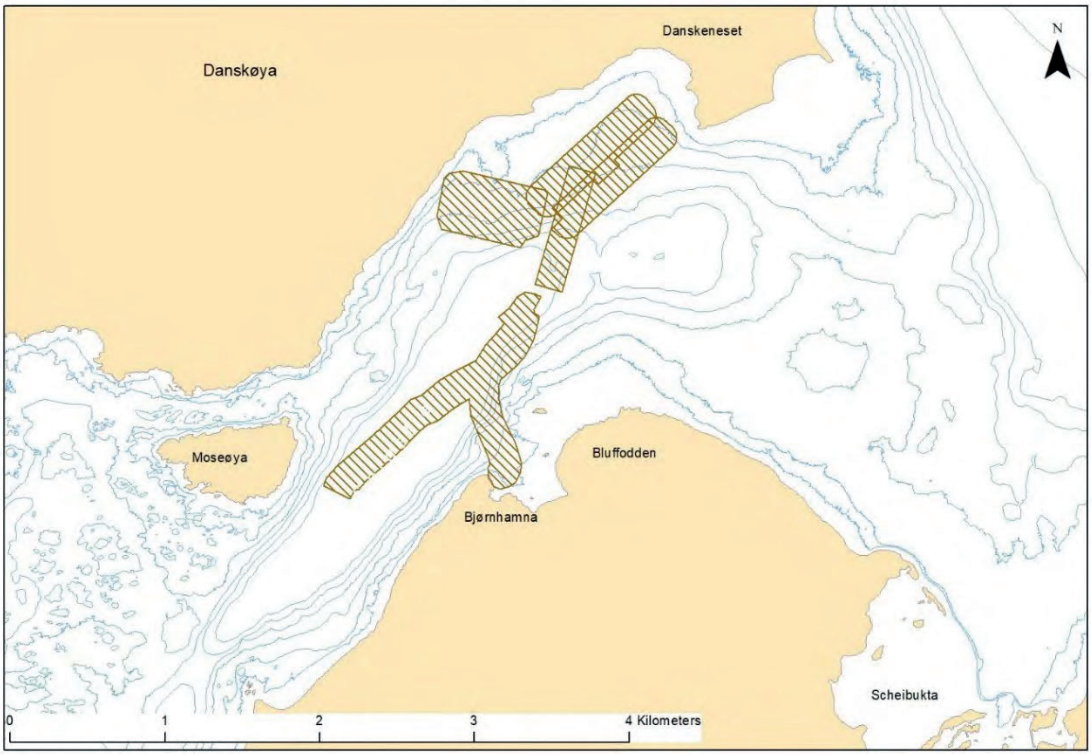

Figure 10: 16.06.2019 LAUV Fridtjof mission in area between Danskerevet and Moseøya Towfish mission in the middle of the deep area between Bjørnhamna and Moseøya.

17.06.2019

LAUV Fridtjof missions continuing from previous day.

Towfish mission in shallow areas west of Danskerevet. Transect across Sørgattet towards Scheibukta.

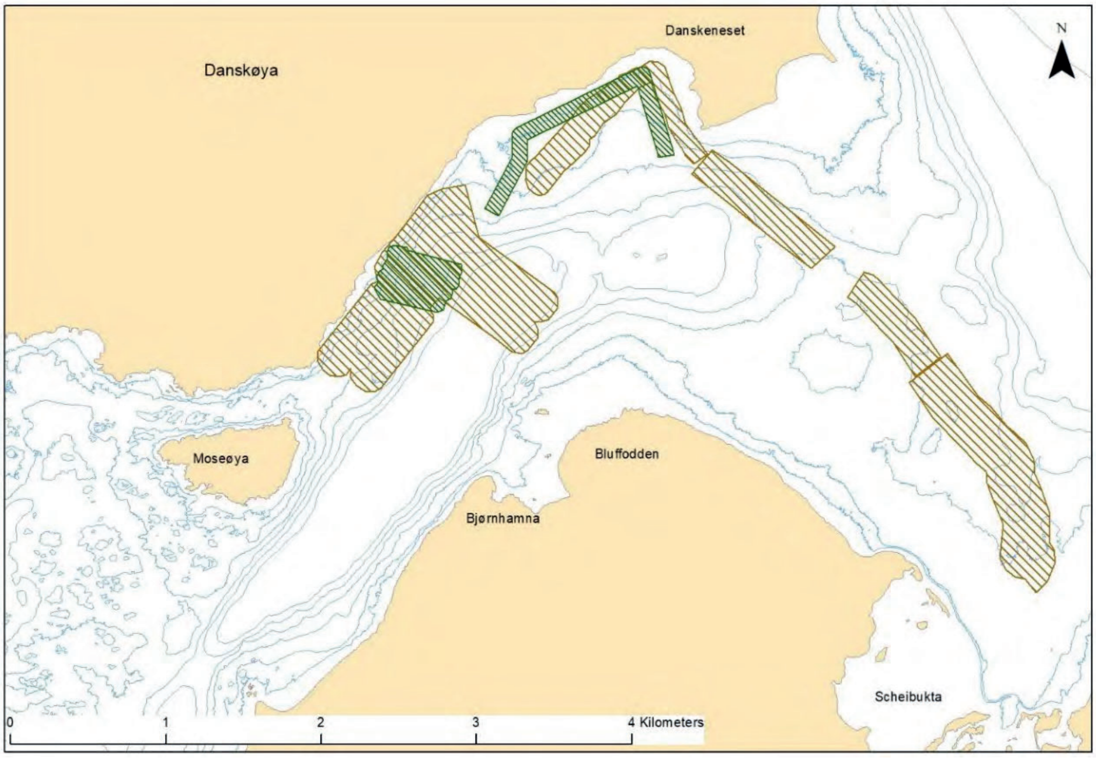

Figure 11: 17.06.2019: LAUV Fridtjof missions continuing from previous day.

Towfish mission in shallow areas west of Danskerevet. Transect across Sørgattet towards Scheibukta.

18.06

Blueye inspection of targets 1 – 2,3,5,8 and 10,11.from LAUV Fridtjof mission 17.06.

Some ice and currents affected positioning of Zodiac and navigation of ROV, difficult to ensure exact relocation of SSS targets.

MS Farm in transit to Danskegattet to establish new base outside Virgohamna.

Øystein and Tore in Zodiac to start LAUV Fridtjof mission in Danskegattet while MS Farm is in transit.

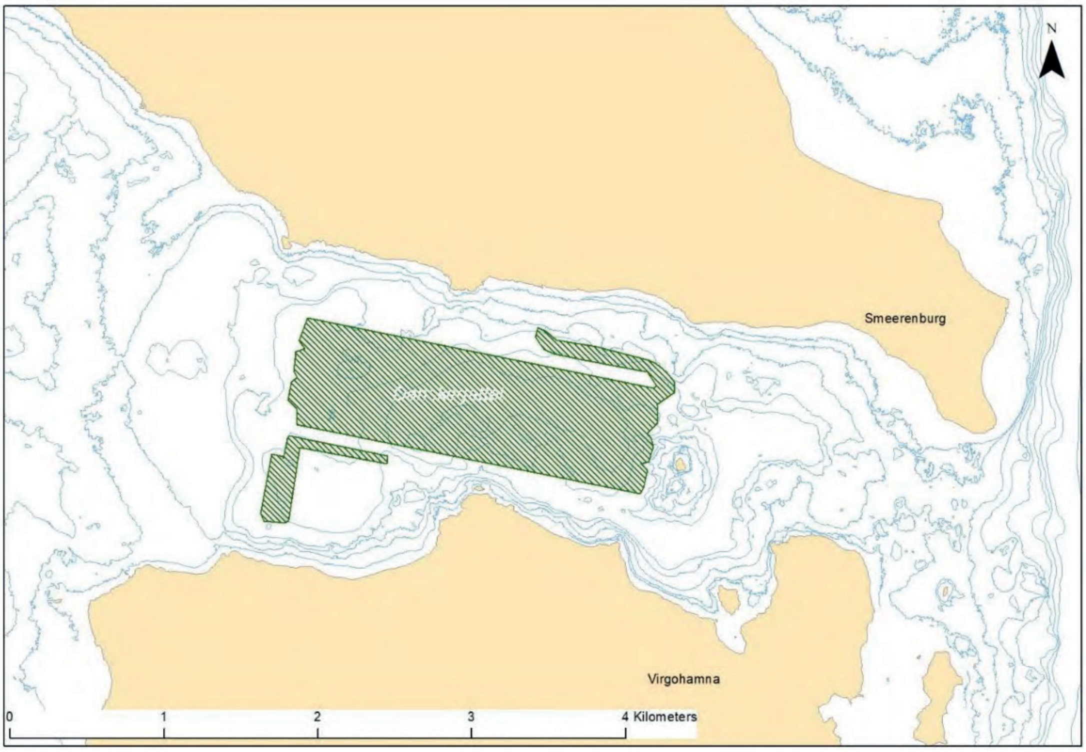

Figure 12: January 2016: REMUS 100 survey area in Danskegattet

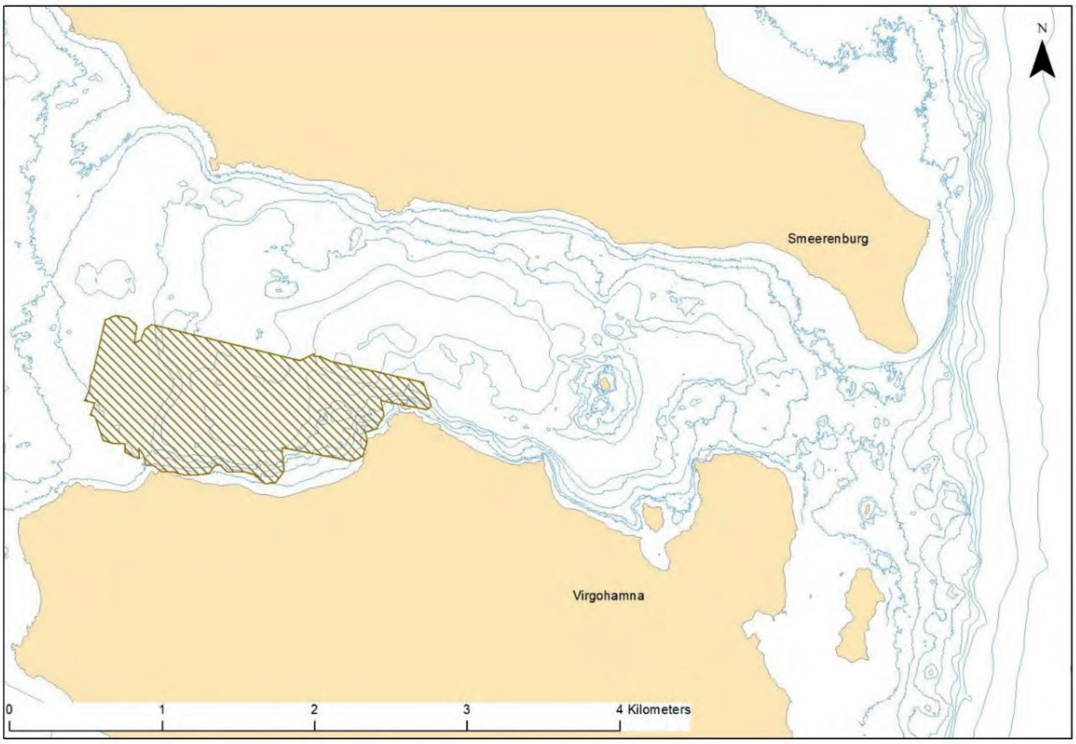

Figure 13: 18.06.2019: LAUV Fridtjof mission in Danskegattet while MS Farm in transit from Sørgattet

19.06.2019

High resolution mapping with LAUV of targets from 2016 REMUS 100 and LAUV data set. Towfish survey along northern shoreline and Virgohamna.

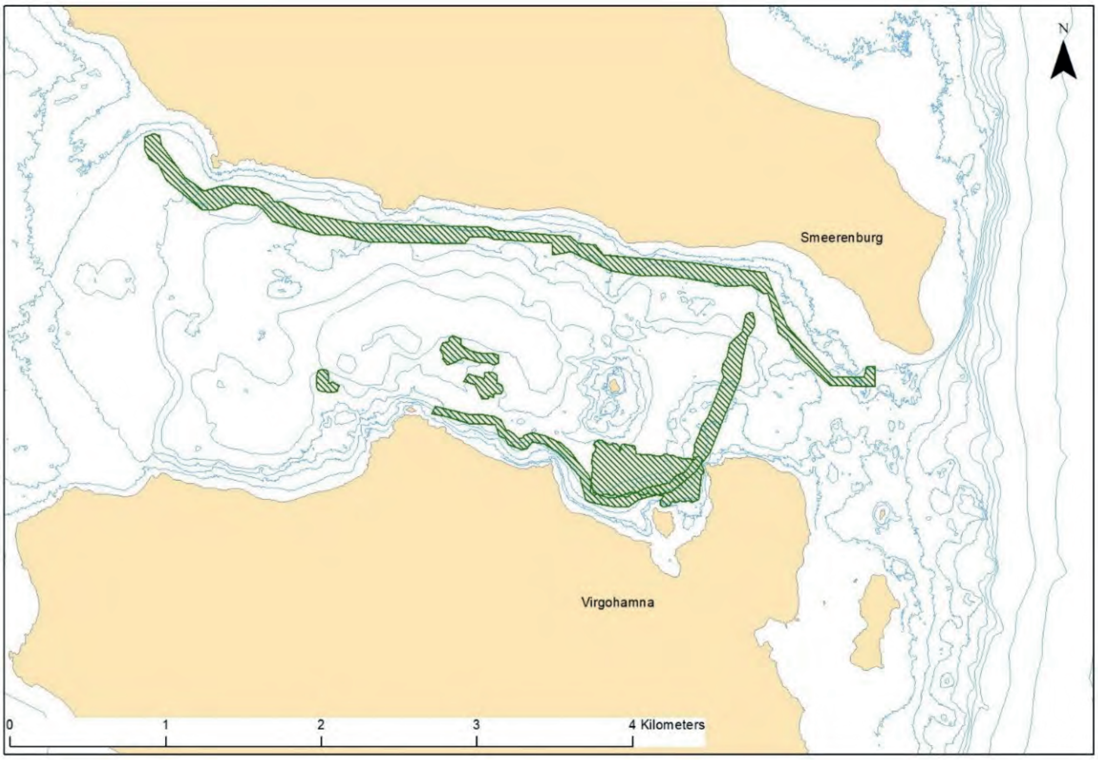

Figure 14: 19.06.2019 Towfish survey along north side of Danskegattet, LAUV Fridtjof survey in Virgohamna and target inspection

20.06.2019

LAUV mission in Virgohamna. Expedition to Kobbefjorden to do towfish survey of deep area. Due to presence of much ice, it was difficult to maintain straight survey lines, resulting in sub optimal sonar image quality.

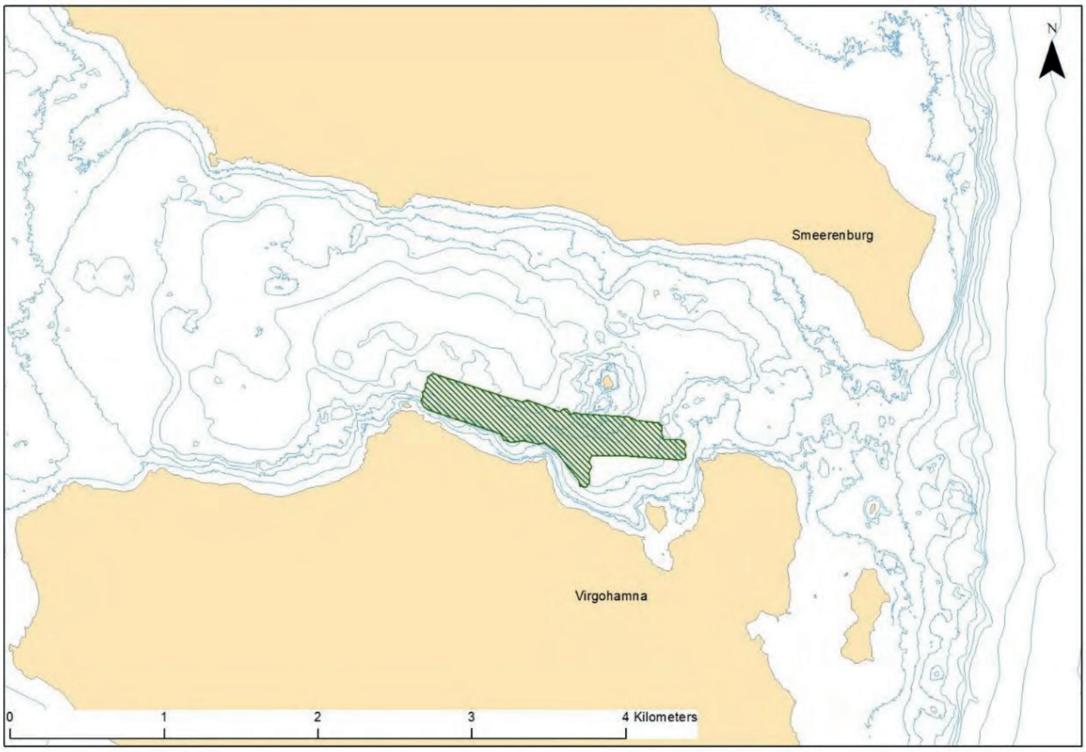

Figure 15: 20.06.2019 LAUV Fridtjof survey in Danskegattet, towfish survey in Kobbefjorden.

21.06.2019

LAUV survey of two small areas remaining in Danskegattet, outside Virgohamna. MS Farm return to Sørgattet. LAUV surveying outside Scheibukta.

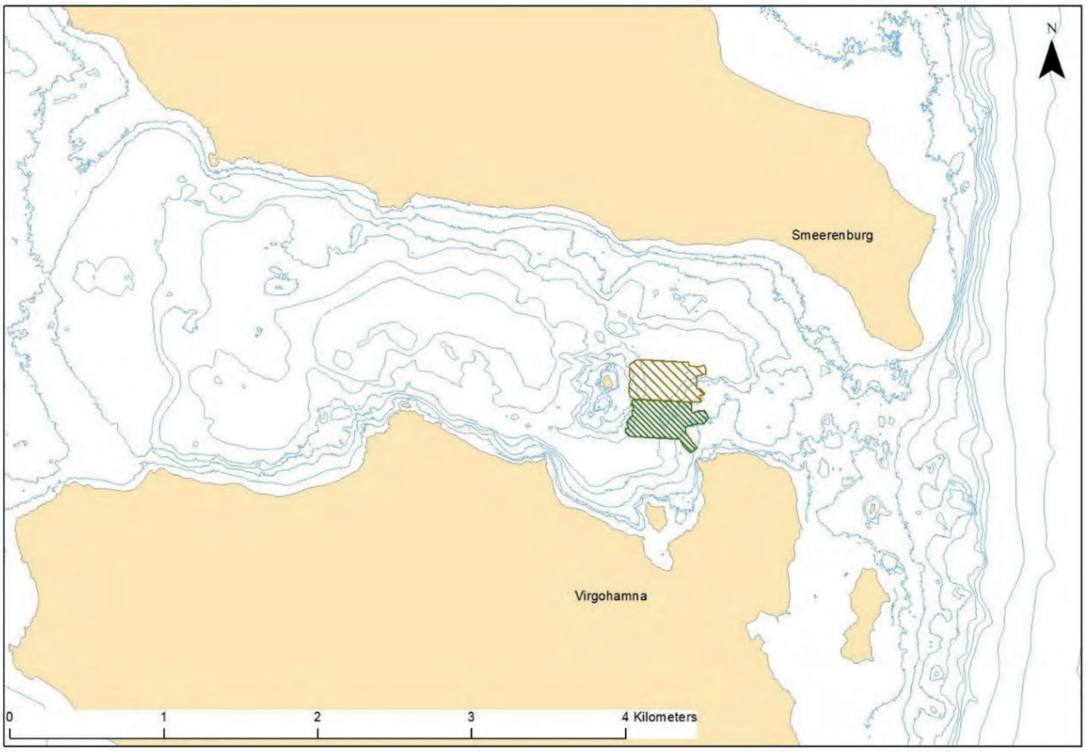

Figure 16: 21.06.2019: LAUV Fridtjof survey outside Virgohamna

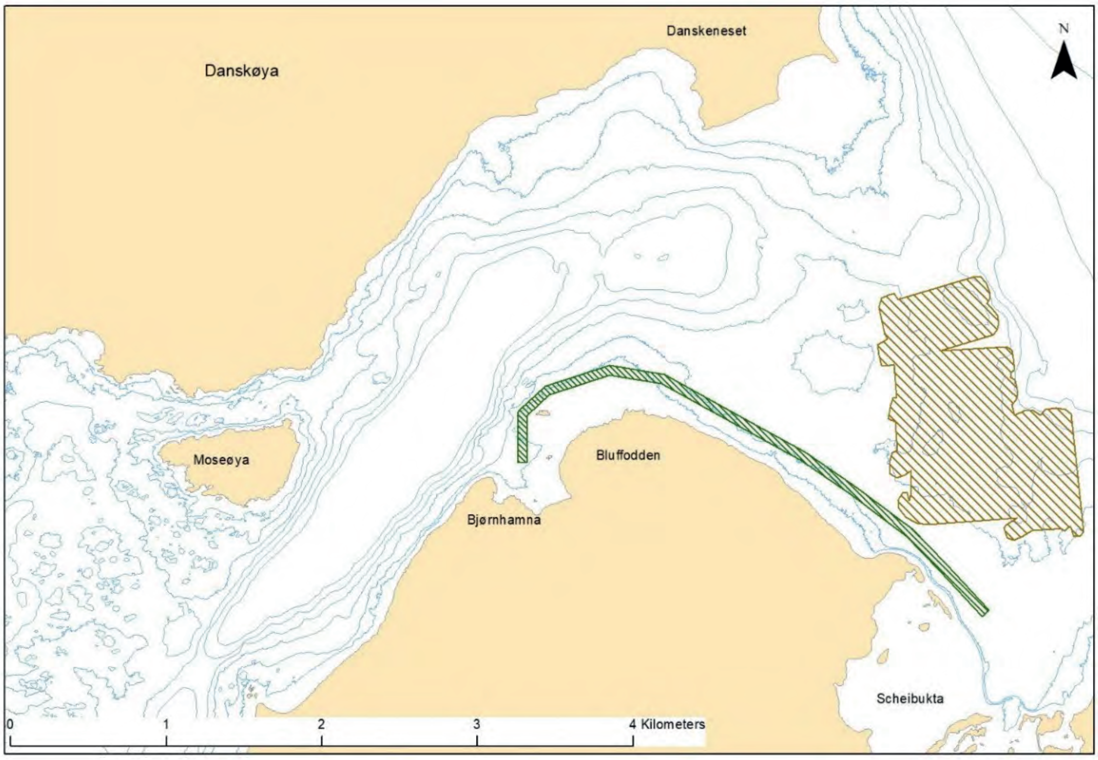

Figure 17: 21.06.2019: LAUV Fridtjof survey outside Scheibukta, Towfish survey from Bjørnhamna to Scheibukta

22.06.2019

Transfer of personnel and equipment to RV Helmer Hanssen for participation in UiT-NTNU Outreach 2019 cruise. Demonstration of LAUV operations on two selected targets (from previous day's survey) outside Scheibukta.

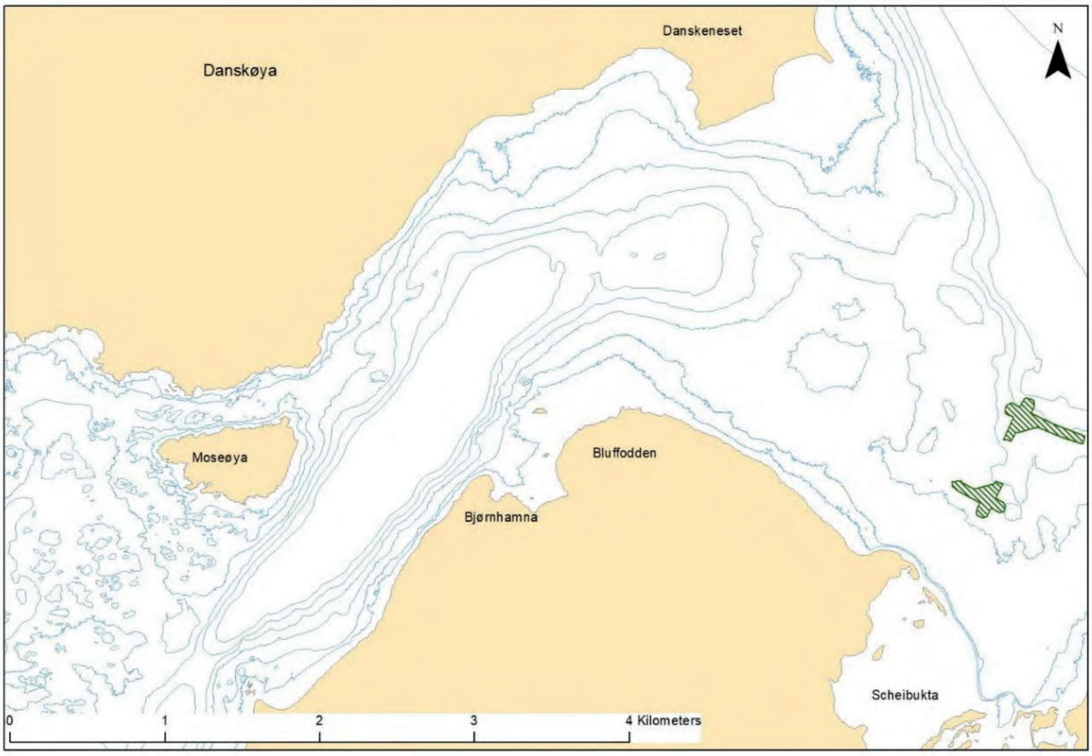

Figure 18: 22.06.2019 Target inspection with LAUV Fridtjof

End of field operations. MS Farm return to LYB with Øystein Sture and Tore Mo-Bjørklund, while the remaining participants joined the UiT-NTNU Outreach 2019 cruise on RV Helmer Hanssen.

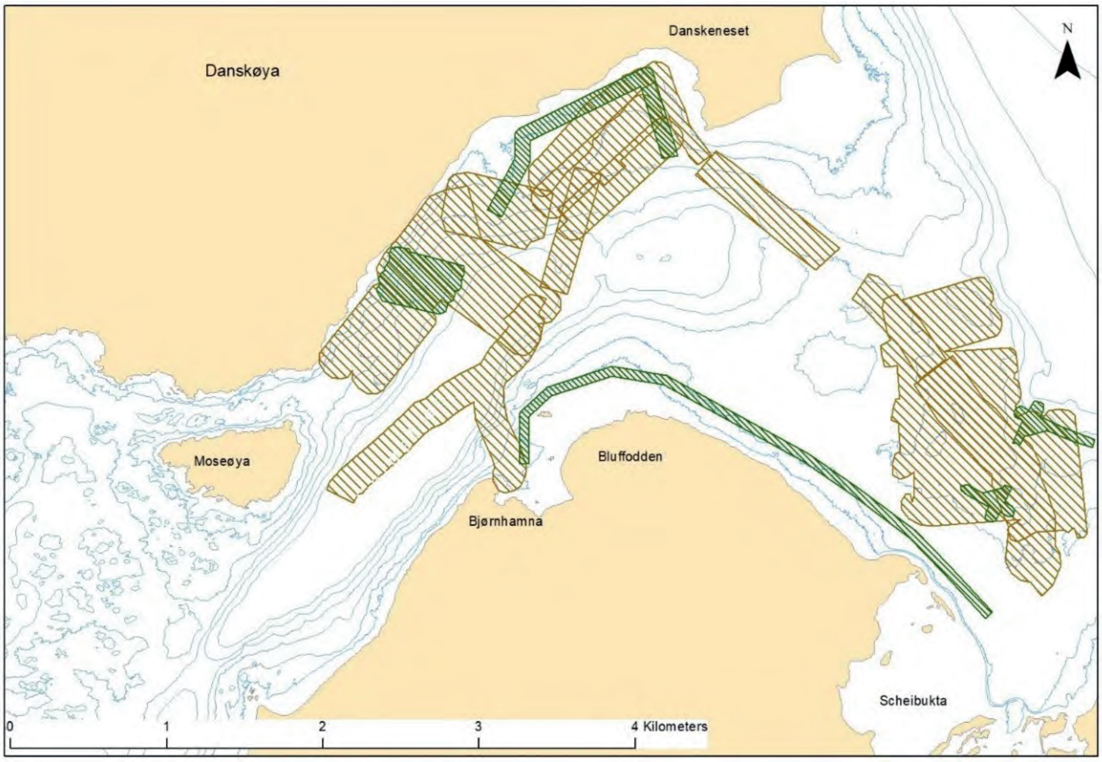

Figure 19: Total area coverage in Sørgattet - 320 kHz in brown, 640 kHz in green.

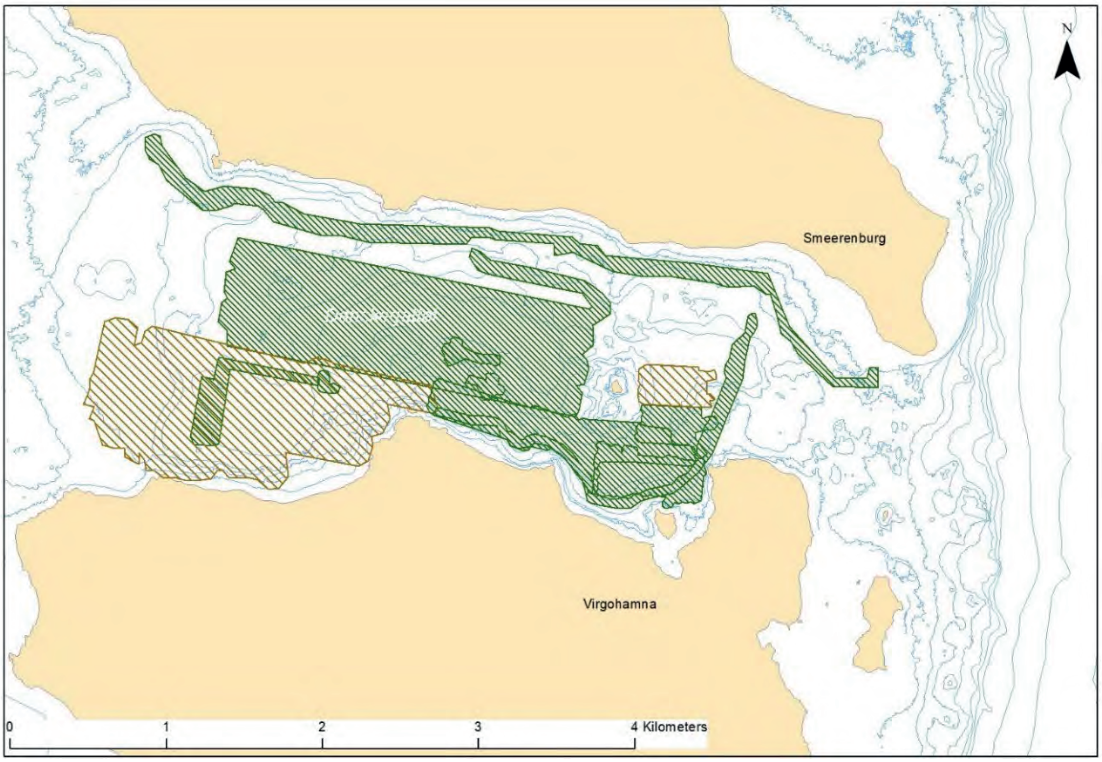

Figure 20: Total area coverage in Danskegattet - 320 kHz in brown, 640/900 kHz in green.

Sidescan seabed mapping

The REMUS 100 AUV experienced a mechanical malfunction in the tail rudder section that could not be resolved during the survey, and the vehicle could unfortunately not be used for any seabed mapping.

LAUV Fridtjof and the positioning buoy Durek II were operated from a Zodiac mk III by two or three persons depending on the mission. The AUV had a DeepVision 340/680 kHz Side Scan Sonar (SSS) for backscatter imaging of the seabed. All mission planning was done in the LAUV operations software. The AUV would be set to follow straight lines in lawn mower pattern with a fixed altitude above the seabed to ensure consistent data acquisition.

Figure 21: Launch of LAUV from Zodiac

Due to drift ice and currents some AUV mission plans could not be executed, or had to be adjusted ad hoc.

In addition to the AUV, a tow-fish with an DeepVision SSS similar to the AUV's, was deployed from another Zodiac for seabed mapping. An iPad with GNSS and navigation software was used for planning and steering along survey lines. Currents and ice floes made accurate navigation challenging, and a more opportunistic survey strategy was adopted for surveying areas not covered by the AUV, typically close to land in shallow areas. Positioning of potential OOIs had to be based on the GNSS track of the Zodiac and a calculated layback (cable length, depth and direction). Depth of the tow-fish was controlled by manually giving out or pulling in cable based on observation of the backscatter displayed in real time on a laptop computer. Vertical movement of the sensor in the water column affects the imagery, often resulting in poor data quality in areas with uneven seabed terrain.

At each end of mission, SSS data were backed up and analysed to make target lists for ROV inspection and potential AZFP profiling.

Figure 22: Danskegattet with ice floes (Photo: Helge Markusson)

ROV target inspections and documentation of objects of interest (OOI)

Two Blueye Mini-ROVs were operated from the Zodiacs by a minimum of two persons. Dive time was ~2 hrs per mission. The ROVs had no positioning systems, so a guide-line (small buoy and drop weight) was used at target positions (GPS) to visually navigate ROV to the features of interest. A total of 10 ROV-dives were done at selected objects of possible interest. Ice floes and currents hindered some operations, and planning had to be opportunistic.

Figure 23: Blueye MiniROV launch and operations.

Acoustic Zooplankton Fish Profiler

The Acoustic Zooplankton Fish Profiler (AZFP) was operated from MS Farm. Transects were made over the main areas in both Sørgattet and Danskegattet to measure biological activity in the water column. See appendix B for a short summary of the AZFP operations and results.

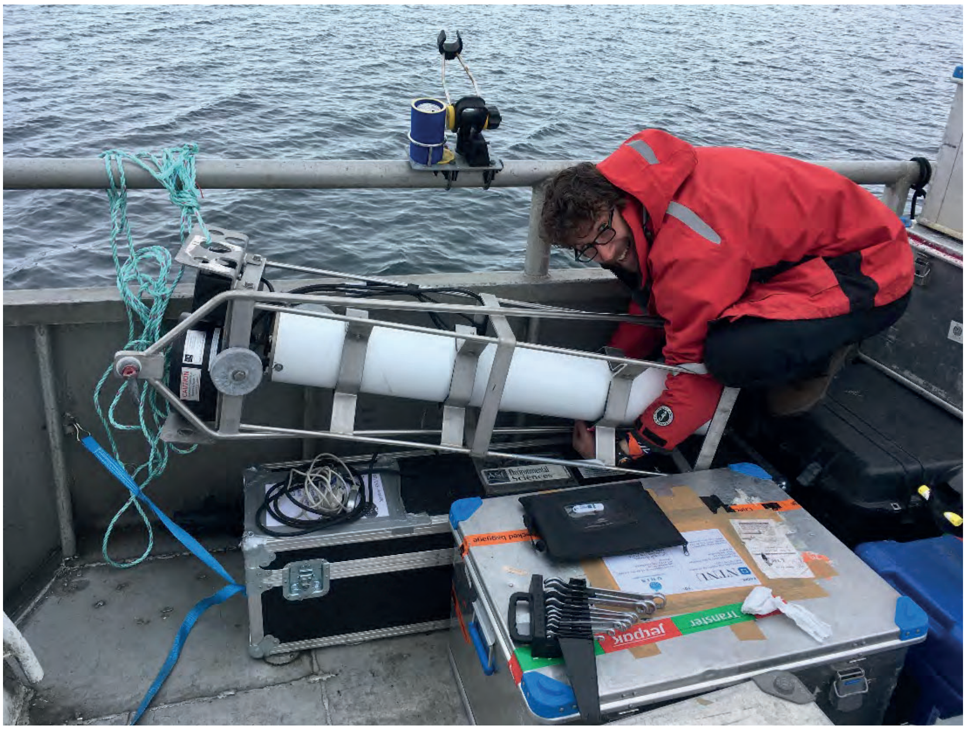

Figure 24: AZFP being redied for operation by Maxime Geoffroy (MUN)

Operational challenges

At high latitudes, the incidence angle of the earth's magnetic field is significant, affecting accuracy of magnetic compass readings. This can cause AUVs to drift off course during submerged navigation, with increasing position error over time. This can be mitigated either by frequent surfacing to obtain GNSS position or by providing position updates to the AUV by acoustic communication. For this project, an actuated surface buoy, *Shaman Durek II*, was custom made and designed to keep station in close proximity to the AUV's survey area and provide GNSS position updates through USBL. The AUV could use these position updates to correct its course to limit deviation during missions.

Figure 25: Zodiac and positioning buoy Durek II on surface, during LAUV mapping mission.

This navigation method worked well, and enabled the AUV to perform transects with limited drifting, while reducing visits to the surface which would have negative effects on the quality of the side scan sonar imagery. An unintended effect of this aided positioning was that the AUV would make small adjustments to its course with every position update, causing repeated yaw-movements of the vehicle. Since side scan sonar images are built by a sequence of scan lines, such yaw movements will affect the side images by creating false line features (fig 26) or mirroring effects (fig 27) in the along-track direction. In addition, communication with the surface through the AUV's acoustic modem interfered with the side scan sonar, generating across track lines impairing the overall sonar image quality. A general loss of detail beyond ranges of 40-50 meters could be observed in most of the sonar imagery.

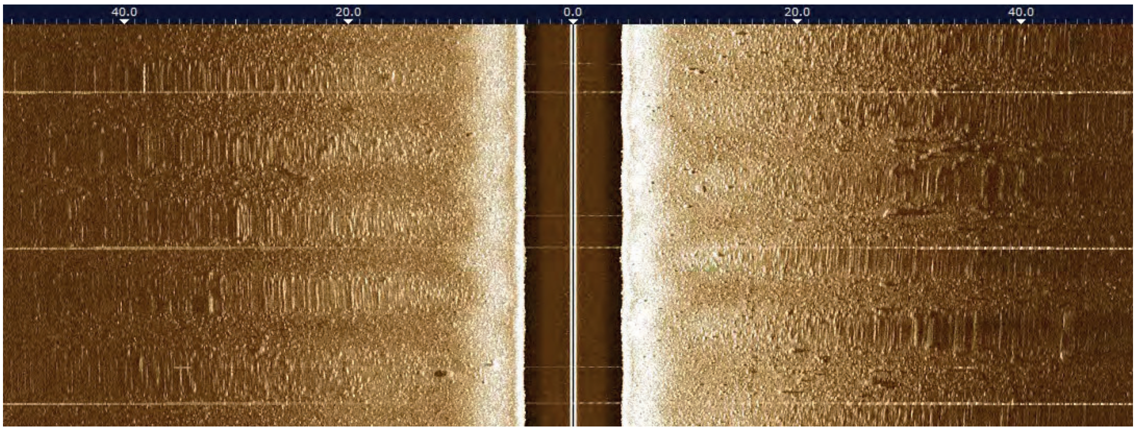

Figure 26: Sonar image with false along track line features, and across track lines caused by modem noise/interference.

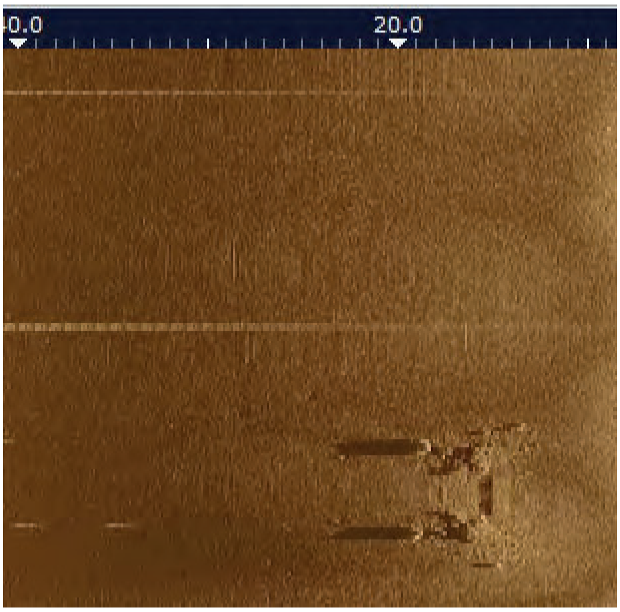

Figure 27: Sonar Image with mirroring effect causing false features (mirroring effect)

Standard mission planning procedures have the AUV return to surface as a safety measure e.g. in case of unexpected mission abort. Operations in areas covered with ice were therefore avoided during planning, due to the risk of possible damage or loss of the vehicle should it attempt to surface under the ice. However, ice floes move with currents and wind, and in some cases missions had to be re-planned or moved to safer areas. There was one incident where the AUV tried to go to the surface whilst under an ice floe, but the vehicle was recovered safely. Dangers in such situations are mainly damage to the GNSS antenna or that the vehicle is stuck.

Results

In total 10.85 km^2 of SSS imagery was acquired, with a total seabed area coverage of 9.25 km^2. 4.4 km^2 with high frequency (640/900 kHz) and 6.44 km^2 with low frequency (320 kHz).

A total of 194 targets were registered as possible objects of interest (Appendix A). No positive identifications of wrecks were made.

10 targets were investigated with mini-ROV. Several were written off as natural formations of rocks. Some targets could not be determined as features were covered with considerable amounts of sediments, or were difficult to locate due to current and low visibility. No positive classifications of any man-made objects were done.

Conclusions

We currently have no reason to speculate that the French reports presented to King Louis XIV should be deliberately inaccurate or in any way contain false information intended to mislead. The apparent absence of wrecks in the survey areas can have several explanations. It is possible that the selection of survey areas was off, and that the wrecks simply are elsewhere. Based on the analysis of all the available relevant information this seems unlikely, in our opinion. Though there are possible anchoring areas outside the surveyed areas, these would not offer the same protection from wind and currents. However, as we have reason to believe that the French officers and crews were in unfamiliar with these areas, we cannot rule out the possibility that a less suitable "holding area" was used to control the captured vessels. A more likely explanation would be that the wrecks are completely disintegrated, and in their current state would not stand out as obvious wrecks in the SSS imagery. Two facts support this scenario. In 2016 a research campaign along the northern coast of Svalbard discovered living wood devouring organisms in a log of drift wood. Wooden hulls exposed to shipworm would likely collapse after three centuries on the seabed. Based on observation of the seabed with the mini ROVs, sedimentation rates seem to be fairly high in the area. Due to the high frequency of the SSS, the acoustic signals would not be able to penetrate more than a few centimetres into the seabed. Any wreck remains or other objects covered by accumulated layers of sediments would therefore not be easily recognizable in the SSS imagery. The combination of shipworms and heavy sedimentation would also explain why no other objects were detected. Driftwood is common on almost any shoreline in this area, and one would expect to find some water-logged timbers on the seabed as well. Furthermore, the seabed area outside Virgohamna – with its long history of activities assumed to produce considerable amounts of refuse and scrap – to our surprise appeared featureless and pristine.

For future investigations of the area, we would recommend sensors with penetrating capabilities (e.g. sub-bottom penetrating echosounder or low frequency instruments like Synthetic aperture sonar). The targets listed in the appendix should be systematically investigated with more powerful ROV with manipulators or thrusters enabling light removal of sediments. Lastly, the surveyed areas should be extended (particularly on the northern side of Smeerenburgodden) to account for the possibility that we were looking in the wrong areas.

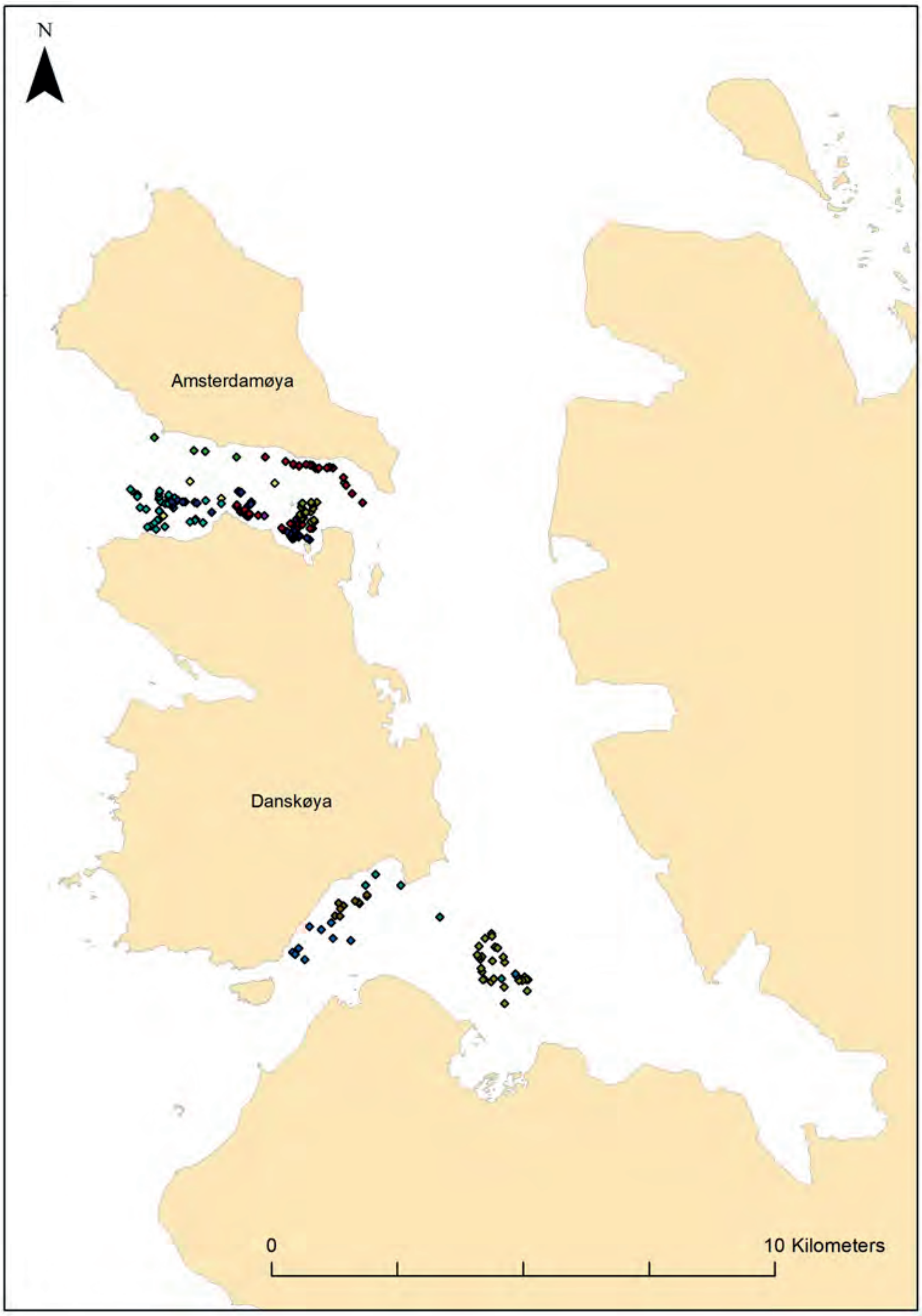

Figure 28: Survey area with all targets

Partners and support

Partners in the project were NTNU (AMOS and University Museum), UiT, UNIS and Memorial University Newfoundland. The project also had logistical support from the Governor of Svalbard. The project was funded by the Svalbard Environmental Fund (19/48) and NTNU AMOS.

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Appendix A

Technical equipment and facilities

MS Farm (Chartered boat)

15.25 m in length 3.8 m in breadth with a maximum draught of 2.0 m.

The vessel has 7 permanent bunks, all of which are situated in the forward cabin. The captain sleeps in the aft cabin.

The vessel's electrical system runs on 24 volts. Separate 12-volt systems operate for communication systems and instrumentation. On board electricity for additional equipment can be obtained at 12 v, 24v, 110 v and 220v.

The cargo compartment is situated aft and accommodates 13 m3. Access is via a hatch (80x100 cm) on the afterdeck, which is equipped with permanently mounted ladders.

The working space of the aft deck / working platform is approx 12 m2 (Total measures 4.5 m x 3.8 m), limited by the position of the crane and the entrance to the aft cabin as well as the cargo hole.

The forward deck measures 3x3 m with limited loading height.

A railing (height 100 cm) runs around the entire periphery of the vessel.

Astern there are permanently mounted ladders for access to the sea.

The vessel's bearing load capacity is limited to approximately 2 tonnes of cargo, depending on the nature of the cargo. Any cargo or equipment to be stored on deck must be packed in suitable containers or wrapping appropriate for handling at sea.

A Zodiac MK 2 with Yamaha 4 Hp outboard is available for operations. Eight portable VHF radios are onboard for communication to MS FARM during trips ashore.

A Zodiac MK 3 and two 25 hp outboard engines were rented from NP.

440 liters (22 jerry cans) of gasoline for outboards and generators.

LAUV Fridtjof

Deep vision Sidescan Sonar 340/680 kHz

Nadir camera

CTD

Positioning buoy Durek II

GNSS

Acoustic modem to communicate with LAUV Fridtjof

*Remus 100**

Marine Sonics Sidescan Sonar 900 kHz

CTD

ECO-puck

O2-optode

* The REMUS 100 vehicle was not operational for the entire project due to mechanical failure.

Towfish

Deep vision Sidescan Sonar 340/680 kHz with 200 m cable. GPS positioning of the laptop used for data acquisition. Layback to be calculated during post processing to estimate position of towfish for SSS mosaic.

Blueye ROV (x2)

With extra GoPro camera in UW housing

AZFP (Acoustic Zooplankton Fish Profiler)

Operated from fixed rig on MS Farm. For specifications see summary by Geoffroy in Appendix C.