ENDURANCE22

Initial Environmental Evaluation

FALKLANDS MARITIME HERITAGE TRUST

Submitted to the Polar Regions Department, Foreign, Commonwealth and Development Office, as part of an application for a permit / approval under the UK Antarctic Act 1994.

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Introduction

The Endurance22 Expedition (the Expedition) is a privately funded expedition organised by the Falklands Maritime Heritage Trust that will involve a 35 to 45-day voyage to the Weddell Sea, Antarctica in February and March 2022 to undertake a search for the wreck of Shackleton's *Endurance*.

The objectives of the Expedition are to:

1. Locate, identify and survey the historic wreck of Sir Ernest Shackleton's ship *Endurance*.
2. Undertake an education and outreach programme and the making of a documentary.
3. Carry out a small programme of scientific research.

The Expedition builds upon the Weddell Sea Expedition 2019. The Expedition will use autonomous underwater vehicles to search for and survey the *Endurance* wreck. The Expedition has chartered the South African Polar research and resupply vessel *SA Agulhas II* to support the search and survey work. The *SA Agulhas II* is a modern, highly capable Polar Class vessel used to support the South African National Antarctic Programme.

The Expedition Leader will be Dr. John Shears (Shears Polar Ltd.) who was the Expedition Leader for the Weddell Sea Expedition 2019.

The subsea search and survey work will be carried out by experts from Ocean Infinity, which specialises in marine technology and Deep Ocean Search, which specialises in search and survey work in deep marine environments. The search and survey work will be undertaken utilising two Sabertooth hybrid autonomous / remotely operated underwater vehicles provided by SAAB Seaeye.

Environmental Impact Assessment Process

In 1991 the Parties to the Antarctic Treaty adopted the Protocol on Environmental Protection to the Antarctic Treaty (the Protocol) which sets out a series of measures to ensure the ongoing protection of the Antarctic environment, including its intrinsic, wilderness and aesthetic values.

Article 8 of the Protocol requires that an environmental impact assessment (EIA) is prepared in advance of any activity taking place in the Antarctic Treaty Area. The level of EIA required under the Protocol is determined by whether the activity in question is identified as having less than a minor or transitory impact; a minor or transitory impact; or more than a minor or transitory impact on the environment.

The EIA provisions of the Protocol are enacted in UK law through the Antarctic Act 1994 and Antarctic Act 2013 and Antarctic Regulations 1995/490 (as amended). The provisions of the legislation apply to any person who is on a British expedition to Antarctica, where a British expedition is defined as an expedition "that is organised in the United Kingdom, or the place of final departure for Antarctica of the persons on the expedition was in the United Kingdom". The Act applies to both governmental and non-governmental activities in Antarctica.

The Act is administered by the Foreign, Commonwealth and Development Office (FCDO) and the Secretary of State makes the final determination on whether an activity may proceed taking into account the FCDO's recommendations. It is an offence under the Act to enter Antarctica without a permit issued by the Secretary of State.

In accordance with these international and national requirements, this EIA has been prepared for the Expedition at the level of an Initial Environmental Evaluation (IEE) and is submitted for assessment and approval to the UK FCDO.

The IEE has been prepared in accordance with the EIA Guidelines prepared by the Antarctic Treaty System's Committee for Environmental Protection (CEP) and applicable Measures and Resolutions adopted by the Antarctic Treaty Consultative Meeting (ATCM).

Scope

The activities that are in scope for this EIA and for which application for a permit is being made to the FCDO are:

- all personnel involved in the Endurance22 Expedition;
- the activities associated with the search for and survey of the wreck of the Endurance, including:
    - deployment and operation of the hybrid autonomous / remotely operated underwater vehicles (SAAB Sabertooth units);
    - establishment of sea-ice camps from which the underwater survey vehicles may be deployed;
    - operation of helicopters to deploy and recover the sea-ice camps and associated equipment and supplies, including the deployment of fuel caches.
- an associated programme of sea-ice research that will be undertaken from the research vessel including the potential for some small sea ice sampling / coring;
- operation of helicopters and remotely piloted aircraft systems (RPA) to support sea ice research and navigation, selection of ice floes to establish sea ice camps, and visual recording of the Expedition for outreach and education purposes and the making of a documentary.

Excluded from the scope of this EIA are:

- the operation and compliance of the research vessel *SA Agulhas II*, which will be authorised by the South African Maritime Safety Authority (SAMSA);
- a small programme of meteorological and oceanographic research and vessel engineering research which will be approved by South African authorities.

The spatial scope of the EIA includes the route followed by the *SA Agulhas II* from when it enters the Antarctic Treaty area, the area of the western Weddell Sea where the search for the wreck will be undertaken and the return passage of the *SA Agulhas II* to when it leaves the Antarctic Treaty area. The precise routes to be followed by the main vessel will be determined by weather and pack ice conditions that are encountered at the time.

The temporal scope of the activities covered by this IEE is up to 45 days. The activities recorded above are planned to be undertaken between 5 February 2022, when the Expedition will depart from Cape Town for Antarctica, and 10 March 2022 when the Expedition returns to Cape Town.

Changes from the Weddell Sea Expedition 2019

The Endurance22 Expedition builds upon and incorporates lessons learned from the previous Weddell Sea 2019 Expedition. This includes:

- **More focussed expedition purpose**. The Weddell Sea Expedition 2019 had multiple research and wreck-search objectives. The Endurance22 Expedition has placed the search for the Endurance as its primary objective, with some research to be undertaken in support of the wreck search.
- **Selection of a different type of subsea vehicle**. The subsea vehicle will be a SAAB Sabertoooth. The main advantage of this vehicle is that it remains tethered allowing permanent surface control and real time supervision for fast action in case of issues. The vehicle is a hybrid vehicle able to:
    - autonomously covering large are of seabed for survey and search;
    - be switched into ROV mode to fly over a dedicated area or for accurate control for surface return.
- **Subsea operations**. A number of lessons related to the management of the subsea operations were learned during the Weddell Sea Expedition 2019 including in relation to: the duration of deployment of the vehicles; the means for maintaining contact with the subsea vehicles and the importance of flexibility in mission planning in the context of ice and weather conditions at the time. These points are expanded upon in section 4.3.2.
- **Pre-deployment trials**. The Endurance22 Expedition is paying close attention to trialling the subsea vehicles prior to deployment to Antarctica. This includes deep water testing (up to 3000m) of the SAAB Sabertooth vehicles and testing of the ice drilling equipment and subsea vehicle launch and recovery system in France in October 2021. This will ensure greater familiarity by the Expedition team with the vehicles and equipment prior to real time deployment in the Weddell Sea.
- **Improved understanding of the operating conditions**. The Weddell Sea Expedition 2019 generated a good understanding of the weather and sea ice conditions, and this information has been used to inform the development of an 'options' approach for the launch, monitoring and recovery of the subsea vehicles (see Section 4.2.1.2). Ideally the SAAB Sabertooth units will be deployed directly from the *SA Agulhas II*. But if ice conditions preclude this (e.g., by preventing the *SA Agulhas II* from getting close enough to the wreck site) the equipment and procedures for deploying the subsea vehicles through holes cut in sea ice have been developed. The increased flexibility that this provides enhances the likelihood of achieving the Expedition objectives.
- **Improved accuracy of search**. Since the Weddell Sea Expedition 2019, analyses have been undertaken to improve the location accuracy of the wreck site, increasing the potential for the Endurance22 Expedition to locate the wreck.
- **Deployment of personnel**. The Weddell Sea Expedition 2019 used an air link to Antarctica operated by White Desert to deploy all Expedition personnel, who joined the *SA Agulhas II* in Antarctica. This carried an element of risk in that flight delays (e.g., for weather reasons reduced

the available time to undertake the planned research and wreck search. Endurance22 will deploy all personnel directly to the *SA Agulhas II* in Cape Town which will remove the risk of flight delays.

- **Air support**. The Endurance22 expedition will have available to it two helicopters which can deploy from the *SA Agulhas II*. These assets will add value to navigating through pack ice by being able to undertake aerial reconnaissance of ice conditions beyond line of sight. They will also provide greater flexibility to the wreck search by being able to deploy equipment and personnel onto the sea ice if direct deployment from the vessel is not possible. The helicopters will also provide search and rescue, and emergency medevac, if required.

Description of planned activities

The Endurance

Sir Ernest Henry Shackleton (15 February 1874 – 5 January 1922) was a polar explorer involved in several British expeditions to the Antarctic in the early 1900s.

Shackleton's Imperial Trans-Antarctic Expedition (1914 – 1917), was an attempt to make the first overland crossing of the Antarctic continent. The ship chosen for the expedition was the Endurance. Endurance was built in Norway and launched on 17 December 1912. She was initially named Polaris and was specifically designed for operating in ice-covered waters.

The expedition left the UK in August 1914, and departed from South Georgia for the Weddell Sea on 5 December. The expedition soon encountered significant sea ice cover and on 18 January 1915 at 76°34'S, Endurance became trapped in the ice.

Several attempts were made to free Endurance from the ice, but to no avail and by the end of February, temperatures had fallen and the ship was frozen in for the winter.

The expedition members remained living aboard the Endurance for several months until 27 October 1915 when Shackleton took the decision to abandon ship. Their position was 69°5'S, long. 51°30'W. The Endurance was then under heavy pressure from the ice which tore away her rudder post and crushed in her stern. The Endurance finally broke up and sank in the Weddell Sea on 21 November 1915.

The survival and eventual rescue of the 28 men of the expedition is one the greatest polar stories. The wreck of the Endurance has not been seen since she sank in 1915.

The Expedition

The expedition will comprise approximately 60 personnel, including an expedition leader, maritime archaeology expert, subsea search engineers and technicians, helicopter pilots and engineers, Antarctic field safety guides , as well as education and outreach personnel and a documentary team.

Expedition personnel will join the *SA Agulhas II* in Cape Town and sail directly to the Weddell Sea for the (up to) 45-day research cruise.

The Expedition's itinerary is summarised in the following table.

Date	Activity
3/4 February 2022	Mobilisation of equipment and personnel on *SA Agulhas II* in Cape Town
5 February 2022	*SA Agulhas II* departs Cape Town for Antarctica
5 to 18 February 2022	At sea trials and transit to wreck survey area in the Weddell Sea
18 February to 28 February 2022	Endurance wreck search and survey
28 February to 10 March 2022	*SA Agulhas II* departs *Endurance* wreck location and transit back to Cape Town
If 10 day extension enacted	
28 February to 10 March 2022	Endurance wreck search and survey
10 to 20 March 2022	*SA Agulhas II* departs *Endurance* wreck location and transit back to Cape Town

To search for and, if found, survey the wreck of the Endurance, the Expedition will utilise two SAAB Sabertooth autonomous underwater vehicles. These subsea vehicles are capable of operating down to a depth of 3000m and carry visual and sonar survey technology.

Whilst the approximate location of the sinking of the Endurance is known the subsea vehicles will need to survey a search box in order to pinpoint the precise location of the wreck on the seabed. How the subsea survey will be conducted depends upon the density and thickness of the pack ice and how close the *SA Agulhas II* can get to the target area.

If pack ice conditions allow, the subsea vehicles will be launched from and recovered to the *SA Agulhas II*. If the pack ice is too dense to allow for deployment of the subsea vehicles from the main vessel, the Expedition has designed a launch and recovery system that will allow for them to be launched through holes drilled in the ice.

An ice auger will be used to drill a suitable sized hole in the ice and the launch and recovery system then placed over the hole. This option for deploying the subsea vehicles through the ice could take place either with the main vessel alongside the ice floe or, using the helicopters, from an ice camp established up to a maximum of 60NM away from the main vessel.

Two helicopters will be carried on board during the Expedition: a Bell 412 EP helicopter and a Kamov 32 B heavy-lift helicopter.

The Expedition will also utilise remotely piloted aircraft ('drones') to assist with navigation of the *SA Agulhas II* through the pack ice, as well to obtain imagery and video for education and outreach purposes.

Alternatives

This EIA has considered alternatives to aspects of the Expedition including the alternative of not proceeding, alternative expedition vessels, alternative timing, reducing the period of operation and reducing the scale of the Expedition.

Not proceeding with the Expedition would eliminate all the anticipated impacts, but would miss a rare opportunity to locate and survey the Endurance wreck. Considering the anticipated 'light footprint' of the

Expedition, and the opportunity to support the historic site designation of the wreck site with comprehensive survey information, the 'do not proceed' option was rejected.

Alternative vessels either did not match the research support capabilities of the *SA Agulhas II* or were unavailable at the planned time for the Expedition.

An alternative timing for the Expedition was rejected given the need to attempt access to the wreck site area during the period of least sea ice cover in the Weddell Sea.

Reducing the duration of the cruise was rejected on the basis that it would make negligible difference to the anticipated impacts and would add un-necessary pressures on achieving the expedition objectives.

Reducing the spatial scale of the Expedition was rejected on the basis that the scale of the activities to be undertaken by the underwater survey equipment would be non-invasive and necessary if the wreck site is to be located.

Reducing the number of people involved in the Expedition was rejected on the basis that it would have no measurable reduction in the environmental impacts, but would significantly impact on the Expedition's ability to meet its objectives.

Description of the Existing Environmental State

The Weddell Sea covers an area of approximately 2.8 million km2. It is fringed to the east by the coasts of Dronning Maud Land and Coats Land and the Riiser-Larsen, Stancombe-Wills and Brunt ice shelves, to the South by the Filchner and Ronne ice shelves, and to the west by the eastern coast of the Antarctic Peninsula and the Larsen C ice shelf.

The Weddell Sea was first discovered in 1823 by British sailor James Weddell. Due to the severe sea ice conditions, relatively few vessels have entered the Weddell Sea since then. It was not until 1947 that the southern coast of the Weddell Sea was surveyed, though by aircraft.

Water depths in the Weddell Sea range from approximately 100m adjacent to ice shelves to about 5,300m in the abyssal plain which covers an area of approximately 2 million km2.

The Weddell Sea represents a point of origin in the Southern Ocean, where water masses form and interact with the atmosphere and where deep and bottom water masses are formed which then drive the global thermohaline circulation. Water circulation is dominated by the clockwise rotating Weddell Sea gyre.

The Weddell Sea is almost entirely covered by thick, partly immobile sea ice in winter, but returns to looser pack-ice conditions across most of its area in summer. Typical ice thickness in the central Weddell Sea is approximately 1.5m in winter though it can reach up to 4m where drifting and pressure ridges form.

Ice shelves in the western Weddell Sea are retreating whilst those to the east appear relatively stable. Large sections of the Larsen-A and Larsen-B ice-shelves collapsed in a matter of weeks in 1995 and 2002 respectively. The Larsen-C ice shelf has been thinning at a sustained rate of -3.8m per decade for the past 18 years.

Macro-zooplankton species richness in the epipelagic layer of the Weddell Sea ranges between 22 and 53 species with significant latitudinal zonation influenced heavily by sea ice and the Weddell Sea gyre. In general, copepods rather than Antarctic krill dominate the zooplankton community in abundance, and often also in biomass.

Macrobenthic communities of the Weddell Sea shelf are characterised by high spatial heterogeneity in biodiversity, species composition and biomass at all spatial scales ranging from meters to hundreds of kilometres. The most conspicuous community is that dominated by suspension feeders comprised of glass-sponges, demosponges, solitary and colonial sea-squirts, coral-related cnidarians or erect soft or calcified bryozoans. In such communities extremely high biomass can be found.

All six species of Antarctic seals are known to occur within the Weddell Sea, though with differing distributions and seasonality. Fifteen species of whales have been observed during research cruises to the Weddell Sea.

Breeding colonies of penguins occur around the eastern, southern and western boundaries of the Weddell Sea. Emperor penguin colonies predominate along the eastern and southern coasts, with Adélie penguin colonies clustered in the north western part.

Several colonies of flying birds occur in the vicinity of the Weddell Sea and depend upon it for foraging purposes. Other seabirds from populations breeding along the northern and western part of the Weddell Sea (i.e. near the tip of Antarctic Peninsula, at the South Shetland Islands, South Orkney Islands, South Sandwich Islands, South Georgia and Bouvet Island) also make seasonal use of the area.

A number of spatial management measures have been implemented through the Antarctic Treaty System to protect identified terrestrial or marine environmental, human heritage and scientific values within the vicinity of the Weddell Sea. Such measures include the designation of Antarctic Specially Protected Areas, Important Bird Areas, historic sites and monuments, marine protected areas, vulnerable marine ecosystems, and ecosystem monitoring sites.

The Expedition will not encounter or enter any of these designated areas, with one exception. The wreck site of the Endurance has been designated as an Historic Site or Monument (HSM) under the provisions of Annex V to the Protocol; HSM No. 93. The Expedition will take a non-invasive approach to its survey of the wreck. No samples or artefacts will be removed from the wreck site, and only multi-beam sonar, laser, video and still images being taken.

Assessment of Environmental Impacts

A full assessment of the potential environmental impacts is included within this EIA.

The Expedition is entirely marine based and no impacts will occur to terrestrial (ice-free) areas or terrestrial fauna and flora, i.e., land-based breeding colonies. No impacts will occur to inland aquatic systems i.e., lakes, ponds and streams.

The table below summarises the environments that could be affected by the various activities planned by the Expedition.

Environmental Element Impacted	Aspect	Actual or Potential Impact
Antarctic Flora and Fauna	Noise emissions from the operation of the main vessel, helicopters and RPA, and the use of equipment at the ice camps and the deployment of the subsea vehicles.	Disturbance to individuals or congregations of foraging birds and penguins; cetaceans and pinnipeds
Antarctic Flora and Fauna	Light emissions from the subsea vehicles	Disturbance to pinnipeds or cetaceans e.g. during a foraging dive
Antarctic Flora and Fauna	Accidental fuel spills	Contamination of the marine environment and toxic effects to flora and fauna
Antarctic Flora and Fauna	Research sampling	Removal of native fauna and flora
Marine Environment	Introduction of non-native species	Competition with native fauna or flora; loss of research value
Marine Environment	Heat emissions from the main vessel and subsea vehicles	Extremely localised warming
Marine Environment	Accidental release of wastes or loss of subsea vehicle or RPA	Contamination of the marine environment
Marine Environment	Water turbulence	Localised water turbulence
Ice Environment	Physical disturbance from ice breaking activities and drilling of ice holes / cores and snow sampling	Physical modification of pack ice and ice floes
Ice Environment	Accidental fuel spill	Contamination of the immediate ice environment
Ice Environment	Accidental release of wastes	Littering with risks of wildlife entanglement or introduction of pathogens
Atmospheric Environment	Exhaust emissions from the main vessel, helicopters and generators and vehicles on ice floes	Localised air pollution and contribution to climate change
Atmospheric Environment	Air turbulence from the use of helicopters and RPA	Localised air turbulence
Wilderness Value	Human presence and associated activities	Loss of wilderness value
Heritage Value	Subsea vehicles operating in the vicinity of HSM 93	Physical disturbance to HSM 93

For each of the identified actual or potential impacts mitigation measures have been identified so as to reduce the consequences of the impacts to an acceptable level and/or to minimise the likelihood of the impact occurring.

Mitigation measures include:

- the use of a modern Polar class research vessel to support the Expedition operated by an experienced Master and Ice Pilot. The *SA Agulhas II* has a modern wastewater plant on board as well waste storage facilities to ensure that no wastes are discharged in Antarctica. The vessel is fully compliant with all relevant International Maritime Organisation (IMO) regulations including the Polar Shipping Code as well as sewage treatment and oil spill response requirements;
- a wealth of specialist skills among the Expedition personnel including Antarctic and subsea search and survey expertise;
- adherence to all relevant provisions of the Environmental Protocol to the Antarctic Treaty as well as relevant Measures and Resolutions adopted by the Antarctic Treaty Consultative Meeting, including biosecurity measures to minimise the risks of introducing non-native species, and waste management and oil spill prevention and response controls for the ice camps;
- comprehensive pre-deployment testing and training, including trialling of the subsea vehicle launch and recovery system and deep sea trials to test the subsea vehicles to 3000m;
- controls to minimise the risk of any damage to the wreck of the *Endurance*.

With these control measures in place, this EIA has determined that the predicted impacts are likely to have less than or no more than a minor or transitory impact on the Weddell Sea environment.

Record keeping

This assessment has not identified the need for dedicated monitoring to be undertaken during the Expedition.

Nonetheless, records will be maintained both for post-Expedition reporting as well as for scientific research purposes. These records will include:

- Details of all subsea vehicle deployments (depth, duration etc), not least for reporting the survey findings;
- Any physical disturbance to the surveyed wreck site. In the extremely unlikely event that such disturbance occurs records will be made of the nature, extent and location of the disturbance;
- Any observed encounters with wildlife such as may occur between the subsea vehicles and diving pinnipeds or cetaceans, as well as any observed bird encounters with the helicopters or RPA. To the extent possible records will be maintained of the species concerned and the location;
- The location of any fuel spill events and the type and volume of fuel spilt (if any) during the Expedition;
- The type and location (as accurately as may be possible) of any equipment lost to the environment;
- All water column sampling locations will be accurately recorded, not least for publication purposes;

Gaps in Knowledge and Uncertainties

No Expedition to Antarctica can be planned with absolute certainty, due to the extreme, changeable and unpredictable environmental conditions. Unknowns for this Expedition include weather and sea-ice conditions in the Weddell Sea which could have a significant impact on reaching the primary target survey area and the manner in which the subsea survey vehicles will be deployed, i.e., from sea ice camps or from the main vessel.

The ongoing implications of the global coronavirus pandemic could also affect the Expedition through delayed delivery of equipment and personnel during the mobilisation phase as well as through changing international travel and in-country restrictions. These factors have no implications for the environmental impacts of the Expedition in Antarctica, but are recorded here as they may affect the overall timing of the Expedition.

Summary and Conclusion

This IEE describes the proposed activities to be conducted by the Endurance22 (Section 4); considers a number of alternatives to various aspects of the Expedition (Section 5); describes what is known about the current environmental state (Section 6); assesses the potential environmental impacts that are likely to, or could arise (Section 7); outlines the mitigation measures to prevent or minimise any potential environmental impacts that may occur (Section 7), and describes the records that will be maintained of environmental impacts that may occur (Section 8).

Even with implementation of control measures, some potential environmental impacts of the Expedition have been assessed as being of no more than minor or transitory significance. These impacts include:

- **Atmospheric emissions from the burning of fossil fuels by the *SA Agulhas II* -** an unavoidable impact, but mitigated by using a fuel efficient vessel that will burn MGO with low sulphur content and optimisation of the vessel's route through sea ice;
- **The accidental introduction of non-native species by the *SA Agulhas II* –** somewhat outwith the control of the Expedition, but assessed as being of low likelihood, though with high consequence if it were to occur;
- **The loss of one of the subsea vehicles –** The WSE2019 expedition lost one of its subsea vehicles in the Weddell Sea. Lessons have been learnt from this loss and the subsea vehicles selected for Endurance22 are different and chosen to minimise the chance of this happening again, including through the use of fully tethered subsea vehicles. However, the risk of another vehicle loss in this challenging and unpredictable environment cannot be entirely ruled out.

Provided the identified control measures are fully implemented, it is concluded that the identified unavoidable and potential environmental impacts of the Expedition are likely to have no more than a minor or transitory impact on the Weddell Sea environment.

1. Introduction

The Falklands Maritime Heritage Trust is planning to undertake a search for the wreck of Shackleton's Endurance in the Weddell Sea. The Endurance22 Expedition will involve a 35 (up to 45) day cruise to the Weddell Sea in February and March 2022 with the objectives of:

1. Locating, identifying and surveying the historic wreck of Sir Ernest Shackleton's ship *Endurance*.
2. Undertaking an education and outreach programme, including the making of a documentary.
3. Carrying out a small associated programme of scientific research.

The Expedition builds upon the Weddell Sea Expedition 2019. The primary purpose of that earlier expedition was to undertake a programme of glaciological and marine research following the major calving event of the Larsen C ice shelf in the western Weddell Sea. The search for the Endurance wreck was, at the time, a secondary objective.

For the Endurance22 Expedition, the primary purpose will be to use underwater vehicles to search for and survey the Endurance wreck. As in 2019, the Expedition has again chartered the South African Polar research and resupply vessel *SA Agulhas II* to support the search and survey work. The *SA Agulhas II* is a modern, highly capable Polar Class vessel used to support the South African National Antarctic Programme.

The Expedition will be overseen and managed by the Falklands Maritime Heritage Trust. The Expedition Leader will be Dr. John Shears (Shears Polar Ltd.), who was the Expedition Leader for the Weddell Sea Expedition 2019.

The subsea search and survey work will be carried out by experts from Ocean Infinity, which specialises in marine technology (https://oceaninfinity.com) and Deep Ocean Search, which specialises in search and survey work in deep marine environments (http://www.deepoceansearch.com/). The search and survey work will be undertaken utilising two Sabertooth hybrid autonomous / remotely operated underwater vehicles provided by SAAB Seaeye (https://www.saabseaeye.com/solutions/underwater-vehicles/sabertooth-double-hull).

Helicopter support will be provided by Ultimate Heli, part of the Ultimate Aviation Group based in South Africa (https://ultimate-aviation.net/service/helicopter-charter/).

Ice camp safety and field support will be provided by White Desert (https://white-desert.com/).

The Expedition's education and outreach programme will be managed and co-ordinated by US educational charity Reach the World (https://www.reachtheworld.org/).

A film unit will also be present to record a documentary of the Expedition.

An organisation chart for the Expedition is shown in Figure 1.

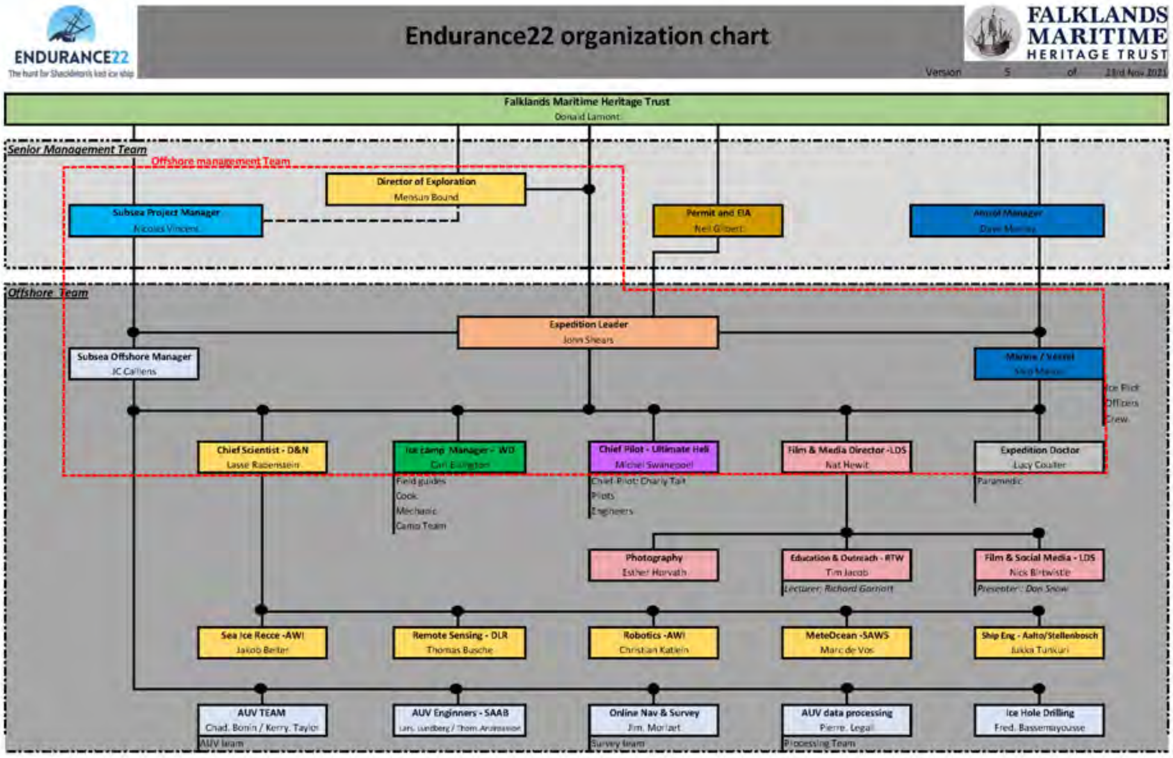

Figure 1. Endurance22 Organisation Chart.

1.1 Falklands Maritime Heritage Trust

The Falklands Maritime Heritage Trust (FMHT; https://fmht.co.uk/) is a charity registered in the UK which is dedicated to preserving the rich and varied seafaring history of the Falklands and those who have been associated with them.

FMHT was established in October 2014 with the aim of advancing the education of the public, including in the maritime history and heritage, both military and civilian, of the Falkland Islands and their neighbouring seas, and the improvement of public understanding of their historical and social significance; in particular through research and exploration.

FMHT carries out expeditions and missions to record, preserve and restore (if appropriate) craft, materials and information of historical significance and educative value relating to the Falkland Islands and their neighbouring seas. This work includes naval and civilian vessels and their related equipment, items and records.

1.2 This Environmental Impact Assessment

This environmental impact assessment (EIA) has been prepared by an independent consultant, Dr Neil Gilbert of Constantia Consulting, to meet the requirements of the Protocol on Environmental Protection to the Antarctic Treaty (in particular Article 8 of and Annex I to the Protocol) as well as the provisions of the UK's Antarctic Act 1994.

The EIA is set out in 10 chapters, including this introductory chapter, as follows:

- Chapter 2 describes the EIA process as it applies to British Expeditions undertaken south of 60^{o} South. Chapter 2 also identifies those agreements made at the annual Antarctic Treaty Consultative Meetings that are applicable to the Expedition.
- Chapter 3 describes the scope of the EIA and sets out what has been included and what has been excluded from the assessment.
- Chapter 4 provides a detailed description of the activities to be undertaken and identifies the environmental aspects arising from those activities.
- Chapter 5 sets out alternatives that have been considered in the planning for the Expedition including alternative support vessels and considers the implications of the alternatives with respect to the environmental impacts.
- Chapter 6 describes the existing environmental state of the Weddell Sea and any features or values that may be affected or impacted by the planned activities.
- Chapter 7 identifies the actual or potential impacts that will or may arise from the planned activities, assesses the significance of those impacts and describes the mitigation measures that will be used to reduce impact significance.
- Chapter 8 records any monitoring or record keeping that has been identified in this EIA or which may be required by the Expedition.
- Chapter 9 sets out the unknowns and uncertainties that remain at the time of preparation and submission of this EIA.
- Chapter 10 summarises the EIA findings and describes the overall conclusions of the impact assessment.

A non-technical summary has been included at the beginning of the document to provide an overview of the EIA in a clear, concise and non-technical manner. Supporting information is provided in a series of appendices.

The EIA has used an evidence based approach to support its assessment and findings.

2. Environmental Impact Assessment Process

2.1 International Requirements

The Protocol on Environmental Protection to the Antarctic Treaty (the Protocol) was adopted by the Consultative Parties to the Antarctic Treaty in 1991. It entered into force in January 1998.

Article 3 of the Protocol sets out environmental principles for the conduct of activities in Antarctica. Article 3 provides that the protection of the Antarctic environment and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research, in particular research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area.

Article 3 also requires that activities in the Antarctic Treaty area are planned and conducted so as to limit adverse impacts on the Antarctic environment and that those activities must be planned and conducted on the basis of information sufficient to allow prior assessments of, and informed judgments about, their possible impacts on the Antarctic environment. Such judgements must take account of:

i. the scope of the activity, including its area, duration and intensity;
ii. the cumulative impacts of the activity, both by itself and in combination with other activities in the Antarctic Treaty area;
iii. whether the activity will detrimentally affect any other activity in the Antarctic Treaty area;
iv. whether technology and procedures are available to provide for environmentally safe operations;
v. whether there exists the capacity to monitor key environmental parameters and ecosystem components so as to identify and provide early warning of any adverse effects of the activity and to provide for such modification of operating procedures as may be necessary in the light of the results of monitoring or increased knowledge of the Antarctic environment and dependent and associated ecosystems; and
vi. whether there exists the capacity to respond promptly and effectively to accidents, particularly those with potential environmental effects.

Article 8 of the Protocol formalises these requirements by requiring an environmental impact assessment to be prepared in advance of any activity taking place in the Antarctic Treaty Area. The level of the environmental impact assessment is determined by whether the activity in question is identified as having less than a minor or transitory impact; a minor or transitory impact; or more than a minor or transitory impact on the environment.

The detailed procedures for preparing and processing environmental impact assessments are set out in Annex I to the Protocol. If a proposed activity is determined, by means of a preliminary assessment, to have less than a minor or transitory impact, then it may proceed. If an activity is determined as being likely to have no more than a minor or transitory impact then an Initial Environmental Evaluation (IEE) must be prepared. If an IEE indicates the potential for the activity to have more than a minor or transitory impact, or if such an impact is otherwise determined to be likely, then a Comprehensive Environmental Evaluation (CEE) must be prepared.

Preliminary assessments and IEEs are processed within the domestic legal and administrative systems of each Antarctic Treaty Party. Draft CEEs are however, required to be made publicly available, and to be made available for consideration by the Antarctic Treaty System's Committee for Environmental Protection (CEP). The CEP's advice on the quality of a draft CEE is provided to the Antarctic Treaty Consultative Meeting (ATCM). Comments and advice provided by other Antarctic Treaty Parties and the ATCM must be addressed in a final CEE, which is used as the basis for making a decision about whether and how the activity in question will be conducted.

The Committee for Environmental Protection (CEP) has prepared guidance material to assist those preparing EIAs. The most recent version of these guidelines was adopted by the 28th ATCM (Resolution 1 (2016) refers). These guidelines have been consulted in the preparation of this EIA.

2.2 National Requirements

The EIA provisions of the Protocol are enacted in UK law through the Antarctic Act 1994 and Antarctic Act 2013 and Antarctic Regulations 1995/490 (as amended). The provisions of the legislation apply to any person who is on a British expedition to Antarctica, where a British expedition is defined as an expedition "that is organised in the United Kingdom, or the place of final departure for Antarctica of the persons on the expedition was in the United Kingdom". The Act applies to both governmental and non-governmental activities in Antarctica.

The Act is administered by the Foreign Commonwealth and Development Office (FCDO) and the Secretary of State makes the final determination on whether an activity may proceed taking into account the FCDO's recommendations. It is an offence under the Act to enter Antarctica without a permit issued by the Secretary of State.

The Act also prohibits the following activities unless a permit is obtained:

- undertaking mineral resource activities
- intentionally, killing, injuring, capturing, handling or molesting any native mammal or native bird
- intentionally disturbing native mammals or native birds
- removing or damaging any native plant so as to significantly affect its local distribution or abundance, or significantly damaging a concentration of native plants
- causing significant damage to the habitat of any native mammal, bird, plant or invertebrate
- introducing any species of non-native animal or plant
- entering an Antarctic Specially Protected Area (ASPA), or an area designated as protected by CCAMLR
- damaging, destroying or removing a designated historic site or monument

The Secretary of State has discretion under the Act to set conditions regarding the proposed activity. Such conditions may relate to, for example, managing compliance, undertaking environmental monitoring and post-activity reporting. Under the provisions of the Act, non-compliance is an offence carrying a penalty of up to two years imprisonment or a fine or both.

This environmental impact assessment covers the proposed activities related to a 35 (up to 45) day marine archaeological cruise in the Weddell Sea, Antarctica during February and March 2022. It constitutes an application for a permit under Sections 3, 6 and 7 of the Antarctic Act 1994, and in accordance with Regulation 5 of the Antarctic Regulations 1995.

Following an assessment at the preliminary environmental evaluation level, it is considered that the Expedition's planned activities are likely to have '**no more than a minor or transitory effect**' on the Antarctic environment, provided proposed mitigation measures are implemented. An environmental impact assessment at the Initial Environmental Evaluation (IEE) level is therefore put forward for consideration by the FCDO.

2.3 Applicable ATCM Measures and Resolutions

In addition to the general provisions of the Protocol outlined above, the ATCM has, over time adopted a suite of additional agreements (in the form of Recommendations, Resolutions or Measures) several of which are pertinent to this planned Expedition: in that they relate specifically to the issue of non-governmental activities in the Antarctic, or to scientific research or human heritage. These include but are not necessarily limited to those measures set out below.

2.3.1 Non-governmental activities and general operations in Antarctica

Measures related to non-governmental activities and general operations in Antarctic and relevant to this Expedition are:

- Recommendation XVIII-1 (1994) – Guidance for Those Organising and Conducting Tourism and Non-governmental Activities in the Antarctic, and Guidance for Visitors to the Antarctic (somewhat superseded by Resolution 3 (2011) noted below)
- Resolution 4 (2004) – Guidelines on Contingency Planning, Insurance and Other Matters for Tourist and Other Non-governmental Activities in the Antarctic Treaty Area
- Measure 4 (2004) – Insurance and Contingency Planning for Tourism and Non-governmental Activities in the Antarctic Treaty Area
- Resolution 6 (2005) – Antarctic Post Visit Site Report Form for Tourism and Non-governmental Activities in Antarctica
- Resolution 3 (2006) – Ballast Water Exchange in the Antarctic Treaty Area
- Resolution 6 (2008) – Maritime Rescue Coordination Centres and Search and Rescue in the Antarctic Treaty Area
- Resolution 6 (2010) – Improving the Coordination of Maritime Search and Rescue in the Antarctic Treaty Area
- Resolution 6 (2011) – Non-native Species
- Resolution 3 (2011) – General Guidelines for Visitors to the Antarctic
- Resolution 7 (2012) – Vessel Safety in the Antarctic Treaty Area
- Resolution 6 (2014) – Toward a Risk-based Assessment of Tourism and Non-governmental Activities

2.3.2 Human heritage in Antarctica

Measures related to human heritage in Antarctic and relevant to this Expedition are:

- Resolution 5 (2001) – Guidelines for handling pre-1958 historic remains
- Resolution (as yet un-numbered) (2018) - Guidelines for the assessment and management of Heritage in Antarctica
- Measure 12 (2019) - Revised List of Antarctic Historic Sites and Monuments: the Wreck of Sir Ernest Shackleton's vessel *Endurance* and C.A. Larsen Multi-expedition cairn

2.3.3 Scientific research in Antarctica

Measures related to scientific research in Antarctic and relevant to this Expedition are:

- Recommendation VIII-10 – Protection and study of Antarctic marine living resources
- Resolution 2 (2014) – Cooperation, Facilitation and Exchange of Meteorological and Related Oceanographic and Cryospheric Environmental Information
- Resolution 5 (2014) – Strengthening Cooperation in Hydrographic Surveying and Charting of Antarctic Waters
- Resolution 6 (2015) – The Role of Antarctica in Global Climate Processes
- Resolution 4 (2018) – Environmental Guidelines for operation of Remotely Piloted Aircraft Systems (RPA) in Antarctica

Where relevant, account will be made of these provisions in the planning and conduct of the expedition and in the elaboration of this environmental impact assessment.

2.4 Other applicable Antarctic-specific guidance material

Additional guidance material is available through the Council of Managers of Antarctic Programs (COMNAP) and includes:

- COMNAP Visitors Guide to the Antarctic (1995)
- COMNAP Emergency Response and Contingency Planning (2004)
- COMNAP / SCAR Checklist for Supply Chain Managers of National Antarctic Programmes for the Reduction in the Risk of Transfer of Non-native Species (2010)

3. Scope of the Initial Environmental Evaluation

3.1 Activities that are included

The activities that are in scope for this environmental impact assessment and for which application for a permit is being made to the FCDO are:

- all personnel involved in the Endurance22 Expedition;
- the activities associated with the search for and survey of the wreck of the Endurance, including:
    - deployment and operation of the hybrid autonomous / remotely operated underwater vehicles (SAAB Sabertooth units);
    - establishment of sea-ice camps from which the underwater survey vehicles may be deployed;
    - operation of helicopters to deploy and recover the sea-ice camps and associated equipment, including the deployment of fuel caches.
- associated sea-ice research that will be undertaken from the research vessel including the deployment of an EM Bird and some small volume ice sampling;
- operation of helicopters and remotely piloted aircraft (RPA) to support sea ice navigation, the research, the selection of ice floes to establish sea ice camps, and the visual recording of the Expedition for outreach, education and documentary purposes.

The spatial scope of the IEE is focussed on the central western area of the Weddell Sea in the vicinity of the wreck of the *Endurance* (Figure 2).

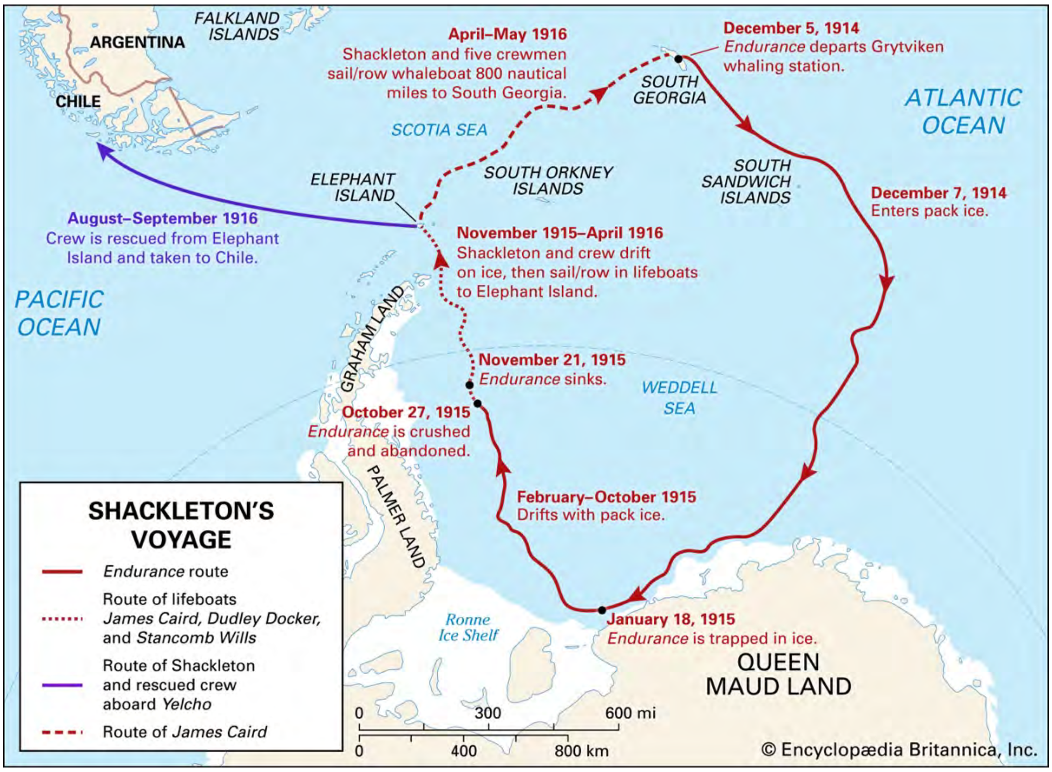

Figure 2. The route taken by Endurance during its 1914/1915 Expedition and the approximate location of its sinking in November 1915. The location of the sinking will be the main area of activity of the Endurance22 Expedition.

The temporal scope of the activities covered by this IEE is 35 (up to 45) days. The activities recorded above are planned to be undertaken between 5 February 2022, when the Expedition will depart from Cape Town for Antarctica, and 10 March 2022 when the Expedition returns to Cape Town.

Transit to Antarctica will occur between 5 and 18 February 2022. Onsite search and survey work will be undertaken between 18 and 28 February 2022. The return trip to Cape Town will take place between 28 February and 10 March 2022.

An additional 10 day contingency period has been built into the contract between FMHT and African Maritime Solutions (AMSOL; the operators of the *SA Agulhas II*), which, if required, would extend the Expedition to a return date of 20 March 2022.

If approved, the period for which a permit is required is 5 February 2022 until 20 March 2022.

3.2 Activities that are excluded

Activities that are excluded from the scope of this environmental impact assessment are:

- the operation and compliance of the research vessel *SA Agulhas II. SA Agulhas II* is a South African flagged vessel that is owned by the Department of Forestry, Fisheries and Environment (DFFE) , South Africa and is approved for operation in Antarctic waters, in support of the South African National Antarctic programme, by the South African Maritime Safety Authority (SAMSA). During the 2021/2022 austral summer season, SAMSA's approval for the vessel will include its operation in the Weddell Sea in support of the Endurance22 Expedition. Nonetheless, given that the *SA Agulhas II* is integral to the Expedition, details of the vessel are provided in this environmental impact assessment where appropriate, so as to reinforce both safety and environmental management provisions;
- the deployment of meteorological balloons and oceanographic floats (ARGO floats) from the *SA Agulhas II* by South African Weather Service researchers. Up to two researchers from the South African Weather Service will be invited to join the cruise, but their activities are not formally part of the Expedition and will be authorised by South African authorities;
- a programme of vessel engineering research that will be undertaken during the cruise. Up to four researchers from Stellenbosch University and the University of Alto will be invited to join the cruise to undertake data collection on the engineering performance of the *SA Agulhas II* throughout the cruise. But this research is not a formal part of the Expedition and will be authorised by South African authorities.

3.3 Changes from Weddell Sea Expedition 2019

The Endurance22 Expedition builds upon and incorporates lessons learned from the previous Weddell Sea 2019 Expedition. This includes:

- **More focussed expedition purpose**. The Weddell Sea Expedition 2019 had multiple research and wreck-search objectives. The Endurance22 Expedition has placed the search for the Endurance as its primary objective, with some research to be undertaken in support of the wreck search.
- **Selection of a different type of subsea vehicle**. The subsea vehicle will be a SAAB Sabertooth. The main advantage of this vehicle is that it remains tethered throughout deployment allowing permanent surface control and real time supervision for fast action in case of issues. The vehicle is a hybrid vehicle able to:
  - autonomously covering large are of seabed for survey and search;
  - be switched into ROV mode to fly over a dedicated area or for accurate control for surface return.
- **Subsea operations**. A number of lessons related to the management of the subsea operations were learned during the Weddell Sea Expedition 2019 including in relation to: the duration of deployment of the vehicles; the means for maintaining contact with the subsea vehicles and the importance of flexibility in mission planning in the context of ice and weather conditions at the time. These points are expanded upon in section 4.3.2.
- **Pre-deployment trials**. The Endurance22 Expedition is paying close attention to trialling the subsea vehicles prior to deployment to Antarctica. This includes deep water testing (up to 3000m) of the SAAB Sabertooth vehicles and testing of the ice drilling equipment and subsea vehicle launch and recovery system in France in October 2021. This will ensure greater familiarity by the Expedition team with the vehicles and equipment prior to real time deployment in the Weddell Sea.
- **Improved understanding of the operating conditions**. The Weddell Sea Expedition 2019 generated a good understanding of the weather and sea ice conditions, and this information has been used to inform the development of an 'options' approach for the launch, monitoring and recovery of the subsea vehicles (see Section 4.2.1.2). Ideally the SAAB Sabertooth units will be deployed directly from the *SA Agulhas II*. But if ice conditions preclude this (e.g., by preventing the *SA Agulhas II* from getting close enough to the wreck site) the equipment and procedures for deploying the subsea vehicles through holes cut in sea ice have been developed. The increased flexibility that this provides enhances the likelihood of achieving the Expedition objectives.
- **Improved accuracy of search**. Since the Weddell Sea Expedition 2019, analyses have been undertaken to improve the location accuracy of the wreck site, increasing the potential for the Endurance22 Expedition to locate the wreck.
- **Deployment of personnel**. The Weddell Sea Expedition 2019 used an air link to Antarctica operated by White Desert to deploy all Expedition personnel, who joined the *SA Agulhas II* in Antarctica. This carried an element of risk in that flight delays (e.g., for weather reasons reduced the available time to undertake the planned research and wreck search. Endurance22 will deploy all personnel directly to the *SA Agulhas II* in Cape Town which will remove the risk of flight delays.
- **Air support**. The Endurance22 expedition will have available to it two helicopters which can deploy from the *SA Agulhas II*. These assets will add value to navigating through pack ice by being able to undertake aerial reconnaissance of ice conditions beyond line of sight. They will also provide greater flexibility to the wreck search by being able to deploy equipment and personnel onto the sea ice if direct deployment from the vessel is not possible. The helicopters will also provide search and rescue, and emergency medevac, if required.

4. Description of the Planned Activities

4.1 Operations and Logistics

The Endurance22 Expedition (the Expedition) aims to:

1. Locate, identify and survey the historic wreck of Sir Ernest Shackleton's ship *Endurance*, which sank in the western Weddell Sea in November 1915,
2. Undertake an education and outreach programme and the making of a documentary,
3. Carry out a small programme of scientific research.

This Chapter describes the activities that are planned to be undertaken to achieve these aims and considers the environmental aspects that will or may occur as a consequence of those activities.

4.1.1 Expedition personnel

The Expedition will comprise approximately 60 personnel (Table 1), including an expedition leader, maritime archaeology expert, subsea search engineers and technicians, helicopter pilots and engineers, Antarctic field safety experts, as well as outreach and education personnel and a documentary team.

Expedition personnel will join the *SA Agulhas II* in Cape Town, South Africa for transit to the Weddell Sea.

Table 1. Expedition personnel.

Name	Nationality	Bio
Voyage Leader		
Dr John Shears, Director, Shears Polar Ltd, UK	British	*Dr John Shears FRGS is a polar geographer and expedition leader. He has over 30 years of experience of working in both Antarctica and the Arctic, first with the British Antarctic Survey, then with the Scott Polar Research Institute at the University of Cambridge. He now runs his own company, Shears Polar Limited, and provides expert lecturing, expedition guiding, and consultancy services for projects in the polar regions. John was also an environmental and operations adviser to the UK government in Antarctic Treaty discussions for more than 20 years, and was a UK Antarctic Treaty Inspector in 2005, 2012 and 2015. He was the expedition leader for the Weddell Sea Expedition 2019 (https://weddellseaexpedition.org/). John is a long-standing Fellow of the Royal Geographical Society and has worked closely with them on many polar education and expedition projects for over a decade. Most recently, he advised the Society on their award-winning Weddell Sea school resources. John was awarded professional accreditation as a Chartered Geographer (CGeog) by the RGS in 2018. In 2019, John was awarded the Polar Medal by Her Majesty the Queen in recognition of his "outstanding achievement and service to the United Kingdom in the field of polar research".*

Name	Nationality	Bios (where known)
Vessel Master		
Captain Knowledge Bengu	South African	*Captain Bengu is a Master Mariner and has amassed a broad base of knowledge operating in the Antarctic regions. He is one of the few seafarers who has sailed to Antarctic in each of the ranks including cadet, spread over both the older S.A. Agulhas and her replacement, S.A. Agulhas II.* *He underwent a long induction process as understudy Chief Officer / Ice Pilot before finally being promoted to Master. He did his first Antarctic voyage in 2013. That year saw the worst ice conditions in 11 years.* *He was the first South African to obtain official STCW training with regards to Ice Navigation.*
Ice Pilot		
Captain Frederick Lighthelm	South African	*Captain Lighthelm is a Master Mariner, Master Surveyor and Ice Pilot. He has over 20 years of seagoing experience working on and captaining a range of operational, research and tour vessels including to the Antarctic and sub-Antarctic. He was the Master for the newly built SA Agulhas II for her delivery voyage and for the vessels first Antarctic voyage.*
Marine Archaeology Team		
Mr Mensun Bound, Marine Archaeologist, University of Oxford, UK	British	*Mensun Bound was the senior marine archaeologist during the Weddell Sea Expedition 2019*
Subsea Survey Team		
Jean Christophe (JC) Caillens Offshore Manager, Ocean Infinity	French	*Jean Christophe (JC) Caillens is a retired French Navy Officer with rank of Commander. Initially cadet at the French Navy aircraft school, JC has finally focus on diving operations. He became first mate of the French Navy Diving school and has been finally appointed as French Navy SUPSALV (Supervisor Salvage and Diving). He has driven all French Navy deep water subsea/survey operations including submarine rescue. JC became French Gov Rep for all civil aviation deep water crash including AF447. Since he's retired from Navy, JC spent 10 years as Offshore Manager for DOS or OI over the most complicated and deepest search and/or salvage including MH370, MS804, AJA San Juan, Sub La Minerve, SS City of Cairo and other confidential projects.*
Nico Vincent	French	*TBP*
Thomas Andreasson	Swedish	*SAAB*
Lars Lundberg	Swedish	*SAAB*
Chad Bonin	American	*Ocean Infinity*
Kerwin Taylor	British	*Ocean Infinity*
Frederic Bassemayousse	French	*Ice Drilling Supervisor* *Ocean Infinity / Deep Ocean Search*
Joseph Leek	British	*Ocean Infinity / Deep Ocean Search*
Pierre Le Gall	French	*Ocean Infinity / Deep Ocean Search*
Francois Mace	French	*Ocean Infinity / Deep Ocean Search*
Robert McGunnigle	British	*Ocean Infinity / Deep Ocean Search*
Gregoire Morizet	French	*Ocean Infinity / Deep Ocean Search*
Jeremie Morizet	French	*Ocean Infinity / Deep Ocean Search*
Maeve Onde	French	*Ocean Infinity / Deep Ocean Search*
Clement Schapman	French	*Ocean Infinity / Deep Ocean Search*
Frederic Soul	French	*Ocean Infinity / Deep Ocean Search*
Helicopter Team		
Charly Tait	South African	*Ultimate Heli* *Chief Pilot*
Vuyisa Mrwebi	South African	*Ultimate Heli* *Pilot*
Waldo Venter	South African	*Ultimate Heli* *Pilot*
Lisa Le Roux	South African	*Ultimate Heli* *Pilot*
Mukapi Khalushi	South African	*Ultimate Heli* *Pilot*

Name	Nationality	Bios (where known)
Ice camp Support Team		
Carl Elkington	South African	*White Desert* *Ice Camp Manager*
Others TBD		
Expedition Doctor		
Lucy Coulter	British	*Expedition Doctor*
Education and Outreach Team		
Richard Garriott de Cayeux	British / American	*Richard Garriott Is the President of the Explorers Club, an American-based international multidisciplinary professional society with the goal of promoting scientific exploration and field study. The club was founded in New York City in 1904, and has served as a meeting point for explorers and scientists worldwide. Mr. Garriott has participated in many expeditions and is the first person to reach both geographic poles, descend to the deepest point in the ocean and fly into space. Mr. Garriott will facilitate the education and outreach programme.*
Tim Jacob **Education and Outreach Coordinator**	American	*Reach the World*
Film Team		
Natalie Hewit **Media Lead**	British	*Little Dot Studios*
Nick Birtwistle	British	*Little Dot Studios*
Dan Snow	British	*Little Dot Studios / History Hit*
Esther Horvath **Photographer**	German	*Ester Horvath Photography*
Research Team – Sea ice		
Dr. Lasse Rabenstein **Chief Scientist**	German	*Lasse Rabenstein is the founder and CEO of Drift & Noise Polar Services. He holds a PhD in geophysics and has significant field experience working in glacial and polar environments.*
Beat Rinderknecht	Swiss	*Drift & Noise.* *Senior Technician.*
Dr. Steffi Arndt	German	*Alfred Wegener Institute* *Sea ice scientist.*
Jakob Belter	German	*Alfred Wegener Institute* *Sea ice scientist.*
Christian Katlein	German	*Alfred Wegener Institute* *Sea ice scientist.*
Alexandra Stocker	Swiss	*Drift and Noise* *Sea ice scientist.*
Mira Suhrhoff	German	*Drift and Noise* *Sea ice scientist.*
Research Team – Remote sensing		
Dr. Thomas Busche	German	*Thomas Busche is a remote sensing specialist working at the German Aerospace Centre - DLR. He has supported sea-ice expeditions both remotely and on-board. He will have access to high resolution TerraSAR-X images during the Expedition.*
Dmitrii Murashkin	Russian	*German Space Agency (DLR)* *Remote sensing expert*

Name	Nationality	Bios (where known)
Research Team – Meteorology		
Marc DeVos **Senior Meteorologist**	South African	*South African Weather Services* *Meteorologist*
Carla Ramjukadh	South African	*South African Weather Services* *Meteorologist*
Research Team – Ship engineering		
James Matthee	South African	*University of Stellenbosch* *Engineer*
Barend Steyn	South African	*University of Stellenbosch* *Engineer*
Jakko Seppanen	Finnish	*Finnish Meteorological Institute*
Jukka Tuhkuri	Finnish	*University of Aalto*

4.1.2 Marine transport

The marine research cruise will be undertaken from the South African flagged Polar research and resupply vessel *SA Agulhas II* (Figure 3). The vessel will be charted from the owners for a period of up to 45 days between 5 February and 22 March 2022.

Figure 3. SA Agulhas II will provide the platform for conducting the research in the Weddell Sea.

The vessel is owned by the South African Department of Forestry, Fisheries and the Environment (DFFE) and is operated by African Marine Solutions (AMSOL). *SA Agulhas II* is used to support marine research activities undertaken by the South African Nnational Antarctic programme and to provide logistical support to South Africa's SANAE IV research station in Dronning Maud land, Antarctica as well as to South African research facilities on Marion Island (SA) and Gough Island (UK).

SA Agulhas II is a modern, highly capable Polar research and resupply vessel. She was built at the STX shipyard in Finland and launched in 2012. A full specification for *SA Agulhas II* is provided at Appendix 1.

SA Agulhas II is a 134m long vessel strengthened for ice class navigation to IACS[1] Polar Class 5 standard. The vessel's IMO number is 9577135. She is registered as a +1A1 passenger vessel with Det Norske Veritas (DNV; registration number 30528).

The main generators supply electrical energy to cover propulsion as well as all other shipboard requirements. The diesel-electric installation employs four Wärtsilä 32-series, 3,000kW engines.

The two electric propulsion motors turn 4.5m-diameter, Rolls-Royce controllable pitch propellers. The system gives a maximum open water speed of 16 knots, for a service speed of 14 knots. Icebreaking performance is such that the ship can force a passage through level, 1m-thick ice at a speed of 5 knots.

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[1] International Association of Classification Societies

The sphere and nature of the vessel's deployments, requiring the utmost dependability and operating precision in harsh weather, sea and ice conditions, has called for advanced functionality as well as very high reliability regarding bridge equipment.

The fully integrated navigation system (INS), compliant with DNV's requirements, was provided by Raytheon Anschütz, and includes a suite of six, wide-screen workstations covering radar, chart radar, ECDIS[2] and conning functions. The INS also incorporates the Dynamic Positioning System, integrated to share information such as waypoints with the navigation system. This is used for the most precise operation within ice fields, and for automatic heading keeping when berthing at the ice shelf, or when bottom-sampling.

One of the radars is equipped as an ice radar, with advanced ice imaging capabilities, assisting the navigators to identify the optimal route through icy waters and reduce fuel consumption and the risk of hull damage. The ECDIS features autopilot remote control. Both bridge wings are equipped with a chart radar, and also have the option for integrating the conning display to provide full navigation data indication during docking operations.

The vessel has eight permanent laboratories and facilities and services for a further six containerised laboratories equipped and instrumented for various fields of marine, environmental, biodiversity, meteorological, climatic and hydrographic research. Deepwater probes can be deployed via a large door on the starboard side, while a hydraulic A-frame on the stern is used for towing sampling nets and dredges, and for putting out and retrieving arrays of sensors.

A structure known as a 'drop keel', housing transducers for measuring the density of plankton layers and small fish and for gathering other data, can be lowered through the hull bottom to a depth of 3m below the ship. The vessel is also equipped with a 2.4m x 2.4m moon pool which extends through three decks and the ship's bottom. This provides an alternative launch area through which to lower sampling probes when the ship is working in pack ice.

SA Agulhas II incorporates hold space for 4,000m^3 of dry cargo in her forward section, served by a 35t heavy-duty crane and three 10t cranes, all of which can be used to transfer scientific equipment, materials and vehicles to and from the ice shelf. Cargo can also be flown off by helicopter. A dedicated heeling tank counters list induced by the swinging out of heavy loads. The ship is the first of her kind to be authorised for carrying both passengers and bulk fuel, specifically polar diesel, Jet A1 helicopter fuel and petrol.

Accommodation is provided for 45 crew, and 100 researchers and passengers. The outfit includes a library, a gym and a small hospital. The vessel has a high endurance factor, equating to 15,000 nautical miles at service speed, and is fitted with a landing area and hangar space that can handle two helicopters.

SA Agulhas II was used for the previous Weddell Sea Expedition 2019 and proved to be entirely suitable for the research and wreck search work undertaken during that expedition (Figure 4).

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[2] Electronic chart display and information system

Figure 4. SA Agulhas II was successfully utilised to support the 2019 Weddell Sea Expedition.

SA Agulhas II – summary

Length overall	134.20m
Breadth, maximum	23.00m
Depth	10.55m
Draught	7.65m
Deadweight	5,020dwt
Gross tonnage	13,000t
Cargo hold capacity	4,000m³
Passenger capacity	100
Crew	45
Main Diesel-electric gensets	
	4 x Wärtsilä 6L32, 3,000kW each
Propulsion motors	2 x 4,500kW
Speed (open water) max.	16 knots
Speed (ice) 1m level ice	5 knots
Classification	DNV +1A1
Ice class	PC-5

4.1.2.1 Vessel safety

As the operator of the *SA Agulhas II* AMSOL is certificated and audited on a regular basis by Lloyds Register, in line with the International Management Code for the Safe Operation of Ships (the ISM Code) and for Pollution Prevention. AMSOL holds a Document of Compliance for passenger ships, oil tankers and other cargo ships. AMSOL is certified with DNV to the International Standards Organisation (ISO) standards – ISO 9001:2015 (Quality Management) and ISO 14001:2015 (Environmental Management) and LRQA - OHSAS 18001 (Health and Safety Management).

To assist with ship navigation in ice-infested waters, dedicated remotely piloted aircraft systems (RPA or 'drones') will be used to provide a real-time video stream of ice imagery to the ship's bridge. All RPA flights in support of ship navigation will be subject to weather conditions (e.g. high winds, blowing snow, fog). For this work, the RPA will be piloted manually. Pre-cruise liaison with the ship's Captain and technical team will take place to ensure clear communication between the drone's video and the bridge.

For the Endurance22 Expedition the *SA Agulhas II* will carry two helicopters that can also assist with navigation through the pack ice (see Section 4.2 below).

In addition to video imagery from the RPA, access to near-real time medium- and high-resolution satellite imagery will be arranged. A combination of optical and all-weather capable radar images is envisaged. Sea ice data and information will be obtained from Drift+Noise in Germany (https://driftnoise.com/), supplemented by data obtained from Polar View (https://www.polarview.aq). The expedition will also use high resolution TerraSAR-X satellite radar imagery provided by the German Space Agency (DLR) (https://earth.esa.int/web/eoportal/satellite-missions/t/terrasar-x).

SA Agulhas II has a fully compliant safety management system (ISM Code Certificate number: DRB 1780048 issued by Lloyds Register EMEA) and carries 2 fully enclosed life boats that can each accommodate 75 persons.

To comply with IMO's Safe Return to Port (SRTP) requirements, the main engines are located in two separate machinery rooms, and the vessel is capable of making port with one engine room flooded.

The vessel has a small hospital on-board and will carry an experienced medical doctor and field para-medic throughout the Expedition.

Emergency measures

SA Agulhas II takes part in the DROMLAN SAR (Dronning Maud Land Search and Rescue) agreement once the vessel enters the Antarctic Circle, which makes all resources in the area available (Maritime, fixed wing aircraft and Helicopters) in the event of an emergency.

The *SA Agulhas II* has a daily reporting schedule to the Cape Town headquarters of the vessel operator in South Africa (AMSOL – African Marine Solutions).

The vessel will report to the relevant Maritime Rescue and Coordination Centre (MRCC) regarding its intended route. In the event of an emergency call from *SA Agulhas II*, the relevant MRCC will be contacted to coordinated an appropriate response. For the majority of its planned activities in the Weddell Sea on the eastern side of the Antarctic Peninsula, the *SA Agulhas II* will move from the South African MRCC area of responsibility into the Argentinian MRCC area of responsibility.

4.1.2.2 Vessel route

Expedition personnel will embark the *SA Agulhas II* in Cape Town and sail directly to the western side of the Weddell Sea.

The precise route to be taken down the eastern side of the Antarctic Peninsula cannot be predicted in advance and will depend entirely upon weather, and more significantly, sea ice conditions at the time. This conforms to standard practice for Polar research vessels, where changing environmental conditions for ship operations mean that cruise planning with detailed itineraries is unrealistic.

Broadly, the vessel will follow a route across the South Atlantic Ocean and northern Weddell Sea so as to arrive on the north-eastern side of the Antarctic Peninsula offshore from James Ross Island and Snow Hill Island (Figure 5). If sea ice conditions allow, the *SA Agulhas II* will transit south along the eastern side of the Antarctic Peninsula to the last known position of Shackleton's Endurance (approximately 150NM off the Larsen C ice shelf) (Figure 5).

Here also sea ice conditions will determine how close to the wreck site the *SA Agulhas II* can get, and in turn, the manner of deployment of the subsea survey vehicles (see Section 4.3 for more detail).

On completion of the wreck survey, *SA Agulhas II* will retrace its passage and transit back to Cape Town via the northern part of the Weddell Sea.

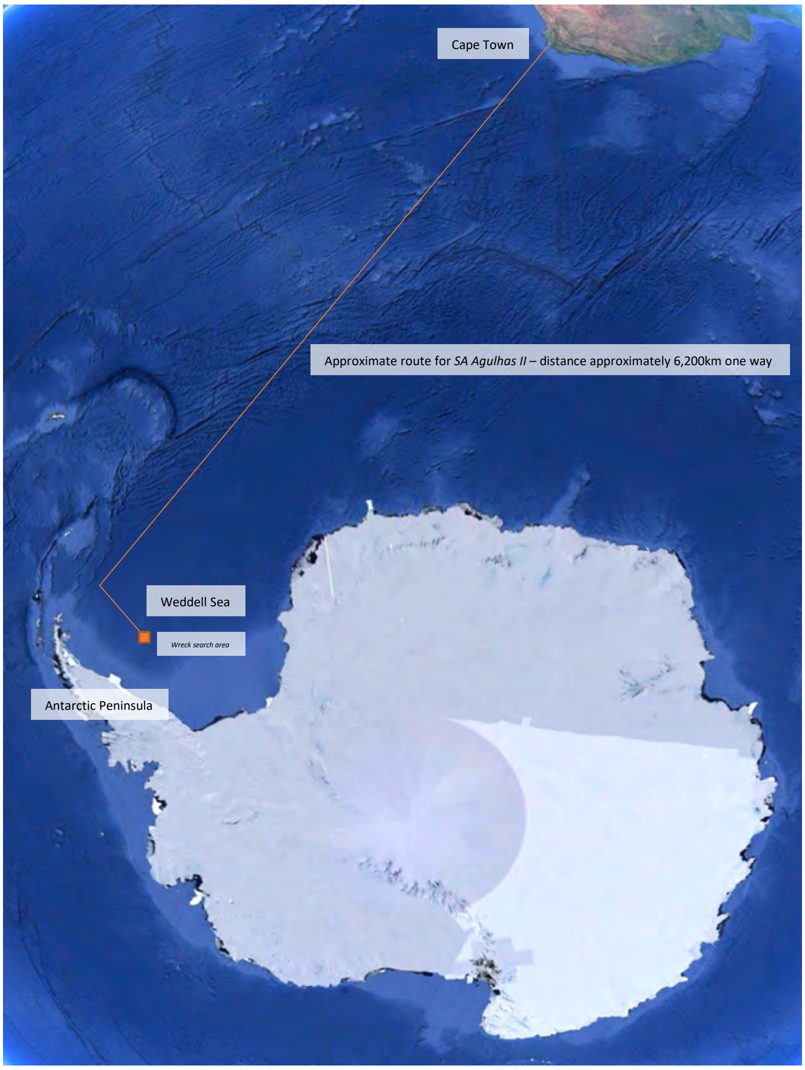

Figure 5. Approximate vessel route from Cape Town to the approximate location of the wreck of the Endurance. Image: Google Earth.

4.1.2.3 Personnel safety and briefings

Prior to joining the Expedition all personnel will be required to undertake and provide evidence of completing a sea survival training course that is equivalent to the requirements of relevant Regulations held under the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW).

All Expedition personnel will also be required to show evidence of passing a medical examination equivalent to the ENG1 Seafarer Medical standard set by the UK's Maritime and Coastguard Agency.

Briefings on vessel safety will be undertaken as soon as Expedition personnel embark the *SA Agulhas II* in Cape Town prior to departure for Antarctica. This briefing will also cover air safety matters (to be provided by Ultimate Heli) as well as a full environmental briefing in accordance with the findings of this EIA and any permit conditions placed on the Expedition by the FCDO.

An Expedition handbook will be prepared to provide a common and consistent source of information for all Expedition personnel.

4.1.2.4 Summary of expedition itinerary

The expedition itinerary is summarised in Table 2.

Table 2. Overview of the Expedition's itinerary.

Date(s)	Location/Route	Activities to be undertaken
4 – 5 February 2022		Mobilisation of equipment and personnel on *SA Agulhas II* in Cape Town
5 February 2022	Depart Cape Town to Weddell Sea aboard *SA Agulhas II*. Precise route will be determined by ice conditions (see graphic below).	On passage. Opportunity for safety and environmental briefings, equipment checking and some educational and outreach activity and on passage scientific research.
11 – 18 February 2022 (approximately)	Enter Weddell Sea and make way down the eastern side of the Antarctic Peninsula	On passage. Opportunity for safety and environmental briefings, equipment checking, educational and outreach activity and some research.
18 February to 28 February 2022 (approximately)	Western Weddell Sea operational area in and around the last known location of the *Endurance*	Conduct search for *Endurance* wreck as well as educational and outreach activity, and an associated programme of scientific research. Deployment of subsea search vehicles from the vessel if sea ice conditions permit. If sea ice too thick or dense for vessel to reach *Endurance* wreck, then the expedition will establish small ice camps on sea ice / ice floes; drilling of holes in the ice and deploying the subsea vehicles to undertake systematic seabed search and archaeological survey of the wreck if found.
28 February to 10 March 2022	Weddell Sea to Cape Town return	Return passage. Complete educational and outreach activity. Continue on-passage scientific research. End of expedition report writing. Packing up and demobilisation of equipment.
NB: An additional 10 days has been included in the Charter Party agreement as an option. This would extend on-site activities in the Weddell Sea until approximately 10 March 2022 and later return to Cape Town on 20 March 2022.		

4.1.3 Environmental aspects arising from vessel operations

Environmental aspects that will or may arise as a result of operating the vessel in Antarctic waters are:

a) Emissions to air of exhaust gases and particulates, including greenhouse gases;

b) Noise emissions to air and the marine environment;

c) Potential introduction of non-native marine species e.g., through hull fouling;

d) Generation of wastes on board including food waste, garbage and human waste;

e) Release of fuel to the marine environment in the event of an accidental spill;

f) Water turbulence.

4.2 Air Support

The Expedition will utilise a Bell 412 EP helicopter (Figure 6) and a Kamov 32 B heavy lift helicopter. The aircraft will be provided and operated by Ultimate Heli based in South Africa. Ultimate Heli have operated in Antarctica since January 2015 providing support to research, ship to shore movements, wildlife surveys and search and rescue operations.

Ultimate Heli have several seasons of experience working from the *SA Agulhas II*.

Primarily, the helicopters will be used by the Expedition to deploy equipment and personnel to the sea ice if the ice-deployment option of the subsea vehicles is pursued.

The helicopters may also be used for reconnaissance purposes to support navigation of the *SA Agulhas II* through the pack ice, and also for search and rescue and emergency medevac.

Figure 6. Bell 412 helicopter (left) operated by Ultimate Heli in support of the South African Antarctic programme. Image: Ultimate Heli; Kamov 32B heavy-lift helicopter (right) operated by the Chinese National Arctic and Antarctic Research Expedition in the Arctic. Image: Radio Canada. NB: The Kamov helicopter pictured here is for illustrative purposes only and will not be the same one used by the Endurance22 Expedition.

4.2.1 Environmental aspects arising from aircraft operations

Environmental aspects that will or may arise as a result of operating the helicopters are:

a) Emissions to air of exhaust gases and particulates, including greenhouse gases;
b) Noise emissions;
c) Release of fuel to the environment e.g., during refuelling.

4.3 Wreck Search and Survey

4.3.1 Background

Sir Ernest Henry Shackleton (15 February 1874 – 5 January 1922) was a polar explorer involved in several British expeditions to the Antarctic in the early 1900s. Shackleton was a member of Captain Scott's *Discovery Expedition* (1901–1904), during which he, Scott and Edward Wilson set a new southern record by sledging to 82°S.

During Shackleton's *Nimrod Expedition* (1907 – 1909) he and three companions achieved a new 'farthest south' record reaching 88°S; just 112 miles short of the south geographic pole.

Shackleton's *Imperial Trans-Antarctic Expedition* (1914 – 1917), was an attempt to make the first overland crossing of the Antarctic continent. The ship chosen for the expedition was the *Endurance*. *Endurance* was built in Norway and launched on 17 December 1912. She was initially named *Polaris* and was specifically designed for operating in ice-covered waters.

The expedition left the UK in August 1914, and departed from South Georgia for the Weddell Sea on 5 December. The expedition soon encountered significant sea ice cover and on 18 January 1915 at 76°34'S, *Endurance* became trapped in the ice.

Several attempts were made to free *Endurance* from the ice, but to no avail and by the end of February, temperatures had fallen and the ship was frozen in for the winter.

The expedition members remained living aboard the *Endurance* for several months until 27 October 1915 when Shackleton took the decision to abandon ship. Their position was 69°5'S, long. 51°30'W. The *Endurance* was under heavy pressure from the ice which tore away her rudder post and crushed in her stern. Shackleton wrote: "*we have been compelled to abandon the ship, which is crushed beyond all hope of ever being righted, we are alive and well, and we have stores and equipment for the task that lies before us. The task is to reach land with all the members of the Expedition. It is hard to write what I feel*".

The *Endurance* finally broke up and sank in the Weddell Sea on 21 November 1915 (Figure 7).

The 28 men of the expedition were isolated on the drifting pack ice hundreds of miles from land, with no ship, no means of communication with the outside world and with limited supplies. The story of their survival and eventual rescue is one the greatest polar stories.

Using three lifeboats from *Endurance,* the men travelled initially across the sea ice and then open water to reach Elephant Island. From there Shackleton and five others used one of the lifeboats, the *James Caird*, to sail to South Georgia to raise the alarm and seek rescue. The remaining expedition members were rescued from Elephant Island on 30 August 1916.

The wreck of the *Endurance* remains one of the most iconic of all shipwrecks and has never been located since it sank in 1915.

For the Weddell Sea Expedition 2019 the search area was based on analyses undertaken by the Scott Polar Research Institute (SPRI) which had available to it the records that F.A. Worsley (the Captain of the Endurance) took of the location of the *Endurance's* sinking.

Since then analyses have been undertaken by the FMHT to refine the potential location of the wreck and hence the search area.

The objective of the search will be to find the *Endurance* and then to survey, photograph and film it and document its condition. The survey work will be non-invasive, and no contact will be made with the wreck or any of the artefacts associated with the wreck. At every stage, the project will observe international best practice for the protection and conservation of historic shipwrecks.

Figure 7. Endurance sinking through the sea ice.

The search will be conducted using two SAAB Sabertooth subsea vehicles (see Section 4.3.2.1) fitted with visual and sonar survey technology.

Once the *Endurance* has been found, she will be surveyed by laser scanner so as to produce a 3D model and full photogrammetric coverage of the wreck and its debris field. The resulting graphical data will be precisely scaled allowing the wreck, together with its equipment, fittings and contents, to be recorded to a level of accuracy comparable to that of an archaeological survey on land.

The historical research and survey data collected by the Expedition will be used as vital base-line information for the future monitoring and protection of the wreck of the Endurance.

The wreck of the *Endurance* was designated an Historic Site and Monument by the 42nd Antarctic Treaty Consultative Meeting (ATCM) in 2019 (HSM Number 93; Measure 12 (2019)). The survey data and information generated by the Expedition will be made available to the FCDO to assist with the management and protection of the wreck site.

4.3.2 Wreck search and survey

A number of lessons were learned from the previous Weddell Sea Expedition 2019 that have guided the planning for the subsea survey aspects of the current Expedition. In particular it is now known that:

- it is critical to maintain supervision of the subsea vehicles in autonomous mode as much as possible, although this is dependent on vessel manoeuvrability and the ice conditions on site. Unpredictable ice conditions can significantly limit or even prevent constant supervision of the subsea vehicles;
- due to drifting ice floes, the vessel cannot be kept stationary at one location for sustained periods of time;
- unpredictable sea ice and environmental factors means that 'handshake' locations between the surface equipment and the subsea vehicles cannot be anticipated prior to the dive and have to be defined throughout the mission;
- mission planning in the sea ice environment cannot be done in advance and can only be built on site when faced with the ice conditions at the time. There are too many unknown environmental variables, which only can be assessed at arrival on site;
- subsea missions should be time-limited at depth because of the changing surface ice conditions, but also the faster drain on the vehicle batteries because of the cold deep bottom water temperatures;
- the subsea vehicle(s) need to be kept in supervised i.e., tethered mode permanently;
- any vehicle needs a full backup system, and comprehensive spare package.

These learnings have influenced two elements of the current Expedition, notably the selection of the subsea search vehicles and the manner of their deployment.

4.3.2.1 Subsea search and survey equipment

The Expedition will utilise two SAAB Sabertooth vehicles (Figure 8).

Figure 8. SAAB Seaeye hybrid AUV/ROV. Source: https://www.saabseaeye.com

The SAAB Sabertooth is highly versatile and can be operated in two different configurations: either as a remotely operated vehicle (ROV) with full operator control, using a thin fibre optic tether, or as an autonomous underwater vehicle (AUV) to carry out programmed missions, with the possibility of operator control around set targets (Figure 9). For the Endurance22 Expedition the vehicles will be operated in tethered mode.

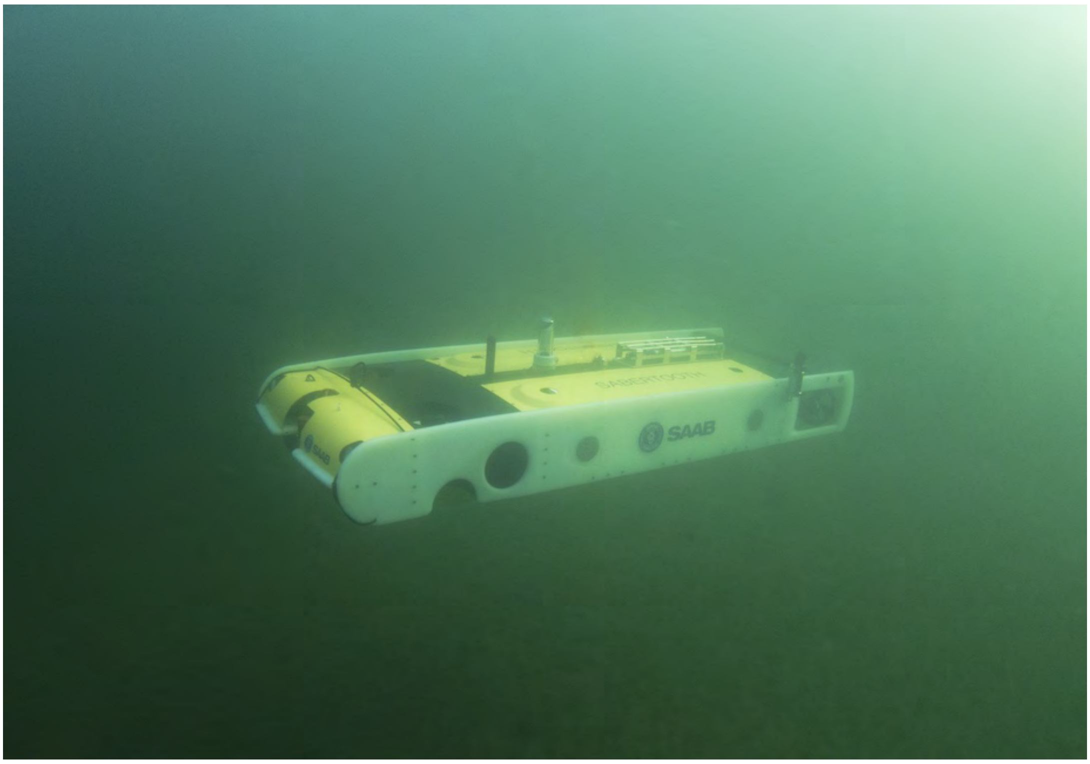

Figure 9. SAAB Sabertooth operating in AUV mode. Image: SAAB Seaeye.

The SAAB Sabertooth has a long excursion range and 360° manoeuvrability. These units are ideal for autonomous inspection and maintenance of subsea installations, and deep water offshore survey work (see Appendix 2).

Key specifications are shown in Table 3.

Table 3. Key specifications of the SAAB Sabertooth vehicles.

Depth rating	3000 metres
Length	4094 mm
Height	670 mm
Width	1400 mm
Weight (in air)	1200 – 1500 kg depending upon payload
Speed	4 knots
Battery capacity	30 kWh
Endurance	>14 hours

Features of the Sabertooth vehicles include:

- an operational depth of 3000 metres;
- battery power allowing long range operations, with either full operator control via a thin fibre optic tether or autonomous operation (with operator control in proximity of targets);
- full AUV functionality with obstacle avoidance, behaviour-based control and underwater docking capability;
- interfaces for a wide range of sensors/auxiliary equipment;
- redundant fault tolerant control system;
- non-invasive self-diagnostics;
- advanced autopilots: heading, depth, pitch, roll, stabilization, altitude, station keeping, vector transition, obstacle avoidance and sonar target tracking.

Each Sabertooth vehicle will be fitted with the following sensors as standard:

- Sonardyne SPRINT5000 INS/DVL
- GPS Novatel
- Keller Depth sensor
- Mini SVS Veleport
- Imagenex 881L obstacle avoidance sonar
- Seaeye camera IPHD on Seaeye Tilt
- 2 x Bowtech LED lamps
- Iridium Novatech iBCN
- Novega PT9 Acoustic pinger
- Bowtech ST6K Strobe light

In addition the Sabertooth vehicles will carry additional payloads depending upon whether they are in search or survey mode. For the survey work the Sabertooths will carry (Figure 10):

- an Edgetech 2105 side scan sonar (SSS) – Frequencies 75 – 230 – 410 Khz
- a multibeam echosounder (MBES) R2SONIC 2024 (with sonar gap filler)

Once the wreck has been located and the detailed survey work can be undertaken, the Sabertooth vehicles will return to the surface and be fitted with:

- a Broadcast 4k camera and lights
- a 2G Robotics laser for 3D visual inspection

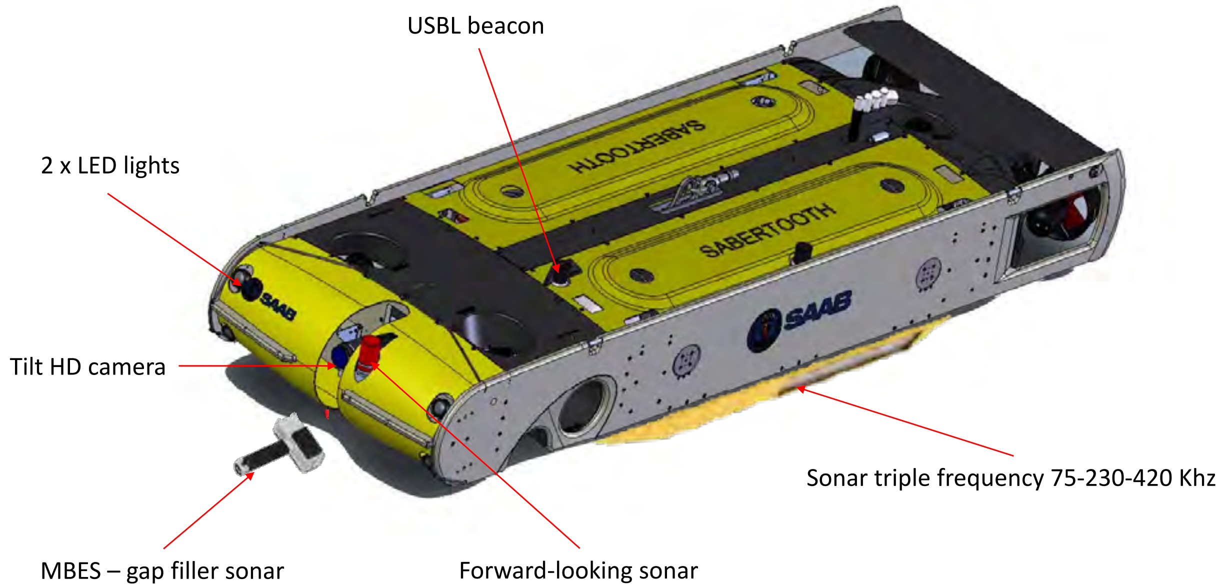

Figure 10. SAAB Sabertooth vehicle in survey mode. MBES = multibeam eco sounder; HD = high density; LED = light-emitting diode; USBL = ultra-short baseline positioning system.

4.3.2.2 Dead vehicle recovery

Based on experience during the Weddell Sea Expedition 2019, the highest risk for subsea vehicles is if the vehicle is lost and becomes dead immediately under the sea ice. In these circumstances, there is a high level of doubt that the ultra-short baseline (USBL) tracking of the vehicle will be able to keep acoustic contact with the transponder on the vessel due to the lack of acoustic coverage immediately below the sea ice (Figure 11).

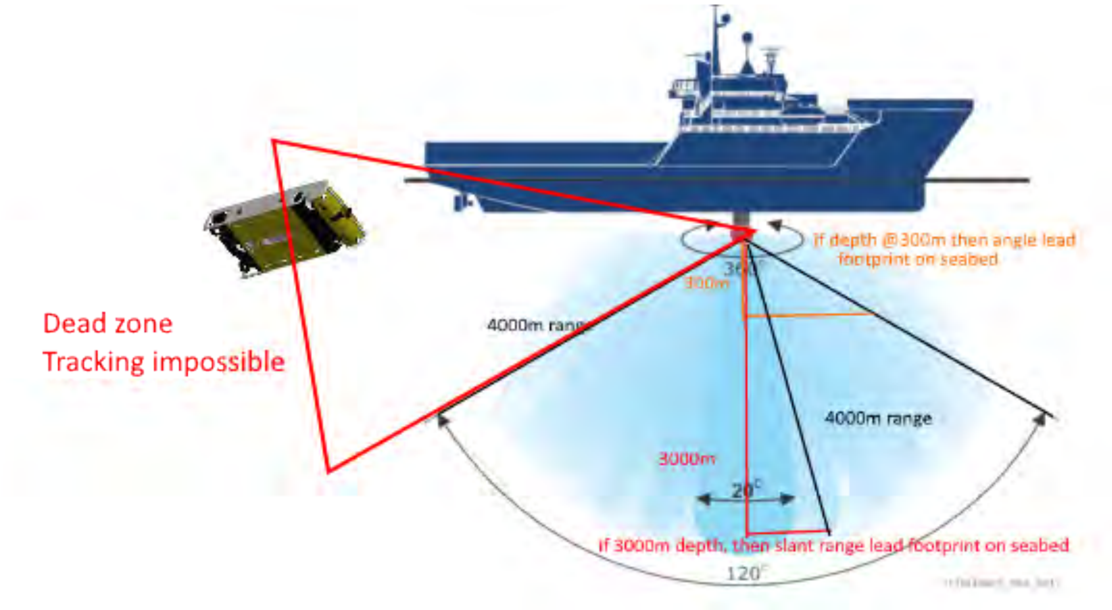

Figure 11. Potential acoustic 'dead zone' if the subsea vehicle becomes trapped beneath the sea ice.

To avoid this issue, each Sabertooth will be fitted with:

- a pinger beacon at 8.8Khz in order to provide an extended detection range. The beacon will be equivalent to those used by commercial aircraft i.e., a blackbox.
- an acoustic receiver to assist the vehicle operators in tracking acoustic sound sources from 8kHz to 45kHz. The receiver can function as an "acoustic transponder interrogator" and provide accurate range and bearing to targets marked with a line of custom acoustic transponders.

Further, each Sabertooth will be able to track the other under ice. The acoustic receiver will also be fitted to a portable pole which will be usable through an ice hole.

Additionally, each vehicle will be fitted with a grab stick and a safety hook to allow each vehicle to be caught and towed by the other.

4.3.2.2 Subsea vehicle deployment

The ability for the *SA Agulhas II* to reach the wreck site and the ease with which the SAAB Sabertooth units can be deployed will be determined almost entirely by the sea ice conditions that are encountered at the time of the Expedition. Consequently, the Endurance22 Expedition has developed an adaptable approach to the deployment of the SAAB Sabertooth units depending upon whether open-water conditions are encountered, or whether ice conditions are light or heavy.

The intent is to develop equipment and procedures that will allow for deployment of the Sabertooth vehicles either from the main vessel or from ice floes, or a combination of both.

Open water scenario – preferred option

In this scenario the pack ice that is encountered is sufficiently limited to allow for deployment of the subsea survey vehicles directly from the stern of the *SA Agulhas II* (Figure 12), and to allow the vessel to move freely across the search area in support of the deployed subsea vehicles.

Figure 12. In light ice conditions the subsea survey vehicles will be deployed directly from the stern of the SA Agulhas II. Image: WSE2019.

Light ice scenario

A second scenario is possible in which the pack ice cover is of a density that allows access to the wreck location but makes it difficult to deploy the subsea vehicles from the *SA Agulhas II* and difficult to use the vessel to 'follow' the subsea vehicles. In this scenario the vessel will be positioned adjacent to an ice floe and the subsea vehicles will be deployed through a hole drilled in the ice floe. Equipment and personnel will be deployed to the ice directly from the *SA Agulhas II* (Figure 13). This will provide for quicker deployment of the subsea survey vehicles compared to a remote ice camp and minimise the need for camp support equipment, with personnel moving to and from the main vessel for food and accommodation.

Figure 13. During the Weddell Sea Expedition 2019, research personnel and equipment were deployed directly to sea ice floes. Image: WSE2019.

The deployment holes in the ice floe will be prepared in a number of ways depending upon ice thickness. For relatively thin ice (e.g., less than a metre thick) chainsaws are likely to be used. For slightly thick ice (e.g., up to 1.5 metres) an auger mounted on a tracked vehicle will be used. For the thickest ice (e.g., >1.5 metres) a purpose-built sledge-mounted auger will be used (Figure 14).

Figure 14. An auger will be used to drill holes in the ice. This will either be used via a tracked vehicle (a), or, for thicker ice, a sledge-mounted ice auger will be used.

Once a hole of sufficient size has been drilled, a subsea vehicle launch and recovery system (LARS) will be erected over the hole (Figure 15). The LARS is a bespoke build specifically for the Endurance22 Expedition and comprises a sledge mounted frame to physically lower and recover the subsea vehicles and a separate sledge-mounted winch system for the fibre optic cable. The winch will be powered by a portable generator unit.

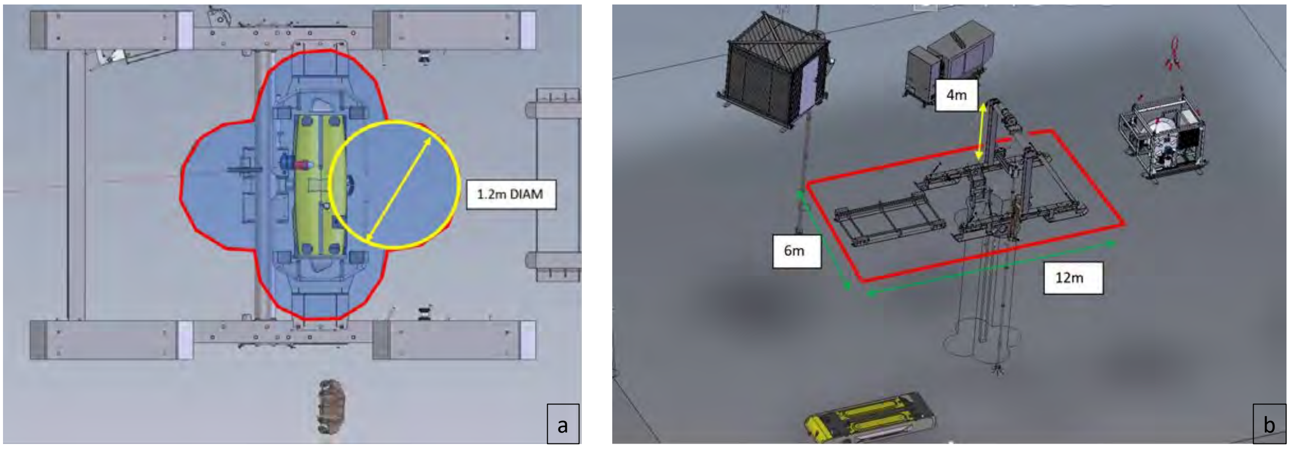

Figure 15. a) Schematic of the SAAB Sabertooth launch and recovery system (LARS). b) Schematic of the equipment associated with sea ice deployment of the subsea vehicles including the LARS, winch, generator and caboose.

The computing and electronics equipment required to follow and communicate with the subsea vehicles will be housed in a separate 'caboose' (Figure 15b).

Heavy ice scenario

In heavy pack ice conditions, the *SA Agulhas II* may not be able to get sufficiently close to the target search area. In which case, it is intended to deploy a field camp by helicopter on to a suitable ice floe and launch the subsea vehicles through a hole cut through the ice - as in the light ice scenario.

The drift of the ice floe will be utilised to maximise coverage of the intended search area.

An ice camp in this scenario will consist of two stages over approximately a four day period. An advance team of 6 people will initially be deployed to drill the ice hole. This is anticipated to take up to 2 days. The advance team will then be recovered and the subsea survey team of 10 people (comprising 2 field safety personnel and 8 subsea survey technicians) will be deployed to launch the Sabertooth vehicles, conduct the subsea survey and recover the Sabertooth vehicles. The survey period is anticipated to last about 24 hours as the ice floe moves over the search area. Recovery of the camp will take an additional day.

To support personnel deployed to the ice, a small tent camp will be established to provide for sleeping and feeding of up to 10 people. This will also require the deployment of fuel for generators and cooking, and food.

A skidoo will also be deployed to the ice camps to assist with the manoeuvring of the auger sledge and LARS.

Heavy ice camps could be deployed up to 60NMkm away from the main vessel.

It is also possible that some combination of the above scenarios may be employed depending upon the ice conditions encountered at the time. For example, if the *SA Agulhas II* is able to get to the area of the wreck, it may be possible to deploy one of the subsea vehicles from an ice floe, whilst extending the search area with a parallel deployment of a second search vehicle from the main vessel.

Search plan

The onsite duration of the expedition is anticipated to be 12 days. This allows for only a small number of 'passes' over the search area; potentially only two in the event of encountering heavy ice conditions, with the remaining few days being used for surveying the wreck if it is located.

Figure 16 provides an overview of the intended search pattern with the drift of the ice floe or vessel moving north-westwards whilst the Sabertooth vehicles are used to sweep laterally across the search area. The red box in Figure 16 denotes the modified search box based on the more recent analyses of the wreck site referred to above.

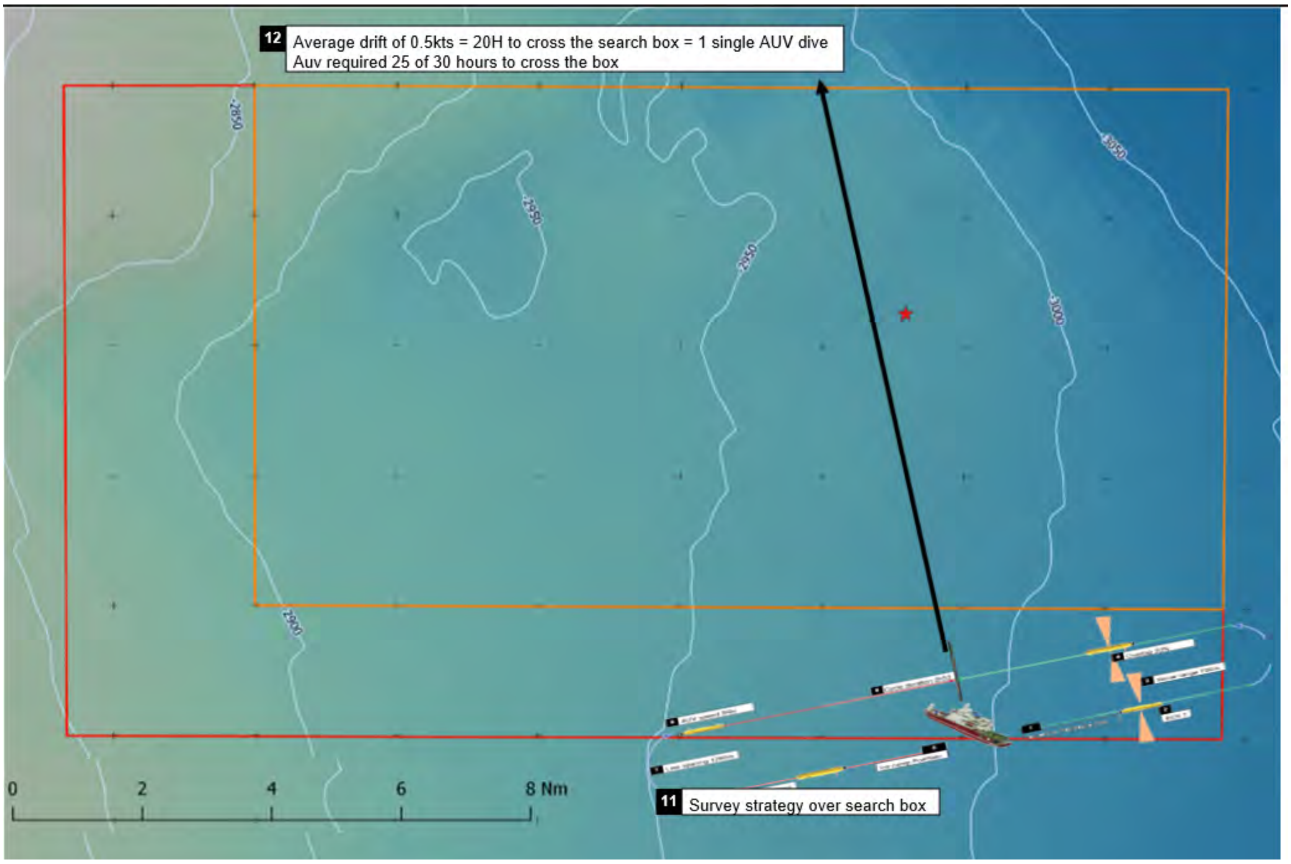

Figure 16. Overview of the search pattern. The slightly extended red search box is based on more recent analyses of the wreck location by FMHT.

The port and starboard sonar units on the Sabertooth vehicles have a horizontal scanning range of 700 metres. A 'gap filler' sonar is also carried to fill in a 70 metre gap that appears between the port and starboard sonars (Figure 17).

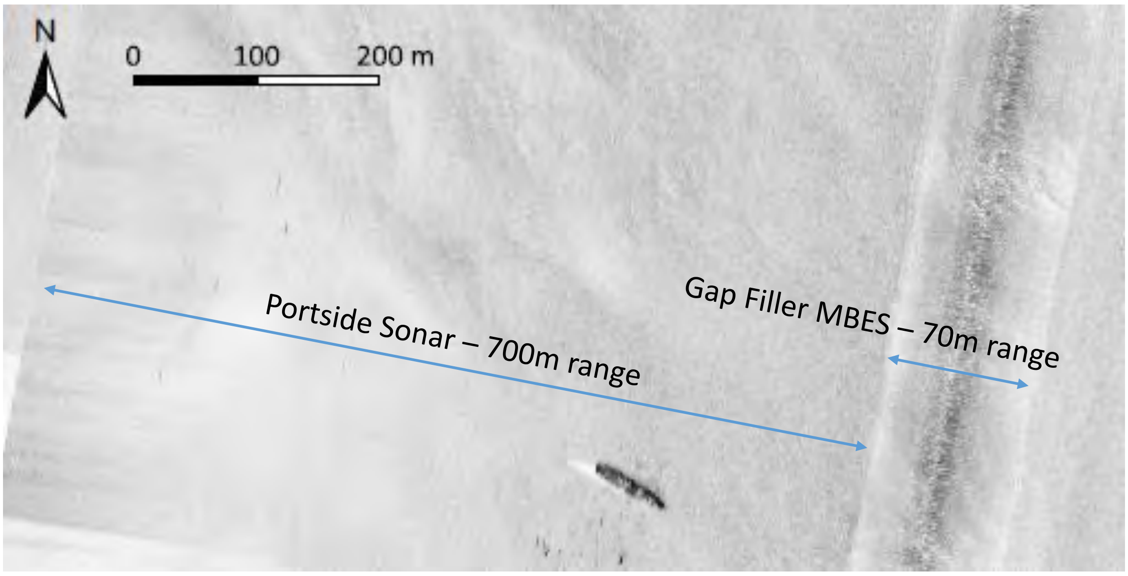

Figure 17. The sonar range of the Sabertooth vehicles is 700 metres to port and starboard. A 'gap filler' multibeam echo sounder (MBES) is carried to cover the area between to the two sonars.

4.3.2.3 Environmental aspects arising from the subsea search and survey

Environmental aspects that will or may arise as a result of subsea search and survey activities will vary depending upon whether the ice camps are needed or not. Assuming that ice camps are required, identified aspects are:

a) Noise emissions to air from the operation of the helicopters;
b) Potential introduction of non-native marine species e.g., through contamination of the Sabertooth vehicles;
c) Generation of wastes at the ice camps including food waste, garbage and human waste;
d) Release of fuel to the ice and/or marine environment in the event of an accidental spill occurring at the ice camps;
e) Loss of equipment to the marine environment e.g., through equipment failure or the inability to recover equipment from the ice floes, including release of the fibre optic cable tether;
f) Noise emissions to the marine environment from the drilling of the holes in the ice floes and noise, heat and light emissions to the marine environment from the operation of the subsea vehicles;
g) Water turbulence from the operation of the subsea vehicles.

4.4 Research Programme

The primary aim of this Expedition is to search for and survey the wreck of the Endurance. Nonetheless, operating in the western part of the Weddell Sea provides an opportunity also to undertake a small programme of associated sea ice research. The Expedition will also support meteorological and oceanographic research as well as a marine engineering research project.

4.4.1 Sea ice research

The Expedition will utilise the expertise of sea ice researchers including a sea ice modeller, through an arrangement with Drift+Noise. Drift+Noise GmbH is a start-up and spin-off company of Germany's Alfred Wegener Institute for Polar and Marine Research (AWI), with more than 15 years of operational experience in polar regions. The company provides support to stakeholders with operational ice information from models and satellites, by leveraging technology from polar research, geophysics, and remote sensing.

The Drift+Noise researchers on the Expedition will be accompanied by sea ice researchers from the Alfred Wegener Institute and two remote sensing specialists from the German Aerospace Centre.

The researchers will assist the Expedition in providing ice navigation support as well as undertaking a programme of pack ice / sea ice monitoring and measurements.

4.4.1.1 Sea ice measurements

To support the research, as well as to assist in locating ice floes that can support the sea-ice camps (if required), ice and surface snow thickness measurements will be undertaken using non-invasive remote sensing equipment operated from the main vessel and from towed sledges on the ice (Figure 18).

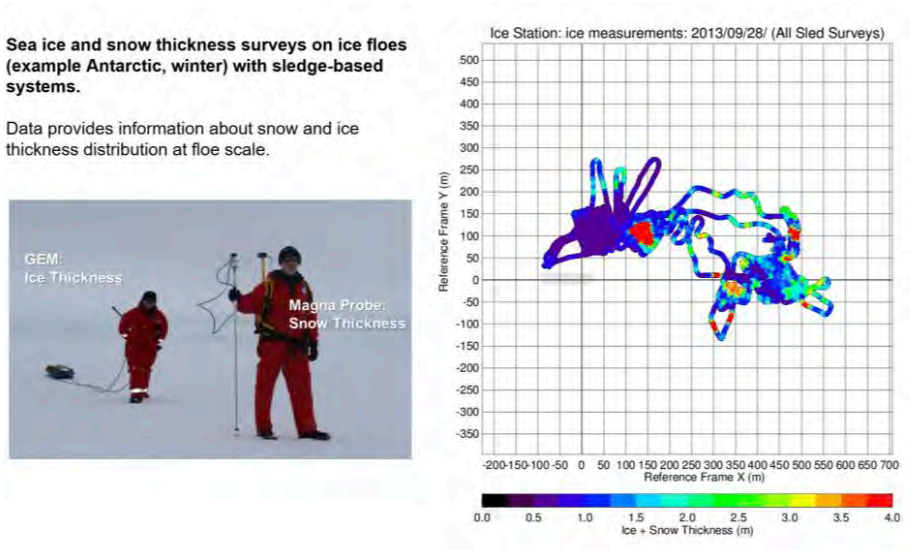

Figure 18. Sledge-based sea ice thickness and snow thickness measurements. Image: Alfred Wegener Institute.

In addition, a maximum of 150 sea-ice cores (1 to 5 metres long and 10cm wide) will be taken from selected ice floes using electric powered ice-coring devices as well as up to 400 snow samples (approximately 500ml each) (Figure 19).

Figure 19. Ice coring devices.Image: Alfred Wegener Institute

Further, up to four 'snow buoys' will be deployed to selected ice floes (Figure 20). The snow buoys are designed to measure the small-scale variability of snow thickness. For this purpose, each buoy is equipped with ultrasonic sensors that measure the distance to the surface. By calibrating it using the snow depth measured during deployment on the ice, it is possible to continuously calculate the change in snow depth. In addition, the air and surface temperature, as well as the air pressure are recorded. With a Jupiter 32 GPS module the position of the buoy is recorded. All recorded parameters are transmitted hourly via an Iridium antenna. Power is supplied by alkaline batteries (69 D cells).

The snow buoys will be left in place and will not be recovered. Eventually they will run out of power and stop transmitting. Once the ice floe melts the buoys will be lost to the marine environment.

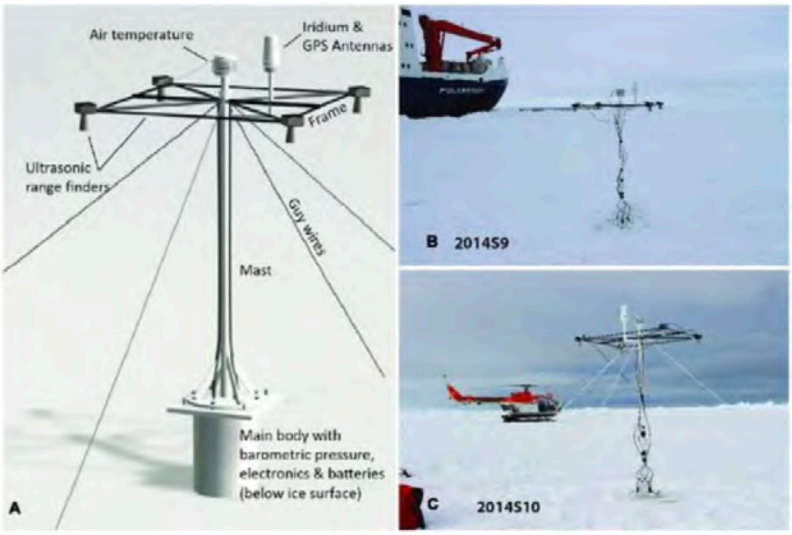

Figure 20. Snow and ice mass balance buoys deployed on to sea ice. Image: Alfred Wegener Institute.

4.4.3 Marine Engineering Research

Through an arrangement with Stellenbosch University (South Africa) and the University of Alto (Finland), space on-board the cruise will be offered for four engineering students to undertake a programme of monitoring of the vessel performance throughout the Expedition. The data gathering will be restricted to on-board measurements and there will be no releases to the environment or sampling from this research.

The marine engineering research is not formally part of the Expedition and will be approved by South African authorities. As such it is out of scope for this EIA, but it is noted here for completeness.

4.4.4 Meteorological and Oceanographic research

Through an arrangement with the South African Weather Service (SAWS), space on-board the cruise will be offered for a meteorologist and an oceanographer. Meteorological and oceanographic measurements will be recorded using on-board equipment throughout the cruise.

The research will also involve the release of several types of expendable research buoys and floats including:

- 12 x ARGO floats (Figure 21; https://argo.ucsd.edu/) to be deployed north of the sea ice zone
- 15 x Sofar Ocean Spotter buoys to be deployed north of the sea ice zone;
- 1 x SHARC prototype buoy to be deployed onto 'pancake ice' if possible.

Figure 21. Argo floats. Photo: Tamaryn Morris.

The research will also involve the release of 16 upper atmosphere meteorological balloons and attached radiosondes.

The meteorological and oceanographic research is not formally part of the Expedition and will be approved by South African authorities. As such it is out of scope for this EIA, but it is noted here for completeness.

4.4.5 Environmental aspects arising from the research programme

Environmental aspects that will or may arise as a result of the research programme that is 'in scope' for this EIA are:

a) Sampling of ice floes and the removal of ice cores and snow samples.
b) Ultimate loss of deployed snow buoys and oceanographic floats to the marine environment.

4.5 Remotely piloted aircraft

Remotely piloted aircraft (RPA) will be deployed in Antarctica during the Expedition for the purposes of assisting with in-ice navigation, supporting the deployment of ice camps and obtaining video and images for the outreach and education programme and for the making of a documentary.

The RPA to be used are:

- DJI - Mavic Mini, MTOW 249g - Aircraft ID: DEU2xu101660kk5o
- DJI - Mavic Pro 2 - S/N 163CGC9R0A6ENA
- DJI - Inspire 2 - S/N 09Y3GAC00SY014

They will be operated by trained and certified pilots James Blake (Director of Photography with Little Dot Studios) and Christian Katlein (Alfred Wegener Institute).

- James Blake - BNUC-S Pilots License- Over 500+ Successful flights including close flying to subjects and surroundings
- Christian Katlein - Certified pilot A1/A3 Open Subcategory, Pilot ID: DEU-RP-4s14vuqdp901

The SA Agulhas II carries its own DJI Phantom RPA for sea ice reconnaissance purposes.

4.5.1 Environmental aspects arising from the use of RPA

Environmental aspects that will or may arise as a result of the use of RPA are:

a) Noise and visual presence during flight operations;
b) Potential release to the environment if the RPA fail to return to the ship.

5. Alternatives

An EIA needs to include a consideration of both the proposed activity and possible alternatives so that a decision maker can more easily compare the potential impacts on the Antarctic environment.

Examples of alternatives for consideration include: use of different locations or sites for the activity; opportunities for international cooperation; use of different technologies, in order to reduce the outputs (or the intensity of the outputs) of the activity, and different timing for the activity.

The alternative of not proceeding with the proposed activity should always be included in any analysis of environmental impacts of the proposed activity.

5.1 Do not proceed

The 'do not proceed' option requires consideration in all environmental impact assessments.

For this Expedition, not proceeding would clearly eliminate all anticipated impacts no matter how significant (or insignificant) they are assessed as being.

However, not proceeding with the Expedition would be a missed opportunity to undertake a compelling search for and survey of the wreck site of Sir Ernest Shackleton's Endurance, which has not been located since it sank in 1915.

A detailed visual and acoustic survey of the wreck and associated artefacts will support measures taken by the Antarctic Treaty Parties to further protect and manage the Historic Site.

The state-of-the-art technology that is planned to be utilised during the Expedition is exceptionally rare in an Antarctic context and beyond the scope of most national Antarctic programmes. Overall, the Expedition is a compelling opportunity to undertake a programme of pioneering maritime archaeology.

Consequently the 'do not proceed' option was rejected.

5.2 Alternative vessels

For the Weddell Sea Expedition 2019, two alternative ice breaking research and resupply vessels were identified as options to support the Expedition; the Russian flagged *MS Murmansk* and the Swedish flagged *Oden*. These vessels were briefly reconsidered for the current Expedition.

5.2.1 MS Murmansk

MS Murmansk ('ледокол Мурманск'; Figure 22) is an icebreaking vessel owned and operated by Rosmorport; a Russian Federal State Unitary Enterprise. The *MS Murmansk* was built in 2015 at the Arctech Helsinki Shipyard in Finland.

The vessel is 120m long with a draught of 8.5m and a deadweight tonnage of 5,370 tons. It is powered by four 6.75 MW diesel-electric engines and has a forward helicopter deck. *MS Murmansk* is classified by the Russian Maritime Register of Shipping as ice class 'Icebreaker 6'. The vessel is able to operate in temperatures as cold as -40°C and has a maximum icebreaking capability of 1.5 m.

Although the MS Murmansk is a more powerful ice-breaking vessel than the *SA Agulhas II*, and may offer a slightly greater chance of reaching the primary research target area, it does not have the same capability to support marine research and lacks, for example, the moon pool that is available on the *SA Agulhas II*.

Consequently, the MS Murmansk was ruled out as an option.

Figure 22. Russian icebreaker Murmansk. Source: http://www.cruisemapper.com/ships/Murmansk-icebreaker-1752

5.2.2 Oden

The *Oden* is a large Swedish icebreaker built and owned by the Swedish Maritime Administration (Figure 23). The vessel was built in 1988 by the Gotaverken shipyard in Arendal, Sweden.

Oden is 108m long with a draught of 8.5m and a deadweight tonnage of 4,906 tons. It is powered by four 4.5 MW diesel-electric engines and has an aft helicopter deck. *Oden* is classified by Det Norske Veritas (DNV) as Polar-20 icebreaker. The vessel is able to break ice up to 1.9m thick at 3 knots and has undertaken several Arctic and Antarctic expeditions.

Although a capable alternative to the *SA Agulhas II*, the *Oden* was unavailable for charter over the planned period of the Expedition.

Figure 23. The Swedish icebreaker Oden pictured in McMurdo Sound, Antarctica in January 2008. Source: http://www.navy.mil/

It is also noted that the *SA Agulhas II* has now demonstrated its ability to access the Weddell Sea and support a programme of subsea survey and research in the area. This coupled with the experience of the Master, Ice Pilot and crew from the Weddell Sea Expedition 2019 make the *SA Agulhas II* the preferred vessel for the Endurance22 Expedition.

5.3 Alternative timing

The environmental impacts of an activity may be reduced or mitigated by undertaking it at a different time. For example, there are seasonal differences in the sensitivity of wildlife to disturbance depending upon the stage of the breeding cycle.

The window of opportunity for undertaking any field research in Antarctica is relatively small and largely confined to the period between November and March; though this reduces with increasing latitude.

The primary factor determining the timing of marine research cruises in Antarctica is sea ice. Research cruises need to be planned during periods of anticipated sea ice minima to allow access to target locations and offer the least disruption to the deployment of research equipment.

As discussed in Section 6.4, sea ice in the Weddell Sea demonstrates significant variability within and between seasons, but generally reaches its minimum coverage in February (Figure 32).

This Expedition is entirely marine and ship-based and requires sea ice to be at its minimum to improve the chances of accessing the target search area.

Additionally, an assessment of the impacts that are likely to arise from the planned activities suggests that none are likely to be mitigated by adjusting the timing of the Expedition. Encounters with wildlife are anticipated to be occasional and no activities will be undertaken close to any known breeding locations.

Accordingly, there are no alternative timing options if the Expedition objectives are to be afforded the best chance of being achieved.

5.4 Reduced scale of operation

Reducing the scale of an activity may also assist in mitigating environmental impacts by reducing the overall environmental exposure to the outputs from the activity.

5.4.1 Reduce the temporal scale

Reducing the duration of an activity may mitigate the environmental impacts by reducing the environmental exposure to a particular output from the activity. For example, the impacts of a direct discharge to air, land or water will be lessened by reducing the duration of the discharge.

This Expedition is planned for a period of 35 (up to 45) days. The only impacts that have been identified that are likely to be mitigated by reducing the duration of the Expedition are the discharges from the *SA Agulhas II*, i.e. exhaust emissions to air and waste water discharges to the marine environment. These discharges are relatively continuous throughout the Expedition and would be reduced by shortening the overall period of operation. However, these discharges are assessed as being no more than minor or transitory (Section 7.5).

All other potential or unavoidable impacts are unlikely to be reduced by a change in the temporal scale of the Expedition. Deployment of the subsea vehicles and the marine sampling work are all short duration activities in themselves (measured in hours only).

Further, the location of the primary target survey area in the remote western part of the Weddell Sea requires adequate time to reach the site, as well as adequate time on site to achieve the Expedition's objectives. Reducing the period of operation increases the risk of not achieving the objectives and adding undue pressure on the subsea survey team.

It is therefore concluded that the benefits of the 35 day cruise are likely to significantly outweigh the minor and transitory consequences of the discharges from the vessel to air and water that will occur.

Consequently, the option of reducing the duration of the Expedition was rejected.

5.4.2 Reduce the spatial scale

Minimising the spatial extent of a proposed activity may assist in mitigating impacts, for example by avoiding sensitive areas or constraining an activity to an already impacted site.

The spatial coverage of this Expedition will on the one hand be significant. Passage across the Southern Ocean, the northern part of the Weddell Sea and down to the primary survey area could cover a distance in the region of 6,200km with a similar return distance. The subsea search vehicles have the potential to survey several 10s of Km^2 if successfully deployed beneath the sea ice.

However, the impacts from the passage of the vessel and the deployment of the subsea vehicles are considered to be no more than, and for the majority of the anticipated outputs, less than minor or transitory (Section 7.5). The survey work to be conducted by the subsea vehicles is entirely non-invasive.

Accordingly, it is concluded that there is no measurable environmental benefit to be gained from attempting to reduce the spatial scale of the Expedition.

5.4.3 Reduce the number of people

The Expedition currently comprises 60 people including the Expedition leader, marine archaeologist, specialist engineers and technicians, field staff, air crew, education and outreach personnel and scientists. If the numbers were reduced this could reduce the volume of wastes generated on-board and emissions to the marine environment. However, reducing the number of personnel on the ship is unlikely to have any measurable environmental benefit in that discharges from the vessel are likely to remain largely the same; other than perhaps a minor reduction in the volume of sewage discharge.

Expedition personnel have been selected based on their particular expertise in order to meet the Expedition objectives. Reducing the number of people would mean losing specific skills or expertise and directly compromise the objectives.

Accordingly, it is concluded that reducing the number of people on the Expedition will have no environmental benefit but would have a significant negative impact on the potential for the Expedition to achieve its research objectives.

5.5 Alternative launch options for the subsea vehicles

As recorded in section 4.3.2.2 above, the Expedition has designed and developed equipment that allows for alternative launch options for the subsea vehicles, depending upon the ice conditions encountered.

The preferred launch option will be directly from the main support vessel. If the density of the pack ice precludes this then the option of deploying the subsea vehicles through the ice will be pursued, either in proximity to the main vessel or at some distance from the main vessel.

The environmental aspects do differ between the deployment options, with aspects associated with aircraft operations arising if the heavy ice scenario is pursued for example. However, the final decision as to which launch option to use will be influenced by operational requirements at the time so as to provide the best opportunity to achieve the Expedition's objectives. Controls to minimise environmental impacts will be employed accordingly.

As such all three alternatives for launching the subsea vehicles are retained at this stage in the planning process, with none being rejected.

Having considered a range of alternatives, it was concluded that the current operational plans have the best chance of balancing the achievement of the Expedition's objectives, whilst minimising the environmental impacts.

6. Description of the Existing Environmental State

6.1 Introduction and early discoveries

The Weddell Sea covers an area of approximately 2.8 million km^2 (Figure 24). It is fringed to the east by the coasts of Dronning Maud Land and Coats Land and the Riiser-Larsen, Stancombe-Wills and Brunt ice shelves, to the South by the Filchner and Ronne ice shelves, and to the west by the eastern coast of the Antarctic Peninsula and the Larsen C ice shelf.

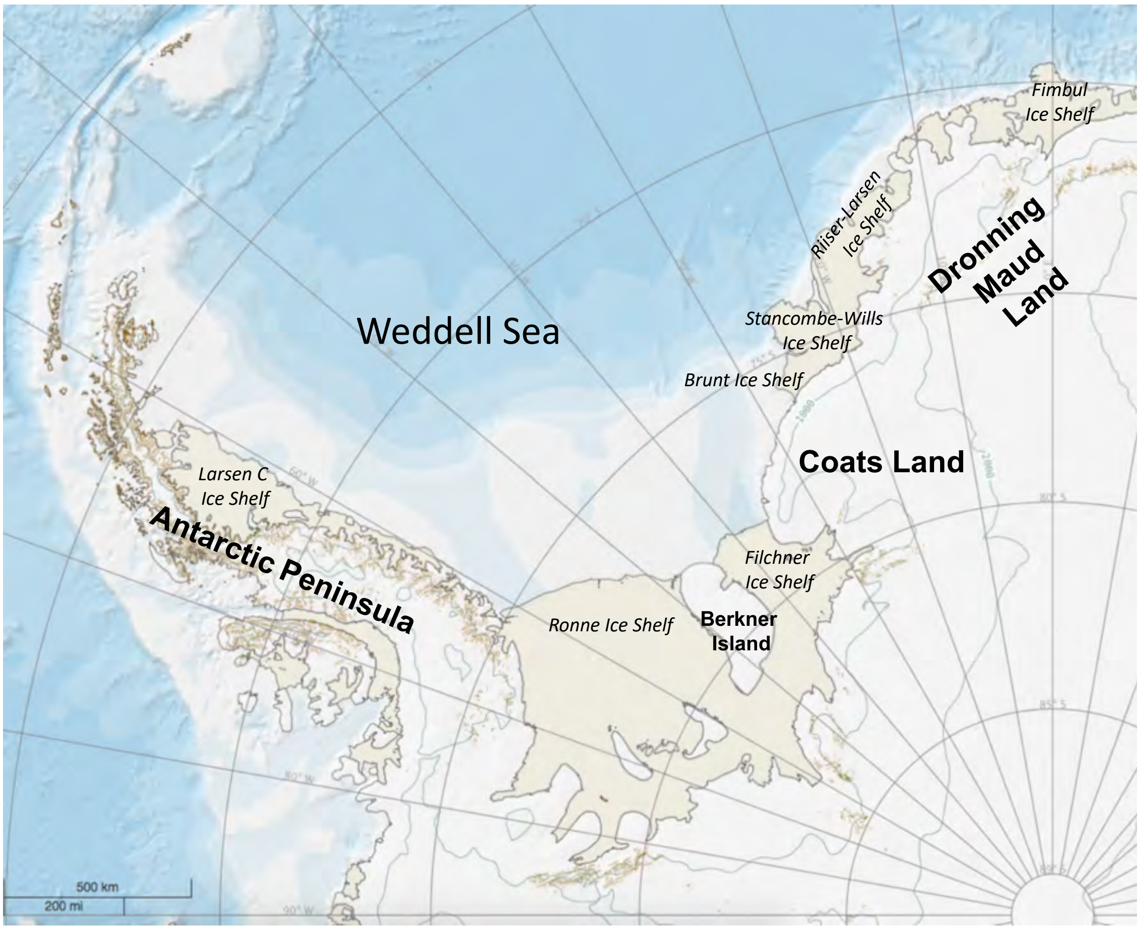

Figure 24. Weddell Sea.

The Weddell Sea was first discovered in 1823 by British sailor and seal hunter James Weddell (Figure 25) who at the time was commanding the brig *Jane.* In search of new locations to prosecute seal stocks, Weddell sailed to 74°15'S; 34°16'45"W – a position further south than any vessel previously. At the time Weddell assumed that the sea continued to the South Pole.

Additional early expeditions to the area included the Scottish Antarctic Expedition led by the biologist William S. Bruce, which in 1903 reached Coats Land on the eastern side of the Weddell Sea.

In 1911/12 the Second German Antarctic Expedition under Wilhelm Filchner was able to prove the southern limits of the Weddell Sea. The intended construction of a station building failed, as the construction area near the ice shelf edge broke off and drifted away. Filchner's vessel overwintered in the central part of the Weddell Sea captured in densely packed sea ice. Observatory buildings as well as stables for horses and dogs were erected on sea ice nearby. By tracking the ships drift they got a first hint of the large current system now known as the Weddell Sea Gyre.

Figure 25. James Weddell. Portrait by P. G. Dodd (British artist, active 1825-1836) - Scan from Gurney 1998. Source: Public Domain, https://commons.wikimedia.org/w/index.php?curid=66451907

In 1914 an expedition under the command of Sir Ernest Shackleton (1874-1922) entered the Weddell Sea with the aim of exploring the region between the Ross Sea and Weddell Sea. But Shackleton was not able to reach the Filchner Ice Shelf. His ship the *Endurance* was crushed by pack ice forcing an incredible journey of survival of the expedition's personnel across pack ice and open water to the relative safety of Elephant Island in the northern Antarctic Peninsula (see Section 4.3.1 in this EIA).

The interwar period was mainly marked by activities of huge European whaling fleets which extended into the Weddell Sea. Only in 1947 did the American Finn Ronne (1899-1980) manage to survey the full southern limits of the Weddell Sea though by aircraft. U.S. American activities after World War II resulted in a first comprehensive description of the whole Antarctic Continent, but it was not until 1949/52 that a Norwegian-British-Swedish scientific expedition overwintered in the Weddell Sea region in the area of the present German Neumayer Station (Figure 26).

Currently, several active research stations are located in the Weddell Sea region of Antarctica (Figure 26).

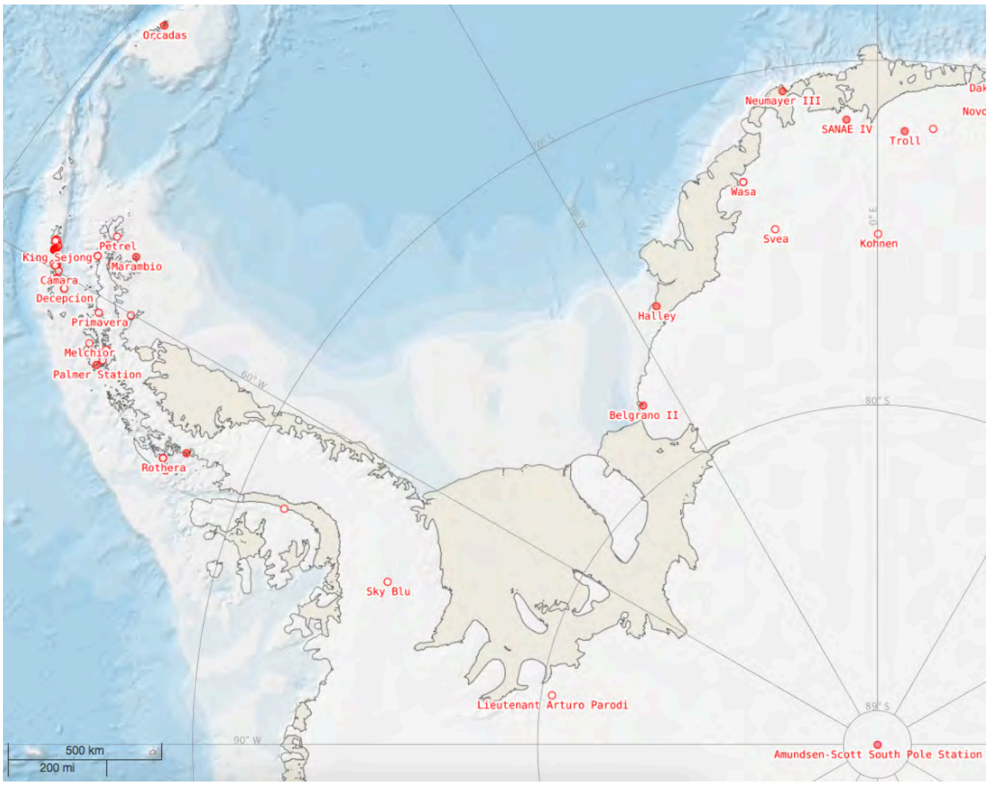

Figure 26. Antarctic research bases in the Weddell Sea region. Source: Antarctic Digital Database and COMNAP.aq

6.2 Bathymetry and Geomorphology

Water depths in the Weddell Sea range from about 100 m at the edge of ice shelves to about 5,300m in the Weddell Sea abyssal plain (Figure 27). Prominent bathymetric features are the relative narrow, complex structured shelf and steep slope in the eastern Weddell Sea, and the broad shelf in the southern Weddell Sea that extends up to 500km from the coast and is cut through by the deeper Filchner Trench (Arndt et al., 2013; Figure 27).

During former glaciations Antarctica's ice sheets extended mostly to the shelf break in the Weddell Sea (Hillenbrand et al., 2014). They shaped the seafloor and created typical glacial-geomorphological features like mega scale glacial lineations or grounding zone wedges on the shelf (Larter et al., 2012). Since the last ice sheet retreat icebergs continuously scour the mostly shallower outer parts of the shelf that is structured in gullies and shows structures of submarine landslides (Gales et al., 2014).

The Western and central part of the continental slope consists of a broad flat ridge terminating at the shelf followed by slopes of steep (around 3%) and lower slope values (1%), respectively, and adjacent canyons (approximately 40-70km width) in perpendicular positions to the slope classified as depressions. Only the Eastern part of the continental slope features a narrow ridge with slope values around 15% that separates the flat ridge from the complex pattern of troughs, flat ridges, pinnacles, steep slopes, seamounts, outcrops, and narrow ridges (structures approximately 5-7km wide) (Jerosch et al., 2016).

The abyssal plain of the Weddell Sea up to 5,300m depth is an extensive flat area of about 2Mkm2 with slopes less than 0.4°, with alternating geomorphic features such as troughs, local depressions, plateaus, narrow ridges with steep slopes up 40° to outcrops and seamounts.

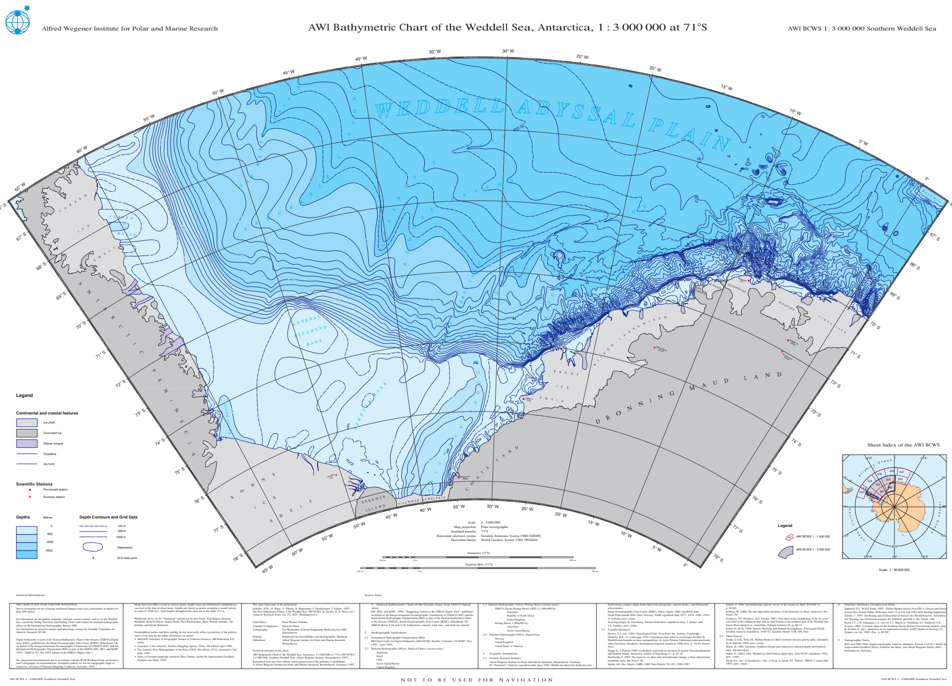

Figure 27. Bathymetric chart of the Weddell Sea. Source: Schenke, 1997.

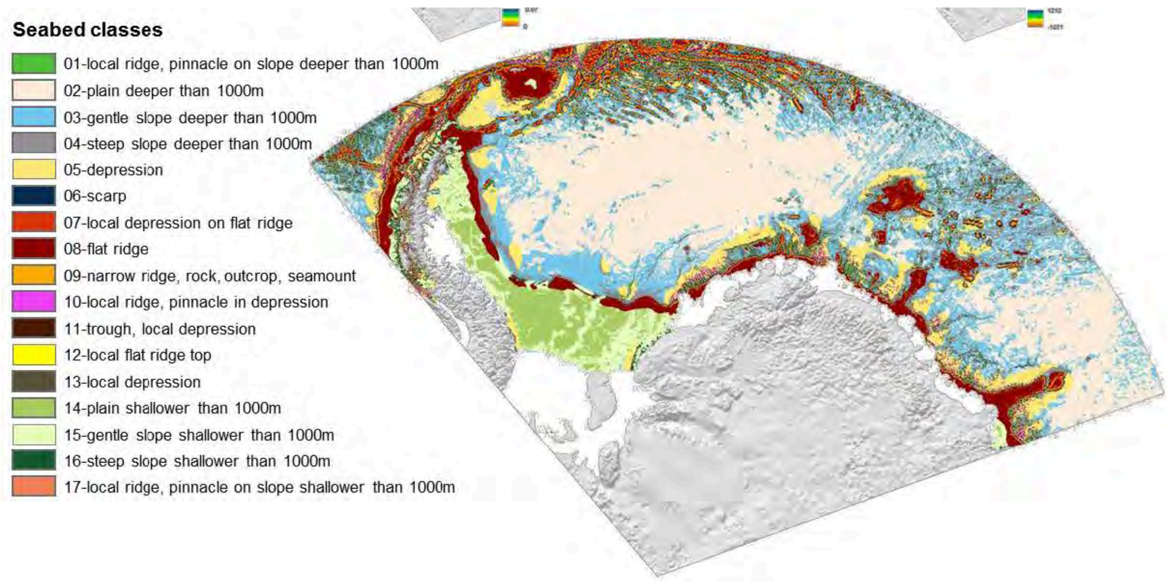

Figure 28. Seabed classification of the Weddell Sea. Source: Jerosch et al., 2016.

The seabed of the Weddell Sea has been classified into 17 classes demonstrating the diversity of the benthic 'landscape'. It includes glacially carved shelf, intensely structured continental slope and the abyssal plain comprising a range of habitat types (Figure 28; Jerosch et al, 2016).

Surface sediment types vary from slightly gravelly muddy sand across the shelf to gravely muds on the slope and slightly gravelly muds across much of the abyssal plain (Figure 29; Jerosch et al, 2016).

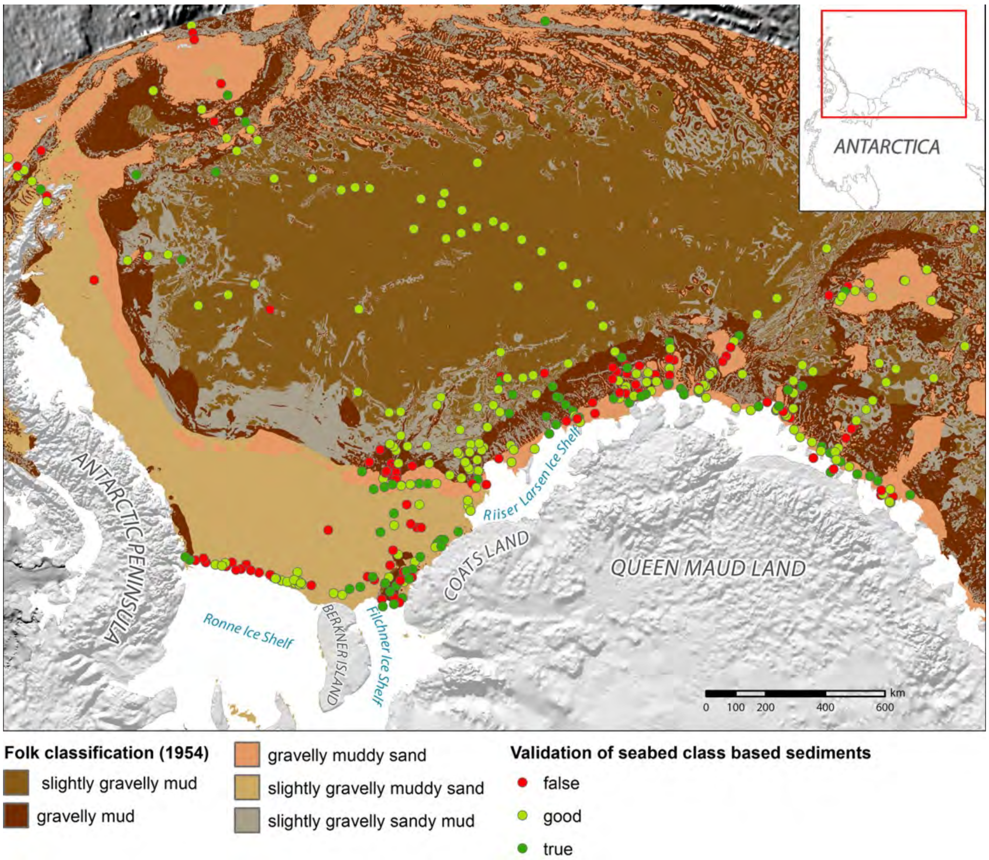

Figure 29. Sea bed morphological classification. Source: Jerosch et al, 2016.

6.2.1 Benthic conditions in the area of the *Endurance* wreck

Dowdeswell et al (2020) report that In the area of the Endurance wreck, the sea floor appears almost flat in the swath-bathymetric data, with a slope angle of no more than 0.3° and a water depth of ~3000 m. The wreck is well below the maximum depth of iceberg keels and will not have been damaged by ice-keel ploughing. The wreck has probably been draped by only a few centimetres of fine-grained sediment since it sank in 1915. They suggest that the wreck of *Endurance* is unlikely to have been disturbed by recent submarine mass-wasting events and that it is being buried only very slowly by modern sedimentation. With cut-down masts and yards trailing behind, drag would have been imposed on the sinking hull, probably reducing the seabed impact velocity of Endurance. Dowdeswell et al (2020) assume that *Endurance* settled on the seabed keel-first, without significant penetration of sea-floor sediments.

6.3 Oceanography

The Southern Ocean is an important driver of Earth’s climate as it transports large quantities of heat, salt and dissolved gases, and supplies ~85% of the global ocean’s nutrients (Keffer and Holloway, 1988; Sarmiento et al. 2004; Lee et al. 2007).

The circulation in the Weddell Sea is dominated by the cyclonic (clockwise rotating) Weddell Sea

gyre (Figure 30) that below the surface shows a double-cell structure with centres on both sides of the Greenwich Meridian (Beckmann et al., 1999). The southern branch of the gyre is part of the circumpolar slope front current, following a water mass boundary that separates cold shelf waters (-1.85°C) from warmer open ocean waters (0.5°C to 0.7°C) and coincides with the position of the continental shelf break.

The northern branch is guided by the topography of the South Scotia Ridge, the American Antarctic Ridge and the Mid-Ocean Ridge interacting at most places directly with the Antarctic Circumpolar Current (ACC).

The Weddell Sea represents a point of origin in the Southern Ocean, where water masses form and interact with the atmosphere (Muench and Gordon, 1995; Talley et al. 2011), and where deep and bottom water masses are formed to participate in the global thermohaline circulation. The characteristics of water masses exported from the Weddell Sea are the result of complex interactions between surface forcing, significantly modified by sea ice processes, ocean dynamics at the continental shelf break and slope, and sub-ice shelf water mass transformations (Beckmann et al., 1999).

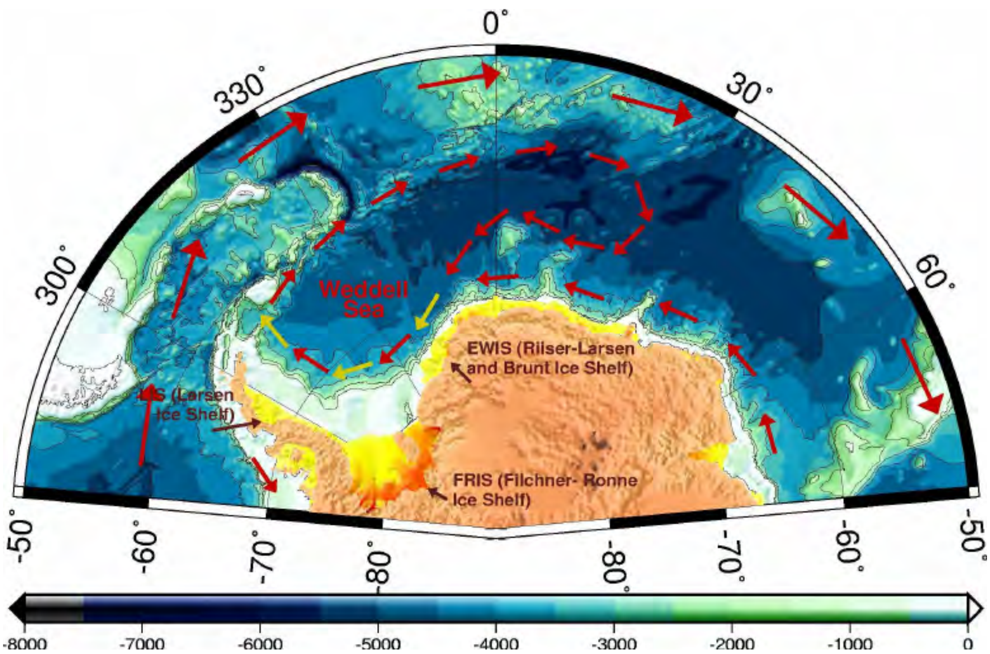

Figure 30. Weddell Sea gyre (small red arrows), showing also the areas of mixing of ice-shelf water (yellow arrows) and the Antarctic Circumpolar Current (ACC; large red arrows). Water depths are in metres. Source: Thoma et al, 2005.

The Weddell Sea is the major source of Antarctic Bottom Water (AABW), contributing about 40% of the total production throughout the Southern Ocean (Meredith 2013). The dense waters are formed through air–sea ice interaction on the continental shelves and below the ice shelves in the southern Weddell Sea.

Processes occurring beneath the Filchner–Ronne Ice Shelf (FRIS) and on the adjacent continental shelf produce two water masses, high-salinity shelf water (HSSW) and ice-shelf water, that are dense enough to descend the continental slope and contribute to the formation of Weddell Sea Deep Water (WSDW) and Weddell Sea Bottom Water (WSBW), precursors to Antarctic Bottom Water (AABW).

HSSW is formed from modified warm deep water (MWDW) and other shelf waters on the continental shelf through cooling and brine rejection (Nicholls et al., 2009). It flows both northward, participating directly in deep water formation as it mixes with warm deep water (WDW) and MWDW at the shelf break (Gill, 1973), and southward into the FRIS cavity (Darelius et al., 2014).

The number of direct observations of these processes is very limited, and, as a consequence, knowledge about interannual and seasonal variability in the production of these waters is relatively poor (Farbach et al., 2011; Darelius et al., 2014; Kerr et al., 2017).

The Weddell Sea has been deemed to have the clearest water of any sea. Researchers from the Alfred Wegener Institute, Germany recorded a Secchi disc visible at a depth of 79.86 metres (262 ft) on 13 October 1986, asserting that the clarity corresponded to that of distilled water (Gieskes et al., 1987).

6.4 Sea ice

The seasonal cycle of sea ice cover in the Southern Ocean represents one of the most pronounced signals of variability in the Earth's climate system. This is true also of the Weddell Sea, which is almost entirely covered by thick, partly immobile sea ice in winter, but returns to broken ice conditions across most of its area in summer (Figure 31).

Figure 31. Weddell Sea sea ice in summer. Image: British Antarctic Survey

Average winter sea ice cover in the Weddell Sea has been estimated at approximately 4,480,000km2, which retreats to approximately 1,420,000 km2 in summer (Teschke et al, 2016). Maximum sea ice extent occurs in September and minimum ice cover in February (Figure 32).

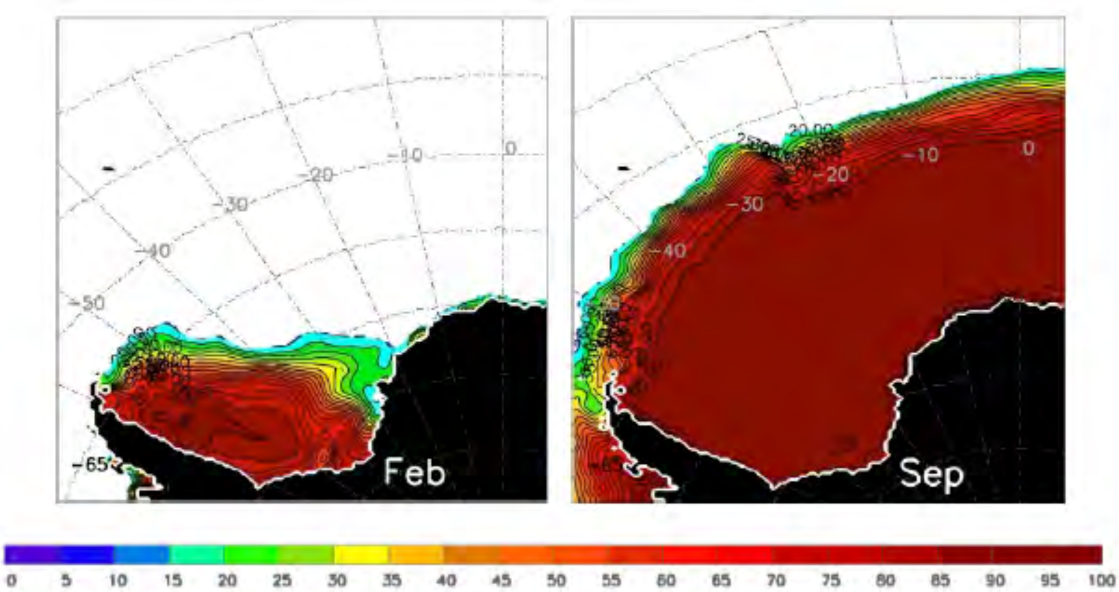

Figure 32. Long-term averaged sea ice concentrations (1979 - 2013) in percent at sea ice minimum (February) and maximum (September). Source: Teschke et al., 2016.

Typical ice thickness in the central Weddell Sea is approximately 1.5m in winter (Behrendt et al., 2013). However, mean ice thickness can increase to 4m and more in areas where convergent drift causes a lot of sea ice deformation and the extensive formation of pressure ridges. Maximum ice thickness is usually found in the western Weddell Sea along the eastern side of the Antarctic Peninsula.

However, superimposed upon the mean seasonal cycle is a substantial interannual variability in sea ice extent (Turner et al., 2014).

Across the Southern Ocean as a whole the inter-annual variability of the total Antarctic sea ice extent is large (approximately 106 km2). Over the period 1979–1990, the total Antarctic sea ice extent decreased at a rate of -153,000km2 per decade (approximately 1.3% per decade). This decrease seemed consistent at the time with the increasing concentrations of greenhouse gases and the loss of ice in the Arctic. However, from about 1990, there has been an overall increase in Antarctic sea ice extent with record annual mean extents in 2003, 2008 and 2013 attributable largely to changing atmospheric forcing conditions. Within these longer-term trends the Indian Ocean and Western Pacific Ocean sectors of the Southern Ocean have experienced an increase in sea ice extent in all seasons. However, the Weddell Sea sector is anomalous in having experienced an increase in sea ice extent in the summer and autumn, and a decrease in the winter and spring (Turner et al., 2014).

Additionally, there would appear to be a tendency towards a redistribution of sea ice, especially in summer, from the north-western to the south-eastern Weddell Sea (Teschke et al., 2016).

Formation of sea ice plays a significant role in deep and bottom water formation (Haid and Timmermann, 2013). The importance of these processes for the global thermohaline circulation and the difficulties in directly observing them demands further field studies to assist understanding of the physical processes in this remote area (Teschke et al., 2016).

6.5 Glaciology / Ice shelves

As recorded above (Section 6.1), the Weddell Sea is fringed with a series of ice shelves to its east, south and west (Figure 26).

Ice shelves play a key role in restraining the outflow of upstream grounded ice, and loss of ice shelves can lead to accelerated outflow which in turn leads to sea level rise.

Understanding ice mass balance across Antarctica has been of increasing importance in the last few decades to better understand the factors causing ice loss from the continent that contribute to global sea level rise. Recent satellite measurements show that the non-floating, grounded, ice mass around Antarctica is generally decreasing and significantly so on the western Antarctic Peninsula and Bellingshausen and Amundsen sea areas (Figure 33; Paolo et al., 2015).

The ice shelves that are currently experiencing the most rapid thinning are in the Amundsen and Bellingshausen seas where melting exceeds calving due to the influence of relatively warm Circumpolar Deep Water (CDW) on the heat content within these ice shelf cavities (Jenkins and Jacobs, 2008; Padman et al., 2012; Jenkins et al., 2010; Schmidtko et al., 2014). The large ice shelves in other sectors (including the eastern and southern Weddell Sea ice shelves) that are not directly influenced by CDW inflows are closer to steady state, suggesting that the transport of ocean heat under these ice shelves has not changed significantly over the observational record (Mueller, et al., 2018).

On the Antarctic Peninsula, ice-shelf retreat has been assessed as retreating by 18% over 50 years (Cook and Vaughan, 2010), and large sections of the Larsen-A, Larsen-B, and the Wilkins ice-shelf collapsed in a matter of weeks in 1995, 2002, and 2008, respectively. Geological evidence suggests that ice-shelf decay of this magnitude is not unprecedented, however prior to 2002 the Larsen-B ice shelf remained intact for the last 11,000 years. While Antarctic ice shelves are in direct contact with both the atmosphere and the surrounding oceans, and thus subject to changes in environmental conditions, they also go through repeated internally-driven cycles of growth and collapse. A calving event is therefore not necessarily due to changes in environmental conditions and may simply reflect the natural growth and decay cycle of an ice shelf (Hogg and Gudmundsson, 2017).

On the Larsen-C ice shelf, ice thinning has been sustained at a rate of -3.8m per decade for the past 18 years (Paolo et al., 2015).

On the Larsen-C ice shelf, a long >200km crack grew, separating a plateau of ice four times the size of London (~6,000km2) from the Antarctic Peninsula. When it calved on 12 July 2017 a giant tabular iceberg was formed, the largest from the Larsen-C since the 1980s, reducing the ice shelf to its minimum extent since satellite observations began. The crack emerged over a decade ago in a large crevasse field formed as the ice shelf flows towards the Gipps ice rise, a small island that anchors and provides structural support to the southern edge of the ice shelf. However, in 2014 the crack started to advance across the ice shelf, growing episodically in bursts of up to 20km at a time at an increased rate of propagation. A secondary spur forked off the main fissure on 1 May 2017. This fracture developed into a network of cracks which provided the final pathway to the ice front, breaking through the remaining 4.5km-wide ice bridge on 12

July 2017. The vast size of the resulting iceberg, combined with the rapid environmental change observed on the Antarctic Peninsula, raises an important question about what impact this calving event will have on the stability of Larsen-C, the largest remaining ice shelf on the Antarctic Peninsula (Hogg and Gudmundsson, 2017).

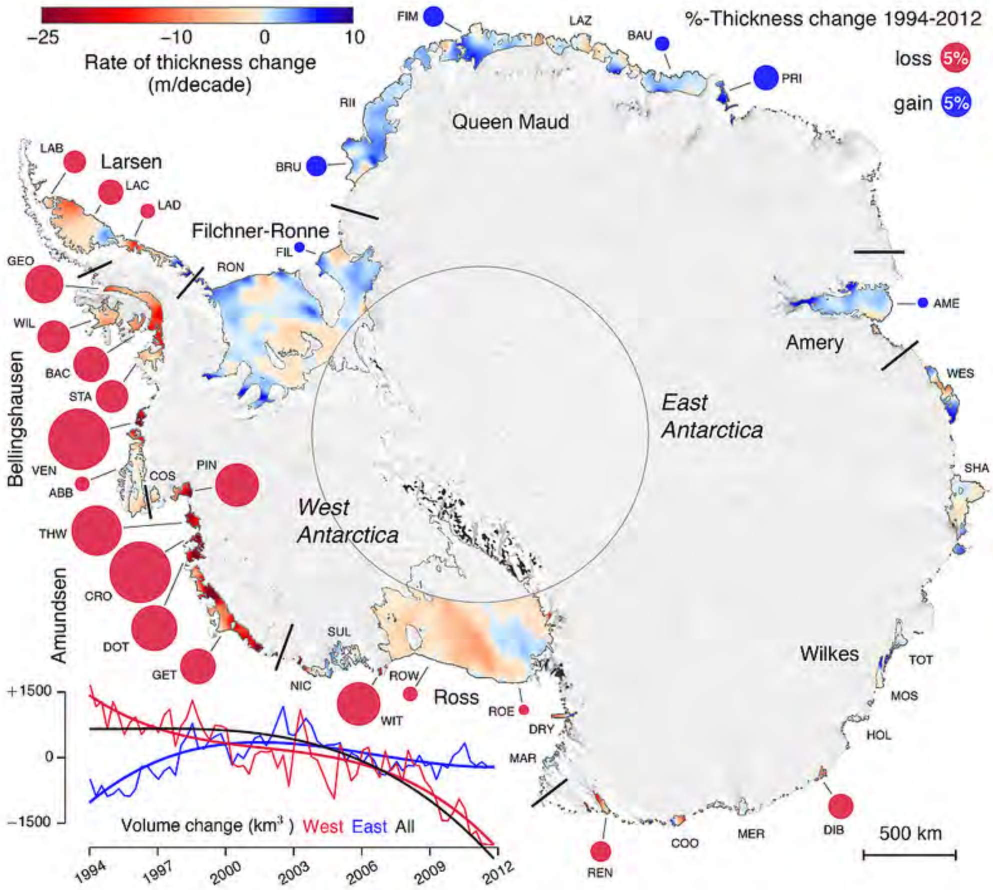

Figure 33. Eighteen years of change in thickness and volume of Antarctic ice shelves. Rates of thickness change (m/decade) are color-coded from -25 (thinning) to +10 (thickening). Circles represent percentage of thickness lost (red) or gained (blue) in 18 years. Background is the Landsat Image Mosaic of Antarctica (LIMA). Source: Paolo et al., 2015.

6.6 Ecosystems

6.6.1 Pelagic ecosystem

The Weddell Sea has been rarely sampled largely due to the challenges of accessibility caused by extensive sea ice even during summer months. The majority of scientific sampling (pelagic and benthic) has been undertaken in the northern and eastern areas of the Weddell Sea (Figure 34; Teschke et al., 2016).

Nonetheless, descriptions across broader areas of the Weddell Sea are likely to provide adequate insight into the environmental conditions and biodiversity of the primary survey area.

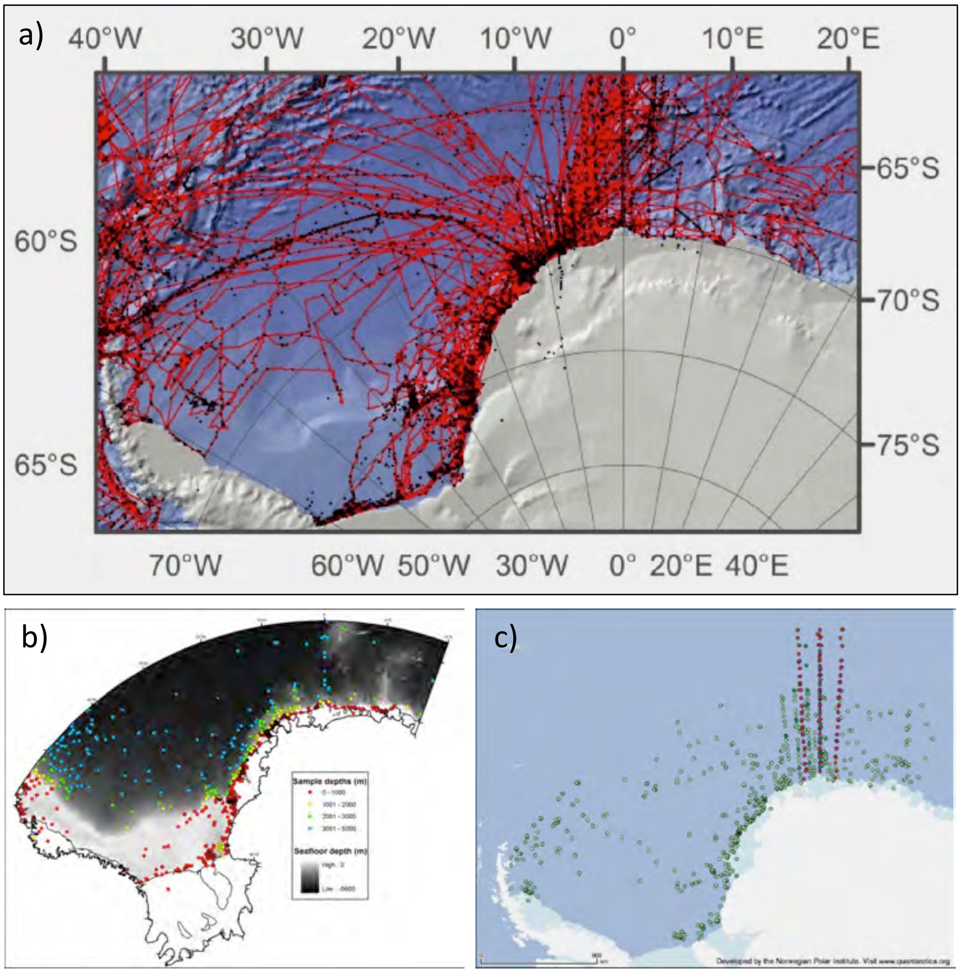

Figure 34. Overview of sampling in the Weddell Sea showing a) track lines of cruises by the German Polar research vessel Polarstern from 1982 to 2014; b) benthic sampling locations, and c) Locations of Weddell Sea zooplankton samples included in the SCAR Biogeographic Atlas of the Southern Ocean (green) as well as samples collected through LAKRIS expeditions 2004-2008 (red) (source: biodiversity.aq). Source: Teschke et al., 2016).

The pelagic environment of the Weddell Sea is heavily influenced by the Weddell Sea Gyre and sea ice cover (Grant et al., 2006; Siegel et al., 1992), resulting in a dynamic habitat due to significant seasonal fluctuations.

Macro-zooplankton species richness in the epipelagic layer of the Weddell Sea ranges between 22 species (Fischer et al., 2004) and 53 species (Siegel et al., 1992), with significant latitudinal zonation. Boysen-Ennen et al. (1991) reported three distinct zooplankton communities in the seasonally and permanently ice-covered parts of the Weddell Sea: an oceanic community, a north-eastern shelf community and a southern shelf community. The latter, likely to be most typical of the primary research target area for this Expedition, was low in species abundance and biomass, with ice krill (*Euphausia crystallorophias*) and copepods predominating.

In general, copepods rather than Antarctic krill dominate the zooplankton community in abundance, and often also in biomass. Sea ice is an important factor controlling zooplankton distribution and productivity. Krill abundance seems to be relatively low in high latitudes of the Weddell Sea and the Southeast Atlantic when compared with long-term results from west of the Antarctic Peninsula and Scotia Sea region (Teschke et al., 2016).

Meso-zooplankton species richness is typically higher than macro-zooplankton. In the north-western and north-eastern Weddell Sea, species numbers of calanoid copepods ranged between 55 and 70 (Schnack-Schiel et al., 2008). The copepod *Calanus propinquus*, the siphonophore *Diphyes antarctica*, and the euphausiids Antarctic krill (*Euphausia superba*) and *Thysanoessa macrura* show a wide distribution across the entire Weddell Sea area.

Most studies on pelagic fish in the Weddell Sea have been carried out in the southern part and on the north-eastern shelf, including the Lazarev Sea (to the north east of the Weddell Sea (see for example: Flores et al., 2008, Hubold, 1991, White and Piatkowski, 1993).

Mintenbeck and Krägefsky (2012) report on a more recent pelagic survey in the area of the Larsen ice shelves. They noted that net catches in the Larsen A and B ice-shelf areas were dominated by *Gymnodraco acuticeps, Pleuragramma antarcticum, Trematomus eulepidotus* and *T. scotti*. *G. gibberifrons* accounted for 37% of total biomass in Larsen A but was absent in Larsen B. The fish community in Larsen C was similar to Larsen B, with *Chaenodraco wilsoni*, the cryopelagic fishes *Pagothenia borchgrevinki* and *T. hansoni*, additionally contributing more than 10% each to the overall biomass.

In the area of Larsen C Mintenbeck and Krägefsky also reported juvenile specimens of *P. borchgrevinki* associated with swarms of *Euphausia crystallorophias* in about 100m water depth.

Overall, species diversity is low in areas adjacent to the Larsen ice shelves compared to the eastern Weddell Sea shelf.

Knowledge about squid in the Weddell Sea is extremely limited with data of squid species largely obtained from stomach samples of Emperor penguins and Weddell Seals, where the presence of squid beaks is used to identify species preyed upon. Such studies (largely confined to the eastern Weddell Sea) have demonstrated the presence of *Psychroteuthis glacialis, Kondakovia longimana, Alluroteuthis antarcticus*, and *Gonatus antarcticus* (Piatkowski and Putz, 1994; Plotz et al., 1991).

6.6.2 Benthic ecosystem

Macrobenthic communities of the Weddell Sea shelf are characterised by high spatial heterogeneity in biodiversity, species composition and biomass at all spatial scales ranging from meters to hundreds of kilometres (Gutt et al., 2013a). The most conspicuous community is that dominated by suspension feeders (Gili et al., 2006) comprised of glass-sponges, demosponges, solitary and colonial sea-squirts, coral-related cnidarians or erect soft or calcified bryozoans. In such communities extremely high biomass can be found (Barthel, 1992; Gerdes et al., 1992).

Additionally, communities dominated by mobile animals such as ophiuroids or the generally rare mobile holothurians of the deep-sea type and infauna can also be observed. Boundaries between all such assemblages are mostly not discrete, though a decrease in the biomass of sessile suspension feeders coincides with an increase in relative abundance of mobile and infaunal animals (Galéron et al. 1992).

For all these communities an estimation based on extrapolations revealed up to 14,000 macrobenthic species, which is high compared to known estimations for comparable areas in the Arctic and temperate seas but low compared to the deep-sea and coral reefs (Teschke et al., 2016).

Despite high heterogeneity, a clear decrease of biomass and abundances with increasing water depth in the Weddell Sea exists, though the depth at which this decline becomes most obvious can vary between approximately 250 and 450m (Teschke et al., 2016).

Iceberg scouring plays a key role in benthic community development, particularly in the South-eastern Weddell Sea. When icebergs run aground they devastate the benthic fauna and modify the sediment composition and bottom topography. They either "scalp" elevations producing parallel furrows or plough up to 30m deep scars. Such disturbance leads to an obvious habitat fragmentation and increase in regional biodiversity (Gutt and Piepenburg 2003).

First invaders following scouring events are usually fish species such as *Prionodraco evansii*, and ophiuroids. In a next stage pioneers recruit and start growing, which can vary in their species composition from scour to scour. First recruits of sessile organisms are some specific bryozoans, ascidians, gorgonians and the stalked sponge *Stylocordyla chupachups*. The development and succession of such assemblages depends on the dispersal capacity of pioneer species (Potthoff et al., 2006) and is difficult to predict.

The effect of the ice shelves collapse is to change an extremely oligotrophic system to a normal high-latitude Antarctic marine ecosystem with a rich phytoplankton bloom in summer (Smetacek et al., 1992) and the occurrence of pelagic key species such as krill and the Antarctic silverfish (Gutt et al., 2011, Gutt et al., 2013b).

Gutt et al. (2011) surveyed the marine ecosystem in the areas of the climate-induced collapse of the Larsen A and B ice shelves, 12 and 5 years after their respective collapse. The benthic fauna associated with conditions before the ecosystem shift was comprised of more deep-sea type organisms when compared to a more typical Antarctic shelf community. More recently, the structure of various ecosystem components appeared to result from extremely different response rates to the change from an oligotrophic sub-ice-shelf ecosystem to a productive shelf ecosystem. Meiobenthic communities remained impoverished only inside the Larsen embayments. On local scales, macro- and mega-epibenthic diversity was generally low, with pioneer species and typical Antarctic megabenthic shelf species interspersed.

Fillinger et al. (2013) repeated the Gutt et al. (2011) Larsen A 2007 survey four years later, finding a doubling in glass sponge biomass and a three-fold increase in abundance, after only two further favourable growth periods (Figure 35). They suggested that Antarctic hexactinellids (glass sponges), locked in arrested growth for decades may undergo boom-and-bust cycles, allowing them to quickly colonise new habitats.

Fillinger et al. (2013) also commented that the seafloor in Larsen A still remained far below carrying capacity even 16 years after ice-shelf collapse.

Gutt et al. (2011) also reported that Antarctic Minke whales and seals utilised the Larsen A and B areas to feed on presumably newly established krill and pelagic fish biomass. They also noted that ecosystem impacts extended well beyond the zone of ice-shelf collapse, with areas of high benthic disturbance resulting from scour by icebergs discharged from the Larsen embayments.

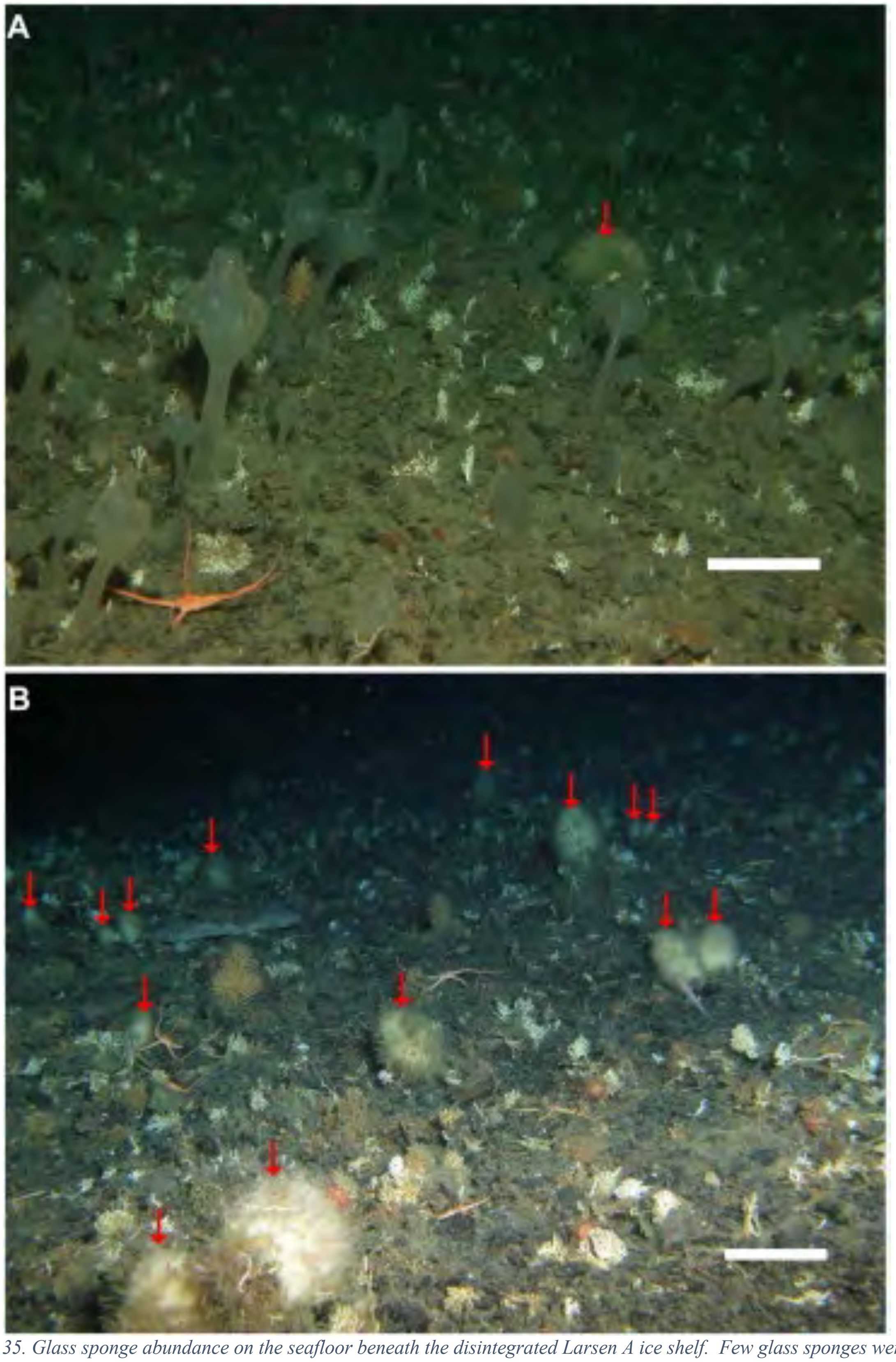

Figure 35. Glass sponge abundance on the seafloor beneath the disintegrated Larsen A ice shelf. Few glass sponges were seen along the 2007 transect, where the megabenthic community was dominated by fast-growing ascidians. In 2011 glass sponges dominated the transect while ascidians had all but disappeared. Source: Fillinger et al., 2013.

6.7 Megafauna

6.7.1 Pinnipeds and cetaceans

All six species of Antarctic seals are known to occur within the Weddell Sea, though with differing distributions and seasonality.

Adult male and female Antarctic fur seals have been observed foraging along the northern fringes of the pack-ice (Ropert-Coudert et al., 2014). Southern elephant seals appear to venture further into the pack ice to forage on the continental shelf for (it is assumed) Antarctic silverfish (*Pleuragramma Antarctica*) (Tosh et al., 2009; McInytre et al., 2010; Biuw et al., 2010).

The Antarctic ice seals (Weddell, Ross, crabeater and leopard) have all commonly been observed in the Weddell Sea with highest concentrations occurring in the eastern Weddell Sea in the areas between the Fimbul and Riiser-Larsen ice shelves and off-shore (Teschke et al., 2016).

Weddell Seals breed on fast ice along the coast of the Weddell Sea spending significant amounts of time hauled out on the ice and ice flows, particularly during summer months, with more time spent in the water diving and foraging during winter months (Boehme et al., 2016).

Foraging behaviour of Weddell Seals varies depending upon local environmental features. Weddell seals at the Drescher Inlet (Riiser-Larsen Ice Shelf) show a tidal activity pattern (Bornemann et al., 1998) and a bimodal dive depth distribution with one mode at 130 to 160m as a result of foraging excursions under the shelf ice and another one at 340 to 450m representing foraging at the sea floor (Plötz et al., 2001, Watanabe et al. 2006).

Weddell seals dive even deeper around the Filchner Trough (Filchner Ice Shelf) as a reflection of the seabed topography (Nicholls et al. 2008). Dietary studies on Weddell seals in the eastern and southern Weddell Sea highlight the importance of *Pleuragramma antarctica* as a food resource (Plötz et al., 2001, Watanabe et al., 2006).

Crabeater seals occur in high abundance in the Weddell Sea, where approximately 50% of their circum-Antarctic population is found (Bester and Odendaal, 2000; Southwell et al., 2012). Studies on their foraging behaviour in the Weddell Sea are scare. Crabeater seals breed on pack ice and tend to be associated with medium to high sea ice concentrations throughout the year. They move extensively within the Antarctic sea ice zone, and individuals may have a potential range extending throughout the entire area of the Antarctic pack ice (Boyd, 2002).

Foraging dives of crabeater seals concentrate on depths shallower than 50m but may extend to depths beyond 500m exceptionally. Crabeater seals are believed to feed almost exclusively on Antarctic krill, but evidently will eat fish and cephalopods when krill is not available, although geographic or temporal variability in their diet is data deficient (Southwell et al., 2012).

Much less information is known about the Ross seal (Southwell 2005, Bester and Hofmeyr 2007). Its circumpolar population status remains enigmatic (Southwell et al. 2008, Bengtson et al. 2011) and their ranging and diving behaviour is poorly known (Southwell et al. 2012). Despite the low detection probability Ross seals are found in relatively high numbers in the eastern Weddell Sea, off Princess Martha Coast (Bester and Odendaal, 2000; Bester et al., 2002).

Ross seals breed on pack ice, and they are more pelagic rather than ice-loving outside of the breeding and moulting seasons (Kooyman and Kooyman 2009). Apart from the description of a few stomach contents and scats (Øritsland 1977; Skinner and Klages 1994), the diet and foraging behaviour of the Ross seal still remains largely unknown. The evidence is consistent with feeding primarily on squid, then fish (*Pleuragramma Antarctica* and myctophid fish), and to some extent krill (Blix & Nordøy 2007) as well as benthic invertebrates (Øritsland 1977).

Leopard seals have been observed in the Weddell Sea (Bester et al., 1995 and 2002), but little studied in this region compared to elsewhere (see Jessop et al., 2004 for example). Observations are limited to just two females that were tagged and monitored off the Dronning Maud Land coast (in the region of the Risser-Larsen ice shelf). These individuals remained mainly within the pack ice for some time before moving to the north with the advancing winter sea ice edge. They performed mostly short (<5 min) dives to depths of 10-50m and only occasionally dived deeper than 200m. Their diving behaviour and foraging movements suggest that they feed on krill, penguins, juvenile crabeater seals and a variety of fish (Nordøy & Blix 2009).

Knowledge about the functional role and the spatial patterns of cetacean activities in the Southern Ocean ecosystem is sparse. Whales and dolphins are highly mobile, often elusive in their behaviour and cover large areas for foraging and migratory reasons. The vastness of the Southern Ocean and the limited access to sea ice covered areas contribute to hampering visual surveys and what data has been collected is patchy at best.

Fourteen cetacean species are considered to be “true Antarctic species”, i.e. “… species whose populations rely on the Southern Ocean as a habitat [that is] critical to a part of their life history, either through the provision of habitat for breeding or through the provision of the major source of food” (Boyd, 2002).

Ropert-Coudert et al., 2014 provide an overview of cetacean distribution throughout the Southern Ocean based on observational and historic catch data.

Table 4 summarises those Antarctic cetacean species that have been observed in the Weddell Sea region. Notably many of the cetacean observations in this region are limited to the northern and eastern fringes of the Weddell Sea, with no recorded observations in the western Weddell Sea in the Larsen ice-shelf area (Ropert-Coudert et al., 2014).

Table 4. Antarctic cetacean species observed in the Weddell Sea region. Adapted from Teschke et al., 2016 (Table 3-2) based on Ropert-Coudert et al., 2014.

Sub-order Mysticeti		
Family	**Species**	**Common name**
Balaenopteridae	*Megaptera novaeangliae*	Humpback whale
	Balaenoptera physalus	Fin whale
	Balaenoptera musculus intermedia	Antarctic blue whale
	Balaenoptera musculus brevicauda	Pygmy blue whale
	Balaenoptera bonarensis	Antarctic minke whale
	Balaenoptera acutorostrata ssp.	Dwarf minke whale
	Balaenoptera borealis	Sei whale
Balaenidae	*Eubalaena australis*	Southern right whale
Sub-order Odontoceti		
Physteridae	*Physeter microcephalus*	Sperm whale
Delphinidae	*Orcinus orca*	Killer whale (ecotypes A, B, C)
	Lagenorhynchus cruciger	Hourglass dolphin
	Globicephala mels	Long-finned pilot whale
Ziphiidae	*Berardius arnuxii*	Arnoux’s beaked whale
	Hyperoodon planifrons	Southern bottlenose whale
	Mesoplodon layardii	Strap-toothed whale

6.7.2 Penguins and Sea birds

Penguins

Breeding colonies of penguins occur around the eastern, southern and western boundaries of the Weddell Sea. Emperor penguin colonies predominate along the eastern and southern coasts, with Adélie penguin colonies clustered in the north western part (Figure 36).

Thirteen Emperor penguin colonies have been identified in the Weddell Sea region (using the Fimbul ice-shelf as the cut-off point). Recently, four colonies have also been recorded as existing on ice-shelves, including the colony on the Jason Peninsula in the western Weddell Sea to the north of the Larsen C ice shelf (Fretwell et al. 2014). The global population of Emperor penguins has been estimated to be approximately 238,000 breeding pairs (Fretwell et al. 2012), of which the 13 colonies in the Weddell Sea region represent around 30% (Fretwell et al., 2012; Figure 36). Emperor penguins have been classified by the IUCN to have a threat status of 'Near Threatened'.

All colonies show a similar breeding schedule regardless of their colony location. Birds gather in autumn, with the development of stable fast ice, usually from April onwards. Courtship, egg laying and incubation take place as winter proceeds, while hatching, brooding and crèche formation occur as spring and early summer approach. Chicks are tended by both parents until fledging occurs in mid-summer, usually during November or December coincident with the breakup of the fast ice. Adults moult in late summer, during February (around the time of this Expedition) usually on fast ice or on consolidated pack (Trathan et al., 2011).

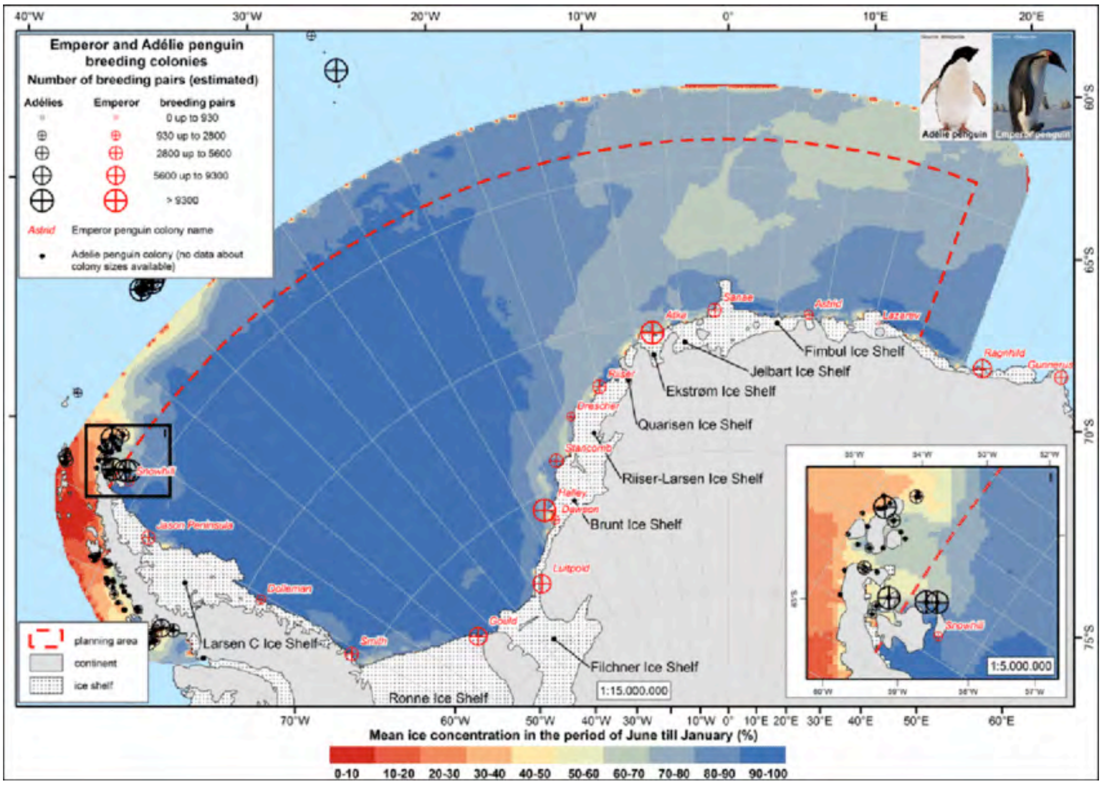

Figure 36. Number of breeding pairs estimated for Emperor (red cross hairs; Fretwell et al. 2012 and 2014) and Adélie penguin colonies (black cross hairs; Lynch and LaRue 2014). Mean sea ice concentration (Jun-Jan) derived from the Institute of Environmental Physics, University of Bremen (Kaleschke et al. 2001, Spreen et al. 2008). Red dashed box: CCAMLR MPA Planning area. Source: Teschke et al., 2016.

The global population of Adélie penguins has been estimated to be approximately 3,790,000 breeding pairs (Lynch and La Rue 2014), of which only a relatively small percentage (approximately 35,098 breeding pairs) occur in the north western Weddell Sea region (Figure 36). Adélie penguins have been classified by the IUCN to have a threat status of 'Near Threatened'.

The breeding schedule is similar across the species range, but the onset of breeding varies with latitude, being later at higher latitude sites (Trathan and Ballard 2013). Birds begin to gather in spring, as ice-free land starts to appear. Courtship, egg laying and incubation take place as spring proceeds. Hatching, brooding and crèche formation occur as summer continues. Chicks are tended by both parents until fledging occurs in late-summer, usually during January or February. Adults moult in late summer, during February, usually on fast ice or on consolidated pack.

Seabirds

Several colonies of flying birds occur in the vicinity of the Weddell Sea and depend upon it for foraging purposes. Other seabirds from populations breeding along the northern and western part of the Weddell Sea (*i.e*. near the tip of Antarctic Peninsula, at the South Shetland Islands, South Orkney Islands, South Sandwich Islands, South Georgia and Bouvet Island) also make seasonal use of the area.

Obligate users of the Weddell Sea for foraging purposes include three species of petrel (Antarctic Petrel, *Thalssoica Antarctica*; Snow Petrel, *Pagodroma nivea*; Wilson's Storm Petrel, *Oceanites oceanicus*). These petrels breed on isolated 'nunataks' in-land from the Weddell Sea. Data on colony sizes and breeding populations are sparse, though the breeding population in the Weddell Sea region is thought to be a considerable portion of the global population for all three species.

Over 300,000 pairs of Antarctic Petrels are known to breed on nunataks close to the coastline of the Weddell Sea (Van Franeker et al. 1999; Figure 37).

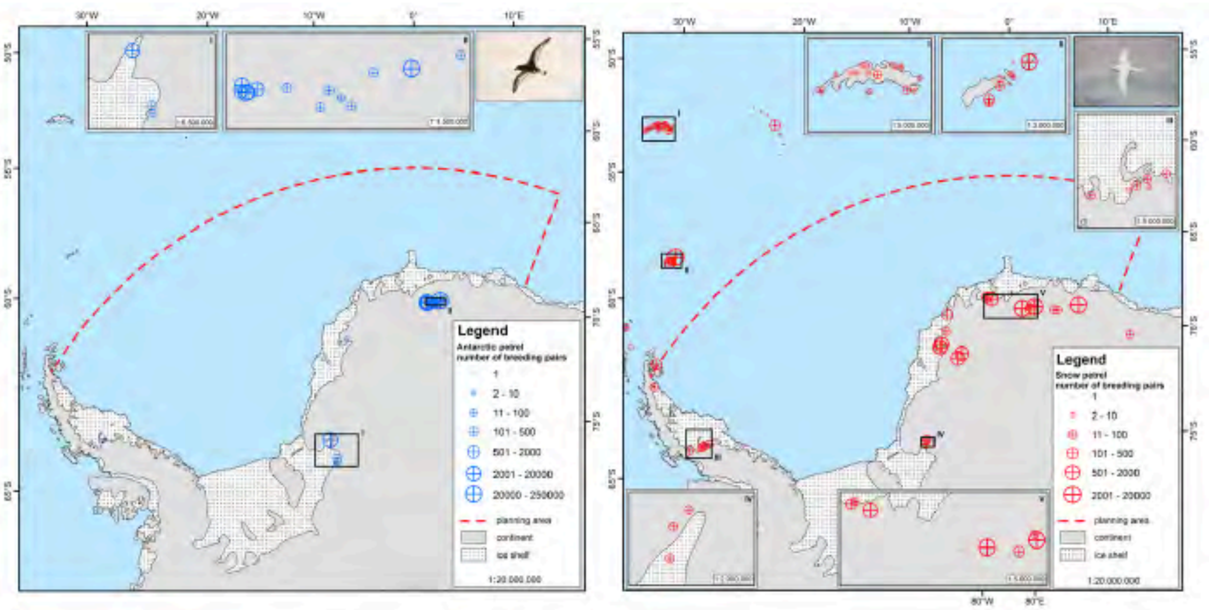

Figure 37. Spatial distribution of breeding pairs of Antarctic petrel (left) and Snow petrel (right). Data based on van Franeker et al., 1999 (Antarctic petrel) and Croxall et al., 1995 (Snow petrel). Red dashed box is the CCAMLR MPA planning area. Source: Teschke et al., 2016.

Almost all Antarctic Petrels breed in a relatively small sector of Dronning Maud Land in and near the Mühlig Hofmann Mountains; there are also smaller breeding aggregations far south in Coats Land. These two sectors hold more than half of the world population of this species.

Snow Petrels also breed in nunatak areas as far south as 80°S. There is considerable discrepancy between the counts of breeding pairs and the probable true numbers of birds in the population. Existing counts total to just over 63,000 breeding pairs around all of the Antarctic with nearly half of this figure thought to be users of the Weddell Sea for foraging purposes (Croxall et al., 1995).

Wilson's Storm Petrels are likely to be the most abundant of the three petrel species, with a global population estimate of over 13 million breeding pairs (Croxall et al., 2012). No population estimates are currently available for the nunataks and mountain ranges in the region of the Weddell Sea.

The South Polar Skua (*Catharacta maccormicki*) also breeds around the fringes of the Weddell Sea. During the penguin and petrel breeding season the species predates eggs and chicks, but also adults of some species. Virtually all petrel colonies, even those in the distant nunatak areas, have breeding pairs of skuas closely associated, but there are no details for local populations.

Important Bird Areas

In 2015, the Antarctic Treaty Consultative Meeting recognised a series of 204 Important Bird Areas (IBAs) in Antarctica using international criteria developed by BirdLife International (Harris et al., 2015; ATCM Resolution 5 (2015)). Several IBAs occur in the Weddell Sea area (Figure 38 and Figure 39), including the major Emperor penguin colonies in the eastern Weddell Sea.

In recognising these IBAs through Resolution 5 (2015), the ATCM recommended to Parties that account be taken of these IBAs in the planning and conduct of Antarctic activities including in the preparation of environmental impact assessments.

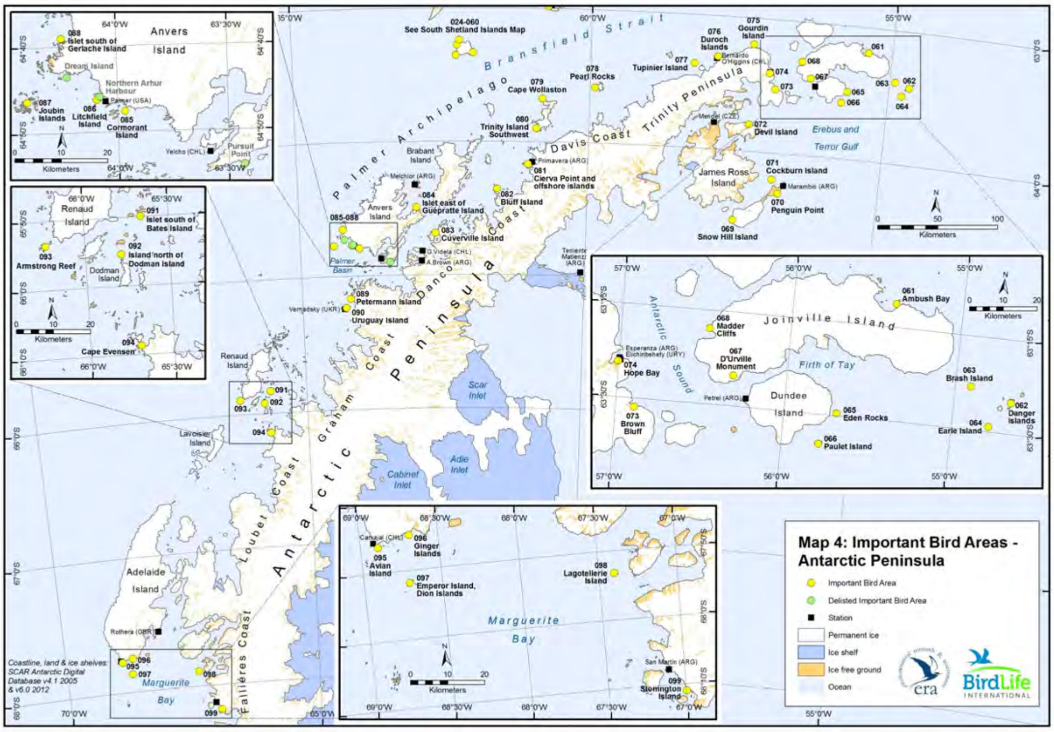

Figure 38. IBAs identified along the Antarctic Peninsula, including those on Snow Hill Island in the north western Weddell Sea. No IBAs have been identified on the eastern side of the Antarctic Peninsula, though some Emperor penguin colonies do occur in this area. Source: Harris et al., 2015.

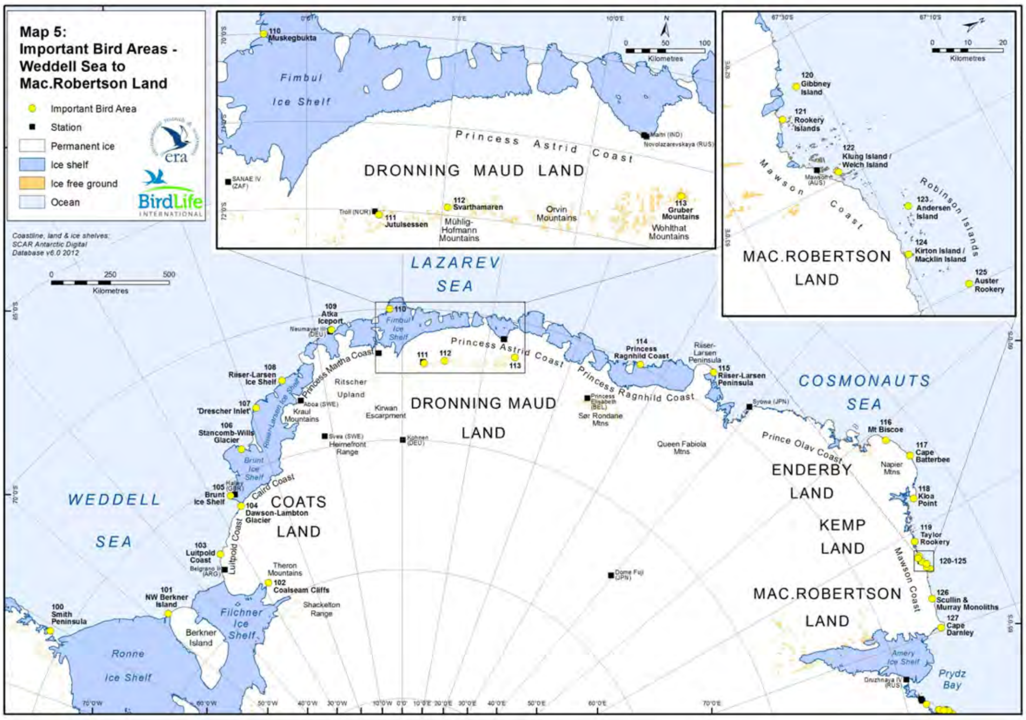

Figure 39. IBAs in the eastern Weddell Sea (and East Antarctica). The major Emperor penguin colonies in the east and south of the Weddell Sea all meet IBA criteria. Source: Harris et al., 2015.

6.8 Protected and Managed Areas

6.8.1 Antarctic Specially Protected and Specially Managed Areas

Any area of Antarctica, including any marine area may be designated as an Antarctic Specially Protected Areas (ASPA) to protect outstanding environmental, scientific, historic, aesthetic or wilderness values, any combination of those values, or ongoing or planned scientific research. An area where activities are being conducted or may be conducted in the future may be designated as an Antarctic Specially Managed Area (ASMA), to assist in the planning and co-ordination of activities, avoid possible conflicts, improve co-operation between Parties or minimise environmental impacts.

Those ASPAs 'in the vicinity' of the Weddell Sea include (see also Figure 40):

- ASPA 119, David Valley and Forlidas Pond in the Pensacola Mountains – designated to protect some of the most southerly freshwater ponds known in Antarctica;
- ASPA 142, Svathamaren in the Mühlig-Hoffmanfjella mountains – designated to protect the largest known inland seabird colony in Antarctica, with snow petrel, south polar skua, and the largest proportion of the known world population of Antarctic petrel (also IBA 112);
- ASPA 148, Mount Flora, Hope Bay in the northern Antarctic Peninsula – designated to protect the site's rich fossil flora and its long history as a geological research site.

Figure 40. Location of Antarctic Specially Protected Areas (ASPAs) in the vicinity of the Weddell Sea Source: Antarctic Treaty Secretariat protected areas database, www.ats.aq.

The Expedition will not encounter nor enter any of these designated Antarctic Specially Protected Areas (ASPAs).

The Antarctic Treaty Parties have designated six ASMAs across Antarctica, none of which are in the Weddell Sea region and none of which will be encountered by the Expedition.

6.8.2 Historic sites or monuments

In 1972 the Antarctic Treaty Parties established an official list of Historic Sites and Monuments (HSMs). Article 8(4) of Annex V to the Protocol provides that listed HSMs shall not be damaged, removed or destroyed. The current list of HSMs is held under Antarctic Treaty Consultative Meeting (ATCM) Measure 9 (2016).

The current list includes 94 HSMs throughout Antarctica. Those HSMs in the vicinity of the Weddell Sea include (see also Figure 41):

- HSM 40 - Bust of General San Martin, grotto with a statue of the Virgin of Lujan, and a flag mast at Base 'Esperanza', Hope Bay, erected by Argentina in 1955; together with a graveyard with stele in memory of members of Argentine expeditions who died in the area.
- HSM 41 - Stone hut on Paulet Island built in February 1903 by survivors of the wrecked vessel *Antarctic* under Captain Carl A. Larsen, members of the Swedish South Polar Expedition led by Otto Nordenskjöld, together with a grave of a member of the expedition and the rock cairn built by the survivors of the wreck at the highest point of the island to draw the attention of rescue expeditions.
- HSM 43 - Cross erected in 1955, at a distance of 1,300 metres north-east of the Argentine General Belgrano I Station (Argentina) and subsequently moved to Belgrano II Station (Argentina), Nunatak Bertrab, Confin Coast, Coats Land in 1979.
- HSM 60 - "Wooden pole and cairn (I), and wooden plaque and cairn (II), both located at Penguins Bay, southern coast of Seymour Island (Marambio), James Ross Archipelago. The wooden pole and a cairn (I) were installed in 1902 during the Swedish South Polar Expedition led by Dr Otto Nordenskjöld. This cairn used to have attached a 4m high wooden pole – nowadays only 44 cm high –, guy-lines and a flag, and was installed to signal the location of a well-stocked deposit, composed of few wooden boxes containing food supplies, notes and letters saved inside bottles. The deposit was to be used in case the Swedish South Polar Expedition was forced to retreat on its way to the south. The wooden plaque (II) was placed on 10 November 1903 by the crew of a rescue mission of the Argentinean Corvette Uruguay in the site where they met the members of the Swedish expedition led by Dr Otto Nordenskjöld.

The Expedition will not encounter or interact with any of these HSMs.

6.8.2.1 Wreck of Endurance

The wreck of Shackleton's *Endurance* was listed as an HSM in 2019 (ATCM Measure 12 (2019); Figure 41):

- HSM 93 - Wreck of the vessel Endurance, including all artefacts contained within or formerly contained within the ship, which may be lying on the seabed in or near the wreck within a 150m radius. This includes all fixtures and fittings associated with the ship, including ship's wheel, bell, etc. The designation also includes all items of personal possessions left on the ship by the ship's company at the time of its sinking. Location records made by Frank Worsley, Shackleton's skipper and master navigator give precise coordinates of the location of sinking of the ship but these have not been verified since 1915.

At ATCM XLI (Buenos Aires, May 2018), the Antarctic Treaty Parties adopted new Guidelines for the assessment and management of Heritage in Antarctica (ATCM Resolution 2 (2018)). If the wreck is located and surveyed by this Expedition, Expedition leaders will be pleased to assist the UK Government in describing the wreck site so as to support the HSM status and any additional protection measures that may be required.

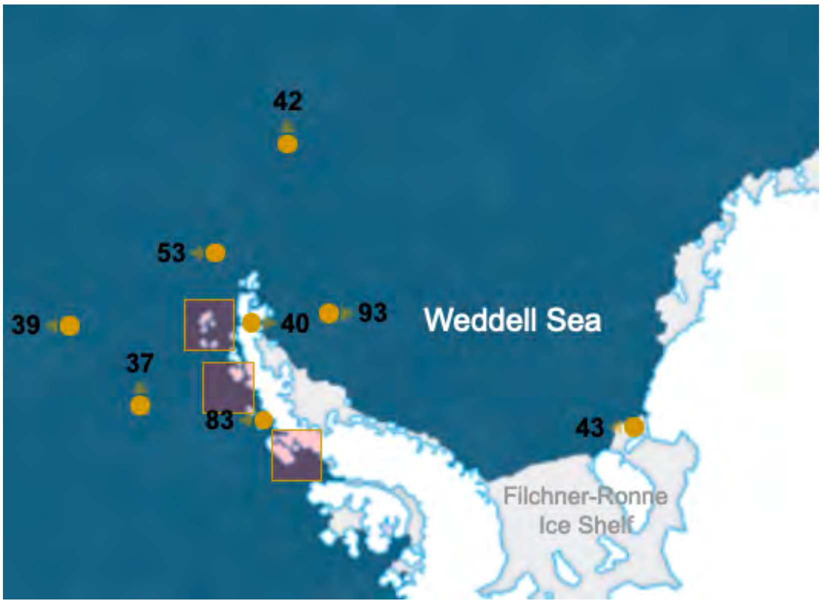

Figure 41. Approximate locations of designated historic sites or monuments in the Weddell Sea region of Antarctica. The wreck of Endurance is HSM 93. NB: the location of HSM 60 is missing from this map and the location of HSM 40 is incorrect. Source: Antarctic Treaty Secretariat protected areas database, www.ats.aq.

6.8.3 CCAMLR marine spatial protection measures

The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) was established by international convention in 1982 with the objective of conserving Antarctic marine life. Being responsible for the conservation of Antarctic marine ecosystems, CCAMLR practises an ecosystem-based management approach. This does not exclude harvesting as long as such harvesting is carried out in a sustainable manner and takes account of the effects of fishing on other components of the marine ecosystem.

CCAMLR utilises a number of mechanisms for protecting important or sensitive marine areas and to protect scientific research and monitoring related to marine ecosystem management. These measures include:

- designation of Marine Protected Areas (MPA) under Article IX(2)(g) of the Convention;
- identification and management of vulnerable marine ecosystems (VMEs);
- identification of research locations to support CCAMLR's Ecosystem Monitoring Programme (CEMP);

- designation of Special Areas for Scientific Study in newly exposed marine areas following ice-shelf retreat or collapse.

6.8.3.1 Marine Protected Areas (MPAs)

CCAMLR has invested significant resource in developing its approach to the identification and designation of MPAs.

In 2011 CCAMLR adopted Conservation Measure 91-04 (CM 91-04) which provides the 'General framework for the establishment of CCAMLR Marine Protected Areas' in accordance with Article IX of the Convention to provide a framework for the establishment of CCAMLR MPAs.

In 2009, CCAMLR established the world's first high-seas MPA, the South Orkney Islands Southern Shelf MPA, a region covering 94,000km2 in the south Atlantic (Figure 42). The South Orkney Islands Southern Shelf MPA bounds the northern part of the Weddell Sea and may fall adjacent to or within the transit route for the Expedition depending upon sea ice / pack ice conditions.

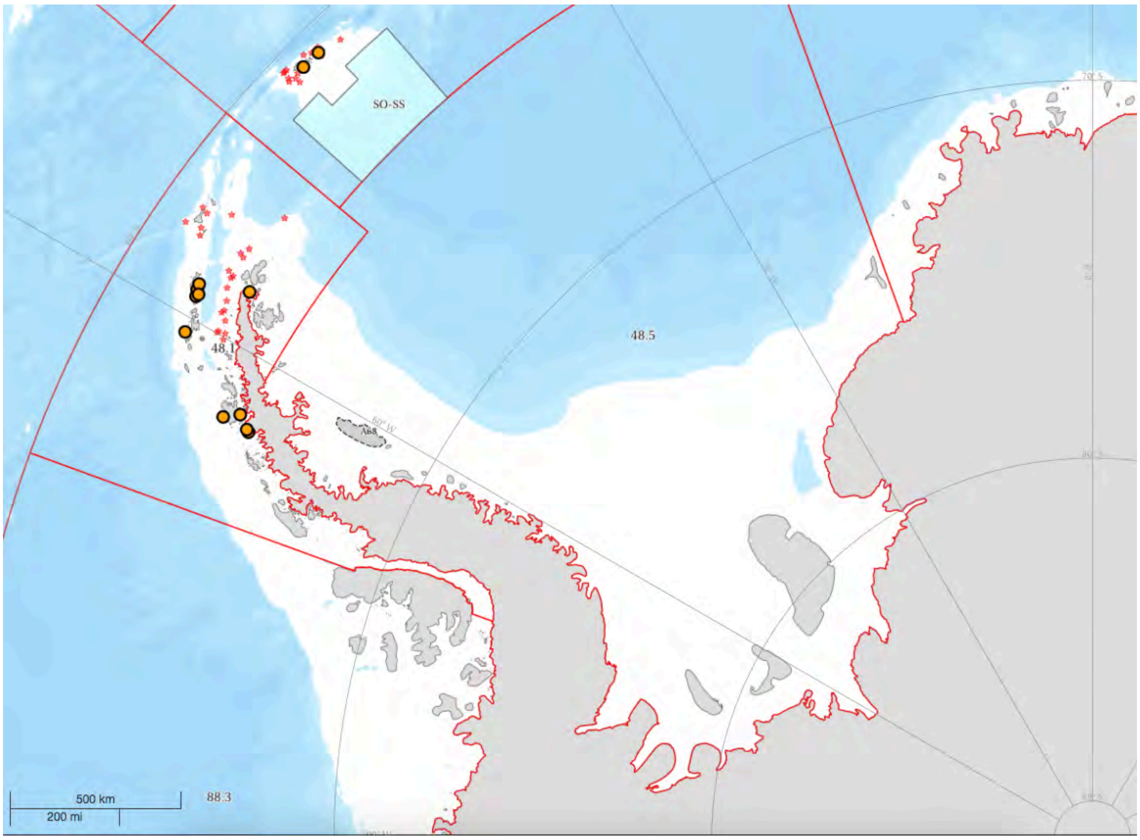

Figure 42. Important marine sites protected under CCAMLR. Light blue box – (SO-SS) the South Orkney Islands Southern Shelf MPA; orange dots – CCAMLR ecosystem monitoring programme sites; red stars – identified Vulnerable Marine Ecosystems; grey dotted boundary – A68 Special Area for Scientific Study following the loss of ice from the front of the Larsen C ice shelf. Source: CCAMLR GIS: www.gis.ccamlr.org.

6.8.3.2 CCAMLR Ecosystem Monitoring Programme (CEMP) sites

In order to provide information of the effects of fishing on dependent species, CCAMLR set up the CCAMLR Ecosystem Monitoring Program (CEMP) in 1989. The two aims of CEMP are to:

1. detect and record significant changes in critical components of the marine ecosystem within the Convention Area, to serve as a basis for the conservation of Antarctic marine living resources;
2. distinguish between changes due to harvesting of commercial species and changes due to environmental variability, both physical and biological.

In response to concerns that activities at some CEMP sites may interfere with the collection of important monitoring data, CCAMLR introduced a Conservation Measure in 1990 to provide protection to CEMP sites. This was originally conservation measure 18/IX, which has since become Conservation Measure 91-01. There are currently no sites afforded protection under Conservation Measure 91-01, however, 7 of the 13 currently active CEMP monitoring sites south of 60°S (Figure 42– orange dots) are within ASPAs or ASMAs and are therefore given additional protection through that mechanism.

This Expedition will have no interaction with any CEMP sites.

6.8.3.3 Vulnerable Marine Ecosystems (VMEs)

VMEs are marine sites that may be particularly sensitive to the impacts of fishing and includes areas such as seamounts, hydrothermal vents, cold water corals and sponge fields.

CCAMLR requires monitoring during fishing activity to identify VME-indicator units recovered in each line segment of bottom-set longlines (or string of pots). Where line segments trigger a specified number of VME-indicator units a report is immediately sent to CCAMLR and a VME risk area is declared. VME risk areas are immediately closed to further bottom fishing, and remain closed until reviewed by the Scientific Committee and management actions are determined by the Commission. Scientific research endorsed by the Scientific Committee is allowed in risk areas. VME fine-scale rectangles (0.5° latitude by 1.0° longitude) are also designated in areas where frequent VME-indicator notifications are made.

Identified VME risk areas are recorded in CCAMLR's VME Registry. There are multiple VMEs identified in the region of the northern Antarctic Peninsula and Scotia Sea (Figure 42). No VMEs are identified in the Weddell Sea. The target areas for research of this Expedition will not encounter any identified VMEs.

6.8.3.4 Special Areas for Scientific Study

In 2016 CCAMLR agreed Conservation Measure 24-04 (CM 24-04) which provides for the designation of Special Areas for Scientific Study in any newly exposed marine area following the retreat or collapse of an ice shelf, glacier or ice tongue in the Antarctic Peninsula region (CCAMLR Statistical Subareas 48.1, 48.5 and 88.3).

The retreat of ice shelves, glaciers or ice tongues is defined as the landward movement of the ice front such that there is a loss of more than 10% of the areal extent of an individual ice shelf, glacier or ice tongue within any 10-year period from 2016 onwards.

Collapse is defined as the break up or disintegration of an ice shelf, glacier or ice tongue over a period that may be shorter than 10 years.

CM 24-04 provides that Special Areas for Scientific Study are designated in two stages:

- Stage 1 Special Areas for Scientific Study shall be designated for a maximum period of two years. Stage 1 is a provisional designation to allow time for detailed review of the available data, including any relevant fishery research proposals;
- Stage 2 Special Areas for Scientific Study shall be designated for a period of 10 years.

CM 24-04 encourages CCAMLR Parties to undertake scientific research in Special Areas for Scientific Study particularly in order to understand the ecosystem processes in relation to climate change.

CM24-04 encourages Parties planning to initiate or undertake any non-fisheries-related scientific research or monitoring on marine living resources within any Special Area for Scientific Study to inform the Scientific Committee of their intended research plans, and to subsequently report any results relevant to the work of the Commission and the Scientific Committee.

In 2017 at its 36th meeting, the CCAMLR Commission endorsed the recommendation of its Scientific Committee that the section of the Larsen C Ice Shelf from which 5,800km2 of ice was lost in the form of iceberg A68, should be designated as a Stage 2 Special Area for a period of 10 years, consistent with CM 24-04, paragraph 10 (Figure 43).

The Commission recognised the scientific importance of this area and welcomed plans for research to be undertaken in the coming seasons (paras 5.84 and 5.85 of the Final Report of CCAMLR XXXVI refer). This Expedition will not enter this Special Area.

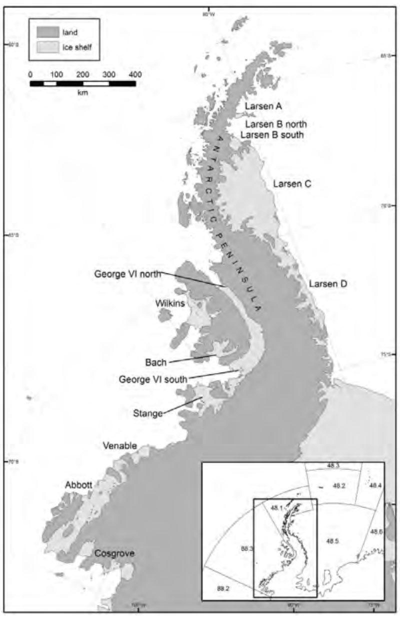

Figure 43.Locations and extent of ice shelves, glaciers and ice tongues in Statistical Subareas 48.1, 48.5 and 88.3. Coastline data from the SCAR Antarctic Digital Database version 7 (2016) (www.add.scar.org).

7. Assessment of the Environmental Impacts

7.1 Methods and Data

Having described the nature and scale of the proposed activity and described the current environmental state, this section of the IEE will identify the potential environmental impacts of the activity in a four-step analysis involving:

i. identifying the **aspects** i.e. the physical change imposed on or an input released to the environment as the result of an action or activity such as emissions, dust, mechanical action on the substrate, fuel spills, noise, light, wastes, heat, introduced species, etc., arising from the proposed activities described in Section 4;

ii. identifying the **exposure** i.e. the interaction between an identified potential output and the environment including flora and fauna, freshwater, marine, terrestrial and atmospheric environments; and

iii. identifying the **impacts** i.e. the change in environmental values or resources attributable to the activity;

iv. assessing the **significance** of the identified impacts by considering the spatial extent, duration, intensity and probability of the potential impacts to each environmental element – with reference to the three levels of significance identified by Article 8(1) of the Protocol (i.e. less than, no more than, or more than a minor or transitory impact).

7.2 Aspects

An ‘aspect’ is a physical change (e.g. movement of sediments by vehicle passage or noise) or an entity (e.g. emissions, an introduced species) imposed on or released to the environment as the result of an action or an activity (EIA Guidelines, 2016).

The main elements of the Expedition are discussed in Section X and include:

1. Ship operations;
2. Marine archaeological survey, including:
    - establishment and operation of ice camps,
    - deployment of subsea vehicles
3. Deployment of research equipment and sampling.

The potential aspects arising from these activities are summarised in Table 5.

Table 5. This page and the next. Potential aspects from the activities to be undertaken by the Expedition that have potential to impact the Antarctic environment. #physical damage to the Endurance wreck would only occur through accidental loss of one of the SAAB Sabertooth vehicles (e.g. through equipment failure) immediately over the wreck.

ACTIVITY	ASPECTS											
	Atmospheric emissions *(burning fossil fuels)*	**Noise emissions**	**Light emissions**	**Heat emissions**	**Air turbulence**	**Mechanical action** *(physical disturbance to ice, marine substrate, or Endurance wreckage)*	**Fuel spills**	**Wastes** *(disposal and discharge)*	**Water turbulence**	**Introduced species**	**Removal of native fauna and/or flora**	**Presence / visual disturbance**
Ship operations (*including transit across the Weddell Sea, and 'on-station' supporting subsea surveys*)	X Exhaust emissions	X Engines and acoustic equipment noise emissions to marine environment		X Emissions to air			X Emergency event leading to fuel release	X Generation of wastes onboard	X Vessel propulsion	X Hull and equipment fouling		X Evidence of human presence
Establishment and operation of ice camps including support to research groups	X Burning of fossil fuels in generators, skidoos, cooking equipment	X Operation of generators, vehicles (including helicopters) and equipment		X Emissions to air from engines and heating equipment	X Action of aircraft rotors		X Accidental release of fuels from drums or during refuelling	X Generation of wastes at ice camps				X Evidence of human presence
Launch, operation and recovery of subsea vehicles		X Drilling of 'launch holes'; noise from subsea vehicles	X Use of lighting on subsea vehicles	X Heat emissions from subsea vehicles		X# Creation of 'launch holes' in ice floes; risk of impact to wreck through equipment failure		X Equipment failure leading to loss of subsea vehicles	X Propulsion of the subsea vehicles through the water	X Biological contamination of the subsea vehicles		X Evidence of human presence

ACTIVITY	OUTPUTS											
	Atmospheric emissions *(burning fossil fuels)*	**Noise emissions**	**Light emissions**	**Heat emissions**	**Air turbulence**	**Mechanical action** *(physical disturbance to ice, marine substrate, or Endurance wreckage)*	**Fuel spills**	**Wastes** *(disposal and discharge)*	**Water turbulence**	**Introduced species**	**Removal of native fauna and/or flora**	**Presence / visual disturbance**
Sea ice and oceanographic research programme						X Taking of sea ice cores / snow samples		X Release of research buoys to marine environment				
Deployment of RPA (*over sea ice and open water)*		X Rotor / motor noise		X Emissions to air from motors	X Action of rotors			X Loss of equipment through equipment failure				X Evidence of human presence

7.3 Exposures

Exposure is the process of interaction between an identified aspect (Section 7.2) and an environmental element or value (EIA Guidelines, 2016).

The environmental elements that are potentially exposed to the activities being undertaken by the Expedition and their outputs (identified in Table 5) are summarised in Table 6. Note: The exposure of an activity's output may vary in significance in differing environments and is not accounted for in this table. The significance of potential impacts is discussed in Sections 7.4 and 7.5 below.

*Table 6. Overview of those environmental elements that have been identified as potentially being susceptible to the outputs of the activities being undertaken by the Expedition. * only through accidental loss of equipment.*

OUTPUT OF ACTIVITIES	**ENVIRONMENTAL ELEMENTS**							
	FLORA AND FAUNA	**FRESHWATER** *(including ponds, streams, rivers, lakes, glaciers and ice)*	**MARINE**	**ICE** *(sea ice and ice floes)*	**TERRESTRIAL** *(including ice free ground, soil and rocks)*	**ATMOSPHERE**	**WILDERNESS VALUES**	**HERITAGE VALUES**
Atmospheric emissions		No impacts to freshwater systems have been identified			No impacts to terrestrial systems have been identified	X		
Noise emissions	X							
Light emissions	X							
Heat emissions			X					
Air turbulence						X		
Mechanical action				X				X*
Fuel spills	X		X	X				
Wastes			X	X				
Water turbulence			X					
Introduced species	X		X					
Removal of native fauna &/or flora								
Presence / Visual disturbance							X	

The Expedition is almost entirely marine focused and ship-based expedition, with the potential to establish small, temporary camps on ice floes. The Expedition will operate from the *SA Agulhas II* and be focussed on the search for and survey of the *Endurance* wreck, with a small programme of associated marine and sea ice research.

No aspects from the activities associated with the Expedition will interact with terrestrial (ice free) or freshwater environments (Table 6). The following assessment of potential impacts is therefore focussed on marine-based flora and fauna, the marine environment, sea ice / ice floes, the atmosphere, wilderness values and heritage values.

7.4 Impacts and Mitigation Measures

The potential impacts (direct, indirect and cumulative) of the Expedition are discussed below. This impact assessment considers the worst-case scenario of the potential impacts that have been identified. The potential impacts are then summarised in Table 9 by their nature, spatial extent, duration, intensity, probability and reversibility. The significance of the identified potential impacts is then evaluated and summarised also in Table 9.

The following definitions are used to describe the different types of impact:

A **direct impact** is a change in environmental values or resources that results from direct cause-effect consequences of interaction between the exposed environment and an activity or action (e.g. decrease of a limpet population due to an oil spill, or a decrease of a freshwater invertebrate population due to lake water removal) (EIA Guidelines, 2016).

An **indirect impact** is a change in environmental values or resources that results from interactions between the environment and other impacts - direct or indirect (e.g. alteration in seagull population due to a decrease in limpet population which, in turn, was caused by an oil spill) (EIA Guidelines, 2016). Often indirect impacts are not known until a direct impact occurs.

A **cumulative impact** is the combined impact of past, present and reasonably foreseeable activities. Cumulative impacts may occur over time and should be assessed by looking at other human activities occurring in the proposed locations. Like indirect impacts, cumulative impacts may not be identified until a direct impact has occurred (EIA Guidelines, 2016).

7.4.1 Impacts to Antarctic fauna and flora

Based on the assessments in Sections 7.2 and 7.3 above, impacts to Antarctic fauna and flora will or may arise from:

- noise emissions from the operation of the main vessel, helicopters, the use of equipment at the ice camps and the deployment of the subsea vehicles and RPA;
- light emissions from the subsea vehicles;
- contamination and toxicity as a result of an accidental release of fuels;
- direct removal of marine biological samples.

7.4.1.1 Impact description: noise disturbance to Antarctic fauna and flora.

Operation of SA Agulhas II

Anthropogenic underwater noise is now recognised as a world-wide problem, and recent studies have shown a broad range of negative effects in a variety of taxa (Williams et al, 2015). Underwater noise from shipping is increasingly recognised as a significant and pervasive pollutant with the potential to impact marine ecosystems on a global scale (Clark et al., 2009; Merchant et al., 2015; Williams et al., 2014).

The impact of marine noise varies greatly depending upon the source, frequency, duration, marine conditions, location and in terms of its impact on different taxa.

The operation of the *SA Agulhas II* in the Weddell Sea will introduce noise as a result of the vessel's engines, which will dissipate through air and water. This Expedition will not use any seismic survey equipment and noise will only be generated from the operation of the vessel's engines and sonar equipment.

The operation of the *SA Agulhas II* through the waters and ice of the Weddell Sea may result in encounters with and disturbance (both audible and visual) to individuals or groups of marine mammals or foraging penguins and sea birds. This may include for example, disturbance of seals resting on ice floes. It is likely that the species concerned will adopt an avoidance approach and move away from the vessel.

Helicopters

The Expedition will utilise helicopters for surveying the sea ice for navigation and research purposes, and potentially to deploy the field camps and equipment in a heavy ice scenario. The helicopters are likely to be the largest single source of noise during the Expedition.

All aircraft operations have the potential to disturb Antarctic wildlife with varying impacts depending upon the aircraft type, the species, the time of the year and the nature of the encounter. The most major disturbance could lead to impacts on the health, breeding performance and survival of individuals or populations (Harris, 2005).

Ice camps

Operation of equipment at the ice camps, including the skidoo, the ice auger, chainsaws and generators will also create noise that has the potential to disturb any local wildlife. The most likely cause of any such impacts would be on seals that may resting on the same ice floe or nearby floes. The likelihood of encountering seals in the vicinity of the location chosen for the ice camps is challenging to assess. In the vast area of the Weddell Sea the likelihood of operating in the vicinity of seals hauled out on ice floes is possible. As above, any seals on ice floes in the vicinity of the ice camps are likely to adopt an avoidance approach and move away.

It is possible that seals, Crabeater Seals in particular, may be attracted to the ice holes once these have been drilled. Such holes in the ice, whether artificial or man-made are used as breathing holes or exit holes by Antarctic seals. Whether seals will be attracted to the drilled holes will depend upon a number of factors including the density of the pack ice at the time. A higher density of pack ice, with less open water will increase the chances of seals being drawn to the drilled holes.

Any seals that are attracted to the ice holes could be disturbed by surface activity including the launching or recovery of the subsea vehicles.

Deployment of subsea vehicles

The deployment of the subsea vehicles in the marine environment will introduce some artificial noise, though this will be negligible. The SAAB Sabertooth vehicles produce very little noise and are unlikely to cause significant disturbance to any marine mammals, cetaceans or diving birds encountered. Any minor disturbance event is likely to be of short duration and result in avoidance by the animal or bird concerned.

No reported disturbance events associated with noise from subsea vehicles could be found in a literature search.

Deployment of RPA

The deployment of RPA will create some noise, which in combination with the visual presence of the RPA, has the potential to disturb wildlife. The use of RPA in Antarctic has increased significantly in recent years for research purposes. This new technology potentially could have undesirable and unforeseen impacts on wildlife, the risks of which are currently little understood (Hodgson and Koh, 2016).

Different wildlife populations can respond idiosyncratically to a RPA in proximity depending on a variety of factors, including the species, environmental and historical context, as well as the type of machine and its method of operation (Hodgson and Koh, 2016; Rummler et al., 2016).

For most operations of the RPA during this Expedition, they will be deployed over open water and / or pack ice. As such no encounters with colonies of birds, penguins or seals ashore will occur.

Encounters with individuals or small groups of birds (e.g. birds or penguins foraging at sea) or seals (e.g. one or two individuals hauled out on ice floes) cannot be ruled out.

The issue of safe environmentally sound operation of RPA in Antarctica has been the subject of considerable discussion within the Antarctic Treaty Consultative Meeting (ATCM) and in particular its advisory Committee for Environmental Protection. At its 41st meeting in 2018, the ATCM adopted new *Environmental guidelines for the operation of Remotely Piloted Aircraft Systems (RPA) in Antarctica* (ATCM Resolution 2018a). In parallel the Council of Managers of National Antarctic Programs (COMNAP) has also developed the *Antarctic RPA Operator's Handbook* (COMNAP, 2017)

Impact type:

Noise emissions may result in both a **direct** and **cumulative** impact on Antarctic wildlife.

Disturbance effects to wildlife would be direct and immediate if they were to occur. The extent of wildlife responses to noise disturbance may vary significantly between species and within species depending upon a wide range of physiological and environmental factors. Responses may range from unobservable physiological responses (e.g. increased heart rate), to observable behavioural responses, such as mild agitation, or avoidance and rapid movement away from the noise source. In general, disturbance effects on Antarctic wildlife appear to have been underestimated suggesting a more precautionary approach to activities in the vicinity of wildlife is required (Coetzee and Chown, 2015).

Such disturbance events may also be cumulative in combination with other disturbance events that may occur (either to the same individuals or the same species) during the 2021/22 season and in past and future seasons.

Mitigation measures:

- If large groups of marine mammals are encountered when the main vessel is underway, the vessel will proceed cautiously including seeking to slow down and avoid such groups so as to minimise interference if safe and practicable to do so.

- The subsea vehicles selected for this Expedition are fully electric with no hydraulic power unit and therefore they are quiet and will not produce noise of any significance.
- The Expedition has available to it a team of highly experienced specialist technicians and operators that will deploy and operate the SAAB Sabertooths.
- Marine mammal and cetacean observations will commence 20 minutes prior to launching the subsea vehicles. Operations that may cause disturbance will be paused if safe and practicable to do so, until the wildlife has moved away.
- If seals are encountered in the holes drilled in the pack ice, operations will cease until the seal moves away.

- All helicopter operations will be conducted over water or pack ice and encounters with seals or birds are likely to be rare. The pilots are highly experienced in Antarctic air operations and will seek to maintain suitable distances from any birds or seals identified on ice floes so as to avoid disturbance without compromising safety of operations.
- In 2004, the 27th Antarctic Treaty Consultative Meeting adopted Guidelines for the Operation of Aircraft Near Concentrations of Birds in Antarctica (ATCM Resolution 2 (2004). The principal recommendations of the guidelines are that bird colonies should not be overflown below 2000 ft (~610 m) above ground level and landings within 1/2 nautical mile (~930 m) of bird colonies should be avoided wherever possible. Whilst no bird colonies will be directly encountered, these guidelines will be taken into account when planning and conducting air operations.

- The RPA will be operated by a highly trained and experienced pilot at all times.
- The RPA will be operated in full conformance with the available guidance material notably the COMNAP *Antarctic RPA Operator's Handbook* (COMNAP, 2017) and the ATCM's *Environmental guidelines for the operation of Remotely Piloted Aircraft Systems (RPA) in Antarctica* (ATCM 2018a).
- RPA will not be launched in the vicinity of large congregations of wildlife.
- Bird observations in the vicinity of the launch site will commence 20 minutes prior to deployment of the RPA. Operations that may cause disturbance will be paused if safe and practicable to do so, until the wildlife has moved away.

Record keeping:

- In the unlikely event that a wildlife disturbance incident occurs, records of the timing, location and nature of the disturbance event and the species involved will be recorded.
- All RPA flights will be fully logged for research as well as reporting purposes.

7.4.1.2 Impact description: light disturbance to Antarctic fauna and flora.

Lights on ships can disorient birds, and bird strikes on vessels operating in the Southern Ocean have been recorded (Tin et al., 2009). The level of mortality is generally, but not always, low. The use of deck lights under conditions of reduced visibility in the vicinity of major breeding sites of burrow-nesting petrels, such as the blue petrel (*Halobaena caerulea* (Gmelin)) and the common diving petrel (*Garrodia nereis* (Gould)), have led to occasional incidents where hundreds of birds collided with ships overnight, and were found dead or dying on the deck at dawn (Tin et al., 2009).

The Expedition will take place during the austral summer in long periods of daylight. As a result there will be minimal requirements for deck lights to be used on the vessel or at the ice camps.

The deployment of the SAAB Sabertooth vehicles will introduce some artificial light into the marine environment, though this will be negligible.

Light impact below the surface is likely to be minor and fleeting. Mobile species such as seals and fish are likely to move away from the immediate 'glare' of the light, though this may result in some minor disturbance to an immediate foraging dive for example.

The subsea vehicles will briefly introduce light onto small patches of otherwise dark benthic environments. No lasting impact is likely to marine invertebrates.

Impact type:

Any light interference is likely to result in a **direct** and immediate impact, although will be of short duration resulting in avoidance by the individuals concerned. No reported disturbance events associated with light from subsea vehicles could be found in a literature search.

Mitigation measures:

Few mitigation measures are required. As noted above, the need for above-surface lighting will be minimal due to the timing of the expedition.

Subsea lighting will be required to achieve the objectives of the expedition, but impacts are anticipated to be less than minor and transitory.

Record keeping:

- Records will be maintained of any observable encounters with wildlife, including (if possible) the location and species encountered.
- All subsea vehicle deployments will be logged for research and reporting purposes.

7.4.1.3 Impact description: implications of a fuel spill for Antarctic marine fauna and flora.

In the extremely unlikely event of significant fuel-related equipment failure or a vessel incident that results in a breach of the main fuel storage tanks of the *SA Agulhas II*, marine gas oil could be released to the marine environment.

Drummed fuel will also be moved onto ice floes for running generators and skidoos. Spills onto ice could also occur e.g., during refuelling operations or from leaks. Any such spills could result in some contamination to any wildlife in the immediate vicinity of the incident as well as oil contaminated water and ice.

Fuel products entering the marine environment through spills or chronic releases are eventually broken down or removed from the environment by natural processes or are diluted to levels well below concentrations of concern. However, from the time the material enters the environment until it is removed or sufficiently diluted, it poses a threat to the environment. The magnitude of that threat varies depending upon the size, composition, location, and timing of the release, the interactions of the introduced fuel with various processes that affect the material after its introduction, and the sensitivity of the organisms that are exposed.

High latitude, cold water environments present additional factors that need to be considered in assessing the risk of marine fuel spills. Extreme weather, ice conditions and isolation can influence the risk of accidents and may impede responses to any contamination incidents that occur (Brown et al., 2016).

Low temperatures coupled with the presence of ice can significantly reduce fuel spreading, increase viscosity and reduce the evaporation rate of the volatile components of oils in polar waters (Fingas and Hollebone, 2003; Faksness and Brandvik, 2008; Brandvik and Faksness, 2009), resulting in prolonged exposure of marine organisms to hydrocarbons in Antarctic waters (Stark et al., 2003).

Fuel spills in Antarctica and the Southern Ocean are rare compared to other regions of the world and the area is considered to be the least polluted region globally (Snape et al., 2008).

Southern Ocean biota can take longer to respond to contaminants than related temperate biota due to their lower metabolic rates, slower uptake kinetics and slower growth / development rates (Raymond et al., 2017).

The most significant fuel spill event to occur from a vessel in the Southern Ocean was in 1989, when the *Bahia Paraiso* ran aground in Arthur Harbour, off the coast of southwest Anvers Island (Antarctic Peninsula) spilling 600,000 litres (approximately 600m^3) of diesel fuel Arctic (DFA; a relatively volatile mixture of diesel and jet fuel).

In the first few weeks after the spill, intertidal macroalgae, limpets, birds, sediments and shores within a few kilometres of the wreck were coated with spilt fuel (Kennicutt et al., 1991). Limpet populations were reduced by 50% within the first few weeks of the spill and had not fully recovered a year after the spill (Kennicutt and Sweet, 1992). Observations and analytical data suggest that a major portion of the Arthur Harbour ecosystem was exposed to the spilt fuel though with varying levels of impact (Kennicutt et al., 1990; Penhale et al., 1997).

Birds breeding in the area were exposed depending upon their behaviour. Adult birds were exposed through foraging for krill and fish, and chicks were exposed to oiled parents and through receiving contaminated food. 80% of the Adelie penguins breeding in the area were exposed with an estimated 16% increase in mortality above normal rates, as a result of exposure to the spilt fuel (Fraser and Patterson, 1997).

However, measurements on subtidal and benthic environments in the vicinity of the spill demonstrated negligible effects (Kennicutt, 1990). Kennicutt and Sweet (1992) suggest that the combination of the volatility of the fuel, wind and surf action and tidal scouring and transport of bottom sediments were factors in reducing the residence time of the fuel and the length of exposure to the ecosystem.

Among Southern Ocean megafauna, penguins are particularly vulnerable to fuel spills because they swim low in the water, must surface regularly to breathe, are less able to detect and avoid petroleum than other seabirds, and often encounter discharges of petroleum when they are at sea (Garcia-Borboroglu et al., 2008; Trathan et al., 2014).

This expedition will be operating well away from any sensitive coastal environments and in deep water areas of the Weddell Sea. This mitigates the impacts of a spill in the very unlikely event that one should occur.

Impact type: direct, indirect and cumulative

A release of fuel would have **direct** consequences for the immediate marine environment any wildlife individuals that could be contaminated or ingest fuel-contaminated water or food e.g. krill. **Indirect impacts** may occur on the young of any individuals contaminated e.g., through feeding of fuel-contaminated krill. **Cumulative impacts** would occur in the sense that any contamination arising from this Expedition would add to past and potentially future contamination events arising from human activities in Antarctica.

Mitigation:

- The Expedition has selected a modern, highly capable Polar class vessel that meets current design and operational standards for operating in Antarctic ice-covered waters. The *SA Agulhas II* has double-skinned fuel tanks and carries an International Oil Pollution Prevention Certificate in accordance with MARPOL Annex 1 - Regulations for the Prevention of Pollution by Oil - Regulation 6.
- In the extremely unlikely event that a fuel spill does occur, the vessel has an approved ship oil pollution emergency plan (SOPEP) in accordance with Annex I of MARPOL 73/78. This includes fuel spill response equipment that can be deployed on the vessel to minimise loss of fuel to the environment from the vessel in accordance with SOPEP rules.
- The *SA Agulhas II* will be captained by a highly experienced captain with several seasons of Antarctic vessel operations.
- The vessel captain will be supported by a highly experienced ice pilot specifically requested by the Expedition. The combined experience of the captain and the ice pilot will ensure that operations 'in ice' are well managed, and carefully planned.
- The experience of the captain and ice pilot will be supported by the use of helicopters and/or RPA to support 'in ice' navigation.
- To support navigation the *SA Agulhas II* will have access to near-real time medium- and high-resolution satellite imagery provided by Drift+Noise (https://driftnoise.com/) TerraSAR-X (https://earth.esa.int/web/eoportal/satellite-missions/t/terrasar-x) and Polarview (https://www.polarview.aq/antarctic).

Record keeping:

Records will be maintained of any contamination incidents in the very unlikely event of a spill occurring. This will include recording the location of any spill as well as the volume and type of fuel lost to the environment.

7.4.2 Impacts to the marine environment

Based on the assessments in Sections 7.2 and 7.3 above, impacts to the Antarctic marine / Weddell Sea environment will or may arise from:

- the potential introduction of non-native marine species from biological contamination of the main vessel or the subsea vehicles;
- heat emissions from the main vessel and subsea vehicles;
- accidental release of fuels;
- accidental release of wastes, including the accidental loss of the subsea vehicles or marine sampling equipment or release of the fibre optic cable tether;
- water turbulence from the operation of the vessel and the subsea vehicles;
- deployment of snow buoys and oceanographic floats for research purposes.

7.4.2.1 Impact description: implications of the introduction of non-native species.

Shipping is recognised as a major vector for the global transfer of non-native marine species. Marine species are routinely transferred through ballast water, hull fouling, in sea chests and on ancillary equipment such as launches, rescue boats, anchors, ropes etc. (Coutts and Dodgshun, 2007; Hewitt et al., 2009).

Although invasions to high-latitude terrestrial ecosystems are now well described (Frenot et al., 2005; Hughes et al., 2015), the same is not true for marine systems. Recent studies have suggested some potential mechanisms for marine introductions to Antarctic coastlines including with rafts of marine debris (Barnes and Fraser, 2003) and on vessel hulls (Lewis et al., 2003, 2004; Hughes and Ashton, 2016). Together, these reports indicate that, despite the apparent isolation of the Southern Ocean, marine introductions can occur, though to date only a single non-native species establishment has been recorded from within the Antarctic marine environment (Clayton et al., 1997) though surveillance and monitoring of the Antarctic marine environment and marine vectors remains extremely limited (Hughes and Ashton, 2016).

Increasing marine traffic, including private yachts and military, national operator, fishing and tourist vessels, in the waters around Antarctica may increase the risk of non-native species introductions (Hughes and Ashton, 2016)).

Scientists and scientific research equipment have been identified as presenting a particularly high risk of introducing non-native species to Antarctica (Chown et al., 2012).

Any fouling of the subsea vehicles with marine species from outside of Antarctica presents a risk of transfer of non-native species into the region. Additionally, the operation of marine equipment in various locations in the Weddell Sea presents a risk of artificially relocating native species beyond natural distributions.

The establishment of a non-native (temperate) marine species in the deep, largely ice-covered waters of the Weddell Sea is likely to be low; though irreversible if it were to occur.

Impact type: indirect and cumulative

Antarctica's marine ecosystems have been isolated for millennia and demonstrate high levels of endemism, increasing the susceptibility of these ecosystems to the impacts of invasive species (Hughes and Ashton, 2016). Any introductions would have an **indirect impact** on the marine environment through the potential introduced competition for habitat, as well as a reduction in the research value at locations 'contaminated' with marine species that have been artificially introduced to the region.

Cumulatively, such an occurrence would be further evidence of human induced pressures on the Antarctic environment and Southern Ocean.

Mitigation:

It is noted that as the Expedition is using a charter vessel, this environmental risk is somewhat out of the control of the Expedition compared with other non-native species risks that can be more actively managed. Nonetheless, the following mitigation measures are applicable:

- The *SA Agulhas II* carries an Anti-fouling System Statement of Compliance to record that its anti-fouling system is compliant with the IMO's Anti-Fouling Convention 2001.
- The vessel will be operating in deep water which reduces the likelihood of introduced species establishing (which are more likely to be shallow water algal and invertebrate species).
- It is noted that the International Maritime Organisation has adopted 'Guidelines for the control and management of ships' biofouling to minimise the transfer of invasive aquatic species' through its Marine Environment Protection Committee in July 2011 (Resolution MEPC.207(62)). However, these guidelines contain no specific measures regarding fouling management in polar locations.
- The IMO has also adopted ballast water management guidelines for use within Antarctic waters (Resolution MEPC.163(56); July 2007). The ATCM has also adopted 'Practical guidelines for ballast water exchange in the Antarctic Treaty Area' (Resolution 3 (2006)). However, this is somewhat academic with regard to this Expedition as no ballast water exchanges will occur whilst the *SA Agulhas II* is operating in the Weddell Sea.
- Relevant guidance information available through the Non-Native Species Manual developed by the Committee for Environmental Protection, and in particular the 'guiding principles' of the Manual, will be made available to and adopted by the subsea vehicle operators (CEP, 2016).
- The subsea vehicles will be inspected and cleaned prior to deployment to Antarctica and prior to each deployment in Antarctica.

7.4.2.2 Potential impact: heat loss to the marine environment

Heat emissions will arise from the operation of the *SA Agulhas II* as well as from the subsea vehicles. However, the implications of these emissions are likely to be negligible in the Antarctic context.

Impact type: direct

Heat losses from the vessel and subsea vehicles will be **direct** though negligible in terms of its impact on the environment of the Weddell Sea.

Mitigation:

None required.

Record keeping:

None required.

7.4.2.3 Potential impact: contamination of the marine environment from the accidental release of fuels

This is covered in section 7.4.1.3 above.

7.4.2.4 Potential impact: contamination of the marine environment through the accidental release of wastes or loss of the subsea vehicles

Wastes from SA Agulhas II

The Expedition will produce several waste types including human waste; food waste; general waste and chemical waste. The volumes of each have not been estimated as no wastes (other than human waste) will be released in the Antarctic.

All wastes with the exception of grey water and human waste will be collected on-board and disposed of through port facilities on return to Cape Town.

Only human waste / grey water will be discharged through the vessel's sewage management system, though as recorded below, the sewage treatment system on-board results in zero discharge of raw effluent.

Loss of subsea vehicles

The deployment of the subsea vehicles beneath a drifting canopy of sea ice increases the risk of equipment loss compared to open water environments.

In the unlikely event that one of the subsea vehicles was unable to be returned to the surface or to the support ship, it may be unrecoverable.

The loss of an autonomous underwater vehicle (AUV) occurred during the previous Weddell Sea Expedition 2019 (WSE2019). Whilst conducting remote surveys of the seabed in the vicinity of the wreck of the *Endurance* the HUGIN AUVs were lost on two separate incidents. On the first occasion the AUV surfaced beneath an ice floe and was recovered by using the *SA Agulhas II* to break into the floe, allowing a remotely operated (tethered) vehicle to be deployed and recover the AUV. On the second occasion contact with a deployed AUV was lost and the AUV was unable to be located or recovered.

In the event of loss of a subsea vehicle and the release or breaking of the fibre optic cable tether, it will either sink to the seabed where it will slowly decay over many decades, or if it floats to the surface it is likely to drift with the sea ice and be carried north away from Antarctica.

Impact type: direct and cumulative

The release of treated waste water from the *SA Agulhas II* will have a **direct**, though negligible effect on the immediate marine environment. The quality of the discharged water is high and dispersion and dilution is likely to be rapid.

The release of treated waste water will add to the past and on-going, though likely less than minor and transitory release of waste water from ships in the Southern Ocean.

The slow decay of a subsea vehicle on the seabed will have a highly localised impact on the surrounding benthos.

Mitigation:

- No wastes will be disposed of in the Antarctic Treaty area. All wastes (other than human waste and grey water) will be retained on-board and disposed of when the vessel returns to port in South Africa.
- The vessel's sewage treatment system is based on zero discharge of raw effluent. The vessel is fitted with an Evac membrane bioreactor system resulting in discharge water at a quality that exceeds the requirements of IMO Resolution MEPC.159(55) 2006 on the implementation of effluent standards and performance tests for sewage treatment plants. This also exceeds the requirements of Annex IV to the Protocol.
- The subsea vehicles have been specifically selected for the expedition with significant lessons learned from the previous WSE2019. The tethering of the vehicles via fibre optic cable means a reduced likelihood of any loss. Updated transponder equipment will be utilised to allow the subsea vehicles to be located and recovered should they become trapped beneath an ice floe.
- No fibre optic cable will be released to the marine environment. The fibre optic tether is permanently fitted to the vehicle to allow real time handshake and permanent safety control on the vehicle. This tether is spooled over an electrical winch that pays in/out the length required by the vehicle.
- In advance of the Expedition departing for Antarctica sea trials will be undertaken to fully test the SAAB Sabertooth vehicles to their operational depth of 3000km. These trials are planned for October 2021. Lesson learned will be incorporated into the Expedition planning.
- Pre-departure testing of the ice auger and the subsea vehicle launch and recovery system will also be undertaken in a dock-side simulation in France in October 2021. Lesson learned will be incorporated into the Expedition planning.

- The moon pool of the *SA Agulhas II* can be used to deploy the HiPAP navigation pole that communicates with the subsea vehicles. Deployment through the moon pool eliminates potential interference by pack ice.
- The Expedition will have available to it a team of highly experienced specialist technicians and operators to oversee subsea vehicle operations.

Record keeping:

- Records will be maintained of the location (if known) of a lost and unrecoverable subsea vehicles.
- All subsea deployments will be fully logged.

7.4.2.5 Potential impact: water turbulence

The movement of ships through water may have an impact on the marine environment including through the generation of waves, propeller-induced turbidity and aeration in the water column, ship's wash contributing to coastal erosion, and the re-suspension of sediments (Ellis et al., 2005).

This Expedition will operate exclusively in deep water such that resuspension of sediments will not occur. Water turbulence, wash and waves from the ship will have limited impact, other than on the already highly mobile pack ice as the ship breaks through.

The operation of the subsea vehicles will produce a small degree of water turbulence in the immediate area of operation of the vehicle.

Impact type: direct

Operation of the vessel will have negligible impact on the marine environment other than disturbance of the already highly mobile pack ice environment on passage.

Only the water in the immediate vicinity of operation of the subsea vehicles will be affected. This will be negligible and dissipate rapidly.

Mitigation:

This is an unavoidable impact with no mitigation possible, or necessarily required. The ships activity will have negligible consequences for the ocean / ice environment of the Weddell Sea.

7.4.2.6 Deployment of snow buoys and oceanographic floats

The research team will deploy four 'snow buoys' to selected ice floes. These buoys are telemetered and will transmit data on snow cover and other parameters for as long as battery life allows or until the ice melts and the buoys are lost to the marine environment. Once released to the marine environment the snow buoys will sink to the benthos where they will slowly decay over many decades with negligible environmental impact.

The oceanographic team will deploy a number of Argo floats to the marine environment. These will operate for as long as battery life allows and will ultimately drift with currents until such time as they sink to the benthos and slowly decay over many decades with negligible environmental impact.

Impact type: direct

The deployment and ultimate loss of the research buoys will have negligible impact on the marine environment.

Mitigation:

This is an unavoidable impact with no mitigation possible, or necessarily required.

Record keeping:

The last known location of the buoys will be recorded for research purposes, although the ultimate resting point will never be known.

7.4.3 Impacts to the ice environment

Based on the assessments in Sections 7.2 and 7.3 above, impacts to the Weddell Sea ice environment will or may arise from:

- physical disturbance of the sea / pack ice from the mechanical action of the vessel as it breaks through the pack ice as well as the mechanical action of the drilling to create the dive holes for the deployment of the subsea vehicles and the mechanical action of coring for sea ice cores and snow samples for research purposes;
- contamination of the ice in the unlikely event of a fuel spill from the vessel or ice camps;
- release of waste including human waste from the ice camps.

7.4.3.1 Potential impact: physical disturbance to the sea ice / pack ice

Physical disturbance to the sea ice and pack ice as a result of the vessel activity, or the drilling through ice floes, is unlikely to have any concerning environmental consequences. The pack ice environment is highly mobile, particularly at the time of year during which the Expedition will occur.

Sea ice does play a role in buttressing marine-based ice shelves and suppressing calving events from the ice shelf front (Robel, 2016; Miles et al., 2017). Sea ice loss in front of ice shelves and glaciers can lead to increased calving or, in combination with other factors, ice shelf disintegration. Any physical disturbance to sea ice and pack ice by this expedition will occur a few hundred kilometres away from the nearest ice shelves on the easter side of the Antarctic Peninsula and is unlikely to have any consequences for ice shelf behaviour.

The drilling of holes in ice floes may attract seals that use such holes for breathing or for exiting the water. The potential impacts associated with this are discussed in section 7.4.1.1 above.

Impact type: direct

The physical impacts on the pack ice from the vessel and drilling / ice coring activity will be **direct** though negligible in terms of its impact on the ice environment of the Weddell Sea.

Mitigation:

None required.

Record keeping:

None required.

7.4.3.2 Potential impact: accidental spill of fuel on the ice

If the density of the pack ice demands that the subsea vehicles are launched from an ice camp, then fuel will need to be taken onto the selected ice floes to power generators and skidoos. In the unlikely event that fuel is spilt onto an ice floe it will quickly penetrate through any surface snow and dissipate through cracks and fissures within the ice floe. This rapid dispersion within the ice makes it challenging to undertake effective clean up and the presence of ice makes the deployment of spill response equipment, such as containment booms, ineffective (Raymond et al., 2017).

Any fuel that leaches through the ice could contaminate algae growing on the base of the ice and any organisms such as krill grazing there.

Impact type: direct, indirect, cumulative

A release of fuel would have **direct** consequences for the immediate ice environment any wildlife individuals that could be contaminated or ingest fuel-contaminated water or food e.g. krill. **Indirect impacts** may occur on the young of any individuals contaminated e.g. through feeding of fuel-contaminated krill. **Cumulative impacts** would occur in the sense that any contamination arising from this Expedition would add to past and potentially future contamination events arising from human activities in Antarctica.

Mitigation:

- Fuel management and handling will draw on guidance contained in the COMNAP Fuel Manual.
- The volumes of fuel taken onto ice floes will be minimised to the extent possible.
- Any fuel taken onto ice floes will be carefully stored to prevent loss of fuel to the ice surface.
- Fuel stores will be regularly checked for any leaks.
- Spill response kits will be taken ashore with any fuel deployed.
- Refuelling of generators and skidoos will be undertaken with a minimum of two people and with a spill response kit available.

Record keeping:

Records will be maintained of any contamination incidents in the very unlikely event of a spill occurring. This will include recording the location of any spill as well as the volume and type of fuel lost.

7.4.3.3 Potential impact: loss of waste materials to the ice environment

In the heavy ice camp scenario, personnel will spend up to a few days at the ice camp. During this time waste materials will be generated including food waste, general waste and human waste. Loss or accidental release of such waste materials could contaminate the local ice and marine environments.

The release of certain waste items, such as plastic packaging bands, can cause entanglement of birds and seals (Hofmeyr et al., 2006). The release of human waste to Antarctic environments risks the introduction of gut microbiota and potentially pathogens (Palmgren et al., 2000).

The only disposal onto the ice floes will be relative small volumes of liquid human waste and greywater. Any such liquid waste will permeate through the ice and be rapidly diluted as it seeps into the water column.

It is also possible that larger equipment, such as the subsea vehicle launch and recovery system and camp infrastructure may be abandoned on the ice floes if personnel need to be evacuated quickly; for example if the weather rapidly deteriorates or the vessel needs to immediately depart the area. This scenario is only likely if the heavy ice camp option is employed in which camps are established on the ice some distance away from the *SA Agulhas II*.

Any abandoned or unrecoverable equipment would drift with the ice until the ice floe melts at an unpredictable location, at which point the various items would sink to the sea floor and slowly decay over years to decades.

Impact type: direct, indirect

A release of waste items or the abandonment of equipment on the ice would have a **direct** impact through the littering of the Antarctic environment. **Indirect** impacts may arise from the interaction of wastes, fuels and oils with Antarctic biota (e.g. entanglement of birds and seals with lost plastic items or the release of contaminants to the benthos in the case of abandoned equipment) or the exposure of wildlife to human pathogens.

Mitigation:

- Waste management and handling will draw on guidance contained in the COMNAP Waste Manual.
- Waste production at the camps will be minimised by reducing the items taken onto ice floes in the first place.
- Waste items will be collected and stored at the ice camps and returned to the ship for ultimate disposal outside of Antarctica.
- A toilet tent will be established at the ice camps. Solid human waste will be collected and returned to the ship for disposal through the ships sewage treatment plant.

- Heavy ice camps will be deployed under controlled conditions involving: assessment of the stability and thickness of the ice; monitoring of weather conditions with threshold conditions triggering return to the main vessel; staged approach to keep deployed personnel and equipment to the minimum required; regular communications with the main vessel.
- In the unlikely event that equipment is abandoned on an ice floe, all attempts will be made to recover it as conditions allow.

Record keeping:

Records will be maintained in the unlikely event that any items are lost to the environment from the ice camps.

7.4.4 Impacts to the atmosphere

Based on the assessments in Sections 7.2 and 7.3 above, impacts to the atmospheric environment will or may arise from:

- exhaust emissions from the *SA Agulhas II* and generators and vehicles used on ice floes;
- turbulence from the operation of RPA.

7.4.4.1 Potential impact: atmospheric emissions from SA Agulhas II.

The burning of fossil fuels for power and propulsion of the *SA Agulhas II*, will result in the release of exhaust gases including greenhouse gases.

The emissions associated with the operation of the *SA Agulhas II* vessel will contribute all of the atmospheric emissions for the Expedition. Sulphur (particularly sulphur dioxide (SO2) and particle emissions together with nitrogen oxides (NOx) and carbon dioxide (CO2) are considered as the shipping emissions that cause the most severe stress to the environment as well as to human health.

Calculations of anticipated fuel use for this expedition are shown in Table 7 below. These figures are considered to be 'worst case' and actual fuel usage is likely to be less that the figures shown.

Activity	Fuel use (metric tonnes / day)	Anticipated number of days	Total fuel use (metric tonnes)
In transit in open water / light pack ice	40	20	800
Heavy pack ice / ice breaking	45	10	450
Research support / on station	20	15	300
		Total	**1,550**

Table 7. Summary of anticipated vessel fuel use during the 45-day Expedition. These figures are considered to be the 'worst case'.

In 2013 the South African Department of Environmental Affairs (DEA – as it was at the time) reported on the fuel use and carbon emissions of the South Africa Antarctic programme (DEA, 2013). The report records that the *SA Agulhas II* used 3,520,000 litres of fuel (approximately, 3,133 tonnes) on a 175-day cruise in the 2012/13 season. This resulted in the release of 9,400.16 tons of CO_2 equivalent (tCO_{2e}; Figure 44); approximately $3tCO_{2e}$ per metric tonne of fuel burned by the *SA Agulhas II*.

Using the 'worst case' estimate for fuel use to be burned, it can be calculated that up to 4,650 tCO_{2e} will be released to the environment from the *SA Agulhas II* during the 35 (up to 45)day Endurance22 Expedition.

Additional emissions will arise from the burning of fossil fuels in the helicopters and in the generator and skidoo used on the ice camp.

The SA Aghulhas II is considerably larger when compared to its predecessor with a gross tonnage of 12 897 tons compared to the SA Agulhas I's gross tonnage of 6 123 tons. Besides the difference in tonnage the time spent at sea has also increased with the SA Agulhas II spending an estimated 175 days at sea during 2012/2013 compared to 152 days spent by the SA Agulhas I during the 2011/2012 reporting period. Fuel consumption data has shown a considerable increase in fuel usage since the previous reporting period from an estimated 2 230 800 litres[21] to 3 520 000 litres. On a tonnage basis the fuel usage amounts to 272.93 litres per ton for the SA Agulhas II compared to 364.33 litres per ton for the SA Agulhas I vessel.

Table 6: Summary statistics related to the Antarctic programme

Type		2010/2011		2011/2012		2012/2013	
		Consumption (litres)	Emissions (tons)	Consumption (litres)	Emissions (tons)	Consumption (litres)	Emissions (tons)
Aviation gasoline	Aviation gasoline	53 827	137.14	53 827	137.3	54 100	137.51
SA Agulhas	Arctic diesel	2 230 800	5 960.70	2 230 800	5 950.88	3 520 000	9 400.16
Antarctic base	Polar diesel (generators)	275 000	734.80	275 000	733.59	275 000	734.39
	Polar diesel (vehicles)	80 000	213.76	80 000	213.41	120 000	320.46
Marion	Polar diesel (generators)	300 000	801.60	300 000	800.28	300 000	801.15
Gough	Polar diesel - generators	100 000	267.20	100 000	266.76	100 000	267.05
GRAND TOTAL		3 039 627	8 115.20	3 039 627	8 102.06	4 369 100	11 660.72
Total per capita			9.86		6.50		8.62

Figure 44. Fuel use statistics for the South African Antarctic programme. The figures for the 2012/2013 season are for the SA Agulhas II. Source: DEA, 2013.

Impact type: direct and cumulative

Emissions to air will be **direct**, though gases and particulate matter will disperse and dilute rapidly, particularly so in windy conditions.

Emissions from this 35 (up to 45) day Expedition will also be **cumulative**, adding to the regional, though (in a global context) minor, emissions from other Antarctic operations (stations, aircraft, ship and other vehicles) during the 2021/22 austral summer.

Mitigation:

- *SA Agulhas II* uses marine gas oil (MGO) with a low sulphur content.
- Fuel use will be minimised to the extent possible by maximising operations in open water and minimising the extent to which the vessel is required to 'work ice', which inevitably requires more power and burns more fuel. This will be facilitated by making use of satellite imagery to carefully plan routes and optimise operations in open water and leads in the pack ice.
- The Expedition has also selected a modern Polar class, fit-for-purpose vessel to support the research and likely one of the most fuel-efficient vessels currently operating in the Southern Ocean.

- Aircraft use and the use of generators and skidoos on the ice will be restricted to meeting operational needs.

7.4.4.3 Potential impact: air turbulence

The deployment of helicopters and RPA will create air turbulence from the propellers and their movement through the air.

Impact type: direct

Air turbulence as a result of helicopter and RPA operation will be negligible within a very short distance from the aircraft.

Mitigation:

An unavoidable impact that will occur as a result of the operation of the RPA. No mitigation options are available nor necessarily required.

7.4.8 Impacts to wilderness values

Based on the assessments in Sections 7.2 and 7.3 above, impacts to wilderness values will or may arise from the presence of the vessel, ice camps and deployed equipment in the Weddell Sea.

7.4.8.1 Potential impact: loss of wilderness values

This Expedition will visit, spend time in and undertake activities in areas that have rarely been visited by humans in the past.

The Expedition's activities have the potential to impact on the wilderness values of Antarctica and, along with other human activities (both governmental and non-governmental) cumulatively add to the evidence of human presence in the region, with the potential insidious loss of wilderness values over time.

Antarctica presents a number of challenges for the application of standard environmental management tools, such as wilderness mapping and the assessment of impacts on wilderness values. The main challenges concern the size of the area relative to the extent of the human impact, and the fact that most human impacts are related to single sites or installations set in the context of an enormous continent with relatively little or no human impact. Antarctica remains almost wholly wilderness with a very high proportion of inviolate areas. Yet, the hitherto unspoilt and un-impacted nature of the region means that any human presence will have a disproportionately high impact relative to its size and context, especially in areas where there is no other human presence and in areas that have never previously been visited by humans (Carver and Tin, 2015).

Impact type: direct and cumulative

The presence of humans will have a **direct** effect on wilderness values whilst the expedition is being undertaken. **Cumulatively** the record of the expedition will add to the growing number of locations that humans have visited in Antarctica.

Mitigation:

- The Expedition is of relatively short duration and has adopted a 'light footprint' approach. The majority of the activities to be undertaken are non-invasive, or likely to have less than a minor or transitory impact.
- All equipment to be deployed will be carefully managed and controlled by highly experienced technicians and operators so as to minimise the risk of equipment loss.
- Sites to be sampled will be carefully selected so as to maximise research benefits and minimise impacts.
- With the exception of sewage discharge from the vessel (in accordance with Annex IV and MARPOL requirements) and disposal of human liquid waste and greywater from the ice camps, the Expedition will dispose of no waste in Antarctica.

Record keeping:

The following will (if required) be recorded and reported on conclusion of the Expedition:

- The location of any fuel spill events and the type and volume of fuel spilt during the Expedition;
- The type and location (as accurately as may be possible) of any equipment lost to the environment;
- All water column sampling locations will be accurately recorded, not least for publication purposes;
- Records of any observed encounters with wildlife such as may occur between the subsea vehicles and diving pinnipeds or cetaceans, as well as any observed bird encounters with the RPA. To the extent possible records will be maintained of the species concerned and the location;
- Records of any physical disturbance to surveyed wreck sites. In the extremely unlikely event that such disturbance occurs records will be made of the nature, extent and location of the disturbance.

7.4.7 Impact to marine heritage value.

Based on the assessments in Sections 7.2 and 7.3 above, impacts to HSM No. 93 (the wreck of Shackleton's Endurance) could occur through accidental collision of the subsea vehicles and the wreck or associated artefacts.

7.4.7.1 Potential impact: physical disturbance to HSM No 93

Operation of the subsea vehicles near to the wreck site presents a risk of collision causing physical disturbance or damage to the wrecks.

Such impact is very unlikely to occur, though if it did a collision has the potential to impact on the value of the wreck including its research and heritage value. There is much information and knowledge to be gained from surveying the wrecks in their current state, which are likely to be largely undisturbed since they sank over a century ago.

Impact type: direct and indirect

The **direct** impact would be an alteration of the current layout of the wreck site and any associated artefacts on the sea floor.

Indirectly, such disturbance has the potential to result in the loss of historical knowledge or information that might otherwise have been gained.

Mitigation:

- The subsea vehicles will be operated by highly trained and experienced operators to standard, planned survey techniques.
- The initial surveys within the vicinity of the wrecks by the subsea vehicles will be conducted from a safe distance (approximately 100 metres) above the sea floor.
- The subsea surveys undertaken from distance will produce high quality visible and sonar imagery of the wrecks, which will then be used to plan the closer, more detailed inspections.
- All wreck searches will be conducted within the principles of the relevant charters of the International Council on Monuments and Sites (ICOMOS): notably the Charter for the Protection and Management of the Archaeological Heritage (1990) and the Charter on the Protection and Management of Underwater Cultural Heritage (1996), as well as the ATCM Guidelines for Handling Pre-1958 Remains (Resolution 5 (2001)).
- The Expedition has adopted a 'zero disturbance, zero collection' policy with respect to the search for the wrecks. No artefacts or any items from the wreck site will be touched or removed.

Record keeping:

In the highly unlikely event that a disturbance incident does occur, it will be recorded and reported at the end of the Expedition.

7.5 Summary and evaluation of impacts

Sections 7.2 to 7.4 identify the potential (direct, indirect and cumulative) impacts of the planned Expedition and the activities to be undertaken. This section evaluates the identified potential impacts by taking into account the three levels of significance that are outlined in Article 8(1) of the Protocol.

In order to evaluate the significance of a given potential impact, the spatial extent, duration, intensity (which also includes a level of reversibility) and probability of the identified potential impacts are considered so as to evaluate the overall significance of the potential impact of each activity.

Table 8 outlines the assessment criteria and definitions that have been used when evaluating the spatial extent, duration, intensity and probability of the identified potential impacts for the environmental elements (table and methodology modified from Oerter, 2000).

Table 9 summarises the significance of the identified impacts with and without the mitigation measures in place, based on the criteria outlined in Table 8. No activities associated with the Expedition are assessed as having more than a minor or transitory impact on the Antarctic (Weddell Sea) environment.

Impact	Environment Element	***Criteria for assessment*** Low (1)	Medium (2)	High (3)	Very High (4)
SPATIAL EXTENT OF IMPACT Area or volume where changes are likely to occur		*Local extent*	*Partial extent*	*Major extent*	*Entire extent*
	Freshwater ***Marine*** ***Terrestrial*** ***Atmosphere***	*Confined to the site of the activity.*	*Some parts of an area are partially affected.*	*A major sized area is affected.*	*Large-scale impact; causing further impact.*
	Flora and Fauna	*Confined disturbance of fauna and flora within site of activity, e.g. individuals affected.*	*Some parts of the community are disturbed.*	*Major disturbance in community, e.g. breeding success is reduced.*	*Impairment at population level.*
DURATION OF IMPACT Period of time during which changes in the environment are likely to occur		*Short term*	*Medium term*	*Long term*	*Permanent*
	Freshwater ***Marine*** ***Terrestrial*** ***Atmosphere***	*Several weeks to one season; short compared to natural processes.*	*Several seasons to several years; impacts are reversible.*	*Decades; impacts are reversible.*	*Environment will suffer permanent impact.*
	Flora and Fauna	*Short compared to growth period/ breeding season.*	*Medium compared to growth/ breeding season.*	*Long compared to growth/ breeding season.*	*Permanent*
INTENSITY OF IMPACT A measure of the amount of change imposed on the environment due to the activity		*Minimal Affect*	*Affected*	*High*	*Irreversible*
	Freshwater ***Marine*** ***Terrestrial*** ***Atmosphere***	*Natural functions and processes of the environment are minimally affected. Reversible.*	*Natural functions or processes of the environment are affected but are not subject to long-lasting changes. Reversible.*	*Natural functions or processes of the environment are affected or changed over the long term. Reversibility uncertain.*	*Natural functions or processes of the environment are permanently disrupted. Irreversible or chronic changes.*
	Flora and Fauna	*Minor disturbance. Recovery definite.*	*Medium disturbance. Recovery likely.*	*High levels of disturbance. Recovery slow and uncertain.*	*Very high levels of disturbance. Recovery unlikely.*
PROBABILITY *Chance of the occurrence of the impact*	***All elements***	*Should not occur under normal operation and conditions.*	*Possible but unlikely.*	*Likely to occur during span of project. Probable.*	*Certain to occur / unavoidable.*

Table 8. Assessment criteria for evaluating the spatial extent, duration, intensity and probability of the potential environmental impacts (modified from Oerter, 2000).

Table 9.Evaluation of the potential environmental impacts of the Expedition activities on the Antarctic environment.

			Uncontrolled Risk Assessment						Residual Risk Assessment				
Environmental Element Impacted	**Aspect**	**Impact**	**Spatial Extent**	**Duration**	**Intensity**	**Probability**	**Significance (without mitigation)**	**Mitigation Measures**	**Spatial Extent**	**Duration**	**Intensity**	**Probability**	**Significance (with mitigation)**
Antarctic Flora and Fauna	Noise emissions from the operation of the main vessel, the use of equipment at the ice camps and the deployment of the subsea vehicles and RPA	Disturbance to individuals or congregations of foraging birds and penguins; cetaceans; pinnipeds	**Low** Individuals within the immediate vicinity of the vessel may be affected	**Low** Even without controls, encounters are likely to be brief (minutes) with wildlife likely to move away if disturbed	**Low** Normal functional activity likely to resume within minutes to hours	**High** With no controls, disturbance events at some point during the 45-day cruise are likely	**No more than minor or transitory**	• *SA Agulhas II* will proceed cautiously around groups of marine mammals if safe and practicable to do so. • Subsea vehicles are quiet. • Highly experienced technicians will operate subsea vehicles. • Marine mammal and cetacean observations 20 minutes prior to launching the subsea vehicles, with operations paused if wildlife disturbance possible. • If seals are encountered in the holes drilled in the pack ice, operations will cease until the seal moves away. • Highly experienced helicopter pilots. Avoidance of any birds or seals on ice floes that does not compromise safety. Operations consistent with the Guidelines for the Operation of Aircraft Near Concentrations of Birds. • RPA operated by a highly trained and experienced pilot and in full conformance with COMNAP and ATCM guidance material. • RPA will not be launched in the vicinity of large congregations of wildlife. • Bird observations in the vicinity of the launch site will commence 20 minutes prior to deployment of the RPA. Operations that may cause disturbance will be paused if safe and practicable to do so, until the wildlife has moved away.	**Low** Mitigation will not greatly affect spatial extent of exposure	**Low** Mitigation may further reduce the duration of any exposure	**Low** Mitigation will reduce intensity of any exposure	**Medium** Mitigation will reduce the likelihood of any adverse impacts to wildlife	**Less than minor or transitory**
	Light emissions from the subsea vehicles	Disturbance to pinnipeds or cetaceans e.g. during a foraging dive	**Low** Emissions constrained to within a very short distance of the vehicles	**Low** Short deployment periods up to hours only	**Low** Minor to negligible impacts with recovery definite	**Medium** Some minor to negligible encounters with wildlife are possible though unlikely	**Less than minor or transitory**	Few mitigation measures are required. The need for above-surface lighting will be minimal due to the timing of the expedition. Subsea lighting will be required to achieve the objectives of the expedition, but impacts are anticipated to be fleeting.	**Low** Emissions constrained to within a very short distance of the vehicles	**Low** Short deployment periods up to hours only	**Low** Minor to negligible impacts with recovery definite	**Medium** Some minor to negligible encounters with wildlife are possible though unlikely	**Less than minor or transitory**
	Accidental fuel spills	Contamination of the marine environment and toxic effects to flora and fauna	**Medium** Large volume spill event would potentially impact a wide area - though somewhat naturally constrained by ice	**Medium** Some persistence of fuels in the marine environment particularly if ice constrained	**Medium** Fuel will dissipate over time in the environment and normal ecosystem functions likely to return	**Medium** Could occur with no controls in place	**More than minor & transitory in case of a large, uncontrolled, accidental spill event**	• *SA Agulhas II* is a modern, highly capable Polar class vessel. The vessel has double-skinned fuel tanks and carries an International Oil Pollution Prevention Certificate in accordance with MARPOL Annex 1. • The vessel has an approved ship oil pollution emergency plan (SOPEP) in accordance with Annex I of MARPOL 73/78. • The *SA Agulhas II* will be captained by a highly experienced captain with several seasons of Antarctic vessel operations. • The vessel captain will be supported by a highly experienced ice pilot specifically requested by the Expedition. • The experience of the captain and ice pilot will be supported by the use of a helicopters and RPA for 'in ice' navigation. • To support navigation the *SA Agulhas II* will have access to near-real time medium- and high-resolution satellite imagery provided by Drift&Noise	**Low** Controls likely to reduce volumes spilt and therefore spatial extent of any impact	**Medium** Any spilt fuels could still persist beyond one season	**Low** Reduced volumes of any spilt fuel will reduce intensity of impact	**Low** Spill event is unlikely	**Less than minor or transitory**

			Uncontrolled Risk Assessment						Residual Risk Assessment				
Environmental Element Impacted	**Aspect**	**Impact**	**Spatial Extent**	**Duration**	**Intensity**	**Probability**	**Significance (without mitigation)**	**Mitigation Measures**	**Spatial Extent**	**Duration**	**Intensity**	**Probability**	**Significance (with mitigation)**
Marine Environment	Introduction of non-native species	Competition with native fauna or flora; loss of research value	**Medium** An introduced species may spread over a wide area	**Very high** Once established non-native species are unlikely to be eradicated	**High** If established non-native species may have long-term consequences for native biota	**Medium** Vessel likely to be carrying non-native species; though risk of establishment in the Weddell Sea environment is likely to be low	**More than minor & transitory (if a non-native species were to establish)**	• Expedition is using a charter vessel and risk mitigation is out of the control of the Expedition compared with other non-native species risks that can be more actively managed. • *SA Agulhas II* carries an Anti-fouling System Statement of Compliance to record that its anti-fouling system is compliant with the IMO's Anti-Fouling Convention 2001. • Vessel will be operating in deep water which reduces the likelihood of introduced species establishing. • No ballast water exchanges will occur in the Weddell Sea. • Relevant Antarctic guidance information will be made available to and adopted by the subsea vehicle operators. • The subsea vehicles will be inspected and cleaned prior to deployment to Antarctica and prior to each deployment in Antarctica.	**Medium** Mitigation focussed on reducing likelihood	**Very high** Mitigation focussed on reducing likelihood	**High** Mitigation focussed on reducing likelihood	**Low** Mitigation will reduce the likelihood of any introductions	**No more than minor or transitory**
	Heat emissions from the main vessel and subsea vehicles	Extremely localised warming	**Low** Emissions constrained to within a very short distance of the vehicles	**Low** Short deployment periods up to hours only	**Low** Minor to negligible impacts with recovery definite	**Low** Some encounters with wildlife are possible though unlikely	**Less than minor or transitory**	No mitigation required	**Low** Emissions constrained to within a very short distance of the vehicles	**Low** Short deployment periods up to hours only	**Low** Minor to negligible impacts with recovery definite	**Low** Some encounters with wildlife are possible though unlikely	**Less than minor or transitory**
	Accidental release of wastes or loss of subsea vehicle or RPA	Contamination of the marine environment	**Low** Impact constrained to area of vehicle only – and highly localised	**Very high** If lost, equipment will persist in the environment for many decades	**Low** Ecosystems negligibly and reversibly affected	**Medium** Loss of subsea vehicles is possible without any mitigation	**No more than minor but more than transitory (if loss were to occur)**	• No wastes will be disposed of in the Antarctic Treaty area. All wastes (other than human waste / grey water) will be retained on-board and disposed of in South Africa. • Vessel's sewage treatment system exceeds the requirements of Annex IV to the Protocol. • Subsea vehicles have been specifically selected for the expedition with significant lessons learned from the previous WSE2019. The tethered vehicles means reduced likelihood of loss. Transponder units will be able to locate a vehicle trapped beneath an ice floe. • Pre-departure sea trials of SAAB Sabertooth vehicles to their operational depth of 3000km will be undertaken in October 2021. • No release of fibre optic cable to the marine environment • Pre-departure testing of the ice auger and the subsea vehicle launch and recovery system will be undertaken in simulated cold weather and ice conditions in November 2021. • The moon pool of the *SA Agulhas II* can be used to deploy the HiPAP navigation pole, eliminating potential interference by pack ice. • Subsea operations overseen by highly experienced specialist technicians.	**Low** Mitigation focussed on reducing likelihood	**Very high** Mitigation focussed on reducing likelihood	**Low** Mitigation focussed on reducing likelihood	**Low** Mitigation will reduce the likelihood of any releases or losses to the environment	**No more than minor or transitory**
	Water turbulence	Localised water turbulence	**Low** Immediate vicinity of the vessel & subsea vehicles only	**Low** Limited to 45-day cruise only	**Low** Natural ecosystem functions unlikely to be affected	**High** Water turbulence will occur	**Less than minor or transitory**	This is an unavoidable impact with no mitigation possible, or necessarily required. The ships activity will have negligible consequences for the ocean / ice environment of the Weddell Sea.	**Low** Immediate vicinity of the vessel & subsea vehicles only	**Low** Limited to 45-day cruise only	**Low** Natural ecosystem functions unlikely to be affected	**High** Water turbulence will occur	**Less than minor or transitory**

			Uncontrolled Risk Assessment						Residual Risk Assessment				
Environmental Element Impacted	**Aspect**	**Impact**	**Spatial Extent**	**Duration**	**Intensity**	**Probability**	**Significance (without mitigation)**	**Mitigation Measures**	**Spatial Extent**	**Duration**	**Intensity**	**Probability**	**Significance (with mitigation)**
Ice Environment	Physical disturbance from ice breaking activities and drilling of ice holes or ice coring or snow sampling	Physical modification of pack ice and ice floes	**Low** Impact will occur over a small area of the Weddell Sea	**Low** Limited to 45-day cruise only	**Low** Natural processes unlikely to be affected	**High** Physical impacts will occur	**Less than minor or transitory**	No mitigation required	**Low** Impact will occur over a small area of the Weddell Sea	**Low** Limited to 45-day cruise only	**Low** Natural processes unlikely to be affected	**High** Physical impacts will occur	**Less than minor or transitory**
Ice Environment	Accidental fuel spill	Contamination of the immediate ice environment	**Low** Fuel will penetrate into ice	**Medium** Any spill on snow and ice is hard to clean up and will persist	**Medium** Natural processes such as melt may be affected	**Medium** Spill event is possible with no controls in place	**No more than minor or transitory**	• Fuel management and handling will draw on guidance contained in the COMNAP Fuel Manual. • The volumes of fuel taken onto ice floes will be minimised to the extent possible. • Any fuel taken onto ice floes will be bunded. • Fuel stores will be regularly checked for leaks. • Spill response kits will be available in camps. • Refuelling will be undertaken with two people and with a spill response kit available.	**Low** Mitigation will reduce volume of any spilt fuel and spatial exposure	**Medium** Any spill on snow and ice is hard to clean up and will persist	**Low** Mitigation will reduce volume of any spilt fuel and intensity of exposure	**Low** Mitigation will reduce likelihood of a spill	**Less than minor or transitory**
Ice Environment	Accidental release of wastes	Littering with risks of wildlife entanglement or introduction of pathogens	**Medium** With no controls waste and garbage could be blown away from the camps	**Low** Ice camps will be of short duration	**Low** Even with no controls waste amounts will be limited and if lost have few implications for natural processes	**Medium** Loss of waste materials likely with no controls in place	**No more than minor or transitory**	• Waste management and handling will draw on guidance contained in the COMNAP Waste Manual. • Waste production at the camps will be minimised by reducing the items taken onto ice floes in the first place. • Waste items will be collected and stored at the ice camps and returned to the ship for ultimate disposal outside of Antarctica. • A toilet tent will be established at the ice camps. Solid human waste will be collected and returned to the ship for disposal through the ships sewage treatment plant. • Heavy ice camps will be deployed under controlled conditions involving: assessment of the stability and thickness of the ice; monitoring of weather conditions; staged approach to keep deployed personnel and equipment to the minimum required; regular communications with the main vessel. • In the unlikely event that equipment is abandoned on an ice floe, all attempts will be made to recover it as conditions allow.	**Low** Mitigation will reduce the spatial extent of impact	**Low** Ice camps will be of short duration	**Low** Mitigation will ensure few implications for natural processes	**Low** Mitigation will reduce likelihood of losing items to the environment. Discharge of greywater and human liquid waste will occur for heavy ice camps (if used)	**Less than minor or transitory**
Atmospheric Environment	Exhaust emissions from the main vessel and generators and vehicles on ice floes	Localised air contamination and contribution to climate change	**Medium** Exhaust emissions will disperse beyond the vicinity of the vessel	**Low** 45 days for the period of this Expedition	**Medium** With no controls emissions could cause localised contamination	**High** Emissions will occur continuously throughout the 45-day Expedition	**No more than minor or transitory**	• *SA Agulhas II* uses marine gas oil (MGO) with a low sulphur content. • Fuel use will be minimised to the extent possible by maximising operations in open water and minimising the extent to which the vessel is required to 'work ice', which inevitably requires more power and burns more fuel. This will be facilitated by making use of satellite imagery to carefully plan routes and optimise operations in open water and leads in the pack ice. • The Expedition has also selected a modern Polar class, fit-for-purpose vessel to support the research and likely one of the most fuel-efficient vessels currently operating in the Southern Ocean. • Aircraft use and the use of generators and skidoos on the ice will be restricted to meeting operational needs.	**Medium** Exhaust emissions will disperse beyond the vicinity of the vessel	**Low** 45 days for the period of this Expedition	**Low** Mitigation will reduce levels of localised contamination from emissions	**High** Emissions will occur continuously throughout the 45-day Expedition	**No more than minor or transitory**
Atmospheric Environment	Air turbulence from the use of helicopters and RPA	Localised air turbulence	**Low** Turbulence confined to the immediate area of the aircraft	**Low** Turbulence only during flying	**Low** Turbulence will dissipate rapidly away from the aircraft	**Low** Impacts negligible under normal operating conditions	**Less than minor or transitory**	No mitigation required	**Low** Turbulence confined to the immediate area of the aircraft	**Low** Turbulence only during flying	**Low** Turbulence will dissipate rapidly away from the aircraft	**Low** Impacts negligible under normal operating conditions	**Less than minor or transitory**

Environmental Element Impacted	Aspect	Impact	Uncontrolled Risk Assessment: Spatial Extent	Uncontrolled Risk Assessment: Duration	Uncontrolled Risk Assessment: Intensity	Uncontrolled Risk Assessment: Probability	Uncontrolled Risk Assessment: Significance (without mitigation)	Mitigation Measures	Residual Risk Assessment: Spatial Extent	Residual Risk Assessment: Duration	Residual Risk Assessment: Intensity	Residual Risk Assessment: Probability	Residual Risk Assessment: Significance (with mitigation)
Wilderness Value	Human presence and associated activities	Loss of wilderness value	**Medium** With no controls lost items and evidence of human presence could disperse beyond the expedition boundaries	**High** Lost items could remain in the environment well beyond the duration of the Expedition	**Low** Impacts of the Expedition will be recoverable	**Medium** Long-term evidence of human activity could occur with no controls	**Minor though more than transitory if permanent impact were to occur (e.g. permanent loss of equipment)**	• The Expedition is of short duration and has adopted a 'light footprint' approach. The majority of activities are non-invasive, or likely to have less than a minor or transitory impact. • Sites to be sampled will be carefully selected so as to maximise research benefits and minimise impacts. • All equipment to be deployed will be carefully managed and controlled by highly experienced technicians and operators so as to minimise the risk of equipment loss. • With the exception of sewage discharge from the vessel (in accordance with Annex IV and MARPOL requirements) and disposal of human liquid waste and greywater from the ice camps, the Expedition will dispose no waste in Antarctica.	**Low** Mitigation will confine any transitory impacts to the area of the expedition only	**Low** The Expedition is planned to be no longer than 45 days	**Low** Mitigation will ensure no disruption to natural processes	**Low** Mitigation will reduce the likelihood of lasting impacts on wilderness values	**Less than minor or transitory**
Heritage Value	Subsea vehicles operating in the vicinity of HSM 93	Physical disturbance to HSM 93	**Medium** Damage likely only to be to a portion of the wreck	**Very high** If damage were to occur it would be permanent	**High** If damage were to occur it would be irreversible but localised	**Medium** Could occur with no controls in place	**More than minor & transitory (if damage were to occur)**	• The subsea vehicles will be operated by highly trained and experienced operators to standard, planned survey techniques. • The initial surveys within the vicinity of the wrecks by the subsea vehicles will be conducted from a safe distance (approximately 100 metres) above the sea floor. • The subsea surveys undertaken from distance will produce high quality visible and sonar imagery of the wrecks, which will then be used to plan the closer, more detailed inspections. • All wreck searches will be conducted within the principles of the relevant charters of the International Council on Monuments and Sites (ICOMOS): notably the Charter for the Protection and Management of the Archaeological Heritage (1990) and the Charter on the Protection and Management of Underwater Cultural Heritage (1996), as well as the ATCM Guidelines for Handling Pre-1958 Remains (Resolution 5 (2001)). • The Expedition has adopted a 'zero disturbance, zero collection' policy with respect to the search for the wrecks. No artefacts or any items from the wreck site will be touched or removed.	**Low** Mitigation will ensure no disruption to the wreck	**Low** Mitigation will ensure no disruption to the wreck	**Low** Mitigation will ensure no disruption to the wreck	**Low** Mitigation will reduce the likelihood of any impacts to the wreck	**Less than minor or transitory**

8. Monitoring and Record Keeping

This assessment has not identified the need for dedicated monitoring to be undertaken during the Expedition.

The Expedition will be of short duration, largely ship-based and marine focused. The wreck search and survey work will be entirely non-invasive. Any marine sampling e.g., water column sampling will have less than minor or transitory impacts.

Nonetheless, records will be maintained both for post-Expedition reporting as well as for scientific research purposes. These records will include:

- details of all subsea vehicle deployments (depth, duration etc), not least for reporting the survey findings;
- Any physical disturbance to the surveyed wreck site. In the extremely unlikely event that such disturbance occurs records will be made of the nature, extent and location of the disturbance;
- Any observed encounters with wildlife such as may occur between the subsea vehicles and diving pinnipeds or cetaceans, as well as any observed bird encounters with the helicopters or RPA. To the extent possible records will be maintained of the species concerned and the location;
- The location of any fuel spill events and the type and volume of fuel spilt (if any) during the Expedition;
- The type and location (as accurately as may be possible) of any equipment lost to the environment;
- All water column sampling locations will be accurately recorded, not least for publication purposes;

The above information will be recorded in a post-Expedition report and provided to the FCDO.

9. Gaps in knowledge and Uncertainties

No Expedition to Antarctica can be planned with absolute certainty, due to the extreme, changeable and unpredictable environmental conditions.

Although the Expedition objectives are clearly described and the activities to be undertaken as well as the equipment to be used have been identified, there remain a number of unknowns that will require flexibility during the Expedition. These are set out below.

9.1 Weather conditions

The weather in Antarctica can be highly variable both between and within summer seasons. Conditions can also change dramatically in short periods of time. This variability and unpredictability will require frequent adjustment of plans.

Weather conditions have the potential to impact on the overall schedule of the Expedition; any storm events could have implications for vessel passage times or delay the survey work.

Weather conditions will also determine the extent of flying that can be undertaken by the helicopters and the extent to which the heavy ice option for deploying the subsea vehicles can be exploited.

Regular weather observations will be undertaken to identify optimum windows for deployment of the various vehicles. The variability of the weather is unlikely to affect the environmental impacts of the Expedition nor the findings of this EIA.

9.2 Sea ice conditions

As recorded in Section 6.4 above, sea ice conditions around Antarctic generally, and in the Weddell Sea in particular can be highly variable within and between summer seasons. This unpredictability means that the precise routes to be taken by the *SA Agulhas II* cannot be planned in advance with any degree of certainty and will need to be adjusted much closer to the time and even on a daily basis during the Expedition.

Sea ice conditions will also determine the extent to which the target survey areas can be accessed.

It is the unpredictability of the sea ice that has required alternative deployment scenarios to be developed as described in Section 4.3. The EIA has considered and described the potential environmental impacts of deploying the subsea vehicles from sea ice as well as from the ship.

9.3 Global Pandemic implications

International travel and national restrictions continue to change as a result of the ongoing global Coronavirus pandemic. Whilst care is being taken to factor these into the Expedition planning, the situation remains fluid and has implications for the mobilisation of equipment and personnel, medical controls and the timing of departure of the Expedition.

With a short deployment window optimised around the sea-ice minimum in the Weddell Sea, any delays could have implications for the success of the Expedition.

These factors have no implications for the environmental impacts of the Expedition in Antarctica, but are recorded here as they may affect the overall timing of the Expedition.

10. Summary and Conclusion

This IEE has described the proposed activities to be conducted by the Endurance22 (Section 4); considered a number of alternatives to various aspects of the Expedition (Section 5); described what is known about the current environmental state (Section 6); assessed the potential environmental impacts that are likely to, or could arise (Section 7); outlined the mitigation measures to prevent or minimise any potential environmental impacts that may occur (Section 7), and described the records that will be maintained of environmental impacts that may occur (Section 8).

Even with implementation of control measures, some *potential* environmental impacts of the Expedition have been assessed as being of **no more than minor or transitory** significance. These impacts include:

- **Atmospheric emissions from the burning of fossil fuels by the *SA Agulhas II* -** an unavoidable impact, but mitigated by using a fuel efficient vessel that will burn MGO with low sulphur content and optimisation of the vessel's route through sea ice;
- **The accidental introduction of non-native species by the *SA Agulhas II* –** somewhat outwith the control of the Expedition, but assessed as being of low likelihood, though with high consequence if it were to occur;
- **The loss of one of the subsea vehicles –** The WSE2019 expedition lost one of its subsea vehicles in the Weddell Sea. Lessons have been learnt from this loss and the subsea vehicles selected for Endurance22 are different and chosen to minimise the chance of this happening again. However, the risk of another vehicle loss in this challenging and unpredictable environment remains a possibility.

Provided the identified control measures are fully implemented, the majority of the identified unavoidable and potential environmental impacts of the Expedition have been assessed as likely to be of **less than minor or transitory** significance.

This assessment was undertaken on a worst-case scenario evaluation. The Expedition aims to prevent or reduce potential environmental impacts through careful planning, training, execution and the availability of highly experienced operators and technicians. Provided the mitigation measures described in Section 7 (summarised in Table 9) are adhered to, the environmental impacts of the Expedition are considered to be largely avoidable or can be minimised.

Overall, this IEE concludes that the potential environmental impacts arising from the proposed Expedition will have no more than a **minor or transitory impact** on the Antarctic (Weddell Sea) environment.

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Appendices

Appendix 1. Specifications for the *SA Agulhas II*

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SA AGULHAS II

PRINCIPAL PARTICULARS					
Vessel Owner	Department of Environmental Affairs			Light Ship (t):	8603
Vessel Manager	Smit Amandla Marine (Pty) Ltd			Length Overall:	134m
Vessel Type:	Steel Hulled, Ice strengthened Antarctic Supply/Oceanographic Research			LBP: (perpendiculars)	121.5m
Flag:	South Africa			Depth Moulded:	10.55m
Call Sign:	ZSNO			Air Draft: (at summer draft)	37.5m
Official Number:	11205			GRT (t):	12897
Port of Registry:	Cape Town			NRT (t):	3870
MMSI:	601986000			Hull Material:	Steel
Builder:	STX-Europe Finland			Beam Overall:	22m
Keel Laid:	2010	Delivery Date:	2012	Dead Weight (t):	5 000T at loaded draught
Delivery Date:	2012			Breadth Moulded:	22m
Yard Number:	NB1369			Freeboard:	2.86m
Total Carrying Capacity:	144 persons			Maximum Draught:	7.7m

CLASSIFICATION INFORMATION	
Classification Society	Det Norske Veritas (DNV
Class Notation	+1A1 Passenger Ship, Ice Class IACS PC5 (ICE-10 for Hull) Winterised Basic, DAT (-35) EO,RP,HELDK-SHF Clean Design, COMF V(2)/C(2), NAUT-AW, TMON,BIS,DYNPOS-AUT,DE-ICE,LFL

ACCOMMODATION

CREW CABINS			
Single Berth	38 cabins	Two Berth	3 cabins
Three Berth	0 cabins	Four Berth	0 cabins

PASSENGER CABINS			
VIP Suites	2 cabins	Single Berth	16 cabins
Two Berth	15 cabins	Four Berth	13 cabins

AMENITIES	
Upper and Lower Passenger Lounges Baggage Room Laundry facilities on each deck Library	Crew Lounge Hospital with Surgery facilities Gymnasium with change room, shower Sauna
Notes: Air Condition with Heating for Arctic conditions, Doctor normally carried onboard	

VESSEL PERFORMANCE

SEAGOING			
Speed: (Max)	18knots @ 90% MCR	Consumption	56.9 m³/day
Endurance:	57 days	Range:	24624nm
Speed: (Eco)	14knots @ 50% MCR	Consumption	32.8 m³/day
Endurance:	99 days	Range:	33264nm

ICE MODE			
Speed: (Max)	18knots @ 100% MCR	Consumption	65.6 m³/day
Endurance:	50 days	Range:	21600nm
When using Ice Mode, vessel is capable of breaking through 1meter thick ice at a speed of 5knots.			

SA AGULHAS II

FUEL, LUBE OIL AND FRESH WATER CAPACITY			
Total Fuel Capacity:	3 660 m³	Preferred Reserve:	400 m³
Usable Fuel Capacity:	3260 m³	Fuel Type:	Marine Gas Oil
Lube Oil Capacity:	20000 Litres	Lube Oil Consumption:	80 Ltrs per day
Fresh Water Capacity:	290 m³	FW production:	35mt per day

MACHINERY AND PROPULSION			
MAIN ENGINE			
Manufacturer:	Wartsila	Engine Type:	6L32
Number of ME's:	Four	Engine Rooms:	2 x Separated ER's
Power Output:	12 000kW (100% MCR)	Power Output:	10 200kW (85% MCR)
PROPULSION MOTOR			
Manufacturer:	Converteam	Engine Type:	N3HXCH2LL8CH
Number of ME's:	Two	Power Output:	9 000kW
Notes: Generated for propulsion at 3.3 KVA, 3 phase, 50 Hz and Hotel Services are supplied at 3 phase, 50 Hz, 400 v			
AUXILARY ENGINES			
Manufacturer:	Mitsubishi	Engine Type:	S12R-Z3MPTAW-4
Number:	One Harbour	Power Output:	1351 KVA, 3 phase, 50 Hz, 400 v. Stamford PM734CZ
Manufacturer:	Volvo-Penta	Engine Type:	D 16 MG
Number:	One Emergency	Power Output:	490 KVA, 3 phase, 50 Hz, 400 v. Stamford HCM534E-1
BOW THRUSTERS			
Manufacturer:	Rolls-Royce	Type:	TT2000 DPN FP
Number:	Two	Power Output:	750kW ea. 1500kW total
STERN THRUSTERS			
Manufacturer:	Rolls-Royce	Type:	TT2000 DPN FP
Number:	One	Power Output:	1200kW

SCIENTIFIC CAPACITY

SYSTEMS

A Network Data System acquires data from selected navigational, meteorological and scientific instrumentation. The data is sent to a dedicated server once per second and mean values logged once per minute. The real time data is transmitted continuously over the LAN and the logged data is made available in a shared folder on the network.
Seabird 911 CTD and Rosette Sampling System, Seabird S38 Remote Temperature Probe
Seabird SBE 45 Thermosalinograph and De-Bubbler , Kongsberg Topaz P18 Sub-bottom Profiler
Moon Pool, dimensions 2.4 x 2.4 m, for CTD deployment in ice covered waters
Drop Keel, extending to a depth of 3.0 m, containing:

- Scientific Echo Sounder, Simrad EK 60, 38/120/200 kHz, Scientific Deep Water Echo Sounder, Simrad EA 600; and
- Acoustic Doppler Current Profiler, RDI Instruments Ocean Surveyor II, 75 kHz

LABORATORIES

1 x Meteorological 1 x Dry Biological 1 x Wet Biological 1 x Wet Geological	1 x Operations Room 1 x Underway Sampling 1 x Liquid Scintillation Counter 1 x General Chemistry

Notes: Provision made for additional 6 "Own-User" Container Laboratories on deck aft.

WINCHES

1 x Hatlapa Electric Windlass with 2 x 349kN/160kN @ 5/15 m/min. Cable Lifters; with 2 x 150kN @ 15/30 m/min. Warping Drums 1 x Rapp Hydema HW 200 E Vertical Plankton Winch, 1650 m x 6.35 mm conductor cable 1 x Rapp Hydema HW 500 E Undulating Vehicle Winch, 760 m x 8.41 mm SWR (100 metres faired)	2 x Hatlapa Electric Capstans, 100kN @ 15/30 m/min 1 x Rapp Hydema HW 2300 E CTD Winch, 6,000 m x 11.73 mm conductor cable 1 x Rapp Hydema HW 2300 E CTD Winch, 6,000 m x 12 mm Kevlar cable 1 x Rapp Hydema DSW-4006 E Deep-water Coring Winch, 5000 m x 14 mm SWR 1 x Rapp Hydema HW 500 E Plankton Towing Winch, 2500 x 11.73 mm SWR 1 x Rapp Hydema HW 500 E General Purpose Towing Winch, 2500 m x 12 mm SWR 1 x Rapp Hydema CF 600 E General Purpose Capstan, 3.0 t @ 12 m/min

SCIENTIFIC WORK AREAS

Poop Deck:	Space of 400 m2 with a 50 m2 wooden working deck served by a hydraulic A-frame with 6 loading points and a vertical sliding stern gate. Also on the after deck is a 4t SWL Deep Corer Davit by Triplex, with a 1t SWL Deep Corer Handling Frame attached
Environmental Hangar:	A Triplex A-Frame with a SWL of 7 tons, operated through a side door for over-side CTD deployment. Moon pool with docking head for deployment of CTD and a 24 bottle rosette.

METEOROLOGY SYSTEMS

2 x Lambrecht Weather Sensors, indicating wind speed and direction, air temperature, barometric pressure and relative humidity, Sea temperature given by the Skipper Log

SA AGULHAS II

GENERAL ARRANGEMENT			
CARGO SPACE			
Hold Max Stack weight:	3.5 t/m²	Hatch Max Stack weight:	Hatch 2&3 = 3.5 t/m² // Hatch 1 = 1.6 t/m²
Dry Cargo: (Bale)	3 801 m³	Dry Cargo: (Grain)	4 602 m³
Oil Cargo:	510 m³	Refrigerated:	79.4 m³
Notes: Three cargo hatches, all with tween-deck and lower hold.			
CARGO LIFTING EQUIPMENT			
1 x TTS 35 t @ 27.5 m knuckle boom cargo crane on forecastle 2 x TTS 10 t @ 10 m knuckle boom cargo cranes forward on cargo deck stbd side 1 x TTS 5 t @ 18 m knuckle boom stores crane aft			
CARGO EQUIPMENT			
1 x 3.0 ton Electric Forklift Truck Two large 10 m inflatable rafts with a working capacity of 15 tons if paired			

NAVIGATION EQUIPMENT			
Integrated Navigation System by Raytheon Anschutz, GMBH, Kiel, Germany			
Gyrocompass	2 x Anschutz Type 22 Digital	GPS	2 x Saab R4 DGPS Receivers
Autopilot	Anschutz NautoPilot 2025	ECDIS	2 x (Main + Secondary) Raytheon Anschutz ECDIS Blackbox Version with Overlay
Echo Sounder	Raytheon Anschutz GDS101 50/200 kHz	Speed log	Skipper DL850 2 Axis Doppler Log
Radars	1 x Raytheon Anschutz S-Band 30 kW ARPA Chartradar Blackbox System 2 x Raytheon Anschutz X-Band 25 kW ARPA Chartradar Blackbox Systems with one fitted with a high-speed scanner 1 x Sigma S6 Integrated Radar Processing System, for ice navigation	Conning Screen	The ship's operating parameters such as position, speed, propeller pitch, rudder angle, wind direction, wind speed, etc., are displayed either in graphic or alpha numeric form on the bridge and in the Captain's cabin
Dynamic Positioning System (Level 1)			
1 x Navis 4001 DP System 1 x Navis 4011 Joystick Control System		1 x Model LID3-G1 DGPS Receiver 1 x Radascan - high accuracy, portable transponder	

HELICOPTER SUPPORT AND FACILITIES	
Helideck Landing Deck Area: 120m² 110t Jet-A1 bunker capacity	Manual sprinkler system for hangar Hanger Facilities: Enclosed hangar capable of fitting two PUMA size helicopters

COMMUNICATION EQUIPMENT	
Radio and Satellite Equipment, to GMDSS Sea Area 4	
BRIDGE Communication Console 2 x Raytheon Anschutz MF/HF DSC Radio Controllers CU 5100 1 x Raytheon Anschutz VHF DSC Controller RT 5022 1 x Sailor Inmarsat C Message Terminal TT3606E 3 x Raytheon Anschutz printers H1252B/TT-3608A for above 1 x Raytheon Anschutz GMDSS Alarm Panel AP 5042 3 x Sailor GMDSS VHF Portable Radios, SP 3520 1 x ICOM Air band Portable VHF Radio (With headset and microphone)	Bridge Main Console 1 x Raytheon Anschutz VHF DSC Duplex Controller RT 5020 1 x Motorola GM 360 UHF radio 1 x Raytheon Anschutz GMDSS Alarm Panel AP 5065 Bridge, Office 22 x UHF Radios, Motorola Navtex Receiver, NCR-333 Weather Facsimile Receiver, Raytheon Anschutz Blackbox FAX-30
Bridge Helicopter Console 1 x Raytheon Anschutz VHF Radio Controller CU 5000 1 x Becker Air band VHF Radio 1 x Motorola VHF Radio DM 3600	Bridge, After Bulkhead 2 x SARTs, Sailor 6913A-SART (1 Port, 1 Starboard) 1 x EPIRB, ACR Satellite II 406 MHz
Bridge Starboard Console 1 x Sailor VHF Radio 6210 Bridge Port Console 1 x Sailor VHF Radio 6210	Monkey Island (Deck 10) 1 x EPIRB (Float Free), TRON 40S Mk II 406 MHz 1 x VDR Capsule

OTHER FEATURES	
Stabilizer tank Double hull Heeling tank/pump system Closed circuit television available to points around the ship 2 x 200 hp 10 man SOLAS Fast Rescue Boats 1 x 230 hp Weedo 710 Tug/Workboat, Bollard Pull 2.2 tons	1 x 40 hp 6 man inflatable dinghy for inshore scientific work NOVEC/CO2 flooding system for machinery spaces and cargo holds Water mist system throughout accommodation spaces Inert gas system for Jet-A1 tank spaces Foam monitors for flight deck and cargo deck helicopter operations Impressed current, Cathodic protection system
Last updated on: 2015-09-11	

Appendix 2. Specifications for the SAAB Sabertooth subsea vehicles

Extreme versatility

With deep water capability, long excursion range, advanced AUV functionality and a six degrees of freedom control system, Sabertooth is the perfect example of Saab's thinking edge in action.

Available in single and double hull versions, Sabertooth is a very powerful but lightweight platform for inspection, maintenance and repair (IMR). Its small size, tether-free operation and manoeuvrability ensure easy and safe access inside and around complex structures, making it ideal for offshore survey work and autonomous IMR of subsea installations and tunnels.

Operational concept

Autonomous
This mode has behaviour-based architecture, supported by an inertial navigation system and Doppler velocity. Features include mission-planning software with the possibility for the customer-intelligent payload to take control, plus Saab's API means that customer/third-party software can act as a backseat driver.

Operator assisted
The vehicle is given step-by-step instructions from an operator over an optical through-water or acoustic communication link. Each step is then verified by video or sonar data and sent back via the through-water communication link.

Manual operation
The vehicle can be operated manually via fibre optic tether or an optical through-water communication link. This mode is typically used during the final approach to a docking node or during intervention. If the link is broken, a pre-programmed emergency routine is enabled.

System overview

The versatile Sabertooth is powered either by battery or via a tether. If used as a subsea resident system, the Sabertooth is housed at the docking unit where its batteries can be recharged. This unit allows for data to be uploaded to the surface and new instructions to be downloaded.

The vehicle can swim autonomously to the docking unit and remain there 24/7 for more than six months without maintenance, eliminating the cost of surface vessels.

This deep-water hovering hybrid AUV/ROV benefits from 360° manoeuvrability with six degrees of freedom, interfaces for sensors and auxiliary equipment. The vehicle also utilises advanced autopilots: heading, depth, altitude, pitch and roll stabilisation, station keeping and vector transitions.

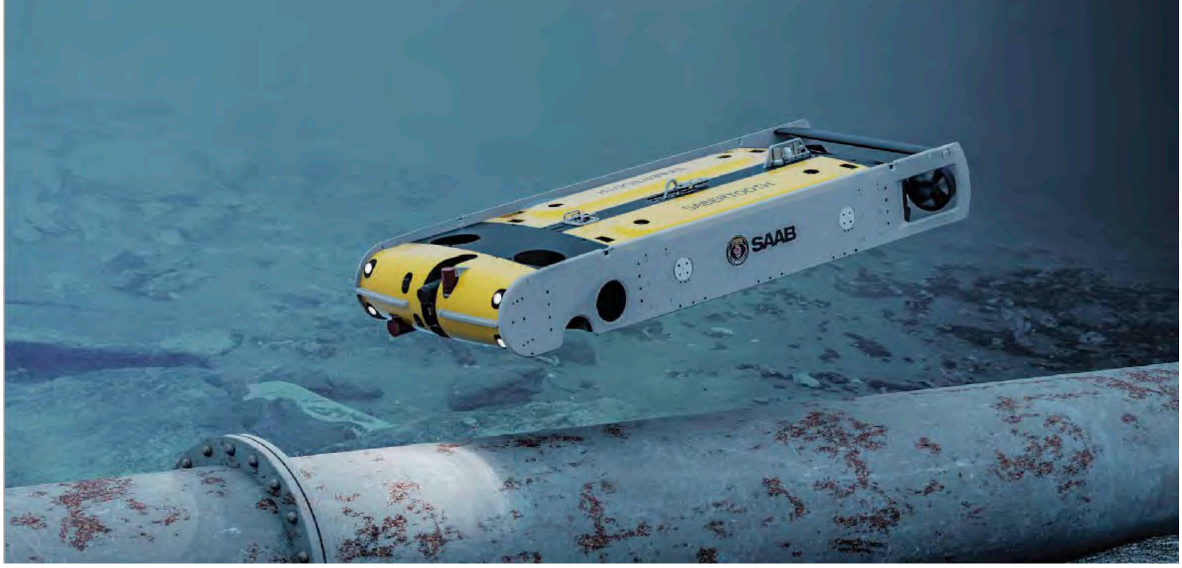
The Sabertooth has the capability for non-invasive self-diagnostics, and includes a fault-tolerant control system. Its remote internet interface can be used as a base for technical support if necessary.

Tooling packages can also be stored in the vicinity and used as required. In ROV mode, a wide range of winches and tethers are available.

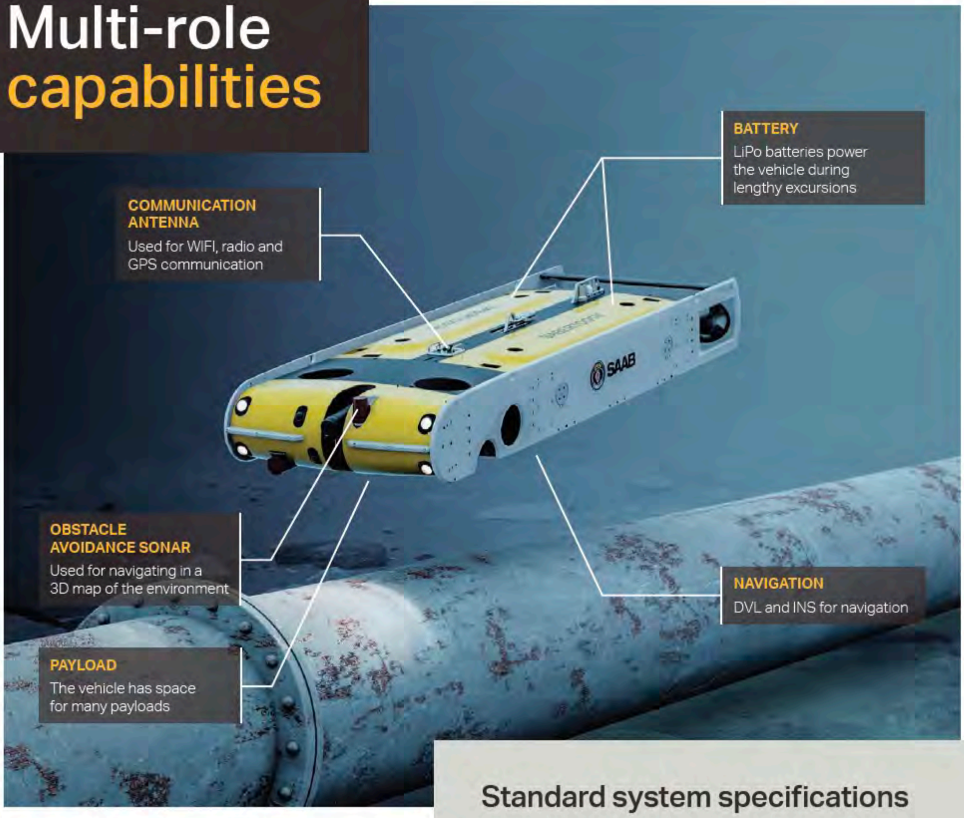
In-service support

Saab works closely with customers worldwide to secure their operational capabilities through our well-established and effective in-service support solutions. Our flexible and scalable range of offerings includes:

- Maintenance and repair
- Supply and logistics
- Operational and technical support
- Training
- Upgrades and modifications
- Obsolescence management



Multi-role capabilities



Brochure, SABERTOOTH – EN – February 2020

Standard system specifications

	Single hull	Double hull
Depth rating	1,200 msw	3,000 msw
Dimensions	3.6 x 0.66 x 0.45 m	4 x 1.35 x 0.67 m
Launch weight	650 kg, max. 800 kg	1,300 kg, max. 2,000 kg
Interfaces	Cameras, sonars, HV tooling/motor	Cameras, sonars, HV tooling/motor
Auto functions	6 DOF, heading, depth, altitude	6 DOF, heading, depth, altitude
Forward speed	5 knots	4 knots
Battery capacity	10 kWh	30 kWh

SCAN TO SEE MORE ONLINE

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