WEDDELL SEA
EXPEDITION 2019

Initial Environmental Evaluation

SA Agulhas II in sea ice. Image: Johan Viljoen

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

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Final version submitted: September 2018

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Non-Technical Summary

Introduction

The Weddell Sea Expedition 2019 is a privately funded, non-governmental research expedition that will undertake a 45-day research cruise to the Weddell Sea in January and February 2019.

With funding provided by the Netherlands based Flotilla Foundation, the programme of research will be led by the Scott Polar Research Institute, University of Cambridge and will involve researchers from: the Nekton Deep Ocean Exploration research institute, University of Oxford; Nelson Mandela University, South Africa; University of Cape Town, South Africa and the University of Canterbury, New Zealand.

The scientific team will comprise researchers from several disciplines, including glaciology, marine-geology and geophysics, marine biology and oceanography.

The primary aims of the Expedition are to:

1. Undertake a major scientific research programme focusing on a pioneering study of the Larsen C Ice Shelf, as well as conducting novel sea-ice measurements and to survey the rich marine life of the western Weddell Sea ecosystem;
2. Attempt to locate and survey the historic wreck of Sir Ernest Shackleton's ship *Endurance* which sank approximately 150NM from the Larsen C ice shelf in 1915.

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 and Commonwealth Office (FCO) and the Secretary of State makes the final determination on whether an activity may proceed taking into account the FCO'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 Weddell Sea Expedition 2019 at the level of an Initial Environmental Evaluation (IEE) and is submitted for assessment and approval to the UK Foreign and Commonwealth Office.

The IEE has been prepared in accordance with the EIA Guidelines prepared by the Antarctic Treaty System's Committee for Environmental Protection (CEP) (Resolution 1 (2016) refers).

Scope

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

- all personnel involved in the Weddell Sea Expedition 2019, and the movement of expedition personnel to and within Antarctica;
- the marine and glaciological research that will be undertaken from the research vessel, including the deployment of autonomous underwater vehicles (AUVs), a remotely operated (underwater) vehicle (ROV), remotely piloted aircraft systems (RPAS), and the biological and sedimentological sampling that will be undertaken;
- the marine archaeological survey and research.

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);
- the operation of the inter- and intra-continental aircraft that will be used to move Expedition personnel into and across Antarctica as well as the operation and maintenance of the ice runways at Wolf's Fang and Penguin Bukta, Dronning Maud Land;
- eight additional post-graduate research assistants and students that will be on-board the SA Agulhas II during its 2018/2019 deployment from South African and Finnish universities.

Description of planned activities

The Weddell Sea Expedition 2019 plans to conduct a programme of marine and glaciological research in the northern and western Weddell Sea, Antarctica, during a 45-day research cruise in January and February 2019.

The primary target research area is the Larsen C ice shelf on the western side of the Weddell Sea and specifically the 5,800 km^2 area of the seafloor recently made accessible through the iceberg calving event of July 2017.

Secondary research and marine archaeology targets have been identified if access to the primary targets is prevented due to sea-ice conditions. Secondary research areas are the Fimbul and Riiser-Larsen ice shelves in the eastern Weddell Sea and the wreck of Nordenskjold's Antarctic close to Paulet Island in the north-western part of the Weddell Sea.

The expedition will comprise 36 personnel, including expedition leaders, researchers, technicians, ice pilot and media.

Expedition personnel will fly to Antarctica from Cape Town, South Africa utilising the air facilities of the tour operator White Desert. Expedition personnel will rendezvous with the South African Polar Class research and resupply vessel *SA Agulhas II*, which will provide the research platform for a 45-day research cruise.

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

Date	Activity
End November 2018	Mobilisation of equipment on *Agulhas II* in Cape Town, including sea trials
6 December	*SA Agulhas II* departs Cape Town for Antarctica
16 December	*SA Agulhas II* arrives Penguin Bukta and starts resupply of SANAE IV base
28 December	Expedition team fly from Cape Town to Wolf's Fang ice runway and then onward to Penguin Bukta to join vessel – 3 aircraft rotations
1 January 2019	*SA Agulhas II* departs Penguin Bukta and commences expedition
16 January	Arrive Larsen C Ice Shelf for research programme
31 January	Depart *Endurance* wreck location, if found
16 - 18 February	Arrive Penguin Bukta. Expedition team fly back to Wolf's Fang and then onwards to Cape Town – 3 aircraft rotations
28 February	*SA Agulhas II* completes SANAE IV base cargo operations and sails back to Cape Town
10 March	*SA Agulhas II* arrives back in Cape Town and demobilisation of equipment starts
16 March 2019	Demobilisation complete. Expedition concludes

The expedition's scientific objectives are:

1. **To use upward-looking multi-beam echo sounding from AUVs to investigate the underwater shape of ice-shelf bases, the roughness of which is a vital parameter in numerical modelling of future ice-shelf stability.**
2. **To use downward-looking multi-beam echo-sounding and sub-bottom profiling from AUVs to investigate the detailed morphology and shallow stratigraphy of the seafloor beneath floating ice shelves, providing key information on past ice-shelf dynamics and stability.**
3. **To map the seafloor using AUV- and ROV-mounted multi-beam systems and high-resolution images, and extract sediment cores from the Weddell Sea shelf and slope, including from the 5,800 km^2 area of the seafloor recently made accessible through the Larsen C iceberg calving event of July 2017.**
4. **To take a series of measurements of the salinity and temperature of the water column adjacent to and beneath floating ice shelves to assess the modern oceanographic setting and melt rate of these ice shelves.**
5. **To use AUV-acquired multi-beam echo-sounder data, including backscatter, from beneath floating ice shelves to characterise the seafloor marine habitat and biota.**
6. **To investigate the marine habitat and biota in areas of the seafloor recently made accessible to icebreaking vessels through the iceberg calving event of July 2017, through the use of multi-coring and imaging from a deep-water ROV.**

7. **To map the seafloor in the region of the *Endurance* and / or *Antarctic* wreck sites using AUV- and ROV-mounted multi-beam echo-sounders and sub-bottom profiler to assess the likelihood of recent submarine slope failure and mass movements which might have altered the sites over the past century, and to deploy AUV- and ROV- mounted instruments to survey the wrecks in detail.**
8. **To use upward-looking multi-beam echo sounding from AUVs to measure the underwater shape of sea ice along a number of transects in the Weddell Sea, and to use RPAS-deployed lidar, radar and cameras to record simultaneously the above-water shape and character of the sea ice.**

The Expedition will utilise an array of equipment to support its research objectives. This includes:

- two Kongsberg HUGIN free-swimming autonomous underwater vehicles (AUVs) provided and operated by Ocean Infinity (https://oceaninfinity.com);
- a General Purpose (GP-50) 60 HP ROV remotely operated vehicle (ROV) provided and operated by Eclipse Group Inc. (EGI; https://www.eclipse.us.com), (subject to the approval of the Flotilla Foundation and the finalisation of contract terms)[1];
- three rotary wing and one fixed wing remotely piloted aircraft systems (RPAS) provided and operated by the University of Canterbury, New Zealand;
- several water column and sea floor sampling devices including: a Conductivity-Temperature-Depth (CTD) and water sampling rosette; a 60µm-mesh net for plankton sampling; a 6m single-barrel sediment corer; a seafloor multi-corer, and a seafloor box corer.

Water, plankton and seafloor biological samples will be collected and analysed on-board the vessel. Long (up to 6m) sediment cores will be collected, divided on-board and returned to the UK for further analysis.

Any core lengths unused in the analysis will be archived in the British Ocean Sediment Core Research Facility (BOSCORF; www.boscorf.org) established by the UK's Natural Environment Research Council (NERC).

The Alfred Wegener Institute of Germany has requested this Expedition to deploy five instrumented 'drifter' buoys in the Weddell Sea in early 2019 to support their oceanographic research programme.

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 undertake a significant programme of research utilising cutting-edge technology. Considering the anticipated 'light footprint' of the Expedition, and the likelihood that the scientific benefits will far exceed the environmental impacts, the 'do not proceed' option was rejected.

[1] The Final EIA will be updated to reflect the final selection of equipment and provider.

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 Larsen C ice shelf 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 research objectives.

Reducing the spatial scale of the Expedition was rejected on the basis that the larger scale activities to be undertaken by the underwater and aerial survey equipment would be non-invasive. Further, the direct impacts that will result from the seafloor coring activity will be highly localised and there is no measurable environmental benefit to be gained from attempting to spatial constrain this aspect of the Expedition any further.

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 research objectives.

Reducing or removing the marine biology sampling programme was rejected on the basis of significant impacts on achieving the research objectives and that the anticipated impacts would be no more than minor and transitory.

Alternative locations for undertaking the research have been explicitly built into the Expedition. Accessing the Larsen C ice shelf is not guaranteed due to the potential to encounter high density pack ice. Consequently, an alternative target for the Expedition's marine archaeological research is to attempt to locate and survey the wreck of Nordenskjold's Antarctic, which sank in 1903 in the vicinity of Paulet Island, north-western Weddell Sea. Alternative marine and glaciological research target locations have been identified as the Fimbul and Riiser-Larsen ice shelves in the eastern Weddell Sea.

Description of the Existing Environmental State

The Weddell Sea covers an area of approximately 2.8 million km^2. 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 km^2.

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 ice-free 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, 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 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.

The Expedition will however aim to enter and conduct research in the area of the Larsen C Ice Shelf from which 5,800 km^2 of ice was lost in the form of iceberg A68 in July 2017. This area has been designated by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) as a Stage 2 Special Area for Scientific Study for a period of 10 years. In designating the area the Commission encouraged Parties planning to initiate or undertake any non-fisheries-related scientific research within the area 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.

If so required, the Expedition organisers will prepare a research plan to assist the UK Government in informing CCAMLR's Scientific Committee of the planned non-fisheries research.

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 areas or terrestrial fauna and flora.

Most of the predicted impacts are considered likely to have less than or no more than a minor or transitory impact on the environments of the Weddell Sea.

The only potential environmental impact of the Expedition assessed as being of **more than minor or transitory** significance is the accidental release of a large volume of fuel as a result of equipment failure or rupture of one of the vessel's fuel tanks. This is an unlikely scenario given the modern, SOPEP-compliant, Polar Class vessel that has been selected for the Expedition, the experience of the Captain and Ice Pilot, and the navigational support that will be available (i.e. the use of RPAS and access to satellite imagery).

Some potential environmental impacts of the Expedition have been assessed as likely to be of **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 (given that the charter of the vessel starts and ends in Antarctica), but assessed as being of low likelihood, though with high consequence if it were to occur;
- **The removal of benthic fauna and micro-flora through direct sampling -** an unavoidable impact, though transitory in nature given the likelihood that denuded areas will be recolonised.

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 includes:

- **Noise generated by the engines and machinery of the SA Agulhas II** – an unavoidable impact, but with negligible environmental consequences;
- **The release of treated waste water from the ship** – an unavoidable impact, but with negligible environmental consequences;

- **Water turbulence created by the ship** – an unavoidable impact, but with negligible environmental consequences;
- **Noise, heat, light emissions and water or air turbulence from operation of the AUVs, ROV, RPAS and sampling equipment** – unavoidable impacts, but with negligible environmental consequences;
- **The accidental loss of an AUV, ROV, RPAS or sampling equipment to the environment** – assessed as being of low likelihood and avoidable provided all mitigation measures are applied;
- **The accidental introduction of a non-native species on deployed research equipment** – assessed as being of low likelihood and avoidable provided all mitigation measures are applied;
- **Physical disturbance of the benthic environment** – an unavoidable impact, but highly localised and less than transitory with recoverability likely;
- **The removal of pelagic fauna and flora samples** – an unavoidable impact, but highly localised and less than transitory with recoverability likely;
- **The production of waste from laboratory use of hazardous substances** – an avoidable impact, with all wastes removed from Antarctica;
- **Physical disturbance to either of the wreck sites** – assessed as being of low likelihood and avoidable provided all mitigation measures are applied;
- **Impact on Antarctic wilderness values**– assessed as being avoidable provided all mitigation measures are applied.

Record keeping

Records will be maintained both for scientific research purposes and for post-Expedition reporting. These records will include:

- 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 unrecoverable equipment lost to the environment;
- All benthic and 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 submersible survey equipment and diving seals or whales, as well as any observed bird encounters with the remotely piloted aircraft. To the extent possible records will be maintained of the species concerned and the location;
- Records of any physical disturbance to the 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.
- Records will be maintained of all AUV, ROV and RPAS deployments;
- Records of the location of deployment of the AWI drifter buoys will be kept.

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 research area in front of the Larsen C ice shelf and the deployability of the marine and air survey equipment.

Additional unknowns include the extent and exact location of sampling that will be undertaken, which will also be influenced by weather and sea ice conditions at the time.

Summary and Conclusion

Overall, this EIA predicts that the potential environmental impacts arising from the proposed Expedition will have no more than a **minor or transitory impact** on the environment. It is concluded that this level of predicted impact is acceptable given the significant scientific knowledge that will be gained as a result of undertaking the Expedition.

1. Introduction

The Netherlands based Flotilla Foundation has generously agreed to financially support a programme of scientific research and marine archaeological survey in Antarctica during the 2018/19 austral summer season.

The Flotilla Foundation exists "to enhance mankind's relationship with the environment in particular Oceans and Seas to create a long term sustainable future for the planet" https://flotillafoundation.org.

The Weddell Sea Expedition 2019 (the Expedition) will undertake a 45-day research cruise to the Weddell Sea in January and February 2019. The primary aims of the Expedition are to:

1. Undertake a major scientific research programme focusing on a pioneering study of the Larsen C Ice Shelf, as well as conducting novel sea-ice measurements and to survey the rich marine life of the western Weddell Sea ecosystem;
2. Attempt to locate and survey the historic wreck of Sir Ernest Shackleton's ship *Endurance*.

In July 2017, a major iceberg calving event from the Larsen C ice shelf exposed a 5,800km^2 area of sea bed offering a rare opportunity for vessel access to undertake research to better understand ice shelf processes in the context of changing climate conditions.

The Expedition has chartered the South African Polar research and resupply vessel SA Agulhas II to support the research programme. The SA Agulhas II is a modern, highly capable Polar Class vessel used to support the South African National Antarctic Programme.

The research will be led by the UK's Scott Polar Research Institute, University of Cambridge, and will involve researchers from: the Nekton Deep Ocean Exploration research institute, University of Oxford; Nelson Mandela University, South Africa; University of Cape Town, South Africa and the University of Canterbury, New Zealand. The scientific team will comprise researchers from several disciplines, including glaciology, marine-geology and geophysics, marine biology and oceanography.

To support the research objectives, the Expedition will have the use of a range of modern underwater and aerial survey systems that will be overseen by specialist technicians and operators. This will include the use of two Kongsberg HUGIN, free-swimming marine Autonomous Underwater Vehicles (AUVs) provided and operated by Ocean Infinity (https://oceaninfinity.com); a General Purpose (GP 50) 60 HP Remotely Operated Vehicle (ROV) provided by Eclipse Group Inc. (EGI; https://www.eclipse.us.com), and a number of fixed-wing and rotary-wing Remotely Piloted Aircraft Systems (RPAS) provided and operated by the University of Canterbury, New Zealand.

The Expedition will also use a range of benthic and pelagic sampling equipment.

A film unit will record a documentary of the Expedition.

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

The EIA examines the actual or potential impacts that will or could arise as a result of the planned activities of the Expedition and in the context of what is known about the existing environmental state of the Weddell Sea. Mitigation measures that can be employed to minimise the impacts are also identified.

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

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 as well as outlining the conclusions arrived at.

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 and Commonwealth Office (FCO) and the Secretary of State makes the final determination on whether an activity may proceed taking into account the FCO'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 45-day research and marine archaeological cruise in the Weddell Sea, Antarctica during January and February 2019. 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 considered appropriate for the activities proposed to be undertaken.

The Weddell Sea Expedition 2019 is multi-national. The Expedition is funded by the Flotilla Foundation based in the Netherlands and organised by Maritime Archaeology Consultants based in Switzerland. The South African flagged and operated SA Agulhas II has been chartered to support the research, and scientists from the UK, New Zealand and South Africa will contribute to the research programme.

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 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 (as yet un-numbered) (2018) – Environmental Guidelines for operation of Remotely Piloted Aircraft Systems (RPAS) in Antarctica

2.3.3 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

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 Applicable CCAMLR Conservation Measures

The target research area adjacent to the Larsen C Ice Shelf was designated as a Stage 2 (or 10 year) Special Area for Scientific Study by CCAMLR XXXVI (2017) in accordance with Conservation Measure (CM) 24-04 (CM 24-04, Annex A).

CM 24-04 provides that "Members planning to initiate or undertake any non-fisheries-related scientific research or monitoring on marine living resources within any Stage 1 or Stage 2 Special Area for Scientific Study are encouraged to inform the Scientific Committee of their intended research plans, and also to subsequently report any results relevant to the work of the Commission and the Scientific Committee".

This matter is covered in further detail in Section 6.8.3.4.

2.5 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 Foreign and Commonwealth Office are:

- all personnel involved in the Weddell Sea Expedition 2019, and the movement of expedition personnel to and within Antarctica;
- the marine and glaciological research that will be undertaken from the research vessel, including the deployment of the autonomous underwater vehicles (AUVs), the remotely operated (underwater) vehicle (ROV), the remotely piloted aircraft systems (RPAS), and the biological and sedimentological sampling that will be undertaken;
- the marine archaeological survey that will be undertaken from the research vessel.

The spatial scope of the IEE includes personnel movements by air between Cape Town and the White Desert ice runway at Wolf's Fang, Dronning Maud Land; the movement of personnel between Wolf's Fang and Penguin Bukta, where the Expedition will rendezvous with the SA Agulhas II, and the research cruise in the northern and western Weddell Sea.

The temporal scope of the activities covered by this IEE is approximately 53 days. The activities recorded above are planned to be undertaken between 28 December 2018, when the Expedition personnel depart from Cape Town for Antarctica, and 18 February 2019 when the Expedition personnel depart Antarctica for Cape Town.

If approved, the period for which a permit is required is 28 December 2018 until 28 February 2019. The latter date extends beyond the planned conclusion of the research cruise but provides for a period of slippage in case of any delays in the planned itinerary.

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 Environmental Affairs, 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 2018/2019 austral summer season, SAMSA's approval for the vessel will include its operation in the Weddell Sea in support of the Weddell Sea Expedition 2019. Nonetheless, given that the SA Agulhas II is integral to the Weddell Sea Expedition 2019, details of the vessel are provided in this environmental impact assessment where appropriate, so as to reinforce both safety and environmental management provisions;
- the operation of the inter- and intra-continental aircraft and the operation and maintenance of the ice runways at Wolf's Fang and Penguin Bukta, Dronning Maud Land. The aircraft and the runways are

operated and managed by White Desert, a private Antarctic tour operator based in the UK. White Desert are a member of the International Association of Antarctica Tour Operators (IAATO). White Desert will submit a separate permit application and environmental impact assessment to the FCO for their 2018/2019 activities in Antarctica, which will include the air support that will be provided to the Weddell Sea Expedition 2019. For completeness, the air transport routes that will be taken by the expedition personnel are described in this environmental impact assessment though the environmental consequences (e.g. emissions to air from the aircraft operations) are not;

- eight additional post-graduate research assistants and students that will be on-board the SA Agulhas II during its 2018/2019 deployment. The South African DEA are funding and supporting six marine research students from the University of Cape Town and Nelson Mandela University, and two engineering researchers from Stellenbosch University in South Africa and/or from Aalto University, Finland. These researchers and students and their science projects are not part of, nor supported by the Weddell Sea Expedition 2019 and therefore are excluded from the scope of this environmental impact assessment and the permit application to the FCO.

4. Description of the Planned Activities

4.1 Operations and Logistics

The Weddell Sea Expedition 2019 plans to conduct a programme of marine and glaciological research in the northern and western Weddell Sea, Antarctica, during a 45-day research cruise in January and February 2019.

The primary objectives of the expedition are to:

1. Undertake a major scientific research programme led by the Scott Polar Research Institute (SPRI), focusing on a pioneering study of the Larsen C Ice Shelf, as well as conducting novel sea-ice measurements and to survey the rich marine life of the western Weddell Sea ecosystem;
2. Attempt to locate and survey the historic wreck of Sir Ernest Shackleton's ship *Endurance*.

Secondary research and marine archaeology targets have been identified if access to the primary targets is prevented, for example due to sea-ice conditions. These secondary targets are discussed in the relevant sections below.

The expedition will comprise 36 personnel, including expedition leaders, researchers, technicians and media. Details are provided in Section 4.1.1 below.

Expedition personnel will fly to Antarctica from Cape Town, South Africa (see Section 4.1.2) and join the Polar research and resupply vessel SA Agulhas II. The vessel will provide the research platform for a 45-day research cruise into the Weddell Sea (see Section 4.1.3).

4.1.1 Expedition personnel

The expedition is comprised of 36 personnel as set out in table 1 below.

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 environmental scientist. He has over 25 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 environmental adviser and a member of the Shackleton Crossing Expedition to South Georgia in 2016. 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. He was the RGS Vice-President for Expeditions and Fieldwork from 2014 to 2017.*

Name	Nationality	Bio
Chief Scientist		
Professor Julian Dowdeswell, Director Scott Polar Research Institute (SPRI), Cambridge, UK	British	*Director of the Scott Polar Research Institute and Professor of Physical Geography. He is a glaciologist, working on the form and flow of glaciers and ice caps and their response to climate change, and the links between former ice sheets and the marine geological record, using a variety of satellite, airborne and ship borne geophysical tools. He has worked on the ice and from airborne platforms, in a number of areas of the Arctic, including Svalbard, Russian Franz Josef Land and Severnaya Zemlya, Iceland, East Greenland and Baffin, Devon and Ellesmere Islands in Arctic Canada. He has also undertaken many periods of work on icebreaking research vessels in the Norwegian-Greenland Sea, in the fjords and on the continental shelves of Svalbard and Greenland, and in Antarctica.*
Marine Geophysics and Glaciology Team		
Dr Christine Batchelor, SPRI / Norwegian Geological Survey	British	*Dr. Batchelor is currently the Rosalind Franklin Research Fellow at Newnham College, Cambridge. Dr. Batchelor is conducting her post-doctoral research as a member of Professor Julian Dowdeswell's Glacimarine Environments group at the Scott Polar Research Institute. Her ongoing research has involved Arctic and Antarctic experience and uses a variety of marine geophysical and geological data to make inferences about the configuration and dynamics of former ice sheets and the patterns and processes of sedimentation that occur beneath ice streams.*
Alexandr Montelli, SPRI / Cambridge University	Russian	*Mr Montelli studied Geography and GIS mapping (BS) at Saint Petersburg State University, followed by a Masters in Geophysics, during which his research focused on examining crustal structure and tectonic history of the Weddell Sea, East Antarctica. In 2015, he was awarded a Gates Scholarship for a PhD at SPRI, University of Cambridge. His research applies three- and two-dimensional seismic datasets to reconstruct Quaternary ice-sheet and oceanographic evolution of the vast mid-Norwegian continental margin*
Dr Dag Ottesen, Norwegian Geological Survey	Norwegian	*Dr Dag Ottesen is a marine geophysicist at the Geological Survey of Norway. He has undertaken many periods of fieldwork in the waters around Svalbard and Northern Norway from scientific research vessels. He has worked extensively on the reconstruction of past ice sheet form and flow in the Arctic, using evidence from the marine geophysical and geological record. He has published more than 50 scientific papers on this and related topics.*
Dr Fraser Christie SPRI	British	
AUV / ROV technicians and operators – up to 12 personnel	TBA	*Final selection of AUV / ROV technicians has yet to be made. It is expected that the breakdown will be: 4 x Ocean Infinity; 3 x Eclipse; 4 x Deep Ocean Search; 1 x Kongsberg Technician. CVs can be provided once personnel have been selected.*

Name	Nationality	Bio
Marine Geology and Coring Team		
Ms Evelyn Dowdeswell, SPRI / Cambridge University	British / US	*Ms. Dowdeswell is a geologist and Research Associate at the Scott Polar Research Institute, University of Cambridge. She has many years' experience on numerous Arctic and Antarctic geological and glaciological research expeditions.*
Dr Jeffrey Evans, Loughborough Universiy, UK	British	*Dr Evans is a Senior Lecturer in physical geography at Loughborough University. His research interests focus on investigating marine and terrestrial landform records to better understand Quaternary ice-mass and environmental change in the Arctic and Antarctic.*
Mr Leon Wuis, Marine Coring Technician, Netherlands Institute of Oceanographic Research	Dutch	*Mr. Wuis, is a Senior Sea Technician in the National Marine Facilities Department of the Netherlands Institute of Oceanographic Research. Mr. Wuis has provided technical coring support on numerous marine research cruises including on the SA Agulhas in South African waters in 2000.*
Ice Vibration Monitoring		
Dr Annie, Bekker, Stellenbosch University, South Africa	South African	
Marine Biology Team		
Dr Michelle Taylor, University of Essex, UK	British	.
Dr Lucy Woodall, Nekton Foundation, University of Oxford	British	*Dr Woodall is a marine biologist with a PhD on the conservation genetics of European seahorses. Her work broadly focuses on the processes that drive biodiversity in the marine biome, including the impacts of human activities. She has undertaken field work in coastal and deep-sea habitats and is an expert in marine litter. Her micro-plastics research was the first to reveal the ubiquity of this pollutant in the deep sea which led to further work on marine debris in our most remote oceans. She leads the scientific research at Nekton, sits on the IUCN SSC for seahorses and pipefish, and provides expert opinion for international marine management organisation and national governments. She was also a scientific advisor to the BBC Blue Planet II Series.*
Marine Biology PhD researcher, Nekton Oxford Deep Ocean Research Institute	British	
Oceanography		
Dr Katherine Hutchinson Oceanographer at University of Cape Town	South African	*Dr Hutchinson is a physical oceanographer at the University of Cape Town. Her areas of research include ocean-atmosphere coupling and response to climate change.*
Dr Thomas Bornman Department of Botany, Nelson Mandela University	South African	*Dr Thomas Bornman was appointed by the South African Institute for Aquatic Biodiversity (SAIAB) as the African Coelacanth Ecosystem Programme (ACEP) coordinator in 2008 and was also seconded to the GEF funded and UNDP implemented Agulhas and Somali Current Large Marine Ecosystems (ASCLME) Project as the research cruise coordinator. In 2011 he was appointed as the manager of the Elwandle Coastal Node of the South African Environmental Observation Network (SAEON). Dr Bornman's research interests include oceanic and coastal phytoplankton, estuarine ecology and GIS and he has supervised 23 post-graduate students from NMMU, UCT and UFH in these disciplines.*
Dr Sarah Fawcett, Department of Oceanology at University of Cape Town	South African	*Dr Sarah Fawcett holds a BA (Hons) from Harvard University and an MA and PhD from Princeton University. Her areas of research include Biogeochemical oceanography, nitrogen isotopes and the nitrogen and carbon cycles, drivers of primary productivity, nutrient drawdown, and the biological pump in the subtropical and polar oceans, the role of the oceans in past, present, and future climate.*

Name	Nationality	Bio
Sea-ice Team / RPAS Operators		
Dr Wolfgang Rack, Gateway Antarctica, University of Canterbury, New Zealand	New Zealand / Austrian	*Dr Rack's research is focussed on satellite and airborne remote sensing of snow and ice with emphasis on the mass balance studies of glaciers & ice sheets. This includes the mapping of glacier dynamics such as horizontal and vertical motion, the mapping of snow pack properties and surface accumulation, surface topography and ice thickness, and the mapping of the spatial extent and temporal variability of glaciers and ice sheets. He has participated in or led several Antarctic field campaigns with the Alfred Wegener Institute, Germany and the New Zealand Antarctic programme.*
Mr Paul Bealing, RPAS Technician, University of Canterbury, New Zealand	New Zealand	*Mr. Bealing is a geospatial science technician at the University of Canterbury, Christchurch, New Zealand. He provides a range of geospatial support services to research programmes including support for survey grade GNSS and conventional surveying and hydrographic surveying; use of Trimble postprocessing software products; incorporation of data products into GIS software and field support for research projects. He is a qualified RPAS pilot and has supported field research programmes and flown RPAS in Antarctica since 2015.* *Mr. Bealing's RPAS qualifications are appended to this EIA (Appendix 1)*
Marine Archaeology Team		
Mr Mensun Bound, Marine Archaeologist, University of Oxford, UK	British	*Mr. Bound is the Triton Senior Research Fellow in Marine Archaeology at Oxford University and a fellow of St. Peter's College, Oxford. In 1980 he established the Marine Archaeological Research (MARE) unit at Oxford. He has produced numerous publications on marine archaeology including several books.* *Mr Bound will oversee the search for and survey of the historic wrecks in the Weddell Sea.*
Media Team		
Mr Tom Stubberfield, Producer, Atlantic Productions, London, UK	British	*Tom first worked at Atlantic in 2013, directing the ancient-engineering series Time Scanners for Nat Geo with Dallas Campbell and world-renowned structural engineer Steve Burrows. More recently he's worked across much of the company's TV and VR output including Galapagos with Liz Bonnin for BBC1 and the epic history series The Emirates Story. Prior to joining Atlantic full-time, Tom produced and directed numerous high-end productions for many of the world's leading broadcasters including Restoration with Griff Rhys Jones for BBC2, Man on Earth with Tony Robinson for Channel 4, Tutankhamun: The Truth Uncovered with Dallas Campbell for BBC1, and Masters of the Pacific Coast with Dr Jago Cooper for BBC4. Specialising in history and science, Tom has extensive experience leading teams on large-scale productions all over the world.*
Plus three Atlantic Productions media personnel	TBA	*To be provided to FCO prior to the departure of the Expedition.*
Expedition Doctor		
Dr. Claire Grogan	British	*UK-based doctor in emergency medicine with an interest in expedition and remote medicine. Fellow of the Royal Geographical Society*
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 Aghulas II for her delivery voyage and for the vessels first Antarctic voyage. Captain Lighthelm's CV is appended to this EIA (Appendix 1).*

4.1.2 Air transport

The Expedition will enter Antarctica by air, flying from Cape Town, South Africa to Wolf's Fang ice runway in Dronning Maud Land (Figure 1). Wolf's Fang ice runway is located on a vast expanse of blue glacial ice situated approximately 20km north of the Kurze Mountains in Dronning Maud Land (71°31'S, 08°48'E).

The aircraft and the ice runway, as well as the ski-way at Penguin Bukta are managed by White Desert; a UK registered Antarctic tour operator that has been providing commercial tourism in Dronning Maud Land since 2005. The Expedition personnel will be flown from Cape Town to Wolf's Fang ice runway on-board a Gulfstream jet (Figure 2). Three flights will be required to move all personnel from Cape Town to Wolk's Fang ice runway. Expedition personnel will then be flown from Wolf's Fang to the Penguin Bukta ski-way on-board a Basler T-67 ski-equipped aircraft (Figure 2). Two aircraft rotations will be required to move all Expedition personnel to Penguin Bukta.

On completion of the marine research cruise, the reverse route will be followed. All Expedition personnel will disembark the vessel at Penguin Bukta, fly back to Wolf's Fang ice runway and then on to Cape Town.

White Desert's activities in Antarctica including the maintenance of the Wolf's Fang ice runway and the Penguin Bukta ski-way, are authorised under a separate permit issued by the UK's Foreign and Commonwealth Office (FCO). White Desert's support to the Weddell Sea Expedition 2019 is held under a commercial contract.

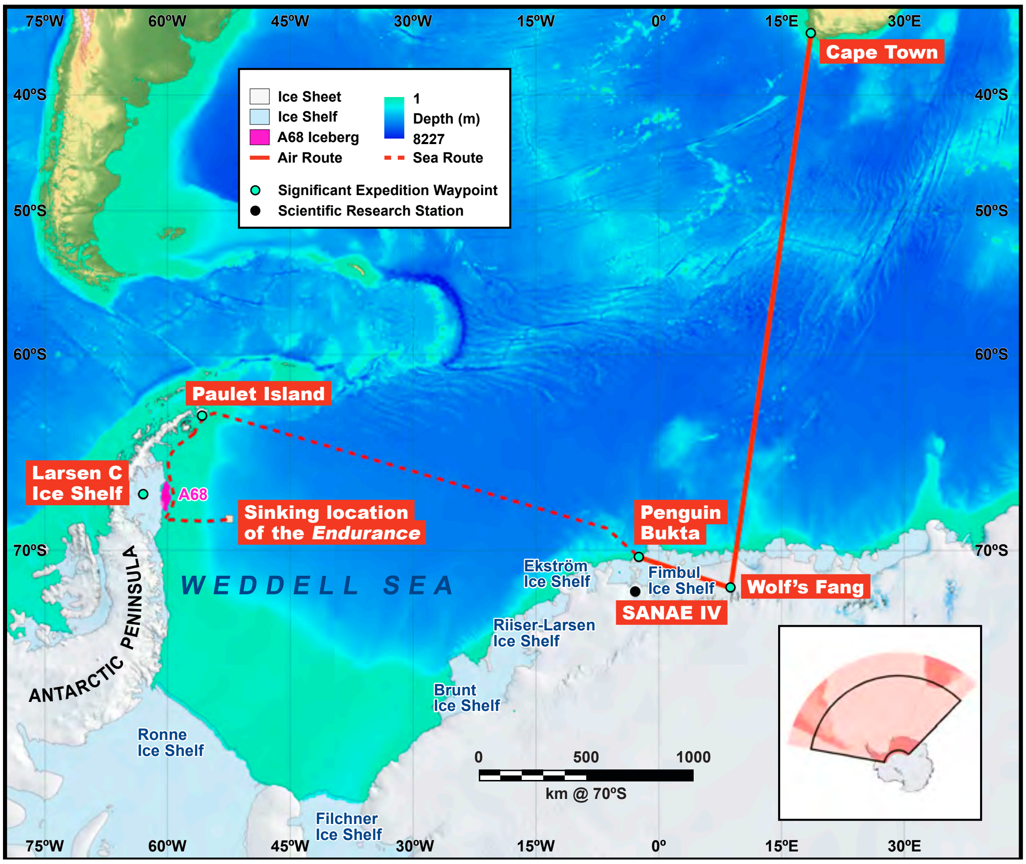

Figure 1. Overview of the routes to be taken by and key research and survey locations for the Expedition.

Figure 2. White Desert's Gulfstream jet (foreground) and Basler T-67 ski-equipped aircraft (background) on the Wolf's Fang ice runway.

4.1.3 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 approximately 47 days between 1 January and 16 February 2019.

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

The vessel is owned by the Department of Environmental Affairs (DEA) in South Africa and operated by African Marine Solutions (AMSOL). SA Agulhas II is used to support marine research activities undertaken by the South African national 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 2. A summary of the vessel is provided in Section 4.1.3.1 below.

4.1.3.1 SA Agulhas II details

SA Agulhas II is a 134m long vessel strengthened for ice class navigation to IACS[2] 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.

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[3] 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. A deep coring facility is installed for sampling seabed

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[2] International Association of Classification Societies
[3] Electronic chart display and information system

sediments to a depth of 5,000m. 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 4,000m³ 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 of Super Puma type or equivalent.

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

4.1.3.2 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 University of Canterbury drones will be available to provide a real-time video stream of ice-ice imagery to the ship's bridge, when required. All RPAS flights in support of ship navigation would be subject to weather conditions (e.g. high winds, blowing snow, fog). For this work, the RPAS will be piloted manually. Some of the science drones have the facility for more extended pre-programmed sorties beyond immediate line of sight if needed. 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.

In addition to video imagery from the RPAS, access to near-real time medium- and high-resolution satellite imagery will be managed for the cruise area and Larsen C Ice Shelf. A combination of optical and all-weather capable radar images is envisaged. Synthetic aperture radar images will be provided by the German Aerospace Agency (DLR) in support of the scientific goals for sea ice validation. These all-weather high-resolution SAR images will provide an additional aid to ship navigation in ice-infested waters. In addition, the European Space Agency's Sentinel-1 radar images will be used. The Scott Polar Research Institute will also be providing the ship with high resolution images from the MODIS satellite on a daily basis.

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 throughout its 2018/19 deployment.

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. As noted in Section 4.3 below, the Alfred Wegener Institute (Germany) will be operating the *Polarstern* in the vicinity of the Weddell Sea in early 2019 and have indicated that the *Polarstern* would respond to any emergency call from the SA Agulhas II.

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.

4.1.3.3 Vessel route

Expedition personnel will embark the SA Agulhas II at Penguin Bukta, on the Fimbul ice shelf at the end of December 2018 (Figures 1 and 4). Prior to supporting the Weddell Sea 2019 Expedition, the SA Agulhas II will arrive at Penguin Bukta for the purpose of resupplying the in-land South African research station, SANAE IV.

Following embarkation of the Expedition personnel (between 28 and 31 December 2018), the SA Agulhas II will sail towards the eastern side of the Antarctic Peninsula. The current planned departure date from Penguin Bukta is 1 January 2019.

The precise route to be taken from Penguin Bukta to 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 scientific practice for Polar research vessels, where changing environmental conditions for ship and equipment operations mean that cruise planning with detailed itineraries for a whole seven-week cruise is unrealistic.

Figure 4. SA Agulhas II undertaking resupply activities at Penguin Bukta on the Fimbul ice shelf.

Broadly, the vessel will follow a route across the north of the Weddell Sea (Figure 1) so as to arrive on the north-eastern side of the Antarctic Peninsula in the region of James Ross Island and Snow Hill Island (Figure 5). In following this route, the location of the South Orkney Islands marine protected area is noted (see Figure 35).

If sea ice conditions allow, the SA Agulhas II will transit south along the eastern side of the Antarctic Peninsula to the Larsen C ice shelf, and in particular the location of the calving of iceberg A68 in July 2017 (Figures 5 and 35). This area has been designated by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) as a Special Area for Scientific Study in accordance with the provisions of CCAMLR's Conservation Measure 24-04 (2016). This is discussed further in Section 6.8.3.4.

The last known position of Shackleton's Endurance is within approximately 150NM of the Larsen C ice shelf. Here also sea ice conditions will determine how close to the wreck site the SA Agulhas II can get, and whether or not a remote search and survey of the site is feasible using the autonomous underwater vehicles and the remotely operated (underwater) vehicle (see Section 4.3 for more detail).

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

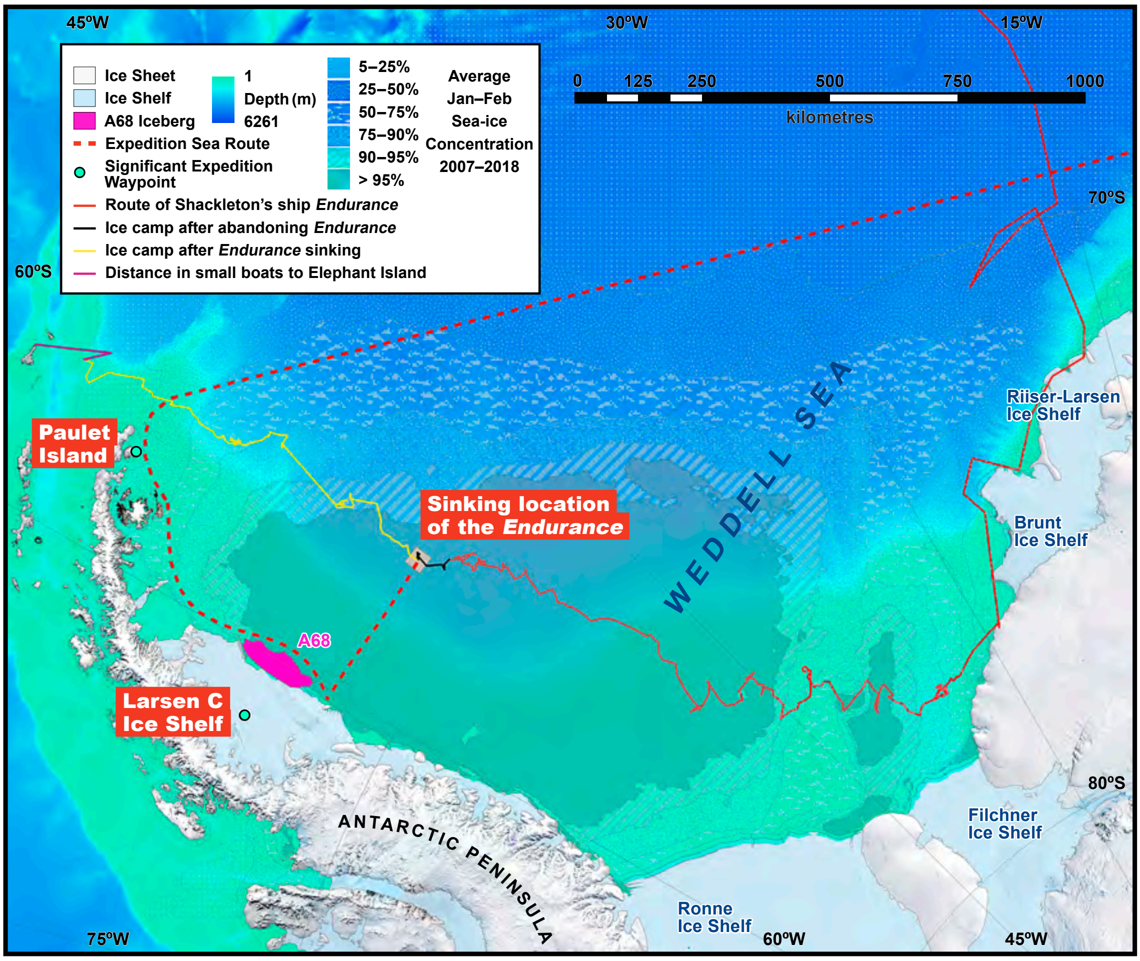

Figure 5. Planned vessel route on the eastern side of the Antarctic Peninsula, showing the primary target research location (A68) and the approximate location of the wreck of the Endurance.

4.1.3.4 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 for all Expedition personnel will take place in Cape Town prior to departure for Antarctica. This briefing will cover air safety matters (to be provided by White Desert) 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 FCO.

A second briefing on vessel safety will be undertaken as soon as personnel embark the SA Agulhas II. This second briefing will be used to reinforce all environmental requirements and conditions.

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

4.1.4 Summary of expedition itinerary

Table 2 summarises the expedition itinerary.

Date	Activity
End November 2018	Mobilisation of equipment on *Agulhas II* in Cape Town, including sea trials
6 December	*Agulhas II* departs Cape Town for Antarctica
16 December	*Agulhas II* arrives Penguin Bukta and starts resupply of SANAE IV base
28 December	Expedition team fly from Cape Town to Wolf's Fang ice runway and then onward to Penguin Bukta to join vessel – 3 aircraft rotations
1 January 2019	*Agulhas II* departs Penguin Bukta and commences expedition
16 January	Arrive Larsen C Ice Shelf for research programme
31 January	Depart *Endurance* wreck location, if found
16 - 18 February	Arrive Penguin Bukta. Expedition team fly back to Wolf's Fang and then onwards to Cape Town – 3 aircraft rotations
28 February	*Agulhas II* completes SANAE IV base cargo operations and sails back to Cape Town
10 March	Vessel arrives back in Cape Town and demobilisation of equipment starts
16 March 2019	Demobilisation complete. Expedition concludes

Table 2. Overview of the Expedition's itinerary.

4.2 Marine Research

4.2.1 Aims and objectives

The aim of this Expedition is to investigate the glaciology, marine-geology and geophysics, marine biology and oceanography of the water-filled cavities beneath floating ice shelves in the Weddell Sea.

The Chief Scientist for the Expedition is Professor Julian Dowdeswell, Director of the Scott Polar Research Institute, University of Cambridge.

The expedition's key scientific objectives are:

1. **To use upward-looking multi-beam echo sounding from AUVs to investigate the underwater shape of ice-shelf bases, the roughness of which is a vital parameter in numerical modelling of future ice-shelf stability.**
2. **To use downward-looking multi-beam echo-sounding and sub-bottom profiling from AUVs to investigate the detailed morphology and shallow stratigraphy of the seafloor beneath floating ice shelves, providing key information on past ice-shelf dynamics and stability.**
3. **To map the seafloor using AUV- and ROV-mounted multi-beam systems and high-resolution images, and extract sediment cores from the Weddell Sea shelf and slope, including from the 5,800km^2 area of the seafloor recently made accessible through the Larsen C iceberg calving event of July 2017.**
4. **To take a series of measurements of the salinity and temperature of the water column adjacent to and beneath floating ice shelves to assess the modern oceanographic setting and melt rate of these ice shelves.**
5. **To use AUV-acquired multi-beam echo-sounder data, including backscatter, from beneath floating ice shelves to characterise the seafloor marine habitat and biota.**
6. **To investigate the marine habitat and biota in areas of the seafloor recently made accessible to icebreaking vessels through the iceberg calving event of July 2017, through the use of multi-coring and imaging from a deep-water ROV.**
7. **To map the seafloor in the region of the *Endurance* and / or *Antarctic* wreck sites using AUV- and ROV-mounted multi-beam echo-sounders and sub-bottom profiler to assess the likelihood of recent submarine slope failure and mass movements which might have altered the sites over the past century, and to deploy AUV- and ROV- mounted instruments to survey the wrecks in detail.**
8. **To use upward-looking multi-beam echo sounding from AUVs to measure the underwater shape of sea ice along a number of transects in the Weddell Sea, and to use RPAS-deployed lidar, radar and cameras to record simultaneously the above-water shape and character of the sea ice.**

4.2.2 Research equipment

The Expedition will have available to it a number of instrumented autonomous vehicles, both underwater and aerial, that researchers will use to collect a range of data at selected target locations.

Marine pelagic and benthic biological and sediment samples will also be taken for analysis on-board and for returning samples to the UK for further analysis and archiving.

4.2.2.1 Underwater vehicles

Two types of underwater vehicle will be operated from the SA Agulhas II: autonomous (untethered) underwater vehicles (AUVs) and a remotely operated (tethered) underwater vehicle (ROV).

Autonomous Underwater Vehicles (AUVs)

The Expedition will have the use of two Kongsberg HUGIN, free-swimming marine AUVs provided and operated by Ocean Infinity (https://oceaninfinity.com; Figure 6).

Figure 6. Ocean Infinity's Hugin Underwater Autonomous Vehicles. Two of these will be available to the Expedition.

These machines are 6.2m in length, highly manoeuvrable with a turning radius of 15m. They are low noise and hydrodynamically stable for supporting a range of payload sensors. They can be operated by a supervisor in a semi-autonomous mode or can be fully autonomous. The AUVs have an endurance of around 60 hours (operating at 3.6 knots), a maximum speed of 6 knots and can operate in depths between 5 and 6,000 metres. The AUVs are equipped with state of the art navigation and sensor arrays, including:

- Side Scan Sonar - EdgeTech 2205
- Multi-Beam Echosounder - Kongsberg Maritime EM 2040
- Sub-Bottom Profiler - EdgeTech 2-16 kHz
- HD Camera - CathX Ocean Still Colour Camera
- Conductivity/Temperature/Depth Sensor – SAIV
- Self-Compensating Magnetometer
- Turbidity Sensor - FLNU (RT)D
- Methane and Cathx Laser Sensor
- Acoustic Positioning - HiPAP 502

One of the 6,000 metre depth AUV has been ordered for use by the Expedition and will be specifically configured for (upward looking) under ice surveys. The second AUV will be configured for downward looking surveys.

Remotely Operated Vehicle (ROV)

A General Purpose (GP 50) 60 HP ROV will be provided by Eclipse Group Incorporated, subject to the approval of the Flotilla Foundation and finalisation of contract terms (EGI; https://www.eclipse.us.com; Figure 7). Eclipse Group, Inc. (EGI) is a marine operations service provider based in Annapolis, Maryland, US. EGI provide turnkey subsea technical solutions to both commercial and government customers worldwide.

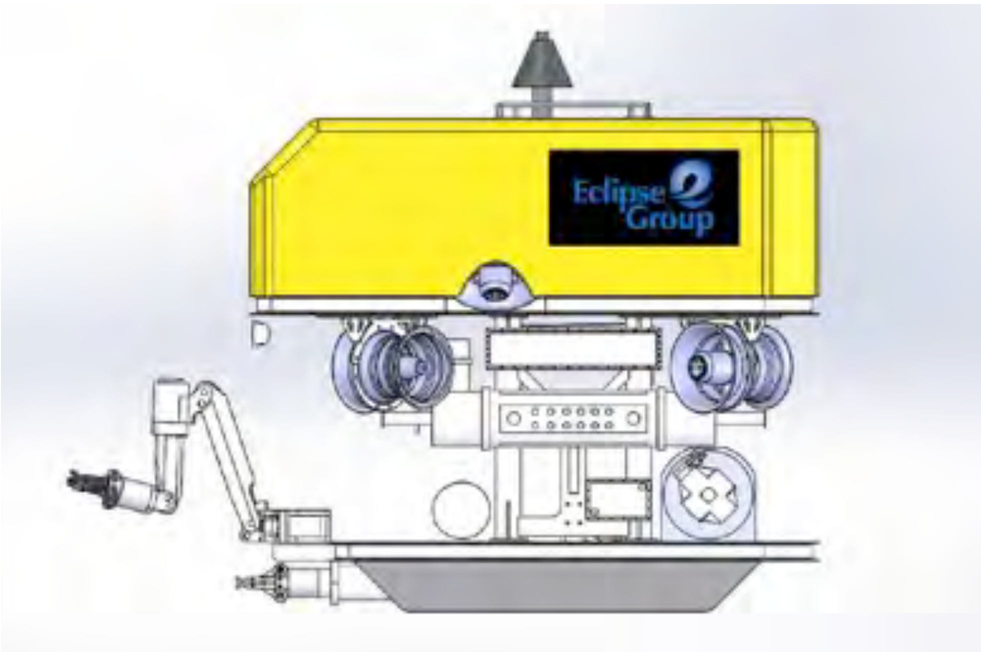

Figure 7. GP 50 ROV to be provided by Eclipse Group Inc.

The EGI GP 50 HP ROV is a robust, durable and highly capable ROV system designed for high payload, with open deck space and skid mounted options. The GP 50 is an EGI designed ROV with emphasis placed on lighting and video to allow for the highest quality video capture. Other features include the ability of the vehicle to recovery heavy objects utilizing thru frame lift. The control system provides advanced diagnostics, precise vehicle control and reduced reactive maintenance offering the benefit of increased dive time, reduced vessel standby and operating costs.

Typical deployments for ROV operations would be dependent on sea ice and open water conditions at individual study sites. If conditions allow then missions of up to 24 hours might be envisaged, with the ROV close enough to the seafloor to acquire clear imagery relating to both biota and geology. Straight-line transects (with the surface vessel and ROV moving at very slow speed) would be the norm.

4.2.2.2 Remotely piloted aircraft systems

Remotely piloted aircraft systems (RPAS) will be used for sea ice research as well as to support navigation of the SA Agulhas II (Figure 8). The University of Canterbury, Christchurch, New Zealand will provide the RPAS units. Associate Professor Wolfgang Rack will oversee RPAS activities. Paul Bealing (Department of Geography, University of Canterbury) will provide specialist RPAS piloting and technical support. Mr. Bealing is a trained and experienced Antarctic RPAS pilot holding all required internationally recognised certificates (Appendix 1). The Expedition will make use of both rotary and fixed wing RPAS.

Rotary wing RPAS

The three rotary wing RPAS types that will be used by the Expedition are summarised in tables 3 to 5.

Airframe	UC Aeronavics Navi 5
Airframe Type	700mm Quadcopter
Wingspan	700mm
MTOW	5.5kg
Battery	10,000mah 6cell
Payload capacity	1.5kg
Endurance	10-20minutes, payload and battery dependent
Launch and Recovery	Vertical take-off and landing
Cruise speed	0-50kph

Table 3. Specification for University of Canterbury Aeronavics Navi 5 rotary wing RPAS that will be used for sea ice research purposes.

Airframe	RS900 Hex
Airframe Type	900mm Hexcopter
Wingspan	900mm
MTOW	9kg
Battery	10,000-20,000mah 6cell
Payload capacity	5kg
Endurance	10-20minutes, payload and battery dependent
Launch and Recovery	Vertical take-off and landing
Cruise speed	0-50kph

Table 4. Specification for RS900 Hex rotary wing RPAS that will be used for sea ice research purposes.

Airframe	DJI Mavic
Airframe Type	335mm Foldable Quadcopter
Wingspan	335mm
MTOW	734g
Battery	Lipo 3 cell, 3830mha
Payload capacity	None – built in camera
Endurance	21 minutes
Launch and Recovery	Vertical take-off and landing
Cruise speed	0-65kph

Table 5. Specification of the DJI Mavic rotary wing RPAS that will be used to support vessel navigation.

Figure 8. A University of Canterbury rotary-wing RPAS being used in the Dry Valleys, Antarctica.

Figure 9. University of Canterbury fixed wing RPAS to be used on the Expedition.

Fixed wing RPAS

The fixed wing RPAS that will be used by the Expedition is summarised in table 6 (see also Figure 9).

Airframe identifiers	UCMTD Imager
Airframe Type	Fixed wing
Wingspan	225 cm
MTOW	5300 g
Battery	LiPo, 17500 mAh, 14.8V
Payload capacity	1500 g
Endurance	40 min
Launch and Recovery	Hand launch
Cruise speed	17 m/s
Failsafe/ Safety features	Parachute recovery Manual/ semi-autonomous backup control Return to launch on comms loss

Table 6. Specifications of the Fixed Wing RPAS to be used for sea ice research purposes.

The RPAS and instrumentation will be launched from the helideck of the SA Agulhas II, initially under manual control, or from the sea ice if safe to deploy personnel on to the sea ice. For research purposes the units will fly a pre-programmed route over sea ice, which will aim to follow the same route as that of an upward-looking AUV to collect coincident data on the submarine and sub-aerial shape of sea ice. On return to the vicinity of the ship, RPAS command will be re-acquired by the pilot to land the RPAS manually.

Equipment to be mounted on the RPAS to support the research programme includes: a newly developed RPAS-mounted snow radar, operating at 3.0 GHz; a lidar, which provides the ground control for the optical camera in combination with a precise GPS; a geometrically calibrated high-resolution stills camera to derive precise surface models (using Structure for Motion methods).

For sea ice research the RPAS will fly at different heights and speeds depending upon the instrumentation being used and the data being collected. Rotary wing RPAS undertaking snow radar measurements will require flights at approximately 5m above ground level (AGL) at 30 knots groundspeed. Aerial videography and photography flights will be flown at or below 120m AGL.

Simultaneous fixed wing RPAS flights while radar measurements are being made will be flown at or below 120m AGL.

To support vessel navigation a rotary wing RPAS equipped with video and providing a real-time feed to the ship's bridge, will be flown up to 1,000m AGL though remaining within the vicinity of the mother ship. For supporting ship navigation, the RPAS will be operated under pilot control from the ship.

The fixed wing RPAS has several advantages over multirotor RPAS for long duration flights. This will be conducted on an opportunity basis if the conditions and overall operation allows. Take-off and landing can be undertaken either from the ship or sea ice near the ship as conditions and other operational requirements allow.

4.2.2.3 Marine sampling equipment

CTD and water samplers

Conductivity-Temperature-Depth (CTD) and water sampling devices are standard measuring and sampling devices used in oceanographic research (Figure 10).

Figure 10. CTD and water sampling device being lowered through the 'environmental hangar' on the SA Agulhas II. Source: www.saeon.ac.za.

As well as conductivity, temperature and depth measurements the sensors are able to collect dissolved oxygen and chlorophyll measurements. Sensors are attached to a 'rosette', which includes 24 x 10-litre bottles that can be shut at any specified depth to collect water samples. These water samples are then measured for salinity, dissolved oxygen and other concentrations, and are used to verify the readings that the sensors provide.

Plankton (bongo) net

A bongo net consists of either a single or paired plankton net with a 60mm diameter mouth opening and varying mesh sizes between 10 and 1000 µm depending on the kind of organism being sampled. Each net consists of a cylindrical collar connected with a yoke. The net(s) are placed in the water from the research vessel, lowered down to the required depth and then brought back up. The zooplankton are caught in the net on its way up towards the surface (Figure 11).

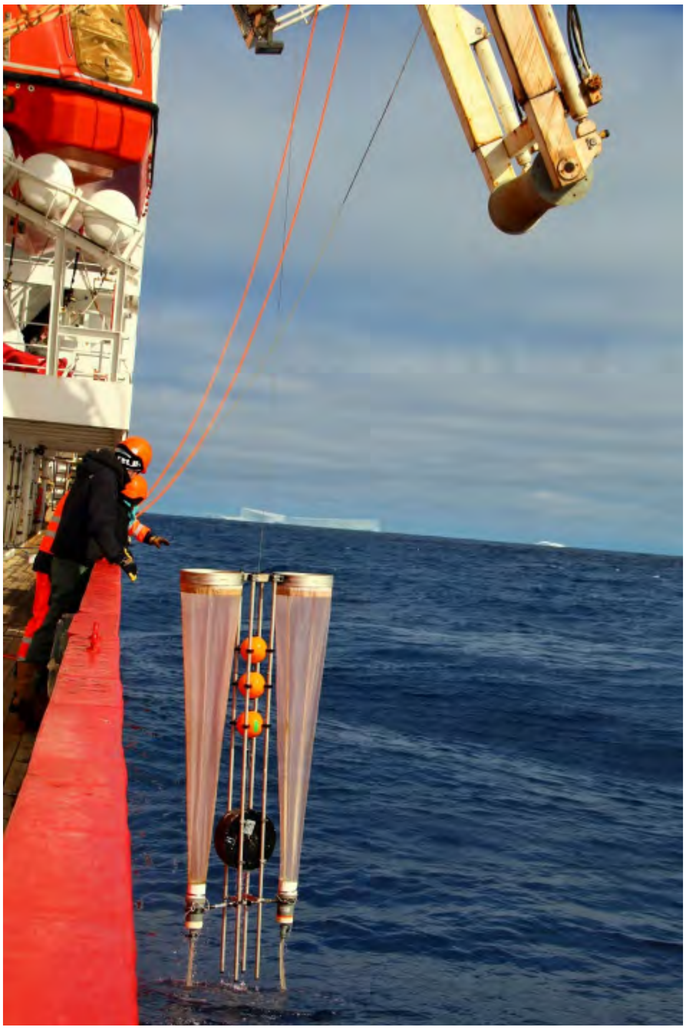

Figure 11. A plankton sampling or 'bongo' net being deployed from a research vessel in the Southern Ocean. Source: https://southernseasatspring.wordpress.com/category/science-on-board/

Multi-corer

A multi-corer is a gravity coring instrument that allows for multiple short cores to be taken in close proximity at the same time (Figure 12) and provides a series of undisturbed samples of the seafloor. This device can be used to study local fauna variations. Samples of the sediment / water interface can also be taken by this device.

The multi-corer is lowered from a research vessel to the seafloor by a cable. A weight is attached on the top of the construction. When the multi-corer touches the seafloor, this weight pushes the assembled cores into the seafloor.

Figure 12. Example of a multi-corer being deployed from RV Meteor around South Georgia in 2017. Photo Oliver Hogg, British Antarctic Survey. Source: http://www.gov.gs/march-17-newsletter/

Sediment gravity corers

Longer, single-barrel sediment cores will be collected through the use of a gravity coring system (Figure 13).

Such coring systems can be assembled with different length cores from 3m to a maximum of 24m. The Expedition will normally use core lengths of up to 6m. The coring unit is deployed from the vessel using a dedicated coring deployment system comprising a winch, overhead coring boom and core handling system.

The coring unit consists of the head weight, coring tube, removable inner core liner and core catcher. The trigger core reaches the bottom first and triggers the release of the main core which free-falls to the bottom and penetrates the silt. The tube is drawn back out of the silt with core catchers preventing the silt from coming out of the coring tube.

Figure 13. An example of a gravity corer being deployed from RV Investigator (an Australian research vessel of the Marine National Facility). Source: http://mnf.csiro.au/Vessel/Investigator-2014/Equipment/Sediment-coring.aspx

Box corers

A box corer will be used at selected target locations to take samples of the surface of the benthos. The box corer allows for a relatively intact sample to be taken of the upper part of the sea floor supporting investigations of the benthic micro- to macro-fauna, geochemical processes and sedimentology (Figure 14).

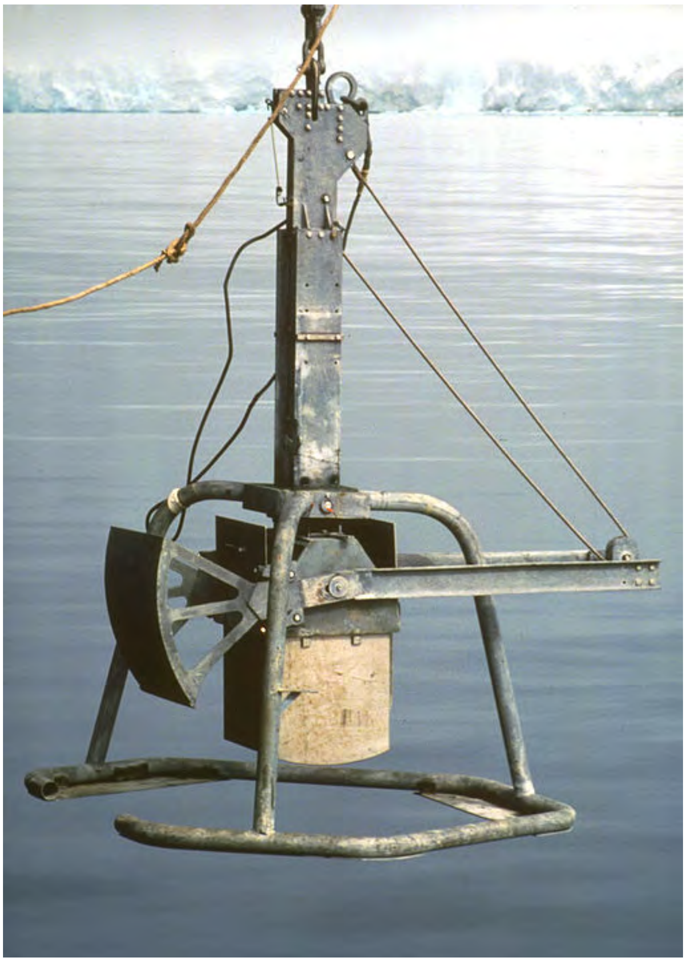

Figure 14. An example of a box corer being deployed from the German Polar research vessel Polarstern in the Southern Ocean. Source: H. Grobe, 2006. Alfred Wegener Institute for Polar and Marine Research. From Wikimedia Commons.

4.2.1 Sub-surface ice-shelf profiling

Research objective 1.
To use upward-looking multibeam echo-sounding from AUVs to investigate the underwater shape of ice-shelf bases, the roughness of which is a vital parameter in numerical modelling of future ice-shelf stability.

The Expedition is likely to have available to it some limited information on the thickness of the ice shelves and the absolute elevation / water depth of the ice-shelf base, acquired previously using airborne or ground-based MHz ice-penetrating radar systems. The grounding line of the Larsen C ice shelf is about 350 - 400m deep and much of the ice shelf base, as far as its geometry is known, is between 220 and 300m below sea level. These existing data will be acquired in advance of the Expedition and will be used during the research cruise to support mission planning and identifying target areas for equipment deployment.

The Hugin AUVs will be deployed under the ice-shelf equipped with upward-looking multibeam echo-sounder so as to profile the underwater shape of the base of the ice-shelf.

The AUVs are likely to be deployed in a staged approach. Initially, it is likely that early deployments will occur along known profiles based on existing ice-shelf thickness profiles. This potentially will involve nominal 5, 10 and 20NM straight-line profiles towards the interior of the ice shelf, either following the known benthic terrain at a suitable height or by following a pre-planned depth profile.

Further AUV deployments using any existing ice-shelf thickness profiles may then be undertaken parallel to the ice margin, either following the known ice-shelf base above a suitable height or by following a pre-planned depth profile.

Finally, longer missions, of 10s of NM, may potentially occur based on knowledge of the ice-shelf base developed from earlier missions. It is likely that the dimensions of the Larsen C Ice Shelf will constrain the maximum extent of under-ice missions. The grounding line at the interior of the Larsen C is, for example, about 80NM from its floating terminus. Thus, a possible upper limit to in-and-out profiles is likely to be a nominal 60NM and reciprocal return. The length of the ice-shelf margin is about 130NM and transects beneath the shelf running parallel to margin might be divided into two legs of about 60NM each and reciprocal return.

Research objective 2.
To use downward-looking multibeam echo-sounding and sub-bottom profiling from AUVs to investigate the detailed morphology and shallow stratigraphy of the seafloor beneath floating ice shelves, providing key information on past ice-shelf dynamics and stability.

In almost all cases, we know nothing about the bathymetry of the sea floor or the size of the water-filled cavity beneath ice shelves. Gaining such knowledge has potential to provide new insights into the dynamics and stability of the ice-shelf and ice / ocean interactions.

The approach to the design of missions for any benthic mapping would follow a very similar design to the sub-surface mapping noted above. Initially, the Expedition will aim to acquire sea floor bathymetry immediately adjacent to the modern Larsen C ice-shelf front using the AUV-mounted multibeam system.

AUV deployments under the ice-shelf would follow nominal 2, 5, 10NM straight-line profiles towards the interior of the ice shelf, following the unknown terrain beneath at a suitable height (constrained by the AUV multibeam system).

Further AUV deployments across the seafloor beneath the ice shelf, orthogonal to the previous transects, would then be undertaken following the unknown terrain beneath at a suitable height.

Longer missions, of 10s of NM, would evolve as knowledge of the seafloor bathymetry beneath the ice shelf developed from earlier missions.

It should be noted that any AUV operation beneath ice shelves, where little or no data exist on cavity morphology, is high-risk but high-reward science.

A UK AUV was lost beneath the Fimbul Ice Shelf in 2005 and the UK's Natural Environment Research Council (NERC) acknowledged at the time that the risks of AUV loss were high prior to sanctioning that science programme. Whilst the risks of loss of an AUV remain, they are assessed as being significantly less than 13 years ago. Technology has improved and modern AUV technology includes sophisticated collision avoidance systems (Pebody, 2008). The AUVs to be used on this Expedition are among the most advanced available and one has been constructed specifically for the Expedition. There is also considerably more expertise and experience available in the operation of and planning for AUV deployments.

Additional mitigation measures to minimise the risk of loss are further discussed in sub-section 7.4.2.2.

4.2.2 Benthic survey

Research objective 3.

To map the seafloor using AUV- and ROV-mounted multi-beam systems and high-resolution images, and extract sediment cores from the Weddell Sea shelf and slope, including from the 5,800 km^2 area of the seafloor recently made accessible through the Larsen C iceberg calving event of July 2017.

A key aspect of the research programme is to assess past behaviour of the Larsen ice-shelf and in particular the Larsen C ice shelf and to assess whether recent calving event and ice shelf retreat is a 'one off' event or part of a repeating pattern over the last 10,000 to 15,000 years. Sediment cores provide a means of interpreting ice-shelf behaviour. Assessing changes in the granularity of the sediment layers of the cores provides an indicator of the proximity of the ice-shelf grounding line to the core location. Carbonaceous micro-organisms in the sediment cores can be used to date observed historic events.

A series of up to 6m long gravity cores will be taken in the vicinity of the Larsen C ice shelf (or adjacent to secondary target ice-shelf research sites). Potentially these will be divided into approximately 1m lengths and returned for analysis in the UK.

The precise number and location of cores cannot be planned in advance and will depend upon the success of accessing the primary target area and sea ice and weather conditions at the time.

Any core lengths unused in the analysis will be archived in the British Ocean Sediment Core Research Facility (BOSCORF; www.boscorf.org) established by the UK's Natural Environment Research Council (NERC). BOSCROF have confirmed their willingness to archive core material obtained by the Expedition.

Research objective 5.

To use AUV-acquired multibeam echo-sounder data, including backscatter, from beneath floating ice shelves to characterise the seafloor marine habitat and biota, and

Research objective 6.

To investigate the marine habitat and biota in areas of the seafloor recently made accessible to icebreaking vessels through the iceberg calving event of July 2017, through the use of multi-coring and imaging from a deep-water ROV.

The investigation of sub-ice-shelf ecology has been identified as a priority by the international Antarctic science community and was the subject of a meeting at Florida State University Coastal and Marine Laboratory in November 2017 (see https://www.scar.org/community-news/ecosystem-workshop/).

The consequences of ice shelf loss on sub-ice-shelf ecosystems are very poorly understood. To date it has only been possible to study such ecosystems after the collapse of ice shelves by which time rapid colonisation of the benthos by pioneer species has at least partially obliterated the existing biota (Fillinger et al., 2013; Gutt et al., 2013, 2015). These studies have nonetheless indicated that the under-ice-shelf fauna may include a high proportion of deep-sea species adapted to oligotrophic conditions as well as at least some hexactinellid sponges (Gutt et al., 2015).

Overall the fauna is thought to be impoverished both in abundance and species richness compared to open shelf environments (Gutt et al., 2015). Likewise, the biota inhabiting the environment on the underside of the ice-shelf itself (sympagic fauna) is also poorly understood. The sympagic fauna in general is poorly studied in the Antarctic, even under sea ice, as a result of accessibility even though it is known to be an important habitat for krill, *Euphausia superba*, and other species such as the fish *Pagothenia borchgrevinki* (Gulliksen & Lønne, 1991).

Under ice-shelf environments are oligotrophic and input of organic material must be through horizontal advection of fresh material from primary production or resuspended material from the seabed (Gutt et al., 2015). Based on previous studies a number of predictions may be made of the structure of sub-ice-shelf communities:

1. The abundance and biomass of seabed megafauna, macrofauna and meiofauna decline with increasing distance from the ice edge to under the ice-shelf.
2. The biodiversity of sub-ice-shelf benthic communities also declines moving further away from open water with an increased prevalence of oligotrophic specialists such as animals from the deep-sea.
3. Although community / assemblage structure is different to the benthos in open waters species are drawn from known Antarctica biota rather than being characterised by a high level of taxonomic novelty.
4. These predictions will be tested by:
    - using the AUV-acquired multibeam and echo sounder data to characterise marine habitat and biota;
    - using the ROV to collect seafloor images (HD Video and stills) to quantify and identify seafloor megafauna both in open ocean areas and from the ice shelf edge to as far under the ice shelf as range permits;

- using the ROV to collect sediment push cores from open ocean and sub-ice shelf environments which will be analysed for macrofaunal and physical data (e.g. particulate organic carbon (POC), granulometry etc.);
- using the multi-corer and box corer to collect benthic samples in areas adjacent to the ice-shelf and in particular the area made accessible by the June 2017 calving event from the Larsen C ice-shelf;
- collecting water samples from open water and under-shelf environments for analyses of phytoplankton, zooplankton, POC etc. These samples would also be used for eDNA studies to characterise the fauna present;
- using the ROV to undertake image surveys of under ice-shelf sympagic communities to test the same predictions as for the benthos.

4.2.3 Sea ice

Research objective 8.
To use upward-looking multibeam echo-sounding from an AUV to measure the underwater shape of sea ice along a number of transects in the Weddell Sea, and to use RPAS-deployed lidar, radar and cameras to record simultaneously the above-water shape and character of the sea ice.

Antarctic sea ice thickness is a major unknown in cryosphere research. Sea ice extent in the Southern Ocean is increasing, in marked contrast to decreasing Arctic sea ice extent – this is often regarded as a climate paradox. The ocean area covered by sea ice is well detected by satellites, but sea ice mass is less well known, as this would require detailed information on thickness as well as extent. However, the annually formed mass of sea ice and its distribution critically influences global climate and the circulation of ocean currents. Sea ice thickness is especially hard to measure as traces of salt make the ice conductive, preventing the use of radar technology. It is also relatively thin (just a few metres thick) and dynamic, which normally excludes direct measurement on the ground because of logistical and safety constraints.

New satellite technology makes use of accurate sea ice freeboard measurements - the detection of the proportion of ice above the water level. The freeboard of sea ice is about one tenth of its thickness, or typically 10-20cm (or even less) for smooth, un-ridged Antarctic ice, a relationship that is further complicated by any low-density snow accumulated on the sea-ice surface. These factors, together with the spatial heterogeneity of sea ice, pose a substantial technological challenge to measurement and this is the primary reason why reliable sea ice thickness data for the Southern Ocean do not exist. The solution is seen in the ground-truthing or validation of satellite-derived measurements. This requires the direct comparison of satellite measurements with in-situ observations of freeboard and snow depth. The local field measurement of freeboard and snow will enable much improved interpretation of satellite data and contribute much needed physical understanding of sea ice processes.

The Expedition will use the RPAS from the SA Agulhas II to measure systematically sea ice freeboard and snow depth in the Weddell Sea. As noted above, the RPAS will be equipped with (over multi-flights): a high-resolution stills camera; a newly developed snow radar (operating at 3 GHz); a lidar, which provides the ground control for the optical camera in combination with a precise GPS, and meteorological sensors to calibrate satellite-measurements of Antarctic cloud cover and sea ice.

In order to understand how freeboard and snow cover relates to total sea-ice thickness, it is planned to simultaneously coordinate RPAS measurements above the sea ice with upward looking AUV-mounted multibeam data of the submarine morphology of sea ice along the same transects. The presence of AUVs on the cruise provides a major opportunity to coordinate these measurements for the first time.

The design of individual missions under sea ice will be dependent on the amount of open water for AUV return and retrieval, with longer missions being increasingly vulnerable since sea-ice conditions change rapidly over hours and even minutes. Mission lengths of a few NM from the ship will be very valuable, with longer missions dependent on open water for retrieval.

An additional, opportunistic, component of the sea ice research will be to examine sea ice microphytobenthos biomass and community composition. Sea ice diatoms (microalgae) are an important food source for *Euphausia superba* (Antarctic krill). Almost 90% of the carbon in the body of krill larvae originates from sea-ice algae (Kohlbach et al. 2017). If an opportunity presents itself to collect under ice scrapes of the microphytobenthos, the Expedition will attempt to determine biomass levels (through chlorophyll-a and POC/PON measurements) and community composition of the microphytobenthos (through microscopy and flow cytometry). These data will be correlated with the stomach contents of krill caught in the vertical 60 µm bongo net and interpreted in the context of ancillary water column biogeochemical measurements (e.g., nutrients, nitrate isotopes, chlorophyll).

4.2.4 Oceanography and marine ecology

Research objective 4.
To take a series of measurements of the salinity and temperature of the water column adjacent to and beneath floating ice shelves to assess the modern oceanographic setting and melt rate of these ice shelves.

Currently there is a rudimentary understanding of the decadal trends and mechanisms associated with the formation of Antarctic shelf and bottom water (AASW and AABW, respectively). AABW is formed by the sinking of near-freezing (−1.9°C) dense shelf waters to the seafloor where it then spreads throughout the ocean basins. The mechanisms responsible for the formation of this dense shelf water are enhanced by extensive surface heat loss over the shelf region and a gain in salinity due to salt-rejection within coastal polynyas. The formation of new water masses over the Antarctic shelf region contributes to global ocean circulation and traps unconsumed nutrients that are then circulated throughout the abyssal ocean. However, compared with other regions (specifically, the overturning circulation in the North Atlantic Ocean), large uncertainties in the strength, heat and salt fluxes of the southern limb of the overturning circulation continue to obscure our full understanding of deep water formation and its role in climate dynamics, CO_2 cycling, and sensitivity to change. Moreover, AABW contributes to the formation of Circumpolar Deep Water (CDW), the greatest volume water mass in the Southern Ocean that, directly or indirectly, supplies nutrients to much of the global ocean.

Recent investigations have suggested that increasing Antarctic shelf water temperatures are a driving force behind the loss of Antarctic ice sheet through increased ice shelf basal melt (Schmidtko et al., 2014). The cause of this melt is believed to be largely influenced by an increase in the shoaling of warmer CDW (Cook et al., 2016). In addition, an increase in the volume flux of CDW in response to changes in wind patterns and buoyancy forcing may also influence ocean temperatures at the Antarctic shelf region. Recent observed trends in water mass properties are alarming, with Antarctica's adjacent seas experiencing more frequent warm-water intrusions of CDW, which has implications for the continued and irreversible retreat of a portion of the West Antarctic Ice Sheet (Hillenbrand et al., 2017).

An improved understanding of the formation of AABW and its importance for Earth's climate system is required.

The Expedition will undertake a series of oceanographic measurements including a number (6-10) of full-depth CTD stations close to the Larsen C ice shelf from which hydrographic data (e.g., temperature, salinity) and seawater samples will be collected. The water samples will be analysed for nutrient (nitrate, nitrite, silicate, phosphate, ammonium) concentrations and nitrate isotopes, as well as dissolved inorganic carbon and alkalinity (from which pCO_2 can be calculated). Together, these data will be used to investigate the rate of AABW formation and downwelling, as well as the physical and chemical characteristics of this water mass and its role in CO_2 cycling and nutrient supply.

Additional oceanographic work will be undertaken where feasible to investigate biogeochemical cycling in the Weddell Sea. This work will aim to investigate:

- the rate of organic carbon biomass formation (i.e., primary production) in Weddell Sea surface waters;
- the importance of different phytoplankton groups for new, regenerated, and export production, as well as for sea ice biogeochemistry;
- the effects of (overlapping) biogeochemical transformations on the signature of water masses formed in the Weddell Sea, and
- how well surface-produced biogeochemical signatures are preserved in diatom microfossils on the seafloor.

To achieve this the Expedition will rely on open water samples being taken for biochemical analyses. Water samples will be obtained from CTD casts at various depths as well as from samples taken at regular intervals from the ship's underway system.

A 60 µm mesh net will be used to collect plankton samples in the upper 200m of water at selected sampling stations. These samples will be used to undertaken phytoplankton taxonomic analyses. The 60 µm mesh nets will also be used to obtain krill samples for stomach content analysis (this is linked to the sea ice microalgal composition work proposed in Section 4.2.3 above).

Sediment cores obtained as outlined above will also be analysed for diatom microfossils to assess historic community composition and N isotopic composition (thought to provide a reliable metric of past nitrate utilisation by phytoplankton).

4.3 Research Cooperation with the Alfred Wegener Institute, Germany

Early discussions with the Alfred Wegener Institute for Polar and Marine Research (AWI) suggested that the German research vessel *Polarstern* would also be operating in the eastern Weddell Sea during the 2018/19 austral summer season. This raised the potential for joint logistical and scientific research with this Expedition and not least the opportunity for conducting a two-vessel campaign, with increased potential for accessing the Larsen C ice-shelf area.

However, a subsequent meeting with AWI in early June 2018 has revealed that the *Polarstern* will not be operating in the Weddell Sea until mid-February, at the conclusion of this Expedition. With no opportunity for adjusting the planned itineraries of either vessel, joint logistical cooperation has now been ruled out.

Nonetheless, discussions have identified the potential for research cooperation. AWI have requested that this Expedition make use of the SA Agulhas II to deploy five instrumented 'ice buoys' on ice floes.

The buoys are manufactured by Pacific Gyre in the USA and are called Surface Velocity Program (SVP) drifters (Figure 15). The 35cm diameter spherical surface buoys will simply be placed on top of sea ice floes were they will record and telemeter a range of data.

Figure 15. Pacific Gyre, SVP Drifter Buoy. Source: https://www.pacificgyre.com/svp-gps-data-buoys.aspx

Although the buoys will be telemeting their position along with other recorded data, it is unlikely that they will be recovered by the *Polarstern* later in the season.

In return for the Expedition deploying these buoys, AWI have indicated that they are willing to assist in obtaining access to high quality, near real-time satellite images of sea-ice cover for the Weddell Sea from the German Aerospace Agency (DLR) (see Section 4.1.3.2) and that the *Polarstern* would be ready to provided search and rescue support to the SA Agulhas II should the latter run in to difficulties during the 2018/19 season.

4.4 Marine Archaeology

Research objective 7.

To map the seafloor in the region of the *Endurance* and / or *Antarctic* wreck sites using AUV- and ROV-mounted multi-beam echo-sounders and sub-bottom profiler to assess the likelihood of recent submarine slope failure and mass movements which might have altered the sites over the past century, and to deploy AUV- and ROV-mounted instruments to survey the wrecks in detail.

Shackleton's 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 was a member of Captain Scott's *Discovery Expedition* (1901–1904), during which he, Scott and Edward Wilson set a new southern record by walking 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 clearly 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 the ship. Their position was 69°5'S, long. 51°30'W. The *Endurance* was under heavy pressure from the ice and not held in a good position. 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 16).

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.

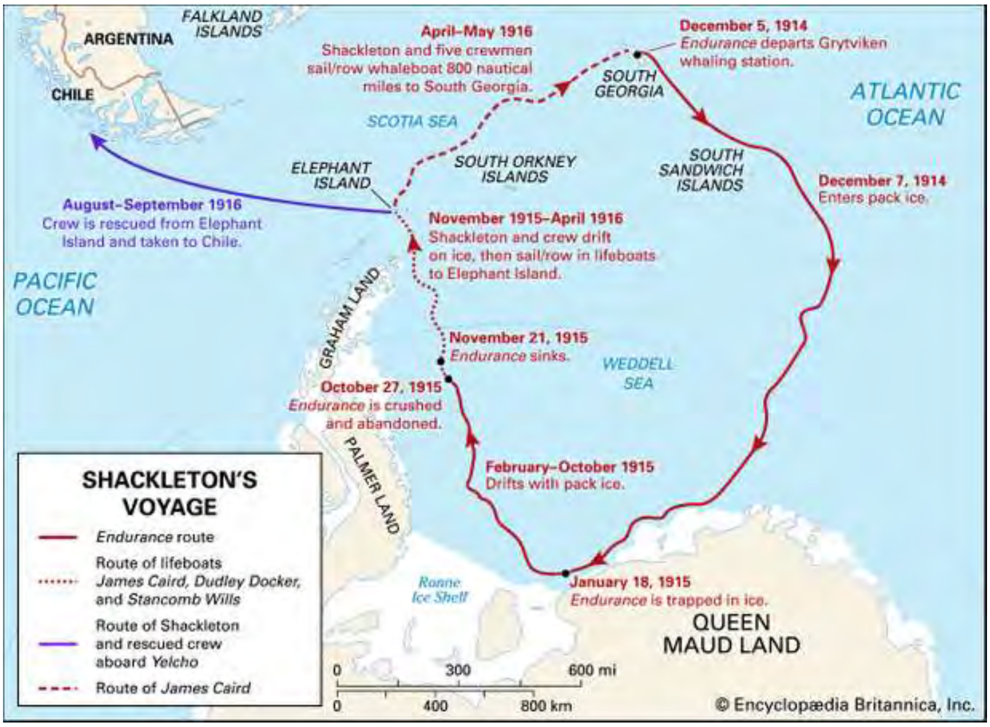

Figure 16. Overview of Shackleton's Weddell Sea voyage. Source: https://www.britannica.com/biography/Ernest-Henry-Shackleton/images-videos.

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

The Scott Polar Research Institute (SPRI) has available to it the records that F.A. Worsley (the Captain of the Endurance) took of the location of the Endurance’s sinking. These will assist in guiding the search and are potentially accurate to within a few hundreds of metres.

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 further damage will be done to the wreck. At every stage, the project will observe international best practice for the protection and conservation of historic shipwrecks.

The search will be conducted using one, or possibly two of the Hugin 6000 AUVs fitted with still-image HD cameras, multi-beam side-scan sonars, magnetometers, and sub- 6 bottom profilers. The latter two instruments may be useful for – respectively – location of metallic items from the wreck, and picking out anomalies in the character of the sea bed, particularly if the wreck has been significantly covered by sediments.

Once the *Endurance* has been found, she will be surveyed using the EGI (GP 50) ROV deployed above the wreck from the SA Agulhas II. The ROV will use a 3D photo scanning system to digitally record and film the Endurance, which will allow 3D modelling and full photogrammetric coverage of the wreck and its debris field. The survey data will be conveyed by an Ethernet/IP link to the onboard computer where high speed processing will allow real-time monitoring by the ROV team and archaeologists. 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 Weddell Sea Expedition will be used as vital base-line information for the future monitoring and protection of the wreck of the Endurance.

The Foreign and Commonwealth Office (FCO) has indicated its interest in proposing to the Antarctic Treaty Consultative Meeting (ATCM) that the wreck be designated as an Historic Site and Monument (HSM). The expedition has offered to assist the FCO in the preparation of this application and will provide any relevant research and data.

Nordenskjold's Antarctic

The Swedish Antarctic Expedition 1901 – 1904 was organised and lead by Dr Otto Nordenskjold. The aim of the expedition was to leave a small over-wintering party as far south as possible to be picked up the following season.

Snow Hill Island was chosen as the overwintering site (Figure 17). Nordenskjöld and five others were left ashore to overwinter and conduct a series of scientific studies. The *Antarctic* then left to spend the Austral autumn and winter on scientific study in the Falkland Islands, South Georgia and Tierra del Fuego.

The following summer of 1902/03 the sea ice did not break up and it remained solid throughout preventing ship access and requiring the overwintering party to remain for a second winter. Four hundred penguins, thirty seals and skuas were taken for food and fuel.

On 12 October 1903, Nordenskjöld and fellow winterer Jonassen saw three men in the distance who turned out to be three colleagues from their ship the *Antarctic.* The three had been put ashore at Hope Bay (Figure 17) to fetch the overwintering party at Snow Hill Island when ship access proved impossible. They made good progress at first but then met with open water blocking their path, so they returned to await the ship back at Hope Bay, but the ship never returned.

In the absence of the ship the three built a small hut with a nearby tent as sleeping quarters, they killed and cached several hundred penguins for food and fuel for the winter. With the arrival of spring, the three knew that if the *Antarctic* had been lost, no-one would know they were there and so they set out for Snow Hill on 29 September 1903, meeting Nordenskjöld two weeks later.

After dropping off the Hope Bay party, the *Antarctic* had been squeezed by the pressure of the surrounding ice and began to leak. The decision was made to abandon the ship and make for Paulet Island 25 miles away across rough and broken sea ice (Figure 16). The *Antarctic* was crushed and sunk beneath the ice on 12 February 1903. The men spent the winter on Paulet Island.

On 8 November 1903, four Argentinian naval officers from the ship *Uruguay* arrived on Snow Hill Island to rescue the abandoned men. The *Uruguay* had set off on a pre-arranged rescue mission at the end of the winter when the *Antarctic* had failed to return to South America for the austral winter. The group left Snow Hill Island and crossed the sea-ice to the *Uruguay*, and the ship went to rescue the remaining *Antarctic* crew from Paulet Island.

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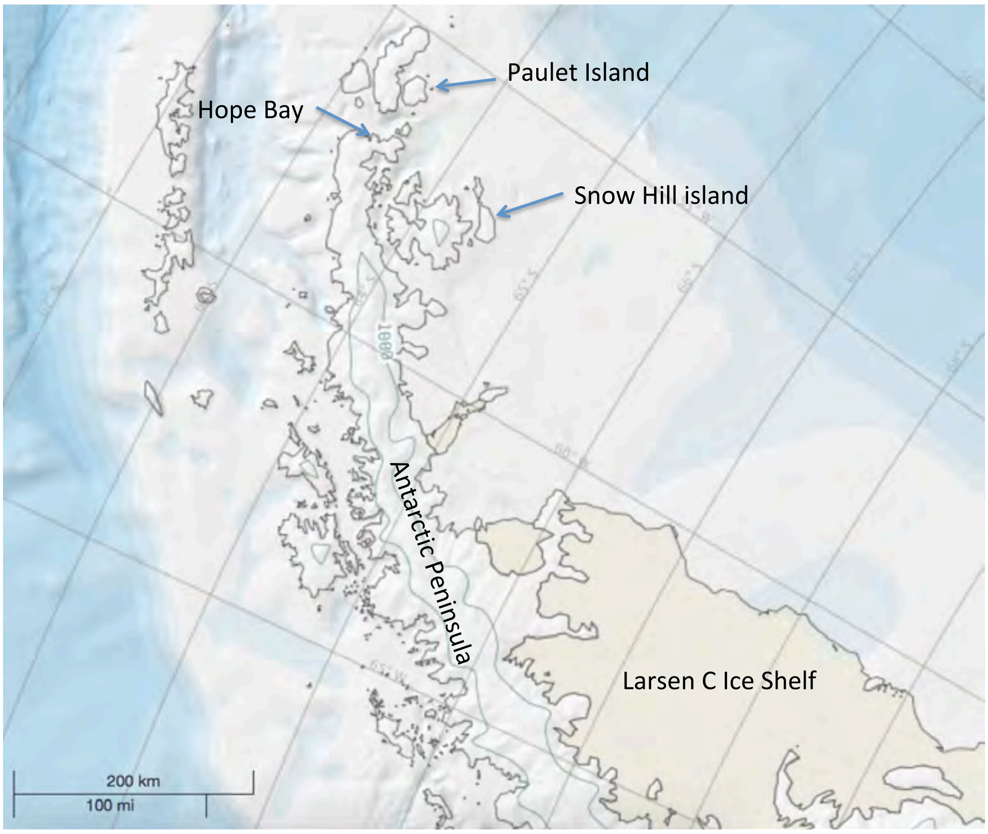

Figure 17. Northern Antarctic Peninsula region showing Snow Hill and Paulet islands and Hope Bay. Key locations for the 1902-03 Nordenskjold Expedition.

The same search and survey approach described above for the *Endurance* will be used for the *Antarctic*.[4]

The availability of the AUVs and ROV on-board will mean that the SA Agulhas II does not need to be immediately over either of the wrecks for the survey work to be undertaken.

It is possible that either of the wreck sites, if located, may be supporting unusual deep water benthic species or assemblages of species. Opportunistic sampling of benthic fauna from or in the vicinity of the wreck sites may be undertaken, but only in circumstances where disturbance or damage to either of the wrecks will not occur. A highly precautionary approach will be taken to such an activity and will be risk assessed among the scientists and ROV technicians on-board. Key components of the decision-making will include:

- a consensus agreement among the scientists that collection or sampling will be of additional research benefit over and above any imagery obtained, and that,
- the ROV technicians are 'highly confident' that sampling will not cause damage or disturbance to the wrecks.

It is explicitly recorded that the intent of the Expedition is only to survey and image the wrecks of the *Antarctic* and *Endurance* if they are located. The wrecks will not be touched or disturbed in any way and no (non-biological) samples or artefacts associated with the wrecks will be removed.

[4] Regarding the proposed attempt to search for the wreck of the Antarctic, the Expedition organisers have been in contact with the Swedish Polar Research Secretariat (SPRS) so as to provide them with information on the potential search and survey. The Director-General of the SPRS has responded positively. They have no particular concerns over the proposals and have expressed interest in receiving any data or information that can be shared with Sweden that may assist in proposing the wreck as an historic site or monument under the provisions of the Antarctic Treaty.

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 likely to be.

However, not proceeding with the Expedition would be a missed opportunity to undertake a compelling programme of scientific research that, if successful, will add considerable knowledge to current understanding of ice-shelf and sea-ice processes.

Under ice-shelf research remains in its infancy and the funding provided by the Flotilla Foundation has provided a rare opportunity to bring together world leading researchers and cutting edge underwater survey technology in order to undertake a globally relevant exploration of the Larsen C ice-shelf.

The ability to use simultaneous AUV and RPAS measurements above and below sea ice has not been undertaken before and will add significant knowledge to our understanding and measurements of sea ice.

The availability of the AUV and ROV survey equipment also provides a rare opportunity to search for a survey the wreck site of Sir Ernest Shackleton's *Endurance*, which has not been located since it sank in 1915.

This combination of technology and international research expertise is exceptionally rare in an Antarctic context and is beyond the scope of most national Antarctic programmes.

Consequently the 'do not proceed' option was rejected.

5.2 Alternative locations

As recorded in Section 6 below, the uncertainties associated with weather and sea ice conditions means that access to the preferred target research area in front of the Larsen C ice-shelf cannot be guaranteed. Consequently, it is prudent to identify alternative target research locations.

For this Expedition, the Chief Scientist (Director of the Scott Polar Research Institute) has reviewed Weddell Sea sea-ice data for the last 16 years and identified patterns which may assist in the final decision making regarding research location. The analysed data suggest that heavy pack ice in the western part of the Weddell Sea (including the Larsen C ice shelf area) during December is reasonably well correlated with heavy pack ice in the same area later in the season during the planned period for this Expedition.

Satellite imagery will be obtained during December 2018 and will provide an indication of sea ice / pack ice conditions at the time. This will assist in deciding upon the target research location prior to, or at least at the commencement of the Expedition. If the likelihood of access to the Larsen C ice shelf area is considered to be low, based on these early-season satellite images, then it may be expedient to avoid spending time crossing the Weddell Sea and instead maximise the opportunity to undertake comparable research on the (potentially) more accessible ice shelves in the eastern Weddell Sea.

5.2.1 Alternative ice shelf locations

Alternate, ice shelf targets will be the floating margins of the Fimbul and Riiser-Larsen ice shelves, relatively close to Penguin Bukta where the Expedition will rendezvous with the SA Agulhas II in late December 2018 (Figure 1).

The research planned for the Larsen C ice shelf can largely be repeated on these ice-shelves and will involve undertaking AUV and ROV surveys of the shelf cavities (both under ice and sea floor) as well as benthic sediment and biological samples in front of these alternate ice shelves. The same methods and research equipment would be used in these locations (as described in Sections 4.2.1 and 4.2.2).

What these alternative ice shelves lack is a significant area of recently exposed benthic environment following a large iceberg calving event, as occurred at the Larsen C in July 2017. Nonetheless, meaningful data and information can be gathered on the behaviour and climate-driven responsiveness of these ice shelves by undertaking similar research to that planned for the Larsen C ice shelf.

The potential environmental impacts and mitigation measures are considered to be very similar to those described for the Larsen C ice shelf (Sections 7.4.2 and 7.4.3).

During transit legs between key target areas, sea-ice morphology will be investigated in a series of transects on an opportunistic basis, and coring and CTD casts will also be undertaken.

5.2.2 Alternative marine archaeological location

If the decision is taken not to cross the Weddell Sea and instead to focus the research effort on the ice-shelves along the eastern Weddell Sea margin, then the marine archaeological objectives of the Expedition will not be realised. A decision that will not be taken lightly.

However, if a crossing of the Weddell Sea is made but access to the location of the wreck of Shackleton's *Endurance* is not possible, an alternative archaeological target is the wreck of Nordenskjold's *Antarctic* that sank approximately 25NM from the island in February 1903 (Section 4.3 and Figure 17).

If time allows, the AUV and RoV survey equipment may be deployed in the region of Paulet Island at the north-eastern tip of the Antarctic Peninsula, to look for the wreck of the *Antarctic*. which provides an excellent alternative to fulfil the marine archaeological objectives of the Expedition.

The method to be used for searching for the *Antarctic* would be identical to that proposed for searching for the *Endurance*. The 'downward looking' AUV would be used to survey the seafloor from a safe distance in the anticipated vicinity of the wreck. If located, the ROV would then be used to undertake a closer photographic and video survey of the wreck.

The same 'zero impact' policy would apply to the wreck of the *Antarctic* as it would to the wreck of the *Endurance* (see Section 7.4.7 for discussion of the potential impacts and control measures).

5.3 Alternative vessels

Two alternative ice breaking research and resupply vessels were identified to support the Expedition; the Russian flagged *MS Murmansk* and the Swedish flagged *Oden*.

5.3.1 MS Murmansk

MS Murmansk ('ледокол Мурманск'; Figure 18) 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 18. Russian icebreaker Murmansk. Source: http://www.cruisemapper.com/ships/Murmansk-icebreaker-1752

5.3.2 Oden

The *Oden* is a large Swedish icebreaker built and owned by the Swedish Maritime Administration (Figure 19). 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 19. The Swedish icebreaker Oden pictured in McMurdo Sound, Antarctica in January 2008. Source: http://www.navy.mil/

5.4 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, sea ice in the Weddell Sea demonstrates significant variability within and between seasons, but generally reaches its minimum coverage in February (Figure 26).

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 research 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.

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

5.5 Reduced period of operation

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 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 discharges to air and sewage 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 autonomous vehicles (aircraft and underwater), water and benthic sampling and archaeological survey work are all short duration activities that are not directly linked to the duration of the Expedition.

Further, the location of the primary target research 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 research objectives. Reducing the period of operation increases the risk of not achieving many of the research objectives and adding undue pressure on the research team.

It is therefore concluded that the research benefits of the 45-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 period of the Expedition was rejected.

5.6 Reduced scale of the research programme

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.

5.6.1 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 northern part of the Weddell Sea and down to the primary target research area in front of the Larsen C ice shelf could cover a distance in the region of 1,200NM with a similar return distance. The AUVs have the potential to survey several 10s of Km^2 if successfully deployed beneath the ice shelves and sea ice.

However, the impacts from the passage of the vessel and the deployment of the AUVs 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 AUVs is entirely non-invasive.

The more direct impacts are anticipated to arise from the benthic sampling regime using the various coring devices (Section 7.4.3). These direct impacts will be constrained to the target research areas and will be spatially negligible in the context of the large scale of the Weddell Sea shelf.

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

5.6.2 Fewer people

The Expedition currently comprises 36 people comprised of Expedition leaders, scientists and specialist technicians. If the numbers were reduced this could reduce the number of flights required to deploy personnel into Antarctica, and thus reduce the aircraft emissions to the atmosphere. However, reducing the number of personnel on the ship is unlikely to have any measurable environment 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 objectives of the Expedition. Reducing the numbers of people would mean losing specific skills or expertise and directly compromise the research objectives and thus reduce the scientific benefits of mounting the Expedition.

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.

5.6.3 Less or no invasive sampling

Direct sampling of biological, geological, sedimentological or glaciological material will always result in direct impacts at the point of removal of the samples. Depending upon the location, frequency and type of collection being undertaken, such sampling also has the potential to have broader direct or indirect impacts, for example by removing a significant proportion of a local population of a species.

The water and planktonic sampling to be undertaken by this Expedition will remove negligible quantities of material in the context of the Weddell Sea and vast Southern Ocean and there are unlikely to be any environmental benefits from reducing or not undertaking this sampling compared to the scientific benefits of doing so.

The benthic sediment and biological sampling to be undertaken will have a direct impact at the point of removal of the material. However, here also the point sampling to be undertaken is likely to have no more than a minor or transitory impact on the benthic environment (Section 7.5). The small areas that will be denuded by the sampling are likely to be recolonised by native benthic species within a period of months to years and the impacts are likely to be undetectable within a few seasons.

Every effort will be made to maximise the research benefits of the benthic sampling to be undertaken.

Accordingly, it is concluded that removing or reducing the Expedition's proposed sampling regime will have negligible environmental benefit but would have a significant negative impact on the potential for the Expedition to achieve its research objectives.

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 20). 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.

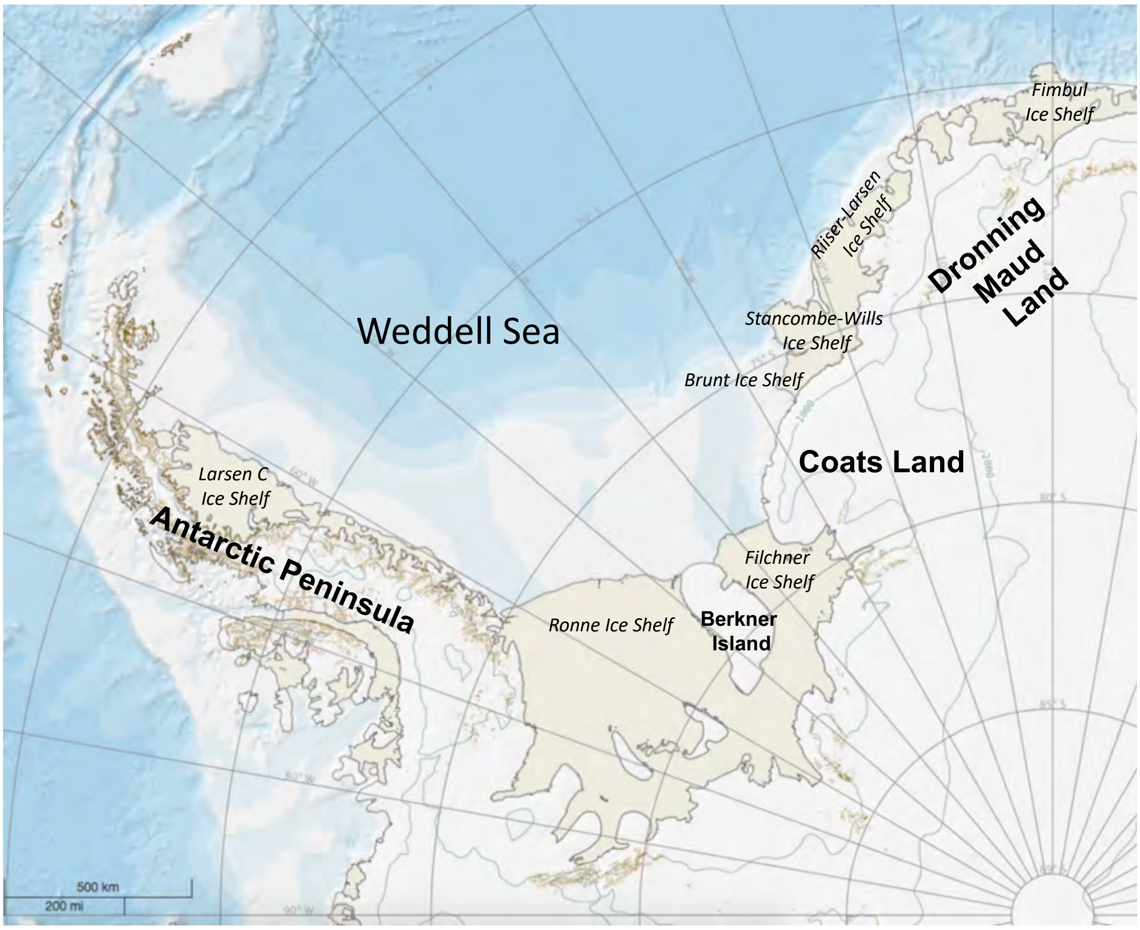

Figure 20. Weddell Sea.

The Weddell Sea was first discovered in 1823 by British sailor and seal hunter James Weddell (Figure 21) 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 21. 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 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 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 overwintering took place in Weddell Sea region in the area of the present German Neumayer Station (Figure 22).

Currently, several active research stations are located in the Weddell Sea region (Figure 22).

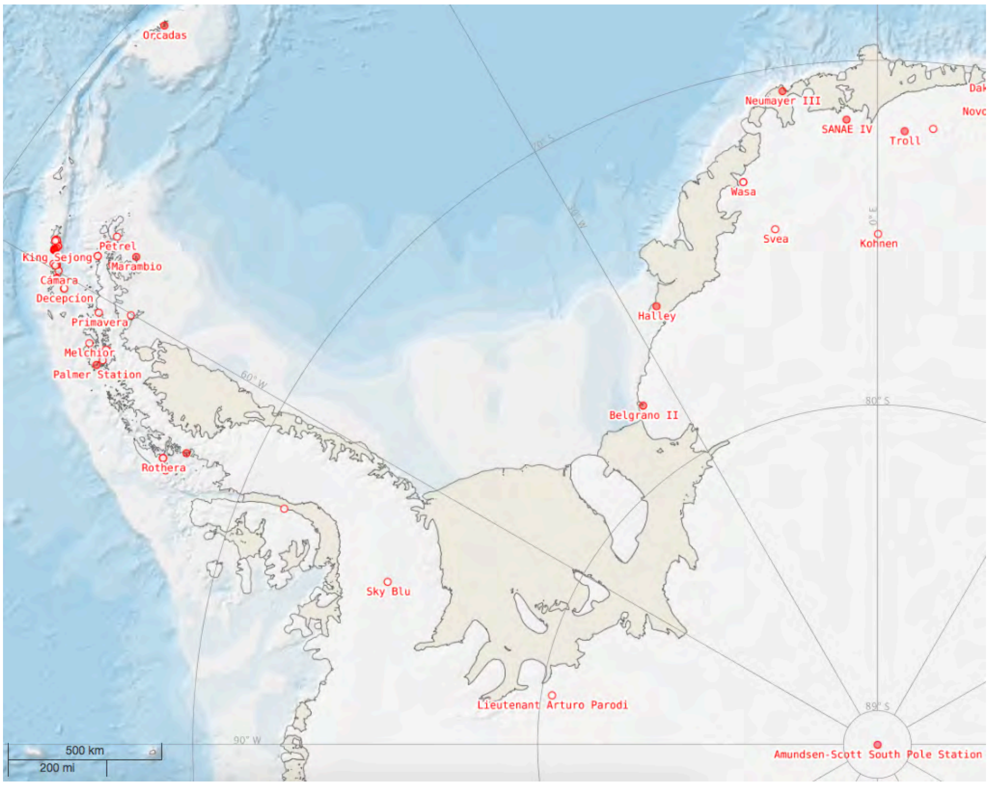

Figure 22. Antarctic research bases in the Weddell Sea region. Source: Antarctic Digital Database and COMNAP.aq

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 23). 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 24).

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 2Mkm^2 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.

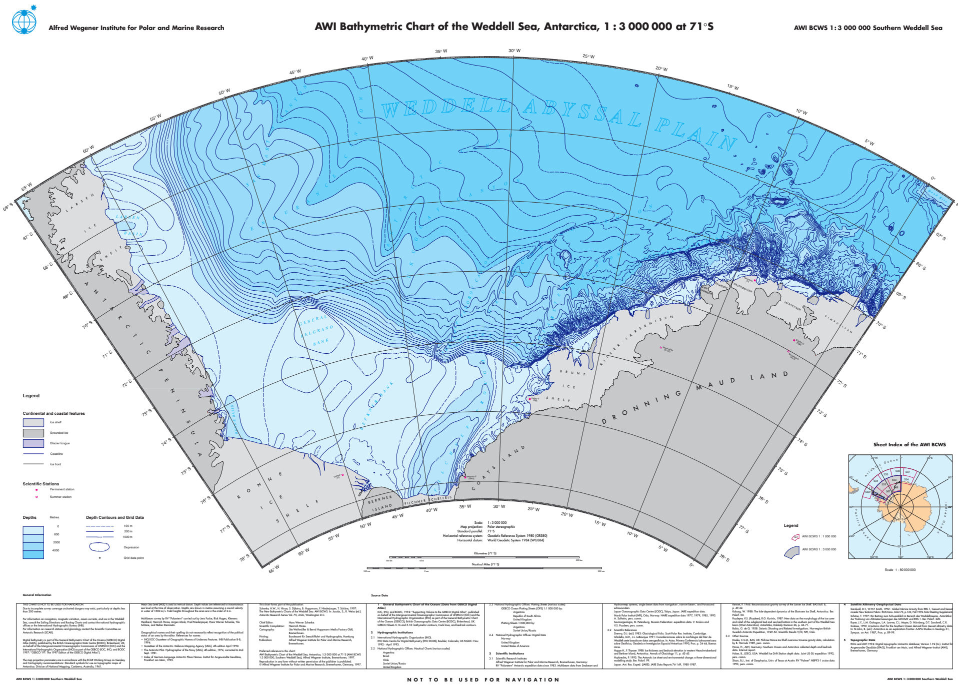

Figure 23. Bathymetric chart of the Weddell Sea. Source: Schenke, 1997.

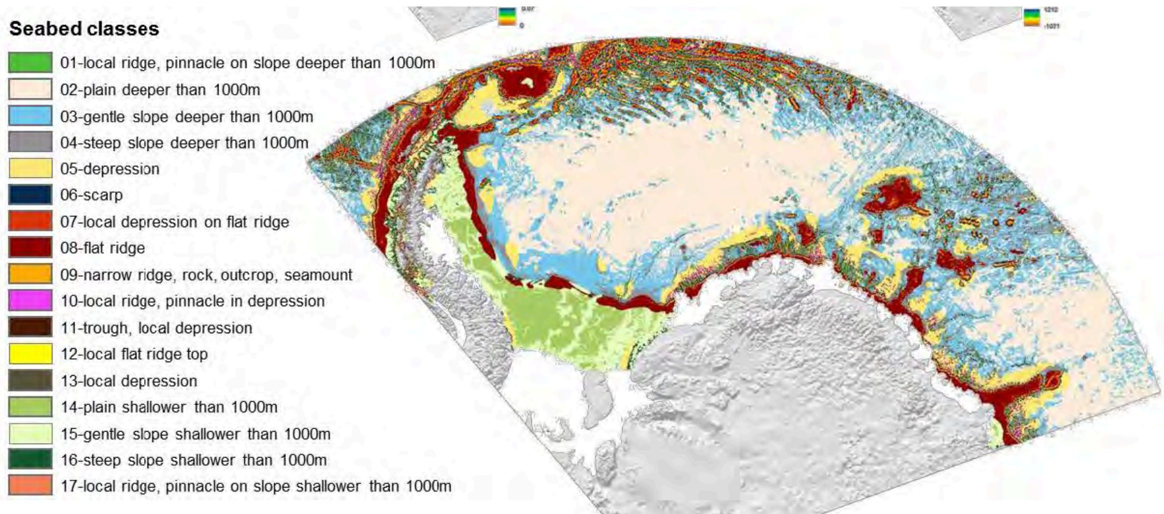

Figure 24. Seabed classification of the Weddell Sea. Source: Jerosch et al., 2016.

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 24; 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 25; Jerosch et al, 2016).

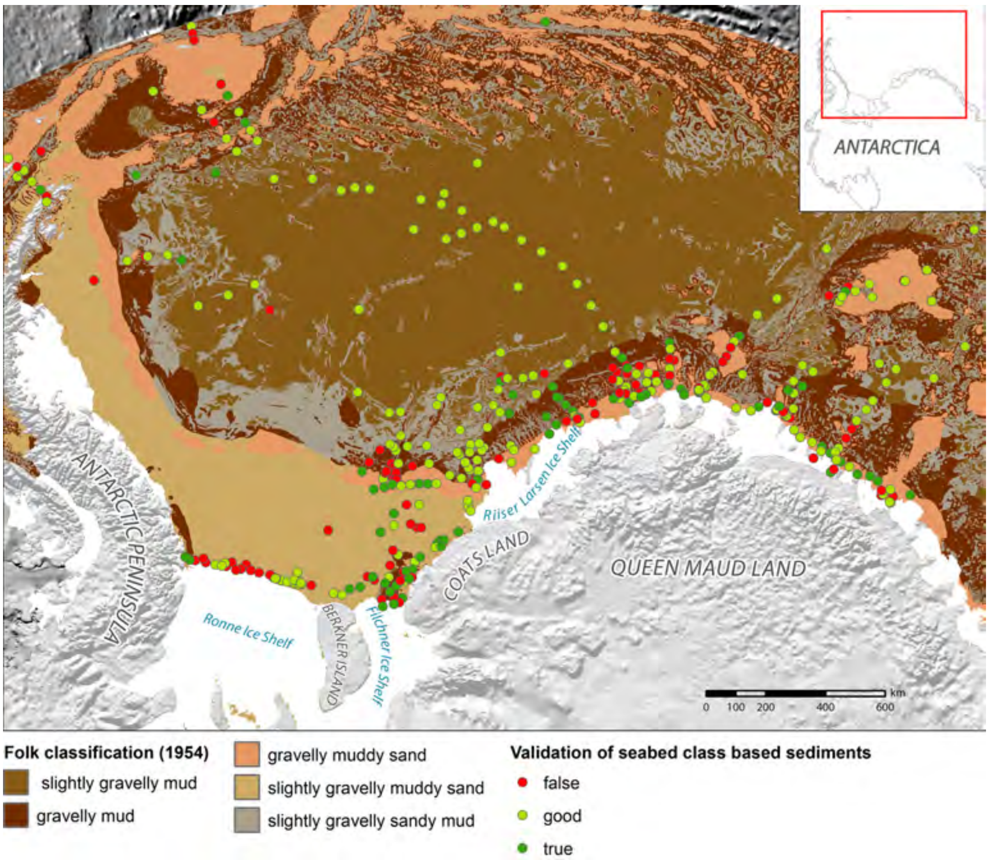

Figure 25. Sea bed morphological classification. Source: Jerosch et al, 2016.

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 26) 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).

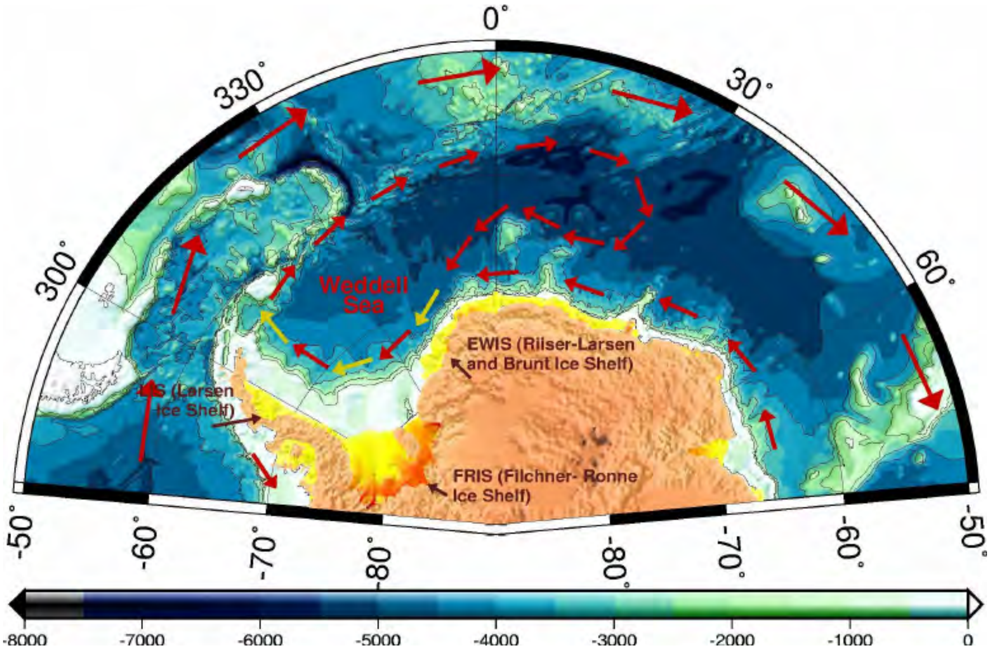

Figure 26. Weddell Sea gyre (small red arrows), showing also the areas of mixing of ice-shelf water (yellow arrows) and the Antarctic Circumpolar Current (ACC; large red arrows). Water depths are in metres. Source: Thoma et al, 2005.

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 ice-free conditions across most of its area in summer.

Average winter sea ice cover in the Weddell Sea has been estimated at approximately 4,480,000km^2, which retreats to approximately 1,420,000 km^2 in summer (Teschke et al, 2016). Maximum sea ice extent occurs in September and minimum ice cover in February (Figure 27).

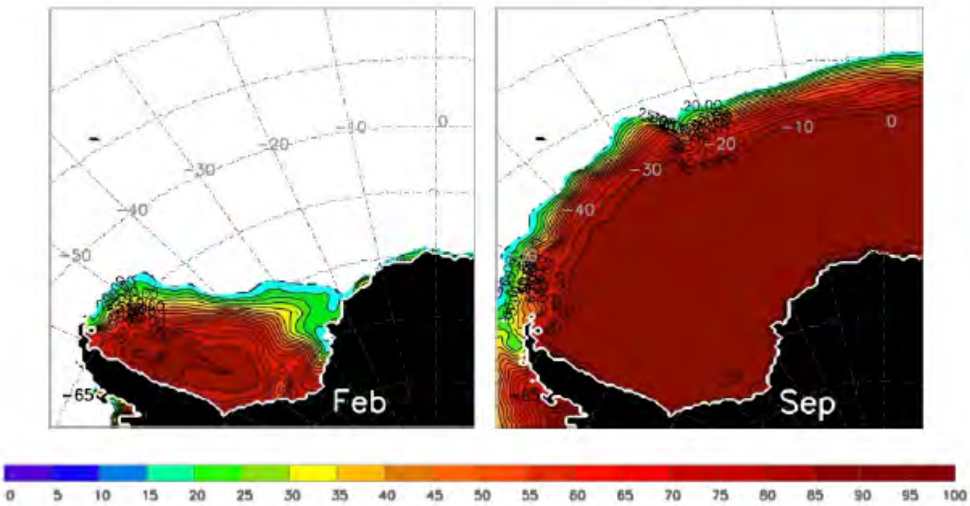

Figure 27. Long-term averaged sea ice concentrations (1979 - 2013) in percent at sea ice minimum (February) and maximum (September). Source: Teschke et al., 2016.

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 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 10^6 km^2). Over the period 1979–1990, the total Antarctic sea ice extent decreased at a rate of -153,000km^2 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 northwestern to the southeastern 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 20).

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 28; 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).

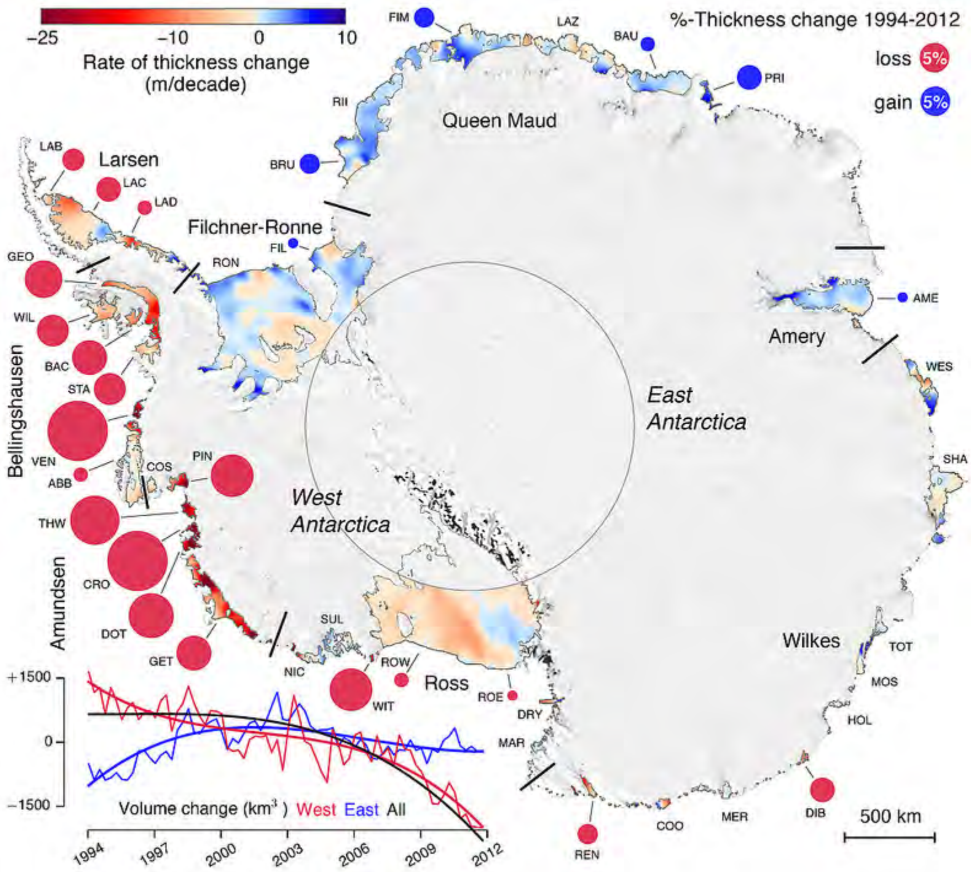

Figure 28. Eighteen years of change in thickness and volume of Antarctic ice shelves. Rates of thickness change (m/decade) are color-coded from -25 (thinning) to +10 (thickening). Circles represent percentage of thickness lost (red) or gained (blue) in 18 years. Background is the Landsat Image Mosaic of Antarctica (LIMA). Source: Paolo et al., 2015.

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.

The response of the remaining Larsen-C ice, now that the large tabular iceberg has calved, is dependent on how strongly this section of the ice-shelf restrained ice flow upstream. Model calculations suggest that the effect may not be particularly strong if the iceberg removes an area termed the 'passive ice shelf ', which does not provide any significant structural support. However, a lot may depend on the exact nature of the calving event. The Larsen-C ice shelf is pinned to the Bawden and Gipps ice rises at the north and south limits of the ice-shelf edge, respectively. Although small icebergs break off ice shelves routinely, if iceberg calving events remove an amount of ice sufficiently large enough to unground the Larsen-C ice shelf from the Bawden ice rise, the remaining ice shelf will be in a much less stable configuration.

The exact mechanical conditions that control the break-up of ice shelves are poorly known, and describing how ice shelves lose mass through iceberg calving is an outstanding unsolved issue in glacier mechanics and a key component of this Expedition's research objectives (Hogg and Gudmundsson, 2017).

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 29; Teschke et al., 2016).

Very little sampling has been undertaken in the vicinity of the Larsen C ice shelf (Figure 29), which provides a challenge in accurately describing the current environmental state in the primary research target area.

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

The pelagic environment of the Weddell Sea is heavily influenced by the Weddell Sea Gyre and sea ice cover (Section 6.3; Figure 26; 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).

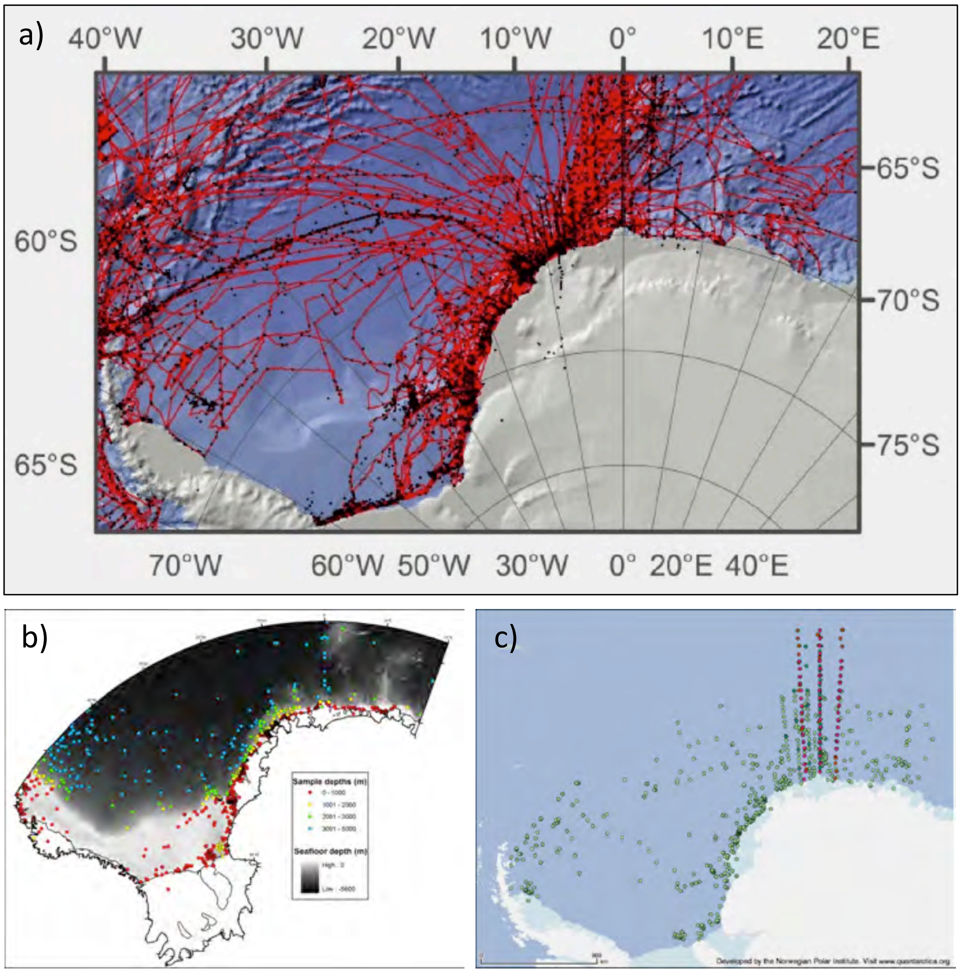

Figure 29. Overview of sampling in the Weddell Sea showing a) tracklines of cruises by the German Polar research vessel Polarstern from 1982 to 2014; b) benthic sampling locations, and c) Locations of Weddell Sea zooplankton samples included in the SCAR Biogeographic Atlas of the Southern Ocean (green) as well as samples collected through LAKRIS expeditions 2004-2008 (red) (source: biodiversity.aq). Source: Teschke et al., 2016).

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).

In a study similar to the one planned by this Expedition, 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 30). 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.

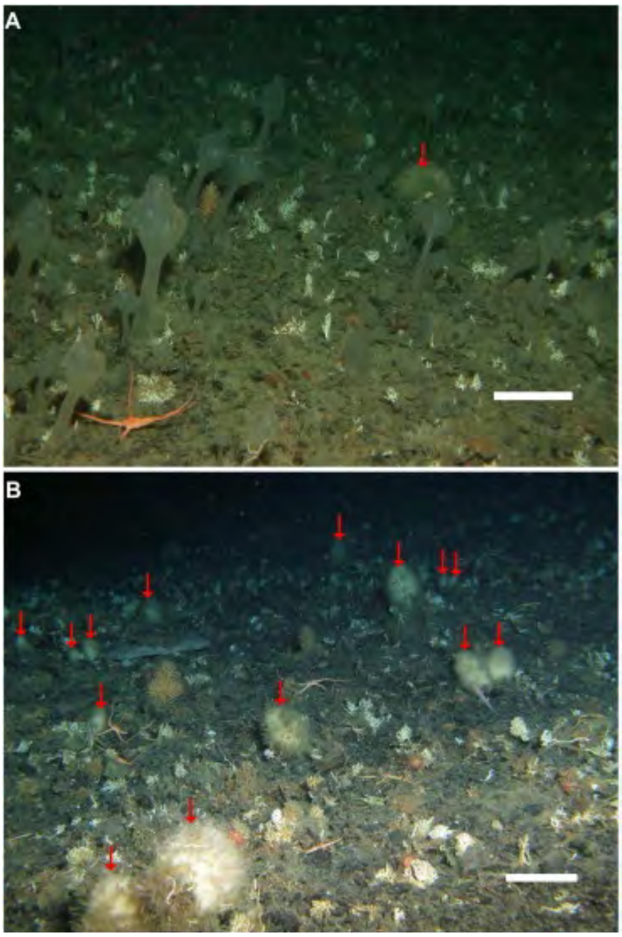

Figure 30. Glass sponge abundance on the seafloor beneath the disintegrated Larsen A ice shelf. Few glass sponges were seen along the 2007 transect, where the megabenthic community was dominated by fast-growing ascidians. In 2011 glass sponges dominated the transect while ascidians had all but disappeared. 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 7 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).

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

Table 7. 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.

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 31).

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 31). 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).

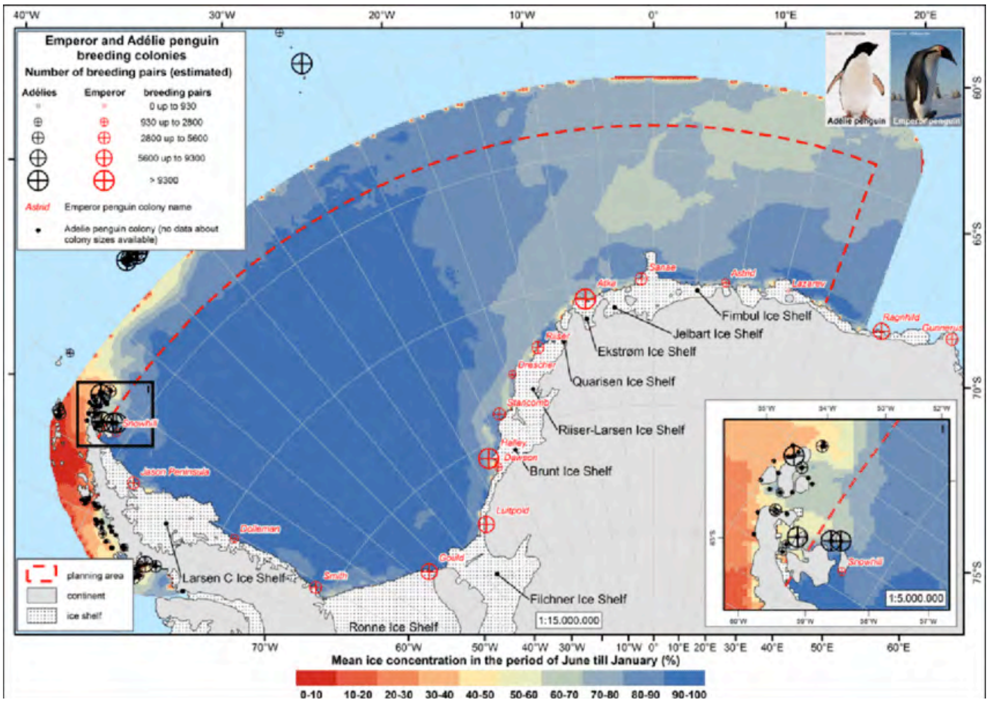

Figure 31. Number of breeding pairs estimated for Emperor (red cross hairs; Fretwell et al. 2012 and 2014) and Adélie penguin colonies (black cross hairs; Lynch and LaRue 2014). Mean sea ice concentration (Jun-Jan) derived from the Institute of Environmental Physics, University of Bremen (Kaleschke et 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 31). 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 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 32).

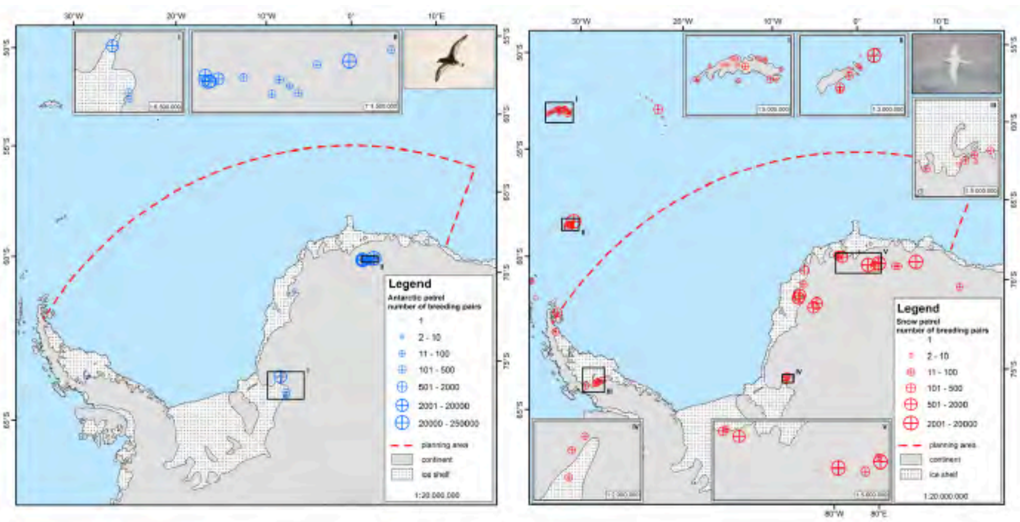

Figure 32. Spatial distribution of breeding pairs of Antarctic petrel (left) and Snow petrel (right). Data based on van Franeker et al., 1999 (Antarctic petrel) and Croxall et al., 1995 (Snow petrel). Red dashed box is the CCAMLR MPA planning area. Source: Teschke et al., 2016.

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 (Figure 32; 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 (Figures 33 and 34), 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.

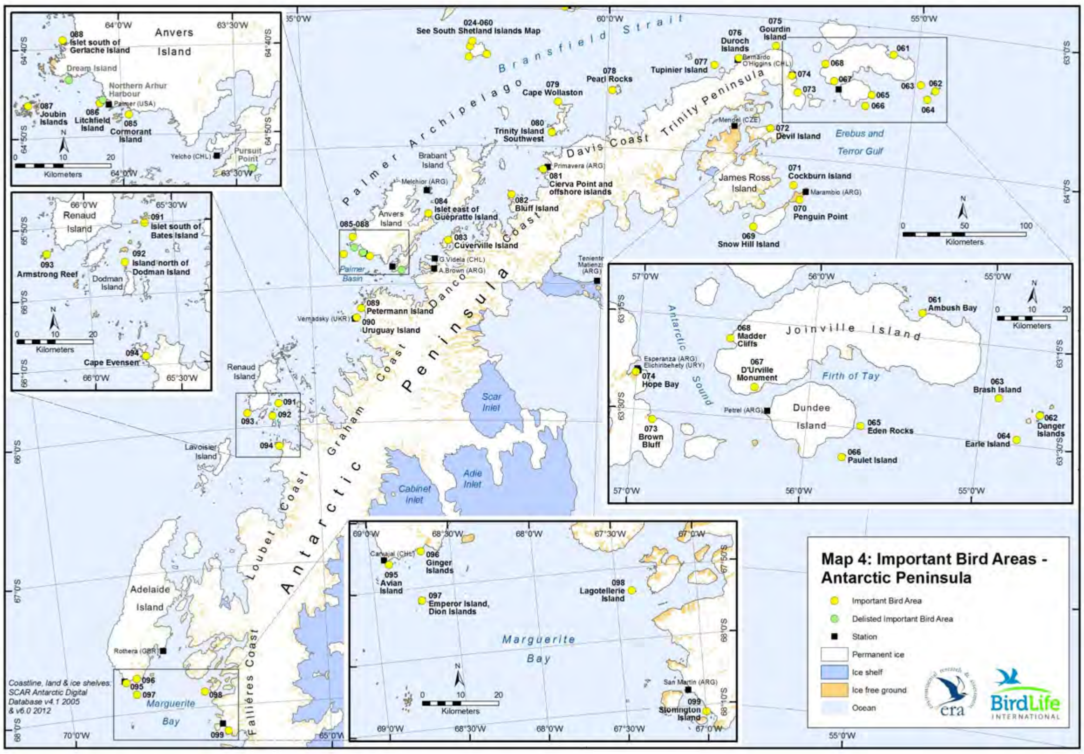

Figure 33. IBAs identified along the Antarctic Peninsula, including those on Snow Hill Island in the north western Weddell Sea. No IBAs have been identified on the eastern side of the Antarctic Peninsula, though some Emperor penguin colonies do occur in this area. Source: Harris et al., 2015.

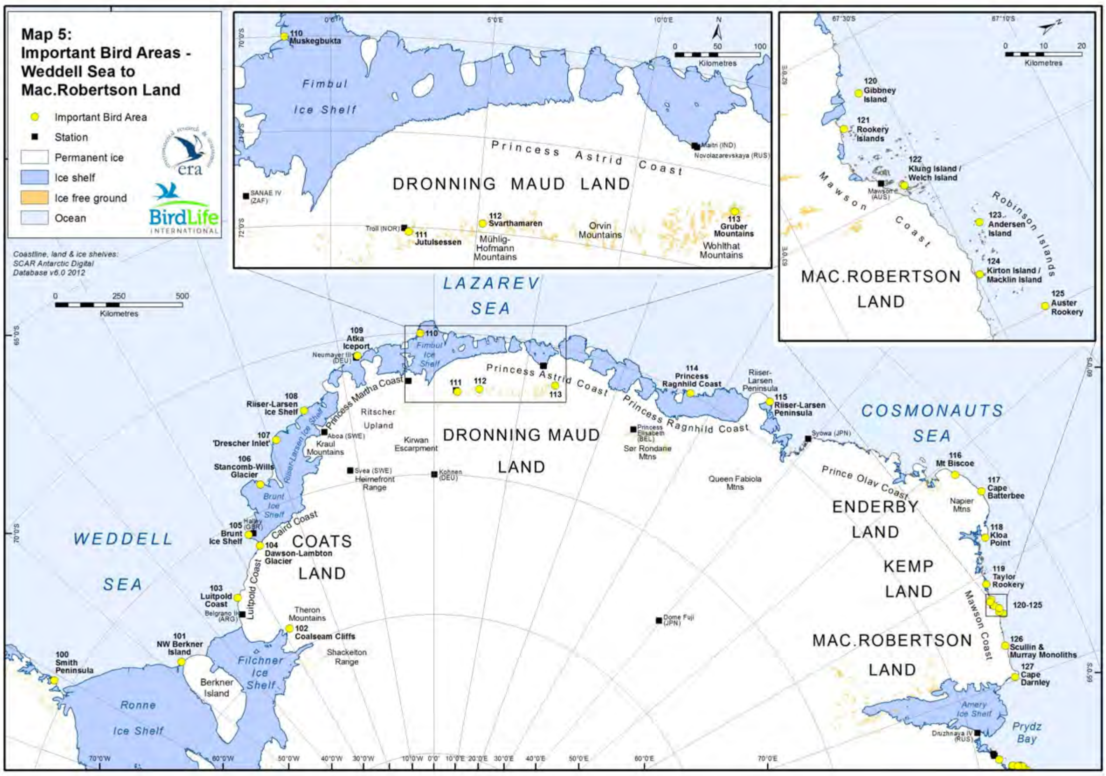

Figure 34. IBAs in the eastern Weddell Sea (and East Antarctica). The major Emperor penguin colonies in the east and south of the Weddell Sea all meet IBA criteria. Source: Harris et al., 2015.

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 35):

- 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.

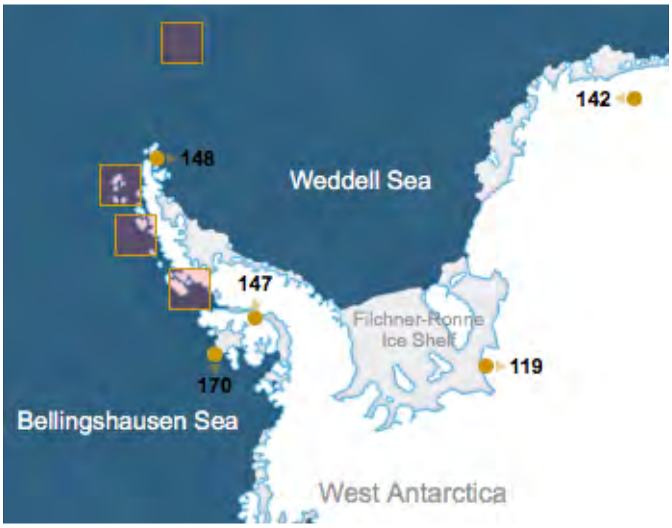

Figure 35. Location of Antarctic Specially Protected Areas (ASPAs) in the vicinity of the Weddell Sea Source: Antarctic Treaty Secretariat protected areas database, www.ats.aq.

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 92 HSMs throughout Antarctica. Those HSMs in the vicinity of the Weddell Sea include (see also Figure 36):

- 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 currently designated HSMs. The wreck of Shackleton’s *Endurance* is not currently listed as an HSM.

At the most recent Antarctic Treaty Consultative Meeting (ATCM; Buenos Aires, 13 to 18 May 2018), the Antarctic Treaty Parties adopted new Guidelines for the assessment and management of Heritage in Antarctica (ATCM un-numbered Resolution 2018). Whilst these guidelines were being finalised the ATCM agreed a moratorium on the designation of any additional HSMs. Consequently, the UK Government has proposed to the ATCM that, should the wreck of Shackleton’s *Endurance* be located by this or any other Expedition, that the wreck receives automatic and immediate protection under the provisions of ATCM Resolution 5 (2001) which gives interim protection to sites of pre-1958 origin.

If the wreck is located by this Expedition, Expedition leaders will be pleased to assist the UK Government in describing the wreck site so as to support the UK's interest in seeking HSM status for the site at future ATCMs.

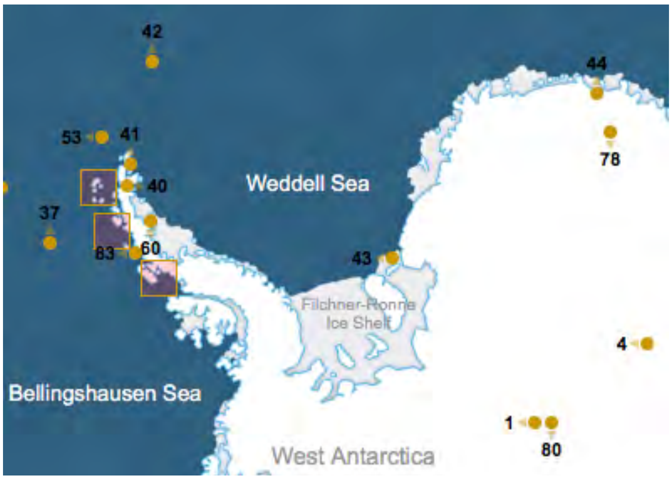

Figure 36. Approximate locations of designated historic sites or monuments in the Weddell Sea region of Antarctica. Note: the location of HSM 60 is not accurately recorded on the map. Source: Antarctic Treaty Secretariat protected areas database, www.ats.aq.

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 37). 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.

In 2016, CCAMLR designated the world's largest MPA in the Ross Sea region of Antarctica covering approximately 1.55MKm2.

Under the leadership of Germany a number of countries are currently collaborating towards developing an MPA proposal for the Weddell Sea (Teschke et al., 2016). The timetable by which a Weddell Sea MPA might be agreed is unknown. The opportunity for research undertaken through this Expedition to contribute to the MPA proposal is actively being sought with the Alfred Wegener Institute (AWI) in Germany.

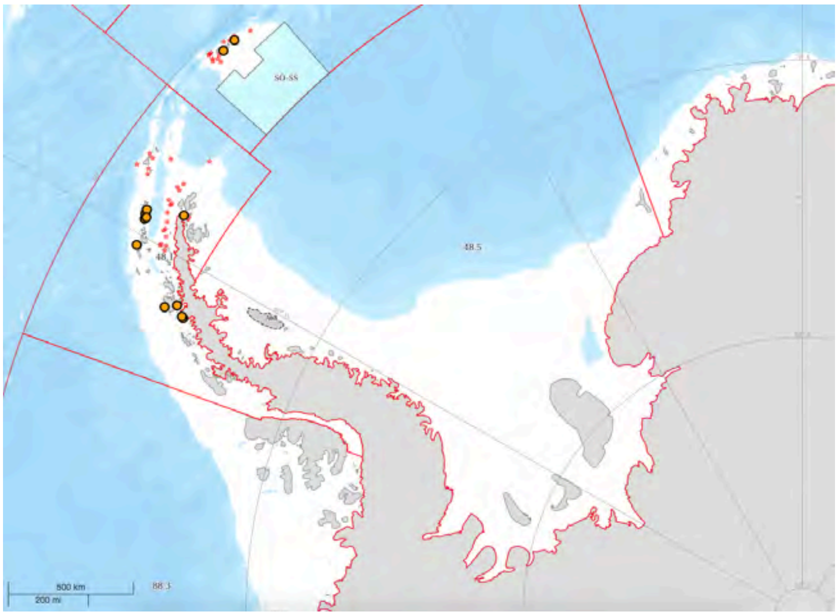

Figure 37. Important marine sites protected under CCAMLR. Light blue box – (SO-SS) the South Orkney Islands Southern Shelf MPA; orange dots – CCAMLR ecosystem monitoring programme sites; red stars – identified Vulnerable Marine Ecosystems; grey dotted boundary – A68 Special Area for Scientific Study 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 37 – 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 37). 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; Figure 37).

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 (Figures 1 and 37).

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 Special Area for Scientific Research is the primary target area for research for this Expedition.

Accordingly the Expedition organisers will prepare a research plan to assist the UK Government in informing CCAMLR's Scientific Committee of the planned non-fisheries research.

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 **outputs** 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 Outputs

An output 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 4 and include:

1. Ship operations[5];
2. Deployment of research equipment and sampling; and
3. marine archaeological survey.

The potential outputs of the various activities within these elements are summarised in Table 8.

[5] Note: the burning and / or accidental release of fossil fuels by the aircraft operated by White Desert (which will be utilised by the Expedition for entering Antarctica and rendezvousing with the SA Agulhas II) have not been assessed here. It is assumed that such emissions will be accounted for in White Desert's separate EIA for their 2018/19 activities.

ACTIVITY	OUTPUTS											
	Atmospheric emissions (burning fossil fuels)	**Noise emissions**	**Light emissions**	**Heat emissions**	**Air turbulence**	**Mechanical action** (physical disturbance to 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 science*)	X	X		X			X	X	X	X		X
Deployment of AUVs (*beneath ice shelves and sea ice*)		X	X	X		X#		X*	X	X		X
Deployment of ROV (*beneath ice shelves and open water*)		X	X	X		X# (the ROV may also be used for push coring)		X*	X	X		X
Sediment sampling at various locations using gravity, multi- and box coring equipment						X		X*		X	X	X
Water and plankton sampling (*in front of ice shelves and open water*)								X*	X	X	X	X
Deployment of RPAS (*over sea ice and open water*)		X		X	X			X*				X
Use of hazardous chemicals								X				

*Table 8. Potential outputs 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 the AUV or ROV (e.g. through equipment failure) immediately over the wreck. *in these situations 'waste' will only be produced through the accidental loss of equipment.*

7.3 Exposures

Exposure is the process of interaction between an identified potential output (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 8) are summarised in Table 9. 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.

	ENVIRONMENTAL ELEMENTS						
OUTPUT OF ACTIVITIES	FLORA AND FAUNA	FRESHWATER (*including ponds, streams, rivers, lakes, glaciers and ice*)	MARINE	TERRESTRIAL (*including ice free ground, soil and rocks*)	ATMOSPHERE	WILDERNESS VALUES	HERITAGE VALUES
Atmospheric emissions					X		
Noise emissions	X		X				
Light emissions	X						
Heat emissions			X		X		
Air turbulence					X		
Mechanical action	X		X				X*
Fuel spills	X		X				
Wastes			X*				
Water turbulence			X				
Introduced species			X				
Removal of native fauna &/or flora	X						
Presence / Visual disturbance			X			X	

*Table 9. 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.*

The Expedition is an entirely marine focused and ship-based expedition. Other than a brief transit across the ice sheet at Wolf's Fang and the Fimbul ice-shelf at Penguin Bukta (for the purposes of Expedition personnel entering Antarctica, changing aircraft and rendezvousing with the ship), the Expedition will operate from the SA Agulhas II and be focussed on marine-based research, sampling and survey. Consequently, no outputs from the activities associated with the Expedition will interact with terrestrial (ice free) or freshwater environments (Table 9). The following assessment of potential impacts is therefore focussed on marine-based flora and fauna, the marine pelagic and benthic environments, 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 13 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 13.

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 Ship operations

7.4.1.1 Potential impact: atmospheric emissions.

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 (SO_2) and particle emissions together with nitrogen oxides (NO_x) and carbon dioxide (CO_2) are considered as the shipping emissions that cause the most severe stress to the environment as well as to human health.

Emissions measurements specific to the SA Agulhas II are not available, however other studies have been undertaken to assess emissions quality from vessels. Winnes and Fridell (2009) report on a study to measure emissions from ships with varying fuel types. An 11,000 tonne (deadweight) vessel with a fourstroke main engine of 4,500KW, burning marine gas oil under different load scenarios resulted in emissions measurements shown in Table 10.

Load (%Maximum continuous rating)	Particulate matter (g/kg fuel)	NOx (g/kg fuel)	CO (g/kg fuel)	CO_2 (g/KG fuel)	SO_2 (g/kg fuel)
55-60	1.8	39	6.3	3180	0.6
70	1.4	47	3.4	3180	0.5
85-90	2.0	50	1.7	3180	0.7

Table 10. Measurements of emissions from a vessel burning marine gas oil under different load scenarios. Source: Winnes and Fridell, 2009.

The measurements reported by Winnes and Fridell are not directly transferable to the SA Agulhas II but are indicative of the emissions produced from burning marine gas oil.

Calculations of anticipated fuel use for this expedition are shown in table 11 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	14	560
Heavy pack ice / ice breaking	45	16	720
Research support / on station	20	15	300
		Total	**1,580**

Table 11. 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) 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 38); approximately $3tCO_{2e}$ per metric tonne of fuel burned by the SA Agulhas II.

Notably, this figure equates to the emission measurements made by Winnes and Fridell (2009) and recorded in table 9 above.

Using the 'worst case' estimate for fuel use to be burned, it can be calculated that up to 4,740 tCO_{2e} will be released to the environment during the 45-day Weddell Sea Expedition.

Using the average measurements reported by Winnes and Fridell (2009) in table 9 above (i.e. vessel operating at 70% load), it can be estimated that the 45-day operation of the SA Agulhas II will also result in (approximate) emissions of 2,212 Kg particulate matter, 74,260 Kg of NO_x, 5,372 Kg of CO and 790 Kg of SO_2.

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 38. 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.

Heat emissions will also arise from the operation of the SA Agulhas II, though heat loss from the vessel, including through exhaust emissions, is likely to be negligible in the Antarctic context.

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 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 2018/19 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.

7.4.1.2 Potential impact: noise including marine noise

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.

Impact type: direct and cumulative

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.

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 2018/19 season and in past and future seasons.

Mitigation:

- If large groups of marine mammals are encountered when the 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.

7.4.1.3 Potential impact: accidental release of fuel.

In the extremely unlikely event of significant fuel-related equipment failure or a vessel incident that results in a breach of the SA Agulhas II's fuel storage tanks, marine gas oil could be released to the marine environment. This may result in some contamination to any wildlife in the immediate vicinity of the incident as well as oil contaminated water and ice.

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 pollution arising from this Expedition would add to past and potentially future pollution events arising from human activities in Antarctica.

Mitigation:

- Every precaution will be taken to avoid such an emergency event occurring.
- 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 Captain's CV is appended to this EIA.
- The vessel captain will be supported by a highly experienced ice pilot specifically requested by the Expedition. The Ice Pilot's CV is appended to this EIA. 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 an RPAS to support 'in ice' navigation. The RPAS will be capable of flying in the vicinity of the ship up to 1,000m providing a far greater outlook on ice conditions.
- In addition to video imagery from the RPAS, access to near-real time medium- and high-resolution satellite imagery will be provided by the German Aerospace Centre (DLR). These all-weather high-resolution images will be an additional aid to ship navigation in ice-infested waters. Use of the European Space Agency's Sentinel-1 radar images is also being explored.

Record keeping:

Records will be maintained of any pollution 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.

7.4.1.4 Potential impact: production and release of waste

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.

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.

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.

Mitigation:

- 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 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.

7.4.1.5 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. Even near-coastal operations will be adjacent to the edge of ice-shelves in water many tens to hundreds of metres deep. Consequently, water turbulence, wash and waves from the ship will have limited impact, other than on the already highly mobile sea / pack ice as the ship breaks through.

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.

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.

7.4.1.6 Potential impact: 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)).

Impact type: indirect and cumulative

If marine species were introduced the indirect impacts would include potential competition with native species 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:

- 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 (see Sections 7.4.2.4, 7.4.3.3 and 7.4.4.3 below). This Expedition will start and end in Antarctica.
- 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.
- Nonetheless, the risk of introducing non-native marine species to the Weddell Sea as a result of this Expedition is considered to be low. Whilst in the Weddell Sea the vessel will be operating in deep water which reduces the likelihood of introduced species (which are more likely to be shallow water algal and invertebrate species) establishing. Further, given that the ship will already have been operating in the Southern Ocean and ice-covered waters prior to the Expedition joining the ship at Penguin Bukta, the abrasive action of already-encountered ice is likely to have acted so as to strip away most of any fouling (Lewis et al., 2004).

- 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.

7.4.2 Research activity: Deployment of AUVs and ROV

7.4.2.1 Potential impact: noise, light and heat emissions

The deployment of the AUVs and ROV in the marine environment will introduce some artificial noise, heat and light into the marine environment, though this will be negligible. Neither the AUVs nor the ROV produce significant noise and are unlikely to cause disturbance to any marine mammals, cetaceans or diving birds encountered.

Deployment of the underwater vehicles (AUV and ROV) may result in encounters with diving / foraging seals or cetaceans, or possibly penguins nearer the surface, resulting in minor disturbance to an immediate foraging event. This is less likely in the primary target research area adjacent to the Larsen C ice shelf, but possible in secondary target locations adjacent to the Fimbul and Riiser-Larsen ice shelves, where marine mammals and birds are known to be more prevalent (Section 6.7; Figures 31, 32 and 34).

AUV and ROV benthic surveys will briefly introduce light onto small patches of otherwise dark benthic environments.

Any heat produced by the AUVs or ROV will be rapidly lost and dissipated in the cold Weddell Sea waters.

Impact type: direct

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 or presence of AUVs could be found in a literature search.

Light impact will be minor and fleeting. Mobile species (e.g. fish) may move away from the immediate 'glare' of the light. No impact is likely to marine invertebrates.

Mitigation:

- The AUVs and ROV selected for this Expedition 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 AUVs and ROV.
- Marine mammal and cetacean observations will commence 20 minutes prior to launching the AUV or RoV.

Record keeping:

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

7.4.2.2 Potential impact: equipment failure leading to loss of underwater vehicles

The deployment of autonomous and remotely operated vehicles under ice-shelves and beneath sea ice increases the risk of equipment loss compared to open water environments.

Any AUV operation beneath ice shelves, where little or no data exist on cavity morphology, is high-risk but high-reward science. So, too, is AUV deployment beneath a drifting canopy of sea ice, even though only a few metres thick, given that open water can come and go on the timescale of hours and even minutes. In the unlikely event that an AUV failed to return to the surface / support ship, it would be unrecoverable and would need to be abandoned.

A UK AUV was lost beneath the Fimbul Ice Shelf in 2005 and the UK's Natural Environment Research Council (NERC) acknowledged at the time that the risks of AUV loss were high prior to sanctioning that science programme. Whilst the risks of loss of an AUV remain, they are assessed as being significantly less than 13 years ago. Technology has improved and modern AUV technology includes sophisticated collision avoidance systems (Pebody, 2008). The AUVs to be used on this Expedition are among the most advanced available and one has been constructed specifically for the Expedition. There is also considerably more expertise and experience available in the operation of and planning for AUV deployments.

The Expedition will take a cautious approach to all under-shelf operations. AUV missions will gradually build up in duration and distance travelled as knowledge and experience is gained. Missions will begin with flights along the front of the ice shelf to collect sea bed bathymetric data beneath the shelf using the side scan sonar. This will then be followed by a short duration mission under the ice shelf at about 100m above the sea floor to collect further bathymetric data and map the terrain. The bathymetric data will be used to develop a digital terrain model, which will be used to help plan a safe escape route for the AUV back to the ship. Only when a safe operating route has been determined will the AUV be used in upward looking mode to survey the underneath of the ice shelf.

The operation of the AUVs also carries the risk of the loss of drop-weights. HUGIN AUVs are neutrally buoyant vehicles during mission operations. Upon complete loss of battery power, or in the event of other critical error states, the AUV control system will either default to or initiate an emergency ascent.

Potential causes are critical height errors, propulsion failures, or terrain avoidance requirements outside of the operating envelope of the vehicle. When power is lost to the AUV, the attached weights will drop by default as they are held in by power. These systems are in place to ensure a safe recovery of the AUV.

With the drop-weights released (two per AUV: one aft and one at the front) the AUV becomes positively buoyant and will float to the surface. The drop-weights are approximately 17kg each and are constructed of steel.

If the drop-weights are released they will fall quickly to the sea-floor where they will remain and likely become colonised over time.

The AUVs will penetrate further beneath the ice shelf than the ROV, which has the advantage of remaining tethered to the support ship.

In the unlikely event that equipment is lost, it would decay over many decades resulting in a small amount of local pollution and impact.

Impact type: direct

Immediate impact where equipment settles. Slow release of pollutants over many decades.

Mitigation:

- The 'upward looking' AUV has been built specifically for this Expedition and to undertake the planned under-ice survey work.
- The AUVs incorporate sophisticated collision avoidance systems.
- The moon pool of the SA Agulhas II can be used to deploy the HiPAP navigation pole that communicates with the AUVs. 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 AUV and ROV operations.
- The Expedition will adopt a 'build-up' approach to AUV missions i.e. short duration, near-vessel deployments increasing to longer and more distant missions.
- If an AUV were to be lost and its location was known, ROV technicians have advised that the ROV could potentially be used to recover the AUV. This would not be the case if the AUV was lost at a significant distance beneath the ice shelf.
- Ocean Infinity (the operators of the Hugin AUVs) calculate the risk of an emergency event involving the release of the drop-weights as 0.7% per hour of operation (0.7 per 100 hours of operation). The technicians are working to reduce this even further for under-ice operations (when emergency ascents become less effective).

- It is noted that the Expedition has the benefit of learning from past under-ice surveys by AUVs and will draw on this previous experience where possible (Nichols et al., 2006; Graham et al., 2013; Dowdeswell et al., 2008).

Record keeping:

- Records will be maintained of the location (if known) of a lost and unrecoverable AUV.
- All AUV and ROV deployments will be fully logged for research as well as for reporting purposes.

7.4.2.3 Potential impact: water turbulence

The operation of the underwater vehicles (AUVs and ROV) will produce a small degree of water turbulence in the immediate area of operation of the vehicle.

Impact type: direct

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

Mitigation:

- This is an unavoidable consequence of operating the underwater vehicles. However, AUVs and the ROV are slow moving and cause little turbulence.

7.4.2.4 Potential impact: introduction of non-native species

As recorded in Section 7.4.1.6 above, the artificial relocation of native species represents one of the most significant threats to biodiversity globally.

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 AUVs or ROV 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.

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.

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.

Mitigation:

- 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 AUV and ROV operators (CEP, 2016).
- The AUVs and ROV will be inspected and cleaned prior to deployment to Antarctica.
- The AUVs and ROV will be inspected and if necessary cleaned prior to each deployment in Antarctica.

7.4.3 Research activity: Deployment of sediment and benthic sampling equipment

7.4.3.1 Potential impact: physical disturbance of benthos

The deployment of all benthic sampling equipment for the purposes of collecting sediment cores and/or benthic invertebrate samples will result in physical disturbance to small areas of the benthos.

Physical disturbance is likely to be highly localised, though multiple benthic locations adjacent to the ice-shelf are intended to be sampled.

Impact type: direct and cumulative

The coring work will result in an immediate and direct disruption to the benthic environment within the footprint of the coring device.

The coring work to be carried out during this expedition will add to the sampling and coring work undertaken by previous and future research programmes.

Mitigation:

- Any samples taken at depths up to approximately 500m will be within the zone for iceberg scour (Dowdeswell and Bamber, 2007). Within the ice-berg scour zone it is assumed that the Antarctic benthos never reaches peak maturity and that iceberg scouring is among the five most significant disturbances that any large ecosystem on earth experiences (Gutt and Starmans, 2002). Accordingly, the disruption caused by the coring activity of this Expedition within this zone is likely to be negligible compared to the ongoing 'natural' perturbation that occurs.
- Benthic disturbance from sampling undertaken at depths beyond the keel of icebergs will be unavoidable, though highly localised.
- Sites will be carefully selected to ensure maximum research benefit.

Record keeping:

Records will be maintained of the sites of all coring activity.

7.4.3.2 Potential impact: loss of sampling equipment

The deployment and recovery of deep-sea benthic sampling equipment carries a degree of risk of loss, through cable breaks, cable snagging (e.g. on the winch, resulting in a failure to recover the coring device and the need to cut the cable) or the equipment becoming caught on the seafloor. Successful sampling in the deep sea using equipment at the end of hundreds to thousands of metres of cable is time-consuming and requires special skill (Gage and Bett, 2008). An additional factor in Polar waters relates to the degree of pack ice cover and the potential for pack ice to move into the sampling area during equipment deployment and hampering recovery.

A search of the academic literature suggests that loss of such equipment is rare, with risks reduced through the use of standardised safe operating procedures and techniques (Mudroch and Azcue, 1995).

Impact type: direct and cumulative

The accidental loss of benthic sampling equipment would result in direct, though minor impact to the seafloor where the equipment settled and, if unrecoverable an addition to the range of other (un-quantified) equipment lost to the environment in Antarctic over several decades of marine research.

Mitigation:

- The Expedition will include experienced specialist coring technicians to oversee all coring activity.
- All benthic coring equipment will be carefully deployed according to weather and ice conditions and forecasts.
- Sampling locations will be carefully selected to maximise research benefits.

- ROV technicians have advised that the ROV could potentially be used to recover any equipment lost to the sea floor if its location was known.

7.4.3.3 Potential impact: introduction of non-native species

As recorded in Sections 7.4.1.6 and 7.4.2.4 above, the artificial relocation of native species represents one of the most significant threats to biodiversity globally.

The operation of the benthic sampling equipment in various locations in the Weddell Sea presents a risk of introducing non-native species as well as artificially relocating native species beyond natural distributions.

This is of particular concern in the newly exposed benthos of the Larsen C ice-shelf following the loss of the A68 ice-berg. The benthos beneath where the ice-shelf used to be prior to the calving event is now exposed to more open-water conditions and likely to result in new colonisers establishing. The area is thus particularly susceptible to artificial relocation of native Antarctic species, which, if it were to occur, would have potential to reduce the scientific value of the area.

Impact type: indirect and cumulative

As recorded in Section 7.4.2.4 above, although the establishment of non-native (temperate) marine species in the deep, largely ice-covered waters of the Weddell Sea is likely to be extremely low, though irreversible if it were to occur.

Mitigation:

- 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 AUV and ROV operators (CEP, 2016).
- The coring equipment will be inspected and cleaned prior to deployment to Antarctica.
- The coring equipment will be inspected and if necessary cleaned prior to each deployment in Antarctica.

7.4.3.4 Potential impact: removal of native fauna and micro-flora

Benthic sampling at selected locations will intentionally remove benthic invertebrate fauna and bacterial micro-flora associated with deep-sea marine sediments. Sampling will attempt to remove representative material so as to allow descriptions of the benthic community to be made. This will result in the loss of faunal and microflora biota, albeit highly localised to within the footprint of the coring device.

Such disruption to the surface benthos within the iceberg scour zone would not be an unusual event (Gutt and Starmans, 2002), though such sampling at greater depths (beyond the keel of ice-bergs) would not otherwise occur.

Impact type: direct

The deliberate removal of benthic samples will have an immediate direct effect on the benthic fauna and microflora within the footprint of the coring devices.

Mitigation:

- The impacts will be unavoidable if sampling is undertaken, although recolonisation of the sampled area from species in adjacent, un-affected areas will occur over time.
- Sampling locations will be carefully selected so as to maximise research benefit.

Record keeping:

Records will be maintained of the sampling locations and the collected material will be carefully described for publication.

7.4.4 Research activity: Water column and plankton sampling

7.4.4.1 Potential impact: loss of sampling equipment

The deployment and recovery of water column sampling equipment (CTD and plankton nets) carries a degree of risk of loss, through cable breaks or cable snagging (e.g. on the winch, resulting in a failure to recover the coring device and the need to cut the cable). Successful sampling in the deep sea using equipment at the end of hundreds of metres of cable is time-consuming and requires special skill (Gage and Bett, 2008). An additional factor in Polar waters relates to the degree of pack ice cover and the potential for pack ice to move into the sampling area during equipment deployment and hampering recovery.

A search of the academic literature suggests that loss of such equipment is rare, with risks reduced through the use of standardised safe operating procedures and techniques are (Mudroch and Azcue, 1995).

The five SVP drifter buoys deployed on behalf of the Alfred Wegener Institute (AWI) are unlikely to be recovered and will be lost to the marine environment. They will be placed on ice floes and allowed to drift with the ice whilst telemeting a range of data until battery power is lost. They would only be recovered in the unlikely event that the German research vessel *Polarstern* was operating in close proximity to one or more of the buoys. Otherwise, these will be regarded as expendable research equipment.

Over time the ice floes they are positioned on will melt and the buoys will eventually fall into the water where they will drift with wind and tide. They will decay over many decades.

Impact type: direct and cumulative

The accidental loss of water column sampling equipment would result in direct, though minor impact to the seafloor where the equipment settled and, if unrecoverable an addition to the range of other (un-quantified) equipment lost to the environment in Antarctic over several decades of marine research.

Mitigation:

- The Expedition will include experienced specialist technicians to oversee all sampling activity.
- All sampling equipment will be carefully deployed according to weather and ice conditions and forecasts.
- ROV technicians have advised that the ROV could potentially be used to recover any equipment lost to the sea floor if its location was known.
- The AWI ice buoys are unlikely to be recovered and will be lost to the marine environment.

7.4.4.2 Potential impact: water turbulence

The movement of the water column sampling equipment, in particular the plankton net, through the water column will produce a small degree of water turbulence in the immediate area of operation of the equipment.

Impact type: direct

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

Mitigation:

This is an unavoidable consequence of operating water column sampling equipment. No mitigation is available or necessarily required.

7.4.4.3 Potential impact: introduction of non-native species

The risks and impacts associated with introduction of non-native species are recorded in Section 7.4.3.3 above.

Inadvertent relocation of native pelagic species is of much less concern in the highly mixed pelagic environment of the Weddell Sea.

Mitigation:

- 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 AUV and ROV operators (CEP, 2016).
- The pelagic sampling equipment will be inspected and cleaned prior to deployment to Antarctica.

7.4.4.4 Potential impact: removal of native fauna and flora

Water column sampling at selected locations will intentionally remove invertebrate fauna (i.e. krill) and phytoplankton.

Impact type: direct

The deliberate removal of water and planktonic samples will be direct though negligible in terms of its impact on the pelagic environment of the Weddell Sea.

Mitigation:

- The impacts will be unavoidable if sampling is undertaken, though negligible in the context of the vast scale of the Weddell Sea.

Record keeping:

Records will be maintained of the sampling locations and the collected material will be carefully described for publication.

7.4.5 Research activity: Deployment of RPAS

7.4.5.1 Potential impact: noise / visual disturbance of wildlife

The deployment of RPAS (both rotary and fixed wing devices) will create some noise, which in combination with the visual presence of the RPAS, has the potential to disturb wildlife. The use of RPAS 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 RPAS 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). 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).

For most operations of the RPAS 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 seas) or seals (e.g. hauled out on ice floes) cannot be ruled out.

The issue of safe environmentally sound operation of RPAS 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 (RPAS) in Antarctica* (ATCM Resolution 2018a).

In parallel the Council of Managers of National Antarctic Programs (COMNAP) has also developed the *Antarctic RPAS Operator's Handbook* (COMNAP, 2017)

Impact type: direct

Disturbance effects to wildlife would be direct and immediate if they were to occur. The extent of wildlife responses 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 RPAS.

Mitigation:

- The RPAS will be operated by a highly trained and experienced pilot at all times.
- The RPAS will be operated in full conformance with the available guidance material notably the COMNAP *Antarctic RPAS Operator's Handbook* (COMNAP, 2017) and the ATCM's *Environmental guidelines for the operation of Remotely Piloted Aircraft Systems (RPAS) in Antarctica* (ATCM 2018a).
- RPAS 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 RPAS.

Record keeping:

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

7.4.5.2 Potential impact: heat emissions

The RPAS will generate some heat during their operation from the batteries and components on-board.

Impact type: direct

Heat loss from the RPAS will be negligible and will rapidly dissipate in the cold Antarctic air.

Mitigation:

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

7.4.5.3 Potential impact: air turbulence

The deployment of RPAS will create some air turbulence from the propellers on-board and their movement through the air.

Impact type: direct

Air turbulence as a result of RPAS operation will be negligible within a very short distance from the devices.

Mitigation:

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

7.4.5.4 Potential impact: loss of equipment

The deployment of RPAS will be both within and beyond visual line of site over pack ice and open water. In the unlikely event that system faults occur, the RPAS will either: return to the launch site; effect a controlled descent (though this will be into the sea / pack ice), or experience an uncontrolled descent into the sea or onto pack ice.

Uncontrolled descents may result from motor or speed controller failures or a flight controller lock-up, though failures of this nature are exceptionally rare.

Sensor or motor failures will either result in the aircraft automatically returning to the launch site (i.e. the ship) or effecting a controlled descent (albeit onto the sea surface or pack ice).

Impact type: direct and cumulative

If lost to the marine environment, the RPAS unit(s) will eventually find its way to the sea floor where it will decay over a long period of time. This will result in direct, pollution impacts at the immediate site where the unit settles, and add to the range of other (un-quantified) equipment lost to the environment in Antarctic over several decades of marine research.

Mitigation:

- All RPAS units will be fully serviced and tested prior to deployment in Antarctica.
- The RPAS will be operated by a highly trained and experienced pilot.
- All RPAS to be used will be fitted with position location devices and in the unlikely event that they fail to return to the launch site, the last known position of the RPAS will be recorded. This will offer some opportunity to locate and recover the unit depending upon the environmental conditions at the time, though this is unlikely.
- The RPAS will be operated in full conformance with the available guidance material notably the COMNAP *Antarctic RPAS Operator's Handbook* (COMNAP, 2017).

Record keeping:

Should any RPAS unit be lost and unrecoverable, its location will be recorded as accurately as possible and reported on conclusion of the expedition.

7.4.6 Research activity: Use of hazardous chemicals

7.4.6.1 Potential impact: production of waste hazardous chemicals

Some hazardous chemicals will be used in laboratory conditions on-board the SA Agulhas II. This will result in the production of waste chemicals, and water and biological samples contaminated with hazardous chemicals.

Impact type: direct

Such hazardous waste material would be potentially harmful if released to the Antarctic marine environment.

Mitigation:

- All chemicals will be used in laboratory-controlled conditions.

- Any waste products will be stored in sealed and labelled containers and disposed of in South Africa on return of the vessel.
- No hazardous substances or waste will be disposed of in Antarctica.

7.4.7 Research activity: marine archaeology

7.4.7.1 Potential impact: physical disturbance to wreck sites

Operation of the AUV and ROV near to the wreck sites (i.e. Nordenskjold's *Antarctic* or Shackleton's *Endurance*) and undertaking sampling for benthic fauna from or in the immediate vicinity of the wreck sites presents a risk of collision causing physical disturbance or damage to the wrecks.

Impact type: direct and indirect

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.

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 AUVs and ROV 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 AUV will be conducted from a safe distance (approximately 100 metres) above the sea floor.
- The AUV 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 ROV 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)).

- Opportunistic sampling of benthic fauna from or in the vicinity of the wreck sites will only be undertaken in circumstances where disturbance or damage to either of the wrecks will not occur. A highly precautionary approach will be taken to such an activity and will be risk assessed among the scientists and ROV technicians on-board. Key components of the decision-making will include:
    - a consensus agreement among the scientists that collection or sampling will be of additional research benefit over and above any imagery obtained, and that,
    - the ROV technicians are 'highly confident' that sampling will not cause damage or disturbance to the wrecks.
- The Expedition has adopted a 'zero disturbance, zero collection' policy with respect to the search for the wrecks. No artefacts or (non-biological) samples of the wrecks will be 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.

7.4.8 Vessel operations and all research activities

7.4.8.1 Potential impact: loss of wilderness values

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

Impact type: indirect and indirect

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).

Mitigation:

- The Expedition is of relatively short duration and has adopted a 'light footprint' approach to its planning. The majority of the research and surveying is 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.
- Benthic sites denuded by sampling are expected to recover through recolonisation within months to years.
- 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) the Expedition will dispose 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 benthic and 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 AUVs or ROV and diving pinnipeds or cetaceans, as well as any observed bird encounters with the RPAS. 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.

7.5 Summary and evaluation of impacts

Section 7.4 identifies 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 as identified 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 12 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).

Impact	Environment Element	Criteria for assessment: Low (1)	Medium (2)	High (3)	Very High (4)
SPATIAL EXTENT OF IMPACT	***Freshwater*** ***Marine*** ***Terrestrial*** ***Atmosphere***	*Local extent*	*Partial extent*	*Major extent*	*Entire extent*
		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.*
Area or volume where changes are likely to occur	***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	***Freshwater*** ***Marine*** ***Terrestrial*** ***Atmosphere***	*Short term*	*Medium term*	*Long term*	*Permanent*
		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.*
Period of time during which changes in the environment are likely to occur	***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	***Freshwater*** ***Marine*** ***Terrestrial*** ***Atmosphere***	*Minimal Affect*	*Affected*	*High*	*Irreversible*
		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.*
A measure of the amount of change imposed on the environment due to the activity	***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 12. Assessment criteria for evaluating the spatial extent, duration, intensity and probability of the potential environmental impacts (modified from Oerter, 2000).

Table 1.Evaluation of the potential environmental impacts of the Expedition activities on the Antarctic environment.

Activity	Potential impact	*Environmental Element Impacted*	Spatial Extent	Duration	Intensity	Probability	***Significance*** *(without mitigation)*	Mitigation of Impact	***Significance*** *(with mitigation)*
Ship operations	Atmospheric emissions: Burning fossil fuels for power and propulsion	Atmosphere	Medium *Exhaust emissions will be dispersed beyond the vicinity of the vessel*	Low *45 days for the period of this Expedition*	Low *Emissions will disperse and dilute quickly*	High *Emissions will occur continuously throughout the 45-day Expedition*	No more than minor & transitory	• Selection of a modern, fuel efficient Polar Class vessel for the Expedition • SA Agulhas uses MGO with low sulphur content • Fuel use will be minimised by optimising vessel route through open water	No more than minor & transitory
	Noise General operation of the vessel's engines and machinery	Wildlife – congregations of foraging birds and penguins; cetaceans; pinnipeds	Low Individuals within the immediate vicinity of the vessel may be affected	Low 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 Encounters with wildlife at some point during the 45-day cruise are likely	Less than minor & transitory	• Vessel will proceed cautiously when pods of cetaceans / seals are observed, including slowing down and avoidance if practicable and safe to do so	Less than minor & transitory
	Pollution Accidental release of fuel through equipment failure or rupture of fuel tanks	Marine environment and any wildlife in the immediate vicinity	Medium Large volume spill event would potentially impact a wide area	Medium Some persistence of fuels in the marine environment particularly if ice constrained	Medium MGO fuel will dissipate over time in the environment and normal ecosystem functions likely to return	Low Extremely unlikely to occur	More than minor & transitory in case of an uncontrolled, accidental large spill event	• Modern Polar Class vessel selected for the Expedition • Double skinned fuel tanks • Emergency response provisions covered by vessel SOPEP • Experienced Captain and Ice Pilot on-board • Use of the RPAS and satellite imagery to support 'in ice' navigation	More than minor & transitory in case of an uncontrolled, accidental large spill event
	Waste Human waste released to the environment	Marine environment Wildlife	Medium Discharges from sewage system will spread beyond the area of the vessel though will be rapidly dispersed and diluted	Low Discharges from sewage system will be disposed only for the 45-days of the Expedition cruise	Low Natural ecosystem functions unlikely to be affected	Very High Discharges from the sewage system will occur daily	Less than minor & transitory	• All food and general wastes will be stored on board and disposed of outside the Antarctic Treaty area • Sewage / grey water disposal based on zero discharge of raw effluent. • Discharged water exceeds quality requirements of IMO Resolution MEPC.159(55) 2006	Less than minor & transitory
	Water turbulence Waves, wash and propeller turbulence	Marine environment	Low Immediate vicinity of the vessel only	Low Limited to 45-day cruise only	Low Natural ecosystem functions unlikely to be affected	Medium Water turbulence will occur as a result of vessel operations	Less than minor & transitory	No mitigation options available • Water turbulence will occur, through with negligible consequences for the Weddell Sea marine environment	Less than minor & transitory
	Introduction of non-native species Hull fouling and ballast water	Marine environment and marine fauna and flora	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)	• No ballast water exchanges will occur during the Expedition • Vessel may already have been working pack ice (to reach Penguin Bukta) with consequential removal of hull fouling	No more than minor & transitory

Table 13 continued

Activity	Potential impact	*Environmental Element Impacted*	Spatial Extent	Duration	Intensity	Probability	***Significance** (without mitigation)*	Mitigation of Impact	***Significance** (with mitigation)*
Research activity: Deployment of AUVs and ROV	Noise, light and heat emissions	Marine environment and marine fauna and flora	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 minor to negligible encounters with wildlife are possible though unlikely	Less than minor & transitory	• Underwater survey equipment is quiet • Experienced technicians will operate the AUVs & ROV Any wildlife encounters will be recorded	Less than minor & transitory
	Waste Equipment failure leading to loss of underwater vehicles and/or loss of AUV drop-weights	Benthic marine environment and associated fauna / microflora	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 AUVs and/or drop-weights is possible. Loss of (tethered) ROV is possible but unlikely.	Less than minor though more than transitory (if loss were to occur)	• One purpose built AUV for under-ice survey • Sophisticated technology on AUVs including collision avoidance technology • Experienced technicians will operate the AUVs & ROV • Build-up approach adopted. Short 'test' missions followed by longer ones • Technicians seeking to reduce scenarios where drop-weights are released • Past experience drawn on where possible • AUVs may be recoverable using ROV. Any unrecoverable equipment will be recorded	Less than minor & transitory
	Water turbulence Propeller wash from the AUVs	Marine environment	Low Immediate vicinity of vehicle only	Low Transitory only – seconds to minutes	Low Any impacts will be reversible	High Turbulence will occur but only within very close proximity to the AUVs	Less than minor & transitory	No mitigation possible • Water turbulence will occur, though consequences will be negligible	Less than minor & transitory
	Introduction of non-native species Fouling of AUVs and RoV	Marine environment and marine fauna and flora	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	Low AUVs and ROV easy to clean and inspect prior to deployment	More than minor & transitory (if a non-native species were to establish)	• Relevant guidance and guiding principles in CEP's non-native species manual will be followed • AUVs and ROV will be inspected and cleaned prior to sending to Antarctica • AUVs and ROV will be inspected and if necessary cleaned prior to each deployment	Less than minor & transitory

Table 13 continued

Activity	Potential impact	*Environmental Element Impacted*	Spatial Extent	Duration	Intensity	Probability	***Significance** (without mitigation)*	Mitigation of Impact	***Significance** (with mitigation)*
Research activity: Deployment of sediment and benthic sampling equipment	Physical disturbance Contact of coring devices with benthos and extraction of cores	Marine benthos	Low Impacts will occur within the spatial extent of the coring device	Medium Disturbance likely to recover within one to two seasons	Low Natural functions will recover and impacts highly reversible	Very High Impacts will occur where coring takes place	Less than minor & transitory	Impacts will be unavoidable at sampling locations • Sampling sites will be carefully selected to maximise research benefit Records of sampled locations will be maintained	Less than minor & transitory
	Waste Accidental loss of sampling equipment	Marine benthos and benthic fauna	Low If lost equipment will sink to seafloor and impact an area within the footprint of the equipment	Very high If lost, equipment will persist in the environment for many decades	Low Ecosystems negligibly and reversibly affected	Low Sampling equipment tethered to vessel at all times	Minor though more than transitory (if loss were to occur)	• Experienced, specialist coring technicians will oversee coring activities • Careful deployment of coring devices according to weather and ice conditions • Careful selection of sampling locations Any lost equipment will be recorded	Less than minor & transitory
	Introduction of non-native species Fouling of sampling equipment	Marine environment and marine fauna and flora	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	Low Coring devices easy to clean and inspect prior to deployment	More than minor & transitory (if a non-native species were to establish)	• Relevant guidance in CEP's non-native species manual will be followed • All sampling equipment will be cleaned and inspected prior to expedition deployment • All sampling equipment will be inspected and cleaned prior to each deployment	Less than minor & transitory
	Native Benthic Fauna and micro-flora Removal by sampling	Benthic fauna and micro-flora	Low Sampling of any one location will be constrained to the footprint of the coring device (though several sampling locations will be selected)	Medium Impacts likely to last beyond same season	Medium Recovery likely with benthic species moving in to sampled area over time	Very High Sampled areas will be denuded where sampling takes place	No more than minor & transitory	Impacts will be unavoidable at sampled locations • Sampling locations will be carefully selected to maximise research benefit Records of sampled locations will be maintained	No more than minor & transitory

Table 13 continued

Activity	Potential impact	*Environmental Element Impacted*	Spatial Extent	Duration	Intensity	Probability	***Significance** (without mitigation)*	Mitigation of Impact	***Significance** (with mitigation)*
Research activity: Water column and plankton sampling	Waste Accidental loss of sampling equipment	Marine benthos and benthic fauna	Low If lost equipment will sink to seafloor and impact an area within the footprint of the equipment	Very high If lost, equipment will persist in the environment for many decades	Low Ecosystems negligibly and reversibly affected	Low Sampling equipment tethered to vessel at all times	Minor, though more than transitory (if loss were to occur)	• Experienced, specialist technicians on-board to oversee sampling activities • Careful deployment of sampling devices according to weather and ice conditions Any lost equipment will be recorded	Less than minor & transitory
	Water turbulence Towing of nets and water samplers through the water column	Marine environment	Low Immediate vicinity of the sampling device only	Low Limited to each sampling activity only	Low Natural ecosystem functions will not be affected	Medium Water turbulence will occur as a result of sampling operations	Less than minor & transitory	No mitigation options available. • Water turbulence will occur, through with negligible consequences for the Weddell Sea marine environment	Less than minor & transitory
	Introduction of non-native species Fouling of sampling equipment	Marine environment and marine fauna and flora	Medium An introduced species may spread over a wide area	Very high Once established non-native species would unlikely to be eradicated	High If established non-native species may have long-term consequences for native biota	Low Sampling devices easy to clean and inspect prior to deployment	More than minor & transitory (if a non-native species were to establish)	• Relevant guidance in CEP's non-native species manual will be followed • All sampling equipment will be cleaned and inspected prior to expedition deployment • All sampling equipment will be inspected and cleaned prior to each deployment	Less than minor & transitory
	Native Pelagic Fauna and Flora Removal by sampling	Pelagic fauna and flora	Low Sampling of any one location will be constrained (though several sampling locations will be selected)	Low Impacts likely to be negligible	Low Ecosystem effects will be negligible	Low Sampling will remove fauna and flora, but consequences will be negligible	Less than minor & transitory	Impacts will be unavoidable at sampled locations • Sampling locations will be carefully selected to maximise research benefit Records of sampled locations will be maintained	Less than minor & transitory

Table 13 continued

Activity	Potential impact	*Environmental Element Impacted*	Spatial Extent	Duration	Intensity	Probability	***Significance** (without mitigation)*	Mitigation of Impact	***Significance** (with mitigation)*
Research activity: deployment of RPAS	Noise / visual presence Disturbance of wildlife	Flying birds, congregated wildlife	Low Some individuals may be affected	Low Impacts likely will be short-term and likely to result in immediate avoidance	Low Impacts likely to result in short-term physiological and behavioural responses only	Low In remote areas of operation of the RPAS encounters with wildlife are unlikely	Less than minor & transitory	• Fully trained and experienced pilot will operate the RPAS • COMNAP RPAS Handbook guidance followed at all times • ATCM Environmental guidance for RPAS operations will be followed • RPAS will not be deployed in the vicinity of large concentrations of flying birds • Bird observations will commence 20 minutes prior to planned launch Any disturbance events will be recorded	Less than minor & transitory
	Heat emissions	Antarctic atmosphere	Low Emissions confined to the immediate area of the RPAS	Low Emissions only during flying	Low Emissions will dissipate rapidly away from the RPAS	Low Impacts negligible under normal operating conditions	Less than minor & transitory	No mitigation options available. • Heat emission will occur though impacts will be negligible	Less than minor & transitory
	Air turbulence	Antarctic atmosphere	Low Turbulence confined to the immediate area of the RPAS	Low Turbulence only during flying	Low Turbulence will dissipate rapidly away from the RPAS	Low Impacts negligible under normal operating conditions	Less than minor & transitory	No mitigation options available. • Air turbulence emission will occur though impacts will be negligible	Less than minor & transitory
	Waste Accidental loss of RPAS unit(s)	Marine environment	Low If lost to the environment impacts will be confined to spatial extent of the RPAS unit	Very high If lost, equipment will persist in the environment for many decades	Low Ecosystems negligibly and reversibly affected	Medium Loss of RPAS units could occur but is unlikely	Less than minor though more than transitory (if loss were to occur)	• RPAS units serviced and tested prior to deployment in Antarctica • Experienced, trained pilot to operate the RPAS units • Careful deployment of RPAS according to weather conditions • COMNAP RPAS Handbook guidance followed at all times Any lost equipment will be recorded	Less than minor & transitory
Research activity: use of hazardous chemicals	Waste Production of hazardous waste	Marine environment and marine flora and fauna (if waste released)	Low Waste will not be released to the marine environment	Low Waste will not be released to the marine environment	Low Waste will not be released to the marine environment	Low Waste will not be released to the marine environment	Less than minor & transitory	• Use of chemicals to laboratory standards • Containment of all waste • Disposal of hazardous waste outside of Antarctica	Less than minor & transitory

Activity	Potential impact	*Environmental Element Impacted*	Spatial Extent	Duration	Intensity	Probability	***Significance** (without mitigation)*	Mitigation of Impact	***Significance** (with mitigation)*
Research activity: marine archaeology	Physical disturbance Damage to wreck from collision by AUV or ROV	Wreck site / Antarctic heritage	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	Low Survey equipment is unlikely to come into contact with wreck	More than minor & transitory (if damage were to occur)	• Highly experienced AUV and ROV operators on-board • Initial seafloor (AUV) surveys will be from a safe distance (100m above sea floor) • ROV surveys will be planned on basis of outputs from AUV surveys • ICOMOS standards adhered to where relevant • ATCM guidance on human heritage adhered to where relevant • No disturbance / no collection policy adopted to guide all wreck survey work	Less than minor & transitory

Table 13 continued

Activity	Potential impact	*Environmental Element Impacted*	Spatial Extent	Duration	Intensity	Probability	***Significance** (without mitigation)*	Mitigation of Impact	***Significance** (with mitigation)*
All operations	Wilderness values Loss of Antarctic wilderness values through growing human presence and impacts in the region	Antarctic wilderness values	Low Unavoidable impacts of the Expedition will be less than minor and transitory	Low Unavoidable impacts of the Expedition will be short-term	Low Unavoidable impacts of the Expedition will be recoverable	Low Likelihood of lasting impact on wilderness as a result of this Expedition is low	Minor though more than transitory if permanent impact were to occur (e.g. permanent loss of equipment)	• Short duration 'light footprint' research expedition • Majority of sampling will be non-invasive • Careful selection of sampling locations • Careful use of all equipment by trained and competent staff to mitigate loss • No disposal of any waste in Antarctica	Less than minor & transitory

8. Record Keeping

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

The Expedition will be entirely ship-based and marine focused. Most of the research will involve non-invasive data gathering e.g. AUV and RPAS surveys, and where invasive sampling is undertaken, the identified impacts are identified in this assessment as likely to be no more than minor or transitory.

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

- 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 benthic and water column sampling locations will be accurately recorded, not least for publication purposes;
- Any observed encounters with wildlife such as may occur between the AUVs or ROV and diving pinnipeds or cetaceans, as well as any observed bird encounters with the RPAS. To the extent possible records will be maintained of the species concerned and the location;
- 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;
- Location of deployment of the AWI SVP ice buoys.

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

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 research objectives are clearly described and the research methods 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. Inter- and intra-continental flights may be delayed due to poor weather conditions at points of departure or destination.

Weather conditions during the marine phase of the Expedition may affect the duration of passage across the Weddell Sea and will determine the extent to which sampling equipment can safely be deployed from the ship.

Weather conditions will also determine the extent of flying that can be undertaken by the RPAS. For maximum data collection the RPAS need to be flown in relatively light wind conditions. This will require regular weather observations to identify optimum windows for deployment of the units.

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 research ship 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 research cruise.

Sea ice conditions will also determine the extent to which the primary research areas in the vicinity of the Larsen C ice-shelf can be accessed.

It is the unpredictability of the sea ice that has required alternative research locations to be identified, as described in Section 5.2.

9.3 Extent of sampling

The precise number and location of sediment, benthic faunal, water and plankton samples to be taken cannot be defined in advance of the Expedition. The sampling that will be achieved will be determined by a number of factors including ease of access to target research areas; weather conditions (which will have significant bearing on the frequency of deployment of sampling equipment); the performance of the sampling equipment and the balance of demands among research priorities.

Every effort will be made to ensure that all invasive sampling that is undertaken maximises research benefit.

10. Summary and Conclusion

This IEE has described the proposed activities to be conducted by the Weddell Sea Expedition 2019 (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).

The only potential environmental impact of the Expedition assessed as being of **more than minor or transitory** significance is the accidental release of a large volume of fuel as a result of equipment failure or rupture of one of the vessel's fuel tanks. This is an unlikely scenario given the modern, SOPEP-compliant, Polar Class vessel that has been selected for the Expedition, the experience of the Captain and Ice Pilot, and the navigational support that will be available (i.e. the use of RPAS and access to satellite imagery). Whilst these mitigation measures are effective in reducing the likelihood of a spill, the consequences would be more than minor or transitory if one were to occur.

Even with implementation of control measures, some potential environmental impacts of the Expedition have been assessed as likely to be of **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 (given that the charter of the vessel starts and ends in Antarctica), but assessed as being of low likelihood, though with high consequence if it were to occur;
- **The removal of benthic fauna and micro-flora through direct sampling -** an unavoidable impact, though transitory in nature given the likelihood that denuded areas will be recolonised.

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 includes:

- **Noise generated by the engines and machinery of the SA Agulhas II** – an unavoidable impact, but with negligible environmental consequences;
- **The release of treated waste water from the ship** – an unavoidable impact, but with negligible environmental consequences;
- **Water turbulence created by the ship** – an unavoidable impact, but with negligible environmental consequences;
- **Noise, heat, light emissions and water or air turbulence from operation of the AUVs, ROV, RPAS and sampling equipment** – unavoidable impacts, but with negligible environmental consequences;
- **The accidental loss of an AUV, ROV, RPAS, AUV drop-weights or sampling equipment to the environment** – assessed as being of low likelihood and avoidable provided all mitigation measures are applied;

- **The accidental introduction of a non-native species on deployed research equipment** – assessed as being of low likelihood and avoidable provided all mitigation measures are applied;
- **Physical disturbance of the benthic environment** – an unavoidable impact, but highly localised and less than transitory with recoverability likely;
- **The removal of pelagic fauna and flora samples** – an unavoidable impact, but highly localised and less than transitory with recoverability likely;
- **The production of waste from laboratory use of hazardous substances** – an avoidable impact, with all wastes removed from Antarctica;
- **Physical disturbance to either of the wreck sites** – assessed as being of low likelihood and avoidable provided all mitigation measures are applied;
- **Impact on Antarctic wilderness values**– assessed as being avoidable provided all mitigation measures are applied.

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 13) 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 environment. It is concluded that this level of predicted impact is acceptable given the significant scientific knowledge that will be gained as a result of undertaking the Expedition.

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Appendices

Appendix 1. CVs for Vessel Master, Ice Pilot and RPAS technician

Please see separately enclosed files.

A. Captain Bengu – Master SA Agulhas II (African Marine Solutions)

B. Captain Lighthelm – Ice Pilot for the Weddell Sea Expedition 2019 (Ship 2 Shore Marine Connection)

C. Paul Bealing – RPAS pilot and technician (University of Canterbury, New Zealand)

Appendix 2. Specifications for the SA Agulhas II

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	

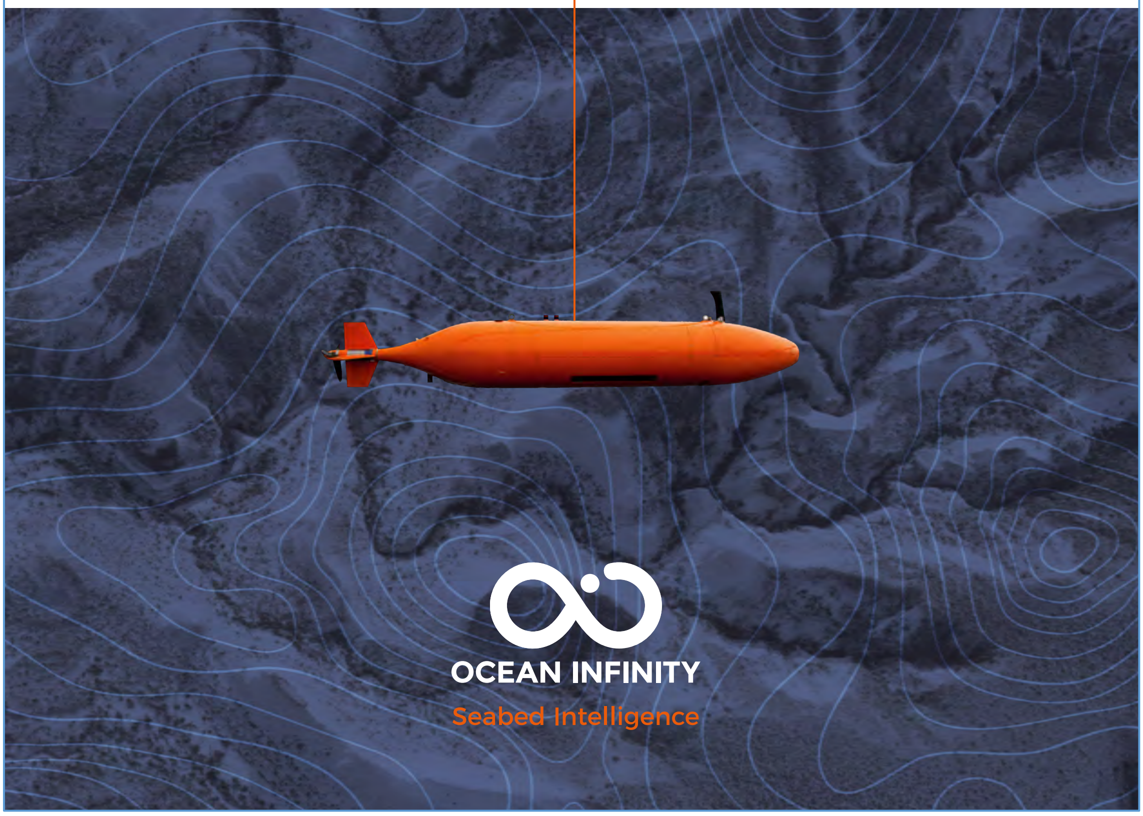
HELICOPTER SUPPORT AND FACILITIES	
Helideck Landing Deck Area: 120m² 110t Jet-A1 bunker capacity	Manual sprinkler system for hangar Hanger Facilities: Enclosed hangar capable of fitting two PUMA size helicopters

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 3. Specifications for the Hugin AUVs

HUGIN 6000 AUTONOMOUS UNDERWATER VEHICLE AUV



FEATURES

Low noise hydrodynamic stable platform for payload sensors

High maneuverability to provide terrain follow and turning radius of 15 m to 20 m

Operator supervised (Acoustic Tether) semi-autonomous or autonomous operation

State of the art navigation from an Aided Inertial Navigation System (AINS)

Highly flexible configuration integration of payload sensors

SENSORS

Side Scan Sonar:	EdgeTech 2205 75/230/400KHz
Multi-Beam Echosounder:	Kongsberg EM 2040
Sub-Bottom Profiler:	EdgeTech 2-16KHz
Camera:	HD CathX Colour Still Camera
Turbidity:	FLNU (RT)D
Magnetometer:	Ocean Floor Geophysical Self-Compensating
Conductivity Temperature Depth Sensor:	SAIV
Optional:	Methane & CathX Laser Sensor

DIMENSIONS

Length:	6.2 m (Approx)
Diameter:	0.875m
Volume:	11.3-1.5m^3
Telemetry:	cNode & Cymbal
Weight:	1,850kg (In Air) Neutrally Buoyant (In Water)
Operating Depths:	5m (Min) - 6000m (Max)

SPEED

Minimum Speed:	2 kn
Maximum Speed:	6 kn

POWER

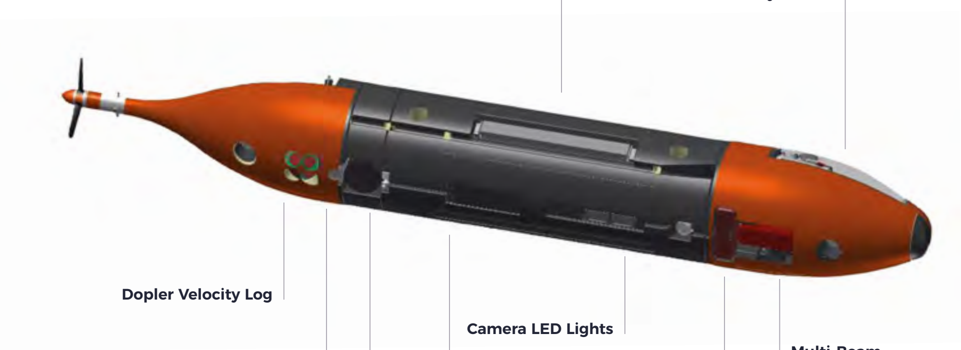
Battery Type:	Rechargable Lithium Polymer
Quantity:	2 Battery Packs Per AUV
Endurance:	60 hr @ 3.6 kn (With SSS/SBP/MBES Operating)

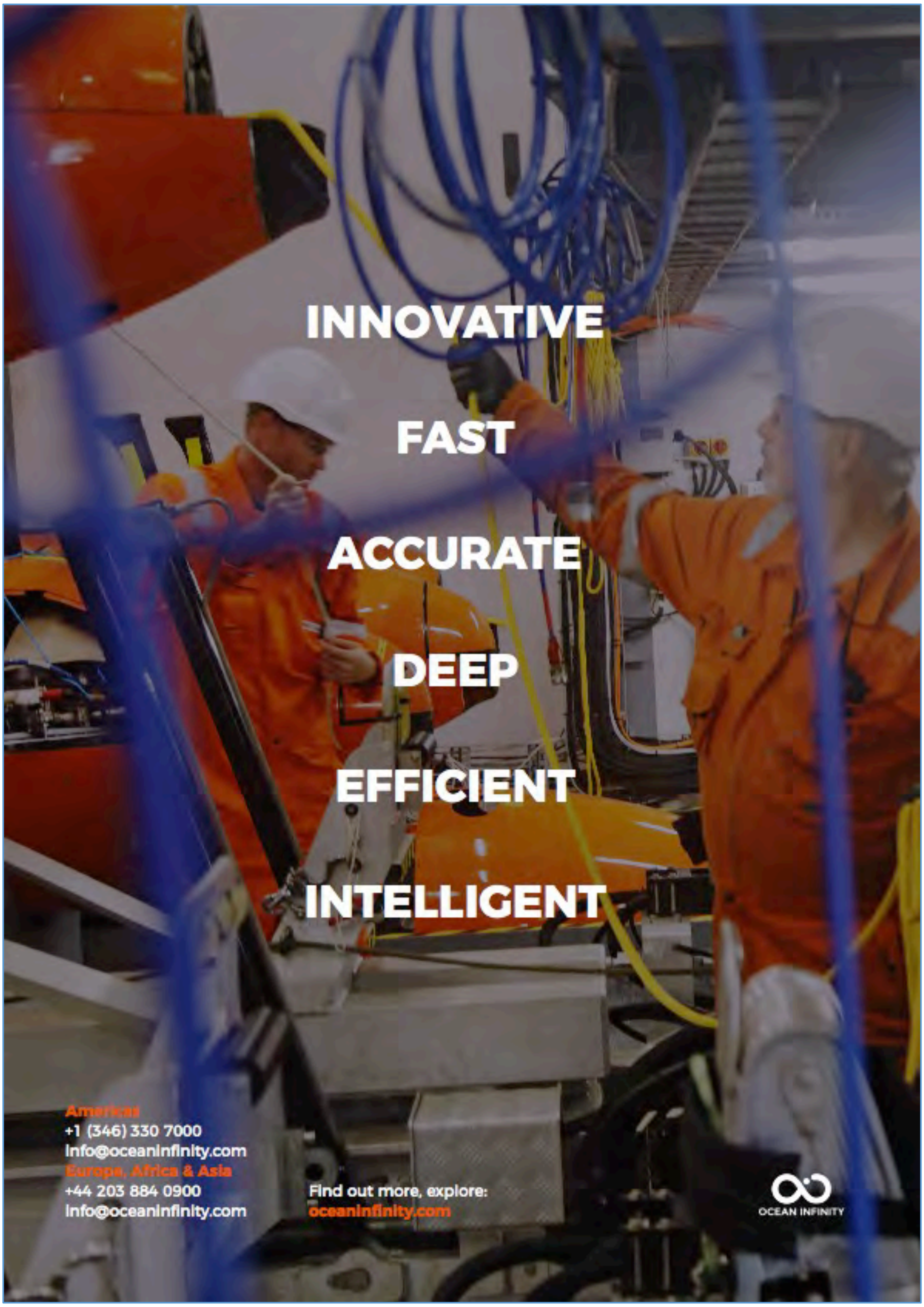
NAVIGATION

IMU:	Honeywell HG 9900
GPS Receiver:	AUV Novatel
Compass:	Leica DMC
DVL:	Teledyne RDI Workhorse Navigator 300KHz
Anti-Collision:	KM algorithms (For improved contour and obstacle avoidance)
Depth Sensor:	DigiQuartz D50 Series 8000
USBL:	Kongsberg cNode Transponder
Altimeter:	Mesotech 200/675KHz (Forward & Downward Facing)
Forward Looking Sonar:	Imegenex Sonar

AUV HUGIN 6000

Find out more at:
oceaninfinity.com

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Appendix 4. Specifications for the EGI (GP 50) ROV

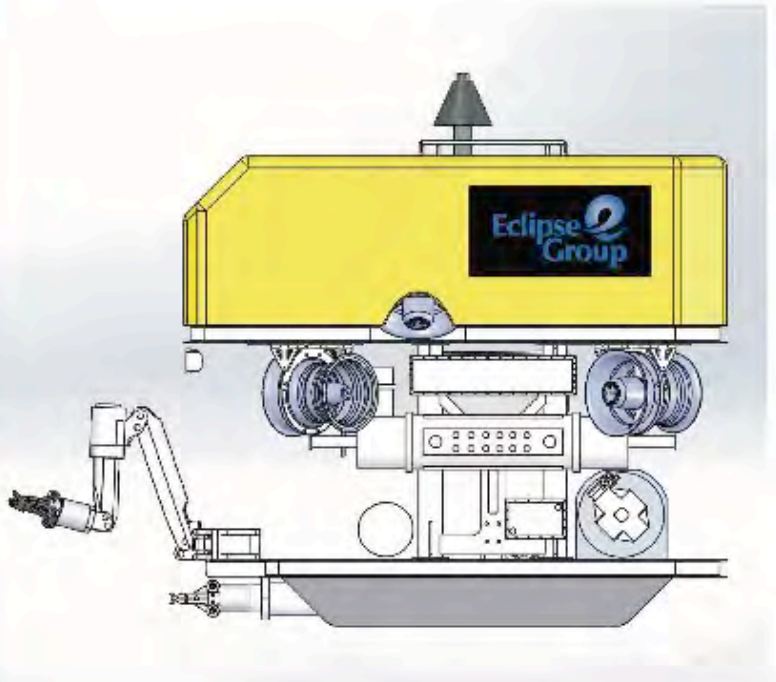
GP 50 ROV

Eclipse Group

GP 50 ROV Specifications

GENERAL	
General	
Depth rating	
Standard	6000msw
Dimensions	
Length	≤3500mm
Width	≤2000mm
Height	≤2000mm
Weight in air (std)	4750kg
Payload	350kg
Through Frame Lift	3000kg

PERFORMANCE	
Bollard Pull	
Forward/aft Lateral	1200kgf
Vertical (up)	650kgf
Thruster Configuration	
Horizontal vectored	4 x 1002 Innerspace Thrusters
Vertical	3 x 1002 Innerspace Thrusters
Hydraulic Power (total)	50 Hp



INSTRUMENTS/TOOLING

Spare Hydraulic Channels

Standard	19 (15LPM), 4 (35LPM), 1 (66LPM)

Video Capability

Video Channels	8 channels composite (All with Focus and Zoom options)
Cameras	1 x Color Camera 1 x Composite Color Camera 4 x Insite Paci ic IT-100 Monochrome Cameras

Sonar & Navigation

Long Range Obstacle Avoidance Sonar	Kongsberg 117 330 kHz Sonar
Gyro	Teledyne MINPOS2 Ring Laser Gyro
Secondary Heading Source	KVH Fluxgate Compass Teledyne
Altitude Sensor	Programmable Sonar Altimeter
Depth Sensor	PSA-916 Paroscienti ic 8CB Depth Sensor

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INSTRUMENTS/TOOLING

Lighting

Standard	4 x 120Vac @ 250W LED Lights 16 x 80W Low Profile LED Lights 4 x 120VAC 80W HID Lights

Camera Pan / Tilt

Standard	2 x Hydro-Lek Hyd. Pan / Tilts
Tilt Units	2 x Hydro-Lek Hyd. Tilts

Manipulators

Standard	1 x 7F Spatially Correspondent Titan 4 Schilling Manipulator
Standard	1 x 3 Function Heavy Duty Grabber

Handling System

A-Frame Standard	Dynacon Model 6010 A-Frame
Winch	7K Cap. Dynacon Model Traction Winch and Storage Drum
Cable	4,900m Rochester .680 electo/optical

Operations Van and Maintenance Container

Standard	20 Ft. Environmentally Controlled Operations Container
Standard	20 Ft. Environmentally Controlled Work Shop Container

Additional Equipment

Option	Water jetting unit
Option	Dredging unit
Option	Jaws of Life
Option	Wire cutters
Option	Grinder
Option	Torque tool
Option	Hot stab
Option	Needle valve tool
Option	XYZ tool