

CONSEC

Research, Conservation and Leadership in Southern Ocean Ecosystems

(An NC-ALI Science programme delivered by BAS Ecosystems)

The Challenge: To understand the links between the biodiversity, structure and function of Southern Ocean ecosystems and the impacts of rapid environmental changes to improve scientific knowledge and inform conservation and management policy.

The Southern Ocean is undergoing climate and societal related changes that are affecting its species, ecosystems and ecosystem services. Further rapid changes are expected in the coming decades driven by multiple physical and chemical processes (e.g., warming, ice loss, changing winds, reduced pH) and direct human impacts (e.g., fisheries and tourism). Changes are clearly taking place, but the drivers, mechanisms, and implications for marine ecosystems and the services they provide are poorly understood. Understanding the combined effects of natural and human-induced environmental stressors on biodiversity, biological processes and biogeochemical cycles is crucial for developing projections of the future state of ecosystems across the Southern Ocean and to inform their conservation and management.

The structure of marine ecosystems is a product of both environmental factors and biological interactions. Environmentally, the Southern Ocean experiences high levels of seasonality and is subject to global climatic cycles that propagate through its ecosystems at different rates. Species must withstand substantial fluctuations in temperature, primary productivity, atmospheric winds and ocean currents and, in some places, sea ice. Biologically, polar ecosystems are characterised by multi-scale interactions of organisms operating at different trophic levels. These ecosystems contain a wide range of food web structures, from short efficient food chains to complex networks. These are influenced by the varied and specialised life cycles of polar organisms which must incorporate short productive seasons and longer overwintering periods. Together, environmental and biological factors result in Southern Ocean ecosystems being highly spatially and temporally variable across multiple scales, all of which are critical for understanding how ecosystem structure is maintained.

Polar ecosystems also carry out globally important biogeochemical functions. Many nutrients essential for global marine productivity are exported from the polar regions and this process is modulated by the biological activity of polar marine species. Some Southern Ocean regions also contain globally important carbon pumps. In these regions, carbon fixed from the atmosphere is rapidly transported to deep ocean depths where it remains for decades to centuries. The marine ecosystem plays a fundamental role in this carbon transport process. However, human-induced environmental stressors (e.g., ocean warming, ocean acidification, plastic and chemical pollution) are threatening how these processes operate. Continuing to refine our parameterisations of these processes and assessing the impacts of different types of stressors is fundamental to understanding the operation of the Earth system. It also emphasises the global importance of conserving polar marine ecosystems.

Environmental change can further result in non-linear responses that may be manifested as the inability of individuals to complete their life cycles or the restructuring and potential collapse of food

webs following declines in the abundance of a key species. These responses may lead to abrupt reconfigurations of ecosystems across large areas. Such rapid changes in state, termed “tipping points”, may be hidden by natural system variability, but may also be too fast for many organisms to adapt to successfully, cascading to produce potentially catastrophic consequences for some species. For polar organisms, the shift poleward of suitable habitat will lead to a contraction of true polar ecosystems, but such changes, involving multiple physical and chemical processes. Discriminating these non-linear responses from natural variability can only be achieved through the continuous monitoring of these systems.

Conservation of polar biodiversity and ecosystems must take into account the changing environment and consider how species respond to change. A further factor is the impact of the harvesting of natural resources in the Southern Ocean. Harvesting of krill and fish is regulated through the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), which, through its ecosystem approach to management, has a remit to minimise the impact of harvesting on the wider ecosystem. Further conservation measures are legislated through bodies such as the Agreement on the Conservation of Albatross & Petrels (ACAP) and the International Whaling Commission (IWC). The Antarctic Treaty Consultative Meeting (ATCM) produces regulations and guidelines for the management of the Antarctic Treaty area, with advice from the Scientific Committee for Antarctic Research (SCAR). It is in the national interest of the UK to drive the agenda within each of these bodies and this can only be achieved through the provision of the best available scientific evidence. CONSEC provides participants to all of these regulatory and advisory bodies, including all of the CCAMLR working groups. Our participation ensures that the most up to date ecosystems science remains a key part of the decision making process.

Much of the geographic focus of UK marine science is on the south-west Atlantic sector of the Southern Ocean. This reflects the importance of this region both ecologically and geopolitically, as well as its accessibility. The south-west Atlantic sector is one of the most productive regions of the Southern Ocean, driven by the supply of limiting micronutrients from the Antarctic Peninsula and island land masses such as the South Orkneys and South Georgia. As a result, this region contains much of the circumpolar population of Antarctic krill, and in turn, large populations of krill-feeding higher predators, including penguins, albatrosses, petrels, seals and baleen whales. It is also the geographic focus of the growing krill fishery. Both the South Orkneys / Antarctic Peninsula region and South Georgia and the South Sandwich Islands are UK Overseas Territories and host Marine Protected Areas (MPAs). There are important fisheries for krill, toothfish and icefish managed by the Government of South Georgia and the South Sandwich Islands. Through CONSEC, BAS science is the primary source of scientific evidence driving conservation and management of marine resources and wildlife within these regions.

Fundamentally, identifying suitable conservation and management measures requires long-term sustained observations and analysis across multiple trophic levels and adequate spatial scales. These critical observations and analyses are provided by the CONSEC programme.

Summary of aims: Our programme focusses on regional ecosystems in the south-west Atlantic sector of the Southern Ocean, including the islands of South Georgia and the South Orkneys, where we undertake long-term monitoring and targeted studies to provide information on how ecosystems are structured considering biodiversity, the life cycles of key species, food-webs and population dynamics. We also consider crucial processes such as predator-prey interactions and the operation of the carbon pump. Environmental stressors, including ocean warming, ocean acidification and plastic and chemical

pollution, impact all these aspects of the ecosystem and are considered both in isolation and combined. We further develop models at regional and circumpolar scales to generate projections and provide clear information and recommendations for conservation and management decision-making.

Path to net zero: CONSEC is committed to achieving its objectives while continually lowering its carbon footprint towards net zero. Over the past decade, it has transitioned towards greater autonomy in its data collection operations through the deployment of moored instrumentation with low-powered autonomous sensors. Power-use and sampling rate are continually being refined to decrease the frequency that these moorings must be visited for re-servicing. The use of a science vessel to conduct its biological oceanographic surveys remains essential to CONSEC but steps are being taken to decrease reliance on such a vessel through the introduction of instrumented gliders and sailbuoys. The coming seasons will be important in terms of cross-calibrating between these instruments and vessel-based sampling methods. On land, the increased use of drones and satellite remote-sensing is being implemented to reduce level of field-personnel and manned aerial surveys required whilst also improving our capacity to determine population sizes of higher predators. The attendance of delegation meetings is an essential part of the work of CONSEC but steps are being taken to increase the utility of hybrid and cluster meetings to minimise long-distance travel.

Equity, Diversity and Inclusivity (EDI): CONSEC is committed to ensuring that its workforce and workplans take full account of EDI. At present, its workforce has a balanced male to female ratio across all levels of seniority. Furthermore, we adapt workplans to accommodate flexible and part-time working. CONSEC scientists are active in a number of schemes to increase levels of diversity and increase numbers of underrepresented groups in our workforce, such as the BAS DiPSI scheme and Polar Horizons initiative.

SCIENCE ACTIVITIES

We deliver the CONSEC programme through four principal scientific **Work packages**:

- WP1** **Quantifying biodiversity, life cycles and food-webs**
- WP2** **Determining ecosystem structure and their biogeochemical function**
- WP3** **Driving policy in conservation and sustainability in the Southern Ocean**
- WP4** **Providing international leadership in polar marine ecosystem research**

The above are supported and overseen by two further work packages, dealing with collection of field samples and data and programme management:

- WP5** **Managing fieldwork and securing the collection of field data**
- WP6** **Programme management**

These work packages incorporate a number of **Tools** in order to meet their objectives, which can be summarised as follows:

- Tool A** **Field datasets of sustained observations**
- Tool B** **Biophysical and ecosystem models**
- Tool C** **Sample collection infrastructure**

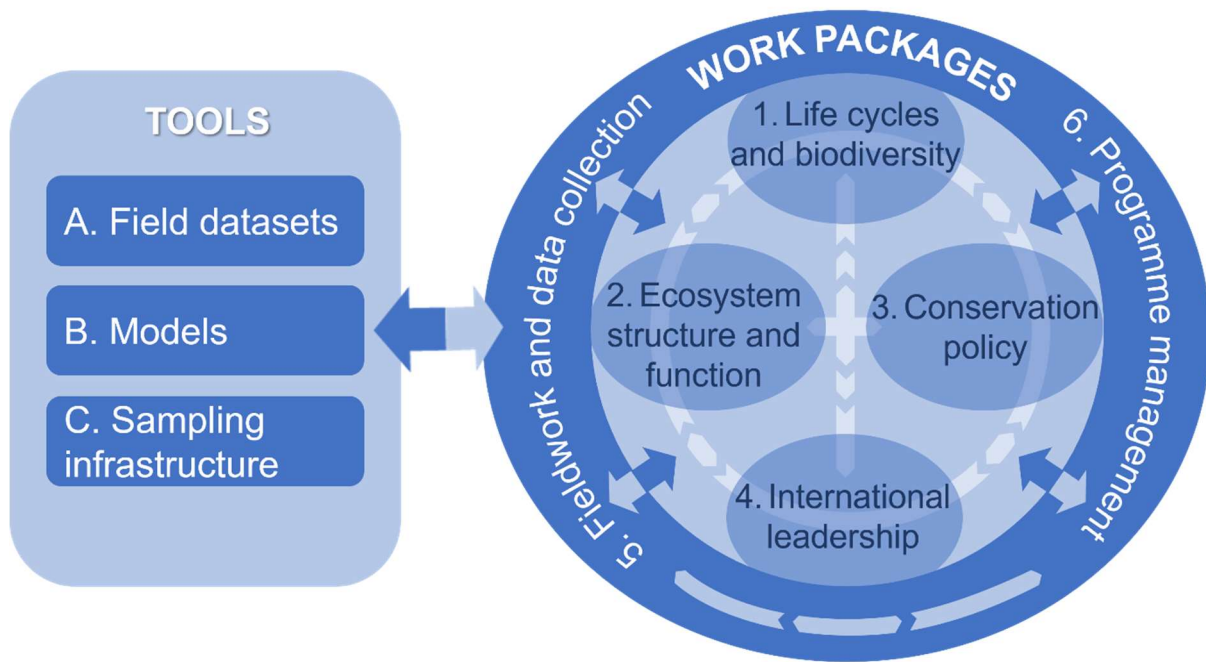


Fig. 1: CONSEC programme structure

Each of the scientific work packages are designed to be strongly interlinked whilst also having their own distinct rationales, as we describe below:

WP1 Quantifying life cycles, food-webs and biodiversity:

WP1 focuses on quantifying the ecological and biological processes that affect the life histories and life cycles of key species in Southern Ocean ecosystems, and how these are affected by changes in the environment, including climate, pollutants, fisheries and other human stressors. This is fundamental to modelling population dynamics and food webs both now and into the future, as well as informing their conservation and management. Our focus is on Antarctic krill, other zooplankton (copepods, salps, pteropods, euphausiids), fish (myctophids, nototheniids) and higher predators (penguins, albatrosses, petrels, seal, whales), particularly species that are abundant and therefore are major prey or consumers, and others that are declining, or listed as threatened by IUCN (International Union for Conservation of Nature) and/or for which there is particular concern under international agreements (e.g. CCAMLR, ACAP, IWC; see below)

As part of WP1, we collect and analyse data both from long-term studies and from targeted fieldwork on ships and moorings (South Georgia Core Box programme, **tools A and C**) and at the BAS and South Georgia government research stations (Bird Island, Signy and King Edward Point, **tools A and C**). The ship-based fieldwork considers community level metrics such as pelagic biodiversity and food-web structure as well as the population dynamics and life-cycle strategies of key pelagic taxa such as Antarctic krill, myctophid fish and salps. Moorings provide further seasonal data on population dynamics and life-history of phytoplankton and zooplankton through active acoustics, sediment traps and water and phytoplankton collectors. Moorings also provide species abundance data on whales via passive acoustic devices. At the research stations, data collection on higher predator species includes population densities, sizes and trends, demography (including survival, recruitment, breeding frequency, and breeding success), genetic structure, distribution (breeding or foraging), movement

strategies (including migration), habitat preferences, foraging success, provisioning rates, body condition and other aspects of ecology and physiology.

We estimate abundance and model population trends, analyse life-cycles and life-history processes, and model population dynamics and resilience (**tool B**). We examine the role of individual variation in behaviour, body condition, habitat use and breeding and moulting strategies in life cycles and population processes. We also quantify trophic linkages among prey and predators (including alternative pathways not involving krill); examine intra and inter-specific competition; and map distribution and consumption for species, age classes and sexes. The analyses are integrated into studies of food webs, impacts of fisheries and recovery from past exploitation, and ecosystem structure.

WP2 Determining ecosystem structure and their biogeochemical function

WP2 focusses on understanding the distribution of key species on seasonal and annual timescales, which is essential for considering how Southern Ocean ecosystems operate. Observations (**tools A, C**) and biophysical models (**tool B**) enable us to determine the influences of physical oceanographic and sea ice processes on the distributions of pelagic species such as Antarctic krill, while monitoring and habitat modelling of land-based predators (**tools A, B**) allows us to generate quantified analyses of seasonal and interannual changes in their habitat. Together with knowledge of species-specific physiological optima and tolerance limits that affect the resilience of species to future environmental change (**tools A, C**), we can use these outputs to project potential changes in the distribution of key species, and hence to the Southern Ocean ecosystem, under varying environmental stressors. This is critical information for the development of conservation and sustainable management policies.

Pelagic ecosystems play a major role in the movement of carbon and nutrients such as nitrogen, phosphorus and silicon from the sea surface to oceanic depths (otherwise termed biogeochemical export or flux). This process is particularly important in the Southern Ocean since the region contains carbon sinks of global importance and exports much of the nutrients used by the global ocean. WP2 is working towards better quantifying the export of biogeochemical elements, over seasonal and annual timescales at key locations, including within the area of high primary productivity northwest of South Georgia (**tools A, C**). In particular, our work focusses on the critical importance of the polar pelagic community in controlling these biogeochemical fluxes. WP2 is therefore improving parameterisations of the influences of pelagic community structure on the intensity of biogeochemical fluxes. This is primarily based on data collected during ship-based expeditions and through moorings (**tool C**), while the use of autonomous instruments (gliders and sailbuoys) is being developed to enhance these observations. We also carry out incubation experiments both on board and within newly developed moored instruments to understand and simulate the effects of human-induced environmental change on pelagic ecosystem. We further consider the trophic interactions that influence the nature, extent and temporal variability of these fluxes (**tools A, C**) enabling us to estimate how these fluxes may change in the future and the potential impacts of these changes on the Southern Ocean ecosystem. We further consider a range of stressors that may affect these processes, either through their own individual influence or through acting synergistically with other stressors.

WP3: Driving policy in conservation and sustainability in the Southern Ocean

WP3 facilitates the provision of scientific advice to conservation and management bodies such as CCAMLR, ACAP and IWC. CONSEC scientists engage at a high level with these bodies, including preparing for meetings, writing papers and reviewing documents submitted by other members, contributing data and advice, and leading and engaging in extensive intersessional work programmes. Our high level roles and commitment to these bodies is described below:

CCAMLR: The Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) is the international organisation responsible for conservation and fisheries management in the Southern Ocean. The Commission meets annually in Hobart, Tasmania and is supported by a Scientific Committee and five working groups. The UK is one of 27 members of the Commission and CONSEC scientists, through the support of NC-ALI Science, have lead roles in providing scientific advice and support to the UK delegation, which is led by the FCDO. CCAMLR adopts an ecosystem approach to fisheries management, with fisheries for Antarctic krill and two species of toothfish being the main harvesting activities in the CCAMLR Convention area. CCAMLR is also responsible for the designation of Marine Protected Areas (MPAs) in the Convention Area, and CONSEC scientists have been instrumental in the development of previous successful proposals, such as the designation of the South Orkneys MPA. CCAMLR has recently incorporated climate change into the Terms of Reference for all its working groups and CONSEC scientists will have a lead role in taking this work forward, through the UK delegation, including co-convening a CCAMLR Climate Change workshop in 2023.

CONSEC scientists/science contribute/s to all five of CCAMLR's Working Groups:

Fish Stock Assessment: deals with the assessment of toothfish and icefish stocks and considers by-catch species. We contribute to biological studies to underpin the stock assessment, including age-determination and diet studies. We also participate in the biennial Groundfish Survey at South Georgia, which is essential for the icefish assessment and provides data on toothfish recruitment.

Ecosystem Monitoring & Management: deals with monitoring and management of the krill fishery, including through the CCAMLR Ecosystem Monitoring Programme (CEMP), but also considers the development and designation of MPAs. We contribute to CEMP with monitoring on South Georgia and Signy, to the development of a new krill management strategy (which includes the spatial overlap analysis, SOA), the development of MPA proposals.

Incidental Mortality Associated with Fishing: discusses fishing-related mortality of seabirds and marine mammals, reviewing data and developing mitigation methods to minimise mortality. We contribute data on trends in seabird populations, ingestion of discarded fishing gear, and entanglements of seabirds and seals.

Statistics, Assessments and Modelling: considers the statistics and modelling that underpins the work of CCAMLR's Scientific Committee and other working groups.

Acoustic Survey and Analysis Methods: considers the application of acoustic surveys to meet CCAMLR's management objectives. Whilst the focus is primarily krill, surveys for other species (e.g. icefish) are also considered. The group is currently co-convened by one of our scientists.

ACAP: Our scientists provide UK engagement with the multilateral Agreement on the Conservation of Albatross & Petrels (ACAP), which coordinates international activities to mitigate threats to the listed species. A CONSEC scientist has responsibilities in convening a working group on populations and conservation status, developing the strategic direction of the agreement and contributing BAS data and analyses of population sizes, trends, distribution and overlap of albatrosses and petrels with fisheries. Outputs from ACAP include syntheses of current knowledge of threats and management,

prioritisation of management and research actions, best-practice seabird-bycatch mitigation in fisheries, and conservation guidelines.

IWC: CONSEC scientists hold leading roles in the International Whaling Commission (IWC) Scientific Committee, chairing the Southern Hemisphere sub-committee and the Stock Definition Working Group, as invited participants to the Sanctuaries Working Group (on Marine Protected Area planning for cetaceans) and Climate Change workshops, and also acting as rapporteurs and contributors to multiple additional scientific sub-committees. We help set strategic priorities in terms of international assessments of Southern Hemisphere whale species. This includes producing research plans and guidance, developing recommendations for future research and helping to set conservation targets for baleen whales in the Southern Hemisphere. We also help IWC connect with CCAMLR on topics of common interest to both bodies.

Other international conservation and management bodies: CONSEC scientists contribute papers and advice to working groups of Regional Fisheries Management Organisations (RFMOs) and other fisheries bodies, the Convention on Migratory Species, and the International Union for Conservation of Nature (IUCN) Red List of threatened species (primarily through BirdLife International, the IUCN Red List authority for birds). BAS population and tracking data from albatrosses and petrels are used to assess overlaps between seabirds and fisheries as part of ecological risk assessments by BirdLife International and national fisheries bodies. The data are also used to identify terrestrial and marine Important Bird Areas (IBAs) and Key Biodiversity Areas (KBAs) by BirdLife International, candidate MPAs and other forms of marine spatial planning by national and international bodies.

WP4 Providing international leadership in polar marine ecosystem research

WP4 has the role of ensuring the effectiveness of our research in terms of both increasing understanding of polar ecosystem process and influencing the agenda on ecosystem conservation and management. CONSEC scientists maintain both lead and contributory roles in numerous international programmes and initiatives. Collectively these efforts place us at the forefront of Southern Ocean and global ocean research, connecting this research with decision-makers and policy at both the Southern Ocean and global scale, and promoting Ecosystems and BAS science on the world stage. For example, we are responsible for driving the strategic direction of programmes and initiatives, leading and conducting relevant research, delivering workshops, conference sessions, peer-reviewed publications in high impact scientific journals, activities of the IPCC (assessment rounds and special reports), the United Nations System (e.g., UN Framework Convention on Climate Change, UN Decade of Ocean Science, UN Sustainable Development Goals), and the Scientific Committee on Antarctic Research (SCAR), including the Standing Committee on the Antarctic Treaty System (SCATS). Our scientists have leading roles in a number of SCAR Special Action Groups (e.g., Plastic in Polar Environments Action Group), the Expert Groups on Birds and Marine Mammals (EG-BAMM) and krill (SKEG), and the co-sponsored programme ICED (see below). We have worked on UK Policy in Overseas Territories, for instance, as part of the Marine Climate Change Impacts Partnership (MCCIP). We take leading roles in SCAR conference sessions and symposia, SCAR horizon scans, peer-reviewed research articles, and policy relevant reports. We also have lead roles within the latest SCAR Scientific Research Programmes (Ant-ICON and AntClim^{now}).

CONSEC scientists lead and contribute to the Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) programme (2008-current). ICED is one of four regional programmes of the Integrated Marine Biosphere Research project (IMBeR), within which we influence the research

agenda on ocean sustainability in the context of global change. We are also involved in the United Nations Decade of Ocean Science for Sustainable Development (2021-2030), leading in the Southern Ocean Task Force which has developed a Southern Ocean Action Plan. We are active in the European Marine Research Network (EuroMarine; 2014- current), serving on the Steering Committee and SC Working Group 4 – Science Foresight (2022-26), and as General Assembly representatives for BAS which is a Member Organisation, contributing to the Scientific Strategy Plan and Grand Challenges.

Our team will continue to hold leadership roles and to develop the strategic directions of these programmes, maximising our impact on the wider scientific agendas for polar ecosystem research, and conservation and management at regional and global scales.

WP5: Fieldwork, collection and analysis of samples and data

The CONSEC programme includes a wide range of sustained field and data collection activities that combine fieldwork on ships, research bases, autonomous data collection (i.e., oceanic moorings, gliders and sailbuoys, aerial drones and wildlife telemetry) and the collation of remote-sensing data (**tool A**). Some of these datasets are interpretable in the raw collection formats, but many require processing before they have any wider value to the scientific community. We also carry out the analysis of field-samples at BAS Cambridge, applying some of latest laboratory-based technologies. All datasets are lodged with and catalogued by the Polar Data Centre which, in turn, makes them publicly accessible and links them with wider international databases as appropriate and in compliance with NERC and UKRI data sharing protocols. This data collection underpins the science activities of WPs 1 to 4 which provide further analysis, interpretation and dissemination of these data. However, the open-access nature of these datasets also allows their use by the wider scientific community. A synthesis of the sustained datasets (**tool A**) collected as part of CONSEC is provided in Table 2.

WP6: Programme management

Coordination and management is a key part to success of CONSEC, especially given its extensive remit and responsibilities to representing UK interests in the international arena. This aspect is therefore a necessary part of staff time allocation. CONSEC achieves its objectives through the provision of 12 FTEs within the BAS Ecosystems Science group. This effort is split between the three BAS Ecosystems groups: (i) Pelagic Ecosystems, (ii) Higher Predators and (iii) Conservation and Management. Two representatives from each group attend a monthly Executive Group meeting, coordinated by the Ecosystems Science Leader, to consider progress and identify any issues on the delivery of CONSEC. The heads of each of the three science groups maintain oversight in delivering NC-ALI science objectives that fall within their respective remits, for instance, the science coordination of field expeditions, the purchasing of equipment and consumables, the maintenance of equipment, the availability and appropriate training of staff for undertaking fieldwork, the provision of reports to international management and conservation bodies and representation at the corresponding meetings.

The following tables detail: our specific objectives within CONSEC (Table 1); the sustained observation datasets we collect (Table 2 [Tool A]); the models we generate to synthesise data and provide a predictive capacity (Table 3 [Tool B]) and the infrastructure we deploy and maintain to make sustained measurements (Table 4 [Tool C]). There are also further annexes that list (i) the conservation and management bodies that we attend and to which we contribute reports, including our lead contacts and (ii) the research programmes currently associated with CONSEC.

Table 1: Tasks and objectives of the Ecosystems NC-ALI Science programme, CONSEC

Work package	WP activity	NC-ALI Tasks and Objectives
1) Quantifying life cycles, life histories, food-webs and biodiversity	1) Biomass and population dynamics	1) Generate robust, species and stage-specific estimates of abundance of key marine organisms 2) Develop quantitative analyses of the life cycle and life histories of krill, other mid-trophic level species and higher predators 3) Analyse population processes of key predators
	2) Life cycles and behavioural traits	Examine interactions between life cycles and behaviour over sub-decadal and decadal timescales
	3) Regional food webs	Quantify trophic linkages and integrate into a balanced model framework
2) Determining ecosystem structure and biogeochemical function	1) Spatial and temporal variability	1) Determine influences of physical oceanographic and sea ice processes using observations and biophysical models to allow the distribution of key pelagic species to be parameterised on seasonal and annual timescales 2) Generate quantified analyses of seasonal and annual changes in habitat for key land-based predator species
	2) Ecophysiology and resilience	Determine physiological optima and tolerance limits for key Southern Ocean species
	3) Quantification of biogeochemical fluxes	Measure elemental fluxes at key locations over seasonal and annual cycles
	4) Influences of community structure on biogeochemical fluxes	Determine trophic interactions influencing nature, extent and temporal variability of biogeochemical fluxes
3) Driving policy in conservation and sustainability in the Southern Ocean	1) Scientific advice for conservation and management	Maintain a leading role in scientific committees and working groups: <ul style="list-style-type: none"> • CCAMLR Commission • CCAMLR Scientific Committee • CCAMLR WG-EMM • CCAMLR WG-ASAM • CCAMLR WG- FSA • CCAMLR WG-IMAF

		<ul style="list-style-type: none"> • CCAMLR Workshops (e.g. CEMP, Climate Change, MPAs) • ACAP • IWC <p>Input to other international treaties and working groups</p> <ul style="list-style-type: none"> • Regional Fisheries Management Organisations and other fisheries bodies • International Union for Conservation of Nature (IUCN) Red List • Convention on Migratory Species
	2) Innovative research in conservation management	<ul style="list-style-type: none"> • Lead in development of science for management of Southern Ocean ecosystems • Lead in development of alternative conservation, monitoring and management strategies
4) Providing international leadership in polar marine ecosystem research	1) Modelling impacts of Southern Ocean change on marine ecosystems	Further develop models at local and regional scales capable of predicting future climate impacts on marine ecosystems
	2) Optimising paths for ecosystems research into policy	Drive ongoing research into enhancing the interaction between stakeholders and scientists
	3) Synthesis of international Southern Ocean science activities	<p>Leadership in key international science steering groups and programmes</p> <ul style="list-style-type: none"> • SCAR, including SCATS • ICED • IMBER • EURO-MARINE
5) Managing fieldwork and securing the collection of field data	1) Facilitate the operation of Bird Island base for collection of population, demographic and diet data	<ul style="list-style-type: none"> • Recruit and train AEP staff • Arrange sampling permits • Oversee provisioning of base for supplies and scientific equipment • Manage AEP staff and provide oversight of data collection • Ensure data and samples are delivered and curated
	2) Facilitate the operation of Signy base for collection of population and diet data	<ul style="list-style-type: none"> • Recruit and train AEP staff • Arrange sampling permits • Oversee provisioning of base for supplies and scientific equipment • Manage AEP staff and provide oversight of data collection • Ensure data and samples are delivered and curated
	3) Collect population and diet data at King Edward Point	<ul style="list-style-type: none"> • Arrange sampling permits • Train AEP staff and provide oversight of data collection • Ensure data and samples are delivered and curated

	4) Lead scientific cruises to South Georgia sustained observation sites (South Georgia Core Box programme) including deployment and recovery of autonomous hardware (moorings, gliders, sailbuoys)	<ul style="list-style-type: none"> • Plan cruise objectives and sampling plan • Interact with cruise planning administration and support • Arrange sampling permits • Oversee preparation of equipment and packing • Implement cruise • Deploy and recover autonomous hardware • Ensure reports, data and samples are delivered and curated
6) Programme management	1) Provide oversight, quality control and strategic direction for delivery of NC-ALI science	<ul style="list-style-type: none"> • Pelagic Ecosystems • Higher Predators • Conservation and management • Executive

Table 2: Tool A (Sustained observation datasets)

	Description	Site	Lead contact(s)
A1	Epipelagic mesozooplankton abundance and biomass	Scotia Sea and South Georgia	Geraint Tarling
A2	Epipelagic and mesopelagic macrozooplankton and nekton abundance and biomass	Scotia Sea and South Georgia	Gabi Stowasser Ryan Saunders
A3	Phytoplankton abundance and biomass	Scotia Sea and South Georgia	Amanda Burson
A4	Macronutrient concentration and spatial distribution	Scotia Sea and South Georgia	Clara Manno Sally Thorpe
A5	Biomass and distribution of Antarctic krill from multifrequency echosounder surveys	South Georgia Core Box programme	Sophie Fielding
A6	Antarctic krill population / length frequency	South Georgia	Sophie Fielding Ryan Saunders
A7	Estimate of krill biomass and swarm shape characteristics from moored array	South Georgia Core Box programme	Sophie Fielding
A8	Temperature and salinity from spatial surveys	South Georgia Core Box programme	Sally Thorpe

A9	Temperature and salinity from moored array	South Georgia Core Box programme	Sophie Fielding
A10	Mesopelagic fish from RMT25 nets	Scotia Sea and South Georgia	Ryan Saunders Martin Collins
A11	South Georgia Groundfish Survey	South Georgia shelf	Martin Collins
A12	Biogeochemical flux biomass	South Georgia Core Box programme; P3 Mooring	Clara Manno
A13	Wandering albatross (population, productivity, survival, breeding, diet)	Bird Island	Ash Bennison Richard Phillips
A14	Black-browed albatross (population, productivity, survival, breeding, diet)	Bird Island	Ash Bennison Richard Phillips
A15	Grey-headed albatross (population, productivity, survival, breeding, diet)	Bird Island	Ash Bennison Richard Phillips
A16	Light-mantled albatross (population, productivity, breeding)	Bird Island	Ash Bennison Richard Phillips
A17	Northern giant petrel (population, productivity, survival, breeding)	Bird Island	Ash Bennison Richard Phillips
A18	Southern giant petrel (population, productivity, survival, breeding)	Bird Island	Ash Bennison Richard Phillips
A19	White-chinned petrel (population, productivity)	Bird Island	Ash Bennison Richard Phillips
A20	Brown skua (population, productivity, survival, breeding)	Bird Island	Ash Bennison Richard Phillips
A21	Macaroni penguin (population, productivity, survival, breeding, diet, provisioning)	Bird Island	Ash Bennison Norman Ratcliffe
A22	Gentoo penguin (population, productivity, breeding)	Bird Island	Ash Bennison Norman Ratcliffe
A23	South Georgia shag (population)	Bird Island	Ash Bennison Norman Ratcliffe
A24	Antarctic fur seal (population, productivity, survival, breeding, diet, provisioning)	Bird Island	Ash Bennison Jaume Forcada

A25	Leopard seal (population, survival, diet)	Bird Island	Ash Bennison Jaume Forcada
A26	Adélie penguin (population, productivity, breeding, diet)	Signy Island	Mike Dunn
A27	Chinstrap penguin (population, productivity, breeding, diet)	Signy Island	Mike Dunn
A28	Southern giant petrel (population, productivity)	Signy Island	Mike Dunn
A29	Gentoo penguin (population, productivity)	Signy Island	Mike Dunn
A30	South Georgia shag (population)	Signy Island	Mike Dunn
A31	Antarctic fur seal (population)	Signy Island	Mike Dunn
A32	Elephant seal (population)	Signy Island	Mike Dunn
A33	Beached marine debris	Bird Island / Signy	Ash Bennison Mike Dunn
A34	Marine plastics and fishing debris ingested by seabirds	Bird Island	Richard Phillips Claire Waluda
A35	Seal and seabird entanglements	Bird Island / Signy	Ash Bennison Mike Dunn
A36	Otolith analysis for commercial fish age structure	South Georgia	Martin Collins

Table 3: Tool B (Biophysical, ecosystem and statistical models)

	Description	Site	Lead contact(s)
B1	High resolution ocean model of South Georgia region	South Georgia	Emma Young
B2	High resolution sea ice-ocean model of South Orkney Islands region	South Orkneys	Emma Young
B3	Distribution and connectivity modelling of key pelagic species	Southern Ocean	Sally Thorpe
B4	Life cycle models of key pelagic species	Southern Ocean	Sally Thorpe
B5	Food-web models	South Georgia and Scotia Sea	Simeon Hill
B6	Krill-predators spatial overlap model	Southwest Atlantic Sector	Vicky Warwick-Evans
B7	Higher predator population dynamics models	South Georgia	Jaume Forcada
B8	Habitat distribution models of pelagic species	Southern Ocean	Jennifer Freer, Geraint Tarling

B9	Habitat distribution models of higher predators	Southern Ocean	Richard Phillips, Norman Ratcliffe
B10	Seabird-fisheries overlap and bycatch analyses	Southern Ocean	Richard Phillips

Table 4: Tool C (Sample collection infrastructure)

	Description	Site	Task	Lead Contact(s)
C1	Biophysical moorings	1) South Georgia Core Box programme (western) 2) South Georgia Core Box programme (eastern) 3) Northern Scotia Sea (P3)	Purchasing consumables, servicing relocation beacons, and physical oceanographic instrumentation	Peter Enderlein (AME)
C2	Sonobuoys (whale acoustics)	1) South Georgia Core Box programme (western) 2) South Georgia Core Box (eastern)	Servicing and recharging	Jennifer Jackson
C3	Sediment traps, water collectors and phytoplankton collectors	1) South Georgia Core Box programme (western)	Servicing, preparation of chemicals, recharging	Clara Manno
C4	Sailbuoys and gliders	1) South Georgia Core Box programme (western)	Servicing and piloting	Sophie Fielding
C5	PIT tag monitoring systems for predators	1) Bird Island 2) KEP	Servicing and operation	Ash Bennison

Annex 1: Management and conservation bodies: attendance and report writing

	Description	Lead contact(s)
D1	CCAMLR Commission	Martin Collins Susie Grant (representing SCAR)
D2	CCAMLR Scientific Committee	Martin Collins Simeon Hill
D3	CCAMLR WG-EMM	Simeon Hill Vicky Warwick-Evans
D4	CCAMLR WG-ASAM	Sophie Fielding
D5	CCAMLR WG- FSA	Simeon Hill Phil Hollyman (KEP Project)
D6	CCAMLR WG-IMAF	Richard Phillips
D7	CCAMLR Workshops (e.g. CEMP, Climate Change, MPAs)	Rachel Cavanagh Claire Waluda
D8	ACAP	Richard Phillips
D9	IWC	Jennifer Jackson
D10	SCAR Standing Committee on the Antarctic Treaty System (SCATS)	Susie Grant
D11	SCAR Action Group on Plastic in Polar Environments	Clara Manno Claire Waluda
D12	SCAR Krill Expert Group (SKEG)	Simeon Hill Geraint Tarling Sally Thorpe Sophie Fielding
D13	SCAR Expert Group on Birds and Marine Mammals (EG-BAMM)	Richard Phillips
D14	Support to KEP Project	Martin Collins (KEP Project) Phil Hollyman (KEP Project) Claire Waluda

Annex 2: Programmes and projects associated with NC-ALI Science programme, CONSEC

	Description	Lead contact(s)	Funder	Summary of remit
E1	KEP Project	Martin Collins Phil Hollyman	GSGSSI & FCDO	Research to support management of sustainable fisheries and the SGSSI Marine Protected Area.
E2	SCOOBIES	Clara Manno Geraint Tarling	NERC NC-SS	To obtain measurements on the flux of organic material to depth, and to measure associated ecosystem processes within the semi-permanent phytoplankton bloom in NW Scotia Sea
E3	Resolving the ecosystem effects of the South Georgia winter krill fishery (2021-2024)	Martin Collins Cecilia Liszka	Darwin Plus	Krill biomass and population processes in relation to higher predator populations in the South Georgia region during winter periods.
E4	Initiating monitoring support for the SGSSI-MPA Research and Monitoring Plan (2020-2023)	Phil Hollyman Martin Collins	Darwin Plus	Fixed wing drone surveys of key predator populations on South Georgia.
E5	Characterising pelagic biodiversity at South Georgia through novel sampling methods	Cecilia Liszka	Darwin Plus	Using standard and cutting edge sampling methods to establish a pelagic biodiversity baseline at South Georgia
E6	Improving identification of fish bycatch in the Antarctic krill fishery	Phil Hollyman Martin Collins	Darwin Plus	Develop improved understanding of the fish by-catch in krill fisheries, including different life stages and their distribution.
E7	Calculating the strength of the Plastic pump In counteracting the Deep export of Oceanic carbon CUPIDO; (2020-2024)	Clara Manno	UKRI Future Leader Fellowship	Investigate the impact of plastic pollution on the efficacy of the biological carbon pump.

E8	Spatial segregation and bycatch risk of seabirds at South Georgia	Victoria Warwick-Evans, Richard Phillips	Darwin Plus	Variation among colonies in distribution and fisheries overlap, and implications for population dynamics
E9	Monitoring albatrosses using very high resolution satellites and citizen science	Peter Fretwell, Richard Phillips	Darwin Plus	New technologies for determining population sizes and trends
E10	Resolving the life-history trade-off paradox: Measuring resource acquisition to reveal life-history trade-offs over different temporal scales	Richard Phillips, Andy Wood	NERC Pushing the Frontiers	Exploring the life-history trade off between breeding and survival in seabirds
E11	Can you hear marine snow falling?	Sophie Fielding, Clara Manno	NERC Exploring the Frontiers	Repurposing oceanographic current meter data to capture Particulate Organic Carbon fluxes at yet unresolved spatial-temporal scales