

King George Island and SCAR Science

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Purpose

The purpose of this paper is to stimulate the dialogue between SCAR and COMNAP on ways in which National Programs on King George Island (KGI) (appearing as 'Isla 25 de Mayo' on Argentine maps) might make a greater contribution to achieving the goals of SCAR's scientific programs. The development of the paper was motivated by discussions during the SCAR Workshop on the "Coordination of King George Island Science", held in St Petersburg on 6 July 2008, and attended by the Chairman of COMNAP, Dr José Retamales, who made several helpful suggestions about the way forward, and by other representatives of KGI operators; the topic was also discussed in broad outline by the SCAR and COMNAP Executive Committees at their joint meeting in St Petersburg. The COMNAP meeting in August 2009 is an opportunity to continue this dialogue. Wide comment was asked for and received from the many nations with long standing and active National Programs of scientific investigation on KGI that have great potential to build on historical partnerships and enhance future contributions to many SCAR scientific programs.

Background

The Scientific Committee on Antarctic Research (SCAR) is a leader and facilitator of international Antarctic science. As such SCAR has agreed to explore with COMNAP ways in which individual scientists and National Programs might improve coordination of science activities across King George Island (KGI) in the interest of encouraging a greater contribution from KGI activities to achieving the goals of SCAR scientific programs. It is recognized that the interests and prerogatives of National Programs remain sacrosanct. However, a coordinated and standard approach to data gathering, observations, logistics and utilization of infrastructure would benefit all nations on King George Island as well as SCAR's scientific programs.

There are scientific as well as economic and environmental protection imperatives for National Programs to work closer together in partnership (See separate paper on "Future Directions in Antarctic Science"). This paper explores the opportunities presented by the densest concentration of National Programs in Antarctica – King George Island (KGI). KGI and its complex of infrastructure, stations, logistics, and scientific programs provide a unique opportunity to explore how cooperation across Antarctica and the Southern Ocean might benefit from closer coordination. This paper summarizes the potential scientific benefits to be derived from joint programs, coordination, and cooperation on KGI, as the basis for discussions with COMNAP about next steps.

At the outset, it is recognised that there are many excellent examples of scientific and logistics cooperation amongst National Programs on KGI, for example: in creating an archive of meteorological and upper air data; in analysing climate parameters; in coordinating glaciological research on the age of the KGI ice cover; in conservation and environmental monitoring in Admiralty Bay; in permafrost dynamics; and in analysing

sea surface temperatures. An example of scientific cooperation is Dallmann Laboratory at Jubany Station. However, additional benefits could be derived by integrating these efforts within the framework of SCAR's scientific programs (see Appendix I for a summary of current programs). These collaborations could establish the foundations for future SCAR programs.

The King George Island Setting

King George Island is one of the South Shetland Islands. It is located close to the northern tip of the Antarctic Peninsula in the Maritime Antarctic climatic zone. Cape Horn of South America is about 900 km to the north. The island is dominated by a pervasive ice cap with more than 90% of the island being glaciated. The ice-free areas and coastal zones of the island include diverse flora and fauna including penguins, seals, petrels and relatively rich tundra vegetation. The following descriptions of Admiralty Bay on King George Island are from the plan for an Antarctic Specially Managed Area (ASMA No.1) and are provided as illustrative of the larger KGI region. Admiralty Bay is typical of bay/fjord settings in the South Shetland Islands. The ice-free areas within Admiralty Bay are formed by pebble-cobble beaches, moraines, mountainous peninsulas, rocky islets, spurs and nunataks. The terrain is heavily shaped by glacial and coastal marine processes. The area of Admiralty Bay is representative of the terrestrial, limnic, coastal, near-shore, pelagic, and fjord bottom ecosystems of KGI. Plants are mostly mosses (about 70 species), liverworts (22 species), and two flowering plants, and fungi and lichens (almost 300 species) are common. Twenty-four species of birds and six species of pinnipeds have been identified in the area, but only thirteen species of birds and three species of pinnipeds breed in the area. The bay ecosystem reflects the general environmental conditions prevailing in the South Shetland Islands, with rocky shores covered by extensive subtidal macroalgal communities. There is a unique site, Napier Roc, where a rich and highly diverse benthic invertebrate fauna is found. Fish are represented by fifteen species of Nototheniidae. The peninsula region is also the area in Antarctica experiencing the most rapid and pervasive global warming on our planet. KGI is a mesocosm of the change that is occurring in response to climate warming and a test-bed for predicting future responses to climate change.

Human Activities on King George Island

King George Island is the site with the greatest concentration of national research activities in Antarctica and arguably the world. Human activities on the island are based on nine permanent stations and an airstrip maintained by the Chilean Air Force. Human activities on KGI date to the early 19th century, when the island was discovered and the first sealers arrived. Within a few years the fur seal and sea elephant populations were harvested almost to extinction. At the beginning of the 20th century whalers used the island's natural harbors and sheltered beaches. Whale bones can still be found on many KGI beaches. Today the following nations have a presence on KGI (those with asterisks have permanent stations): Chile*, Argentina*, Poland*, Germany, Uruguay*, Brazil*, Peru, Ecuador, China*, Korea*, and the Russian Federation*. Others; like the Netherlands, UK and USA; also carry out research on the island.

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Scientific activities on KGI include: meteorological, hydrological, geophysical, biological, geological, sea ice, greenhouse gases, and glaciological research. Many features of KGI

are of considerable scientific interest and of direct relevance to SCAR scientific activities and programs. Existing and future research efforts on KGI have the potential to significantly contribute to SCAR science. The SCAR KGI Geographical Information System (GIS) provides a framework for integrating collected data and information, and for training. The studies being conducted in and around KGI have been broadly categorized as pertaining to the geosciences, the life sciences, or the physical sciences (as defined by SCAR), as the basis for highlighting how KGI activities might contribute to SCAR scientific programs. It is recognized that many of the nations that conduct research on KGI are active participants in SCAR science projects and partnerships, and so linkages, coordination, and partnerships already exist in many instances. The intent is to explore synergy amongst programs and identify where mutually beneficial enhancements might be achieved.

During 2001 to 2003, three KGI scientific meetings were held at Artigas Stations (URG) with the logistics support organizations, resulting in a fruitful exchange of information and sharing of experiences by researchers from all the stations on the island. This is a model for future interactions.

Life Science – Studies of marine and terrestrial biology, including physiology and adaptation of Antarctic fish and krill; taxonomy and ecology of marine benthic fauna and flora (micro- and macro-algae), vascular plants, mosses and lichens; terrestrial and marine ecology; and migration and dispersion of birds is being conducted on KGI. There is also a CliCOPEN project on the response of marine and terrestrial ecosystems to deglaciation related to regional warming, in which Poland, Argentina, Chile, Uruguay, and Korea participate. A long-term research project on the biology and dynamics of bird populations (mainly Pygoscelid penguins) has been carried out by the US Antarctic Program since 1976. There has been routine collection of data on the distribution and reproduction of the Southern Giant Petrel and on skuas on KGI.

A excellent example of scientific collaboration is that by the Argentine-Germany jointly-managed laboratory (Dallmann), which has operated at Jubany Station since 1994 as the first bi-national facility in Antarctica. This facility operates from September to March each year developing joint scientific projects (including participation by the Netherlands). The main focus of research is the communities of the marine terrestrial transition zone and the shallow water environment of Potter Cove.

The Admiralty Bay Benthos Biodiversity Database (ABBED) is a cooperative project initiated by the Royal Institute of Natural Sciences of Belgium and the University of Lodz, Poland in collaboration with the Federal University of Rio de Janeiro, and the University of Sao Paulo, Brazil. The project is developing an interactive database on the biodiversity of benthic communities of Admiralty Bay, the largest fjord of KGI, for scientific monitoring, sustainable management and conservation purposes. Networking activities are coordinated by Belgium under SCAR-MarBIN. This project compiles, integrates and disseminates information on Admiralty Bay biodiversity and ecology.

These studies and others are particularly relevant to the science of the SCAR Standing Scientific Group on the Life Sciences, its Expert Group on Birds and Marine Mammals, and its Scientific Research Program on Evolution and Biodiversity in the Antarctic (EBA). These KGI studies and data support the overall EBA objectives of understanding the evolution and biodiversity of life in the Antarctic and provide objective scientific advice to the conservation policies of the Antarctic Treaty System. KGI studies also

inform EBA's objective of understanding how evolution and diversity have led to the present status of ecosystems in the Antarctic and how these ecosystems will respond to future change.

The EBA research agenda would benefit from inclusion of marine and terrestrial biological and ecological data from KGI in addressing the following scientific objectives:

- Determining the spatial and temporal variations in diversity at different spatial scales within the Antarctic and within defined time frames.
- Understanding the ability of Antarctic organisms to cope with daily, seasonal and longer-term environmental changes.
- Study of ecological responses to latitudinal and environmental gradients on local, regional and global scales.
- Discerning the role of natural and anthropogenic dispersal processes in gene flow and population structure.
- Understanding interactions between introduced and indigenous species, the effects of abiotic change on biota, and how environmental change and organism responses are linked to climate.

KGI terrestrial and freshwater biological data enhances SCAR's Antarctic Biodiversity Database at the Australian Antarctic Division (<http://data.aad.gov.au/aadc/biodiversity/>). SCAR-MarBIN is a distributed system of interoperable databases, forming the Antarctic Regional Node of the international Ocean Biogeographic Information System (OBIS, which is part of the Global Biodiversity Information Facility (GBIF)). KGI biological and ecological data is also relevant to the CCAMLR Ecosystem Monitoring Program (CEMP) and the work of the SCAR Scientific Committee on the Antarctic Treaty System that deals with the protection status of various Antarctic species. Marine biological studies contribute to SCAR's Census of Antarctic Marine Life (CAML).

Geosciences - Studies on King George Island include geology, geophysics, and paleontologies as well as glacio-marine sedimentation in Admiralty Bay. These various studies do, or have the potential to, support the science programs of SCAR's Standing Scientific Group on Geosciences.

Magnetic data from KGI is part of SCAR's Antarctic Digital Magnetic Anomaly Project (ADMAP). A year-round seismic and Earth-magnetism observatory, established at Arctowski Station in 1978, was the first station of its kind in the South Shetland Islands. Studies on geomagnetism have been conducted at Ferraz Station since 1984. A permanent seismic observatory has been operated at Jubany Station since 2004, as part of the Antarctic Seismological Argentina-Italy Network (ASAIN). These studies will be important to the emerging SCAR Scientific Research Program on Solid Earth Responses and Influences on Cryosphere Evolution (SERCE), which will improve the coverage of geophysical data across Antarctica

An absolute value of gravity was determined for the first time in KGI in Dec. 1997 at Jubany station. Two geodetic GPS sites, DAL1 (1995) and DALL (1997), were integrated into several SCAR Epoch GPS Campaigns (now SCAR Epoch Crustal Movement Campaigns). DALL was a Continuous GPS (CGPS) site for almost four years (1997-2001). DAL2 is a CGPS site at Jubany, and has operated since Feb 2003. Tide gauges were also deployed several times for geodetic purposes between 1996 and 2000 at Jubany

gathering multi-year data sets. Complementing the GPS observations, a seismological station was deployed at Jubany for geodetic purposes in 1998 for several months to better understand regional geodynamic behavior. A permanent seismic observatory has been operated at King Sejong Station (KOR) since 1990. A broad band seismometer was installed and has been in operation since 2001. As an observatory of INTERMAGNET, supported by USGS, the site has measured an absolute value of the geomagnetic field since 2003, and provided a base-line for geomagnetic observations since 1990. A permanent GPS site was established by Korea in 2005.

Uruguay, at Artigas station, has participated in the SCAR EPOCH program since 1997, operating a water level recorder since 1989 and reporting the data to the PSMSL program on tidal predictions

Terrestrial evidence of Antarctica's paleo-climate are the outcrops on KGI of the tillite of the alpine Eocene glacial event in Harve Cove, the early Oligocene glacial and glacial marine sediments of the Polonez Formation, and the Miocene glacial marine diamictite of the Melville Formation (investigated recently by SCAR's Antarctic Climate Evolution [ACE] program).

Physical Sciences – KGI is undergoing dramatic glacier recession and environmental change. The glaciological setting of KGI and the predominance of an ice cap make it an ideal location for glaciological and climate change studies. Short- and long- term climate and weather observations and information from ice cores complement SCAR science programs of the Standing Scientific Group on Physical Sciences.

In the 1990s, three international expeditions carried out extensive investigations on the King George Island (KGI) ice cap. They were organized and logistically supported by the Brazilian Antarctic Program organized as the “Glaciology of the South Shetland (GLASS)” program supported by SCAR. Topics included: 1) mapping and monitoring of glacial drainage basins fluctuations using remote sensing techniques, 2) a shallow firn and ice coring program, 3) geophysical surveys to determine ice thickness and internal structure, and 4) climatology of the ice cap. Results showed an ice cover of 1,044 km² (91.7% of KGI) with a maximum thickness of 395 m. The KGI ice cap lost 65 km² from 1956 to 2000 in response to an increase of the mean annual atmospheric temperature of 1.1°C from 1947 to 1995. The upper 2-3 m of the snow pack provide data representative of the original precipitation composition (Simoes et al, 2004 Pesquisa Antártica Brasileira (2004) 4: 1-8, ISSN 0103-4049).

Studies of glacial retreat (including historical documentation covering the last 50 years) and recovery of ice cores contribute to the AGCS study of global and regional climate signals to establish better quantitative relationships between ice core data and measures of high latitude climate variability. KGI data support AGCS efforts to model natural and anthropogenic forcings on the Antarctic climate system as a basis for estimating expected climate change over Antarctica during the next 100 years. Ice core records of climate change from KGI contribute to SCAR's International Trans-Antarctic Scientific Expedition (ITASE) designed to study the last 200 years of Antarctic climate and environmental change.

More recently, IMCOAST, an interdisciplinary research project, links the causes and effects of rapid climate change in the marine coastal environment of the Antarctic Peninsula. IMCOAST builds directly on IPY-34 clicOPEN (climate change in coastal

areas of the Antarctic Peninsula) and is planned to be a high-resolution investigation focused on KGI. The study capitalizes on the unique facilities of the nine permanent research stations and historical information on coastal system status and functioning during the past 15 – 50 years. A team of glaciologists, geochemists, geologists and biologists will study the impact of regional warming, the effects of retreat of glaciers on the coastal sedimentary environment, and patterns of deposition and sediment transport to the open ocean. The effect of changes in run-off and suspended matter will be linked to observed shifts in coastal ecosystems, including studies of water column and benthic systems. The program will evaluate the impact and strength of late Holocene warm phases on KGI coastal systems. A joint database will be established for archiving new data as well as historical KGI data sets, adhering to accepted data archiving and access standards. IMCOAST strengthens international cooperation by bringing together nine European and three South American institutions combining long-standing experience in Antarctic research and novel data collection techniques at a regional scale.

A meteorological station has been operational at Arctowski Station since 1977, at Ferraz Station since 1984, and at King Sejong Station (WMO Index No. 89251) since 1988. These sites collect basic data to support logistic operations but also support broader scientific investigations. The parameters measured include atmospheric observations including trace gas concentrations (including green house gases), energy flux, and physical aerosol properties. Stratospheric total ozone measurements have been measured since 1997 at the King Sejong Station using a Brewer Ozone Spectrophotometer. Spectrophotometers for ozone measurements have been installed and operate year-round at Artigas Station (URY). Research on upper atmosphere winds is being developed at Machu Picchu Station (Peru) using MST radar. Since 1998, temperature and winds in the upper atmosphere have been measured at King Sejong Station using optical instruments such as FPI (Fabry Perot Interferometer), Michelson Interferometer, and SATI (Spectral Airglow Temperature Imager), and Meteor Radar.

Meteorological and climate data from KGI, the Antarctic Peninsula, and southern South America are important to regional climate models for climate forecasts by SCAR's Scientific Research Program on Antarctica in the Global Climate System (AGCS). KGI meteorological studies contribute to AGCS's study of decadal time scale variability of Antarctic climate and the SCAR Expert Group on Operational Meteorology in the Antarctic, which is designed to assist in real-time weather forecasting. A much larger number of surface meteorological observations are being made across KGI, and support improved understanding of micrometeorological responses to local topographic variation. KGI data are provided to the WMO Global Synoptic Network for climate studies. SCAR has developed a centralized archive for meteorological measurements in its READER database. In the past, KGI meteorological research has also provided upper air data obtained by balloon-launched radiosondes. These measurements were suspended in 1999. Reinstatement of the radiosonde program could be facilitated by making use of the launch facilities at the Bellingshausen Station (RUS). Since February 1994 a joint Argentine-Italy programme has monitored atmospheric CO₂ concentrations at Jubany Station taking two samples per second year round.

Studies on the ionosphere and astrophysics have been conducted at Ferraz Station since 1984. These studies support the objectives of the SCAR Research Program on Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR).

Environmental Protection - A comprehensive study of the state of the environment in the area is underway at Ferraz Station including analysis of biotic and abiotic variables. Results from this KGI program serve as a baseline for future monitoring and for implementing environmental management of the ASMA. These studies inform ongoing discussions about the design of monitoring programs now before the Committee on Environmental Protection (CEP) of the ATS. As a location of human activity and known disturbance, data and observations of contaminants at KGI support the objectives of the SCAR Expert Group on Environmental Contamination in Antarctica. KGI monitoring is carried out to support the IPY-ALIENS project on invasive species as well.

Summary

As can be seen from the above partial summaries of current and past scientific activities at KGI, the real and potential linkages with SCAR scientific programs are many and varied. The opportunities for KGI operations to support and enhance SCAR science programs are exceptional. Close cooperation between KGI National Programs and SCAR science programs can add value to KGI studies by providing a regional, continental and global context for interpretations and comparisons. Standardized techniques and measurements, common sets of variables, and open access to data are essential for cross-comparison of data sets from diverse locations and scientific teams not only at KGI but more broadly in Antarctica. Because of the extensive life science, geoscience, and physical science studies being conducted at KGI, greater inter- and multidisciplinary integration is possible than can be achieved at most locations. Unforeseen synergies and assimilation of coordinated scientific research will most assuredly be an outcome of closer collaboration, coordination, and partnership. These outcomes will benefit National Programs on KGI as well as SCAR. Access to archived scientific data and information is essential for realizing these synergies. Mutually beneficial cooperation and partnerships can be realized at KGI if duplication of efforts is minimized, infrastructure and logistics are shared to reduce costs and impacts, and standard techniques and sets of variables are agreed. The realization of these opportunities can best be achieved through enhanced, mutually beneficial partnerships and bi- and multi-lateral agreements to advance common goals. SCAR is ready to assist National Programs in moving forward for the benefit of the wider scientific community and the stewardship of Antarctica.

APPENDIX I

SCAR SCIENTIFIC ACTIVITIES

(for details see <http://www.scar.org/researchgroups/>)

Standing Scientific Group on Geosciences

ACE: Antarctic Climate Evolution

ADMAP: Antarctic Digital Magnetic Anomaly Project

GIANT: Geodetic Infrastructure of Antarctica

IBCSO: International Bathymetric Chart of the Southern Ocean

PPS: Permafrost and Periglacial Environments

SALE: Subglacial Antarctic Lake Environments (joint with life sciences, below)

SERCE: Solid Earth Responses and Influences on Cryosphere Evolution

SIeGE: Sub-Ice Geological Exploration

Standing Scientific Group on Life Sciences

BAMM: Birds and Marine Mammals
CAML: Census of Antarctic Marine Life
CPR: Continuous Plankton Recorder
CSHM: Cold Seeps and Hydrothermal Mounds
EBA: Evolution and Biodiversity in the Antarctic
HBM: Human Biology and Medicine
MarBIN: Marine Biodiversity Information Network
PCPBEA: prediction of Changes in the Physical and Biological Environment of the Antarctic (joint with SSG-PS – below)

Standing Scientific Group on Physical Sciences

AAA: Antarctic Astronomy and Astrophysics
AGCS: Antarctica in the Global Climate System
ASPeCt: Antarctic Sea Ice Processes and Climate
ECA: Environmental Contamination in Antarctica
GWSWF: GPS for Weather and Space Weather Forecasting
ICESTAR: Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research
IPICS: International Partnerships in ice Core Science
ISMASS: Ice Sheet Mass Balance and Sea Level
ITASE: International Trans-Antarctic Scientific Expedition
Oceans: SCAR/SCOR Oceanography Group
OpMet: Operational Meteorology
PACT: Polar Atmospheric Chemistry at the Tropopause
PAntOS: Pan-Antarctic Observing Systems Network