PCAS 15 (2012/2013)

Supervised Project Report
(ANTA604)

Compilation and Critique of PCAS Environmental Monitoring

Fixed Point Photo Survey and Visual Assessment of Ground Disturbance

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Executive summary

Since 2004, environmental monitoring has been undertaken in the vicinity of Scott Base by students participating in the Postgraduate Certificate of Antarctic Studies (PCAS). This is performed on behalf of Antarctica New Zealand (AntNZ) and, as a part of a wider environmental impact assessment scheme, fulfils monitoring obligations under national and international regulations. PCAS students have gathered a range of information for five projects; a fixed point photo survey, a waste audit, visual assessment of ground disturbances, vegetation monitoring, and litter surveys. A selection of these projects is performed annually and the results and recommendations supplied to AntNZ. To date there has been no compilation of data collected each year and therefore a lack of meaningful results showing temporal trends. There has also been no administrative review of the projects since the pilot in 2004/05 and the reports and recommendations provided to AntNZ annually range in quality and utility.

This report compiles the data from the fixed point photo survey and visual assessment of ground disturbance projects. A critique of each project is also included including suggesting changes to project design in the future. The compiled fixed point photos show little change in the Scott Base environment since 2006. The majority of the changes track the movement of temporary storage around the base. This information is superficial and of little use to AntNZ. It is recommended that the project include more photo points looking away from Scott Base to track growth in the Scott Base footprint. To allow better comparison of photos a database of original photos should also be established. Data from visual assessment of ground disturbances has limited usefulness in its raw form. Location of monitoring has differed each year and so analysis of temporal changes is not yet possible. There has also been variation in the quality of observations in past years so the assessment form has been changed to provide clear criteria for future observers. Geographic Information System (GIS) software was used to analyse compiled data and the maps created suggest that, as would be expected, disturbance decreases with distance from Scott Base facilities and infrastructure. If this data is used as a baseline to monitor changes over time, this project has the potential to effectively track cumulative impacts in the Scott Base environment.

Accompanying Materials

Along with this report a range of materials are provided for both Gateway Antarctica and Antarctic New Zealand to supplement this report and for use in the future by students and staff.

- Database of project documents including digital copies of previous reports, administration documents and other relevant reports written by PCAS students. These files have been renamed to provide clarity and assist in future file storage.

- Spreadsheet with a list of participants of photo, visual and vegetation projects since 2004/05 (In folder named 'Data compiled by Josie').

- Spreadsheets and documents with compiled photo survey and visual disturbance data. Please note that I have filed these in a separate folder ('Data compiled by Josie') to clearly show which documents I have created for this individual project. They should be moved to their relevant folders once marking is completed.

- GIS geodatabase with digitised data from photo and visual projects which can be added to by future participants with GIS skills. This geodatabase also includes a number of reference layers provided by LINZ and Google Earth. Please note that files from this folder should not be moved or edited unless through ArcGIS software.

- PDF files of maps created using GIS to showing key results of photo and visual projects these are referred to in the text of this document.

- PDF of paper written Campbell *et al.,* in 1993 that outlines the visual assessment of ground disturbance method and which is not readily available online.

Contents

Background

New Zealand has operated a permanent scientific base in Antarctica for 55 years. The collection of huts established for the Trans-Antarctic Expedition in 1957 has evolved into a network of 11 buildings connected by covered walkways, with 6 outbuildings and a number of storage facilities (some permanent and others temporary). During this period Pram Point, on which Scott Base is located, has been extensively modified by human activity. Human disturbance of Antarctic environments is a major issue as the climatic conditions make the ice free areas of the continent prone to damage. As a consequence of slow vegetative growth and minimal movement of soil material these disturbed areas also show slow recovery rates (Campbell, Balks, & Claridge, 1993, p. 321).

Some environmental disturbance is unavoidable when working in Antarctica, especially when conducting large scale activities such as establishing and operating a scientific base. Recognising this issue, both national and international governing bodies have implemented regulations on human activity in Antarctica. These regulations require that all activities be carefully planned to identify potential environmental impacts and reduce or mitigate any adverse effects. These regulations also require operators to monitor their established activities to continuously improve on their environmental management systems (Kennicutt, Sayers, Walton, & Wratt, 1996).

The Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol), established in 1991 states:

> "*Regular and effective monitoring shall take place to allow assessment of the impacts of on-going activities, including the verification of predicted impacts [and] to facilitate early detection of the possible unforeseen effects of activities carried on both within and outside the Antarctic Treaty area on the Antarctic environment…*" – Article 3, 2(d) and (e).

The regulations in the Madrid Protocol are enforced in New Zealand through the Antarctica (Environmental Protection) Act of 1994.

Further to its requirements for monitoring as an operator in Antarctica, Antarctica New Zealand (hereafter AntNZ) has adopted principles of sustainability into their core values. They aim to "incorporate principles of social, environmental and financial sustainability into everything that they do" (Antarctica New Zealand, 2010, p. 2). AntNZ performs a

range of monitoring programmes around the Scott Base to fulfil its monitoring requirements. These include monitoring of; non-native species incursions, waste water treatment, waste production, energy management, water use and fuel use and spills. While these are important monitoring projects, none capture the cumulative effects on the environment that occur around Scott Base. Cumulative impacts can be difficult to measure as they occur gradually over time, but monitoring is important to assess the health of an environment affected by constant and long-term human activity.

In 2004 AntNZ approached Gateway Antarctica with the possibility of conducting environmental monitoring of cumulative impacts as a part of the Postgraduate Certificate in Antarctic Studies (PCAS). Each PCAS group travels to Antarctica for two weeks in late December or Early January and can undertake data collection during the time spent at Scott Base. PCAS is well suited to perform environmental monitoring as they return at a similar time each year, have the required manpower and have the skills and knowledge needed to undertake monitoring and make useful interpretations of data. A pilot study was conducted by PCAS in 2004/2005 and has continued, in different forms, for the last eight summer seasons.

PCAS students have gathered information for five projects; fixed point photo monitoring, a waste audit, visual assessment of ground disturbances, vegetation monitoring, and litter surveys. A selection of these projects is performed annually and the results and recommendations are supplied to AntNZ for incorporation into their environmental management system.

To date, there has been no compilation of the data collected annually by students. Each year students have compared results to a previous years' report. However there has been no consistent comparison method and temporal patterns have not been recognised as were expected in the original aims. Further problems have arisen due to administrative changes. With staffing and role changes in both AntNZ and Gateway Antarctica the responsibility for PCAS monitoring projects has become unclear. Over the past few years the projects have not received the attention by either organisation that is needed to provide sound, useful information to AntNZ.

This year two PCAS students, Richard Kennedy and I, have addressed these issues in for our individual projects. Richard has reviewed the litter survey and waste audit projects

while I have focused on the photo monitoring and visual assessment projects. The vegetation survey has been omitted as there was only three years of data which was of poor quality and difficult to analyse.

The following report compiles and analyses the data collected by PCAS students for the photo monitoring and visual assessment projects. A critique of each project has also been carried out, using criteria outlined in Kennicutt *et al.* (1996 p.37). This outline is included in Appendix 1. Lastly, recommendations are made to AntNZ and Gateway Antarctica for changes to the projects that will increase the quality and usefulness of results in the future.

1. Fixed Point Photo Monitoring

1.1. Compilation of Data

1.1.1. Report History

The fixed point photo monitoring project is the longest running project PCAS participates in. Photo data for Scott Base has been collected around Scott Base since 1994. The objective of this project is to identify and quantify the extent of any observable changes in the vicinity of Scott Base by taking panoramic photos at 7 fixed points around the base and comparing them to photos from the previous years. This method allows for the medium to long-term assessment of cumulative impacts in the local area. The photos provide a valuable long-term record of changes to Scott Base and the surrounding area.

Before PCAS took on the monitoring project data collection and analysis was completed by AntNZ staff. These photos were mostly captured on film and are stored at AntNZ. In 2004/05 a PCAS student, Nicola Jackson, analysed the photos collected in the ten year period 1994- 2004. In her analysis she used a grid method to quantify changes in land use over time at Scott Base. This involved placing a grid over the photos and counting the number of units covered by each land use category. The results showed little change in the Scott Base footprint over the 10 year period. The author also noted that the quality of results was severely limited by the analysis technique. Variables such as snow cover and the focal length of photos made tallying grid squares in comparable areas between the photos difficult (Jackson, 2005).

PCAS took over the photo monitoring project in the 2005/06 season and has, for the most part, used the same method established by AntNZ in 1994. The grid analysis technique has

been replaced with qualitative assessment of changes observed. There have also been different points and perspectives for photos added by various participants over the years. Variation in the material provided for students each year to locate photo sites however, meant that students did not always replicate new points added by previous students. Only one point, Site 8, has been continued with any consistency by successive student groups.

1.1.2. Methods

To compile the photo point data reports from the previous years were collected and sorted to create an organised database. There are a number of reports missing from the database which are noted in the spreadsheet; including all reports from 2005/06 (possibly monitoring did not take place that year although successive reports make reference to them).

The GPS location of photo points were gathered, where available, from reports and recorded in an excel spreadsheet (included in accompanying materials). These points were then plotted using GIS software (ArcGIS 10.1). This allowed comparison of photo point locations over the last 7 years. GIS was used for analysis of both photo monitoring and visual disturbance data. With this software data is used to create 'layers' that are overlaid on maps to display data spatially. There were some reference layers available from Land Information New Zealand (LINZ) such as coastlines, roads and topographic maps. However the topographic maps were not of a high resolution so were not useful at a large scale (close up), Since no other resources or aerial photos were available images sourced from Google Earth were imported and georeferenced (matched up) to known locations. Due to perspective distortion of aerial photography it is difficult to accurately match georeferenced photos to features. This problem was experienced during my analysis, for example where some points appear to lie on top of buildings. The maps provided with this report should therefore be used as a reference only until better imagery can be sourced.

To compare the photos by year the photos were copied from previous years' reports into a single document (included in accompanying materials). There were no original photos available ant AntNZ or Gateway for any of the last 8 years. The photos submitted with each report were often compressed and of a poorer quality than the originals and is a significant limit to the quality of this analysis. Changes between years were found by comparing photos and also by reviewing the reports from previous years. These were compiled in the photo survey spreadsheet.

1.1.3. Results

The changes observed by students at each site are documented in the compilation spreadsheet. Brief summaries of these changes are recorded below.

Site 1: HFC

This area is one of the more dynamic areas of Scott Base as it is the main entry to the base off the back transition. It is used for temporary storage of containers, wanagans, trailers and other items that don't need to be dragged further up the hill. Traffic through the area is high but tracks are mostly confined to the centre of the road. Each year shows changes in the items stored here although it appears as though items have been stored in a more orderly manner since 2009/10 (excluding 2011/12).

Site 2: Garage

This area shows the 'backyard' of Scott Base which appears to be used as a long-term storage yard. There are lots of construction materials stored here in various states of order. Major permanent changes are limited to two permanent storage containers near the HFC and the addition of the HFC walkway in 2009.

Site 3: Base Panorama (Back)

Site 3 gives a very good shot of Scott Base and its 'disturbance footprint'. Changes in the storage of items occur each year but generally there is no increase in the footprint up toward the camera site.

Site 4: Aerial Farm

The aerial farm is a little disturbed area of Scott Base with no vehicle tracks and human movement restricted to walking tracks. Little change is observed over the years but debris can be seen in many photos and is clearly not in use but has not yet been cleaned up.

Site 5: Shoreline

This site is also a low traffic area and little change has been noted over the years. Activity seems to be restricted to the vicinity of the waste water treatment plant.

Site 6: Base Panorama (front)

This site is another good panorama of Scott Base. The whole front of the Base can be seen along to the Hangar. Changes in storage are evident around the Hangar and the Administration building deck has been extended in 2009. Otherwise most of the traffic keeps to the road leading to the front transition. This is clear because snow has melted near the road in 2012/13 but still clean and untracked off the road, suggesting that these areas are not driven on.

Site 7: Flagpole

The flagpole site tracks the changes in storage containers around the Hangar. Apart from a wood storage area build on the side of a vehicle garage in 2010/11 there has been little permanent change.

Site 8: Inside HFC

This site was added by survey participants in 2007/08 and has been replicated another three times since then. These photos give an excellent view of the temporary storage area near the back transition. Changes in items stored are noted but have been confined to the same areas each year and have not 'crept' outward. Some areas are even cordoned off to protect areas from disturbance by vehicle traffic.

Over the last seven years there has been little major change observed in the photos taken of Scott Base facilities. Minor permanent changes in buildings, such as the walkway around the HFC (installed in 2009) and the extension of the administration building deck (also 2009) can be tracked in the photos. Most of the observed changes are in the movement of containers and equipment in the short and long term storage yards around the working areas of Scott Base. It was observed that vehicle traffic around base stays on the road, with no tracking observed off main routes running around Scott Base. Overall there has been no observed increase in the footprint of Scott Base, constant and long term activity has been confined to the same areas since 2006/2007. This suggests that activity around Scott Base has been well managed and further extension of working areas has been actively discouraged.

1.2. Project Critique

1.2.1. Project Design

As outlined above (section 1.1.1) the photo monitoring project aims to track changes in the Scott Base vicinity and assess the cumulative impacts of human activity over time. The current design of the report provides valuable photographic records of Scott Base at known locations over time. The photo points have been fixed now for almost 20 years and during this time the footprint of Scott Base has almost certainly grown. The last 7 years of observations have not recorded any increase in the footprint and while this is a good result it may also suggest that the photos are not 'looking' in the right direction. All of the original photos look inward toward the base from near the edge of the Scott Base footprint. These perspectives mainly record changes to the Scott Base buildings. This is at best a superficial look at the changes occurring around the base and does not provide AntNZ with any information that they will not already have in building and maintenance records. Furthermore many of the areas between the photo points and buildings are subject to heavy and constant traffic (both human and vehicular). These areas are already highly disturbed and it is unlikely that these areas will see observable degradation or improvement between years.

To better record the cumulative impacts occurring around Scott Base AntNZ should seriously consider modifying the photo points to have a more 'outward looking' view of activities around Scott Base. This observation has been made by almost every report produced by PCAS students since 2007/08. Change to an 'outward' view could be achieved by adding new points and retiring some of the older, less useful photo points or by adding new perspectives to each location.

Some new points and perspectives have already been added over the years, with varying levels of success. Site 8 was added in 2007/08 and has been replicated by three out of five successive years. The site is high up and looks out over a dynamic area of Scott Base. Future points should follow this criteria and be taken from high points around the base looking down on working areas around Scott Base. Such places would be; other windows in the HFC or the library in Q hut, verandas, and on the hills overlooking the base. In 2009/10 the photographers took photos in the opposite direction from each photo point in addition to the standard perspective. These views were replicated again in 2010/11 and 2011/12. The report by Chris Gregory in 2011/12 has the first clear comparison of these new perspectives, and a few minor changes were observed. Some of these 'opposite' photos

capture outward looking views while others look directly at buildings. The table in Appendix two reviews the current points (including the added perspectives from 2009/10) and suggests possible locations for new points. It is not expected that all suggestions be implemented because it would then be too time consuming for students to take photos for all of the locations however some change should be seriously considered.

1.2.2. Preparation and Materials

There is little preparation needed in New Zealand before carrying out this project at Scott Base. The students however need to be able to take quality panoramic photos and operate a GPS. Generally the quality of panoramic photos has been high, the project has probably attracted students that are interested in photography and they would have the skills and equipment necessary to collect quality data. On the other hand there has been variation in the quality of GPS information supplied by students. In some years no GPS points are taken at all and in others they are recorded inaccurately. Basic GPS training in New Zealand would be helpful for students doing this project.

The tools necessary for this project are a camera, tripod and GPS. While it was useful taking photos with the same camera each year when film was still in use, this no longer an issue. Digital photography technology improves constantly and a camera used specifically for this project would outdate quickly, while the students are likely to have modern, high quality cameras. The tripod and GPS have typically been supplied by the University of Canterbury Geography department and it is important that the students arrange this equipment before they head south.

1.2.3. Data collection

Over the last 7 years PCAS students have had little trouble locating the photo monitoring sites. The descriptions supplied to the students usually have a combination of GPS points, site descriptions and a photo of the camera setup at the sites. As a result the photos have been replicated well each year. Appendix 3 contains a map showing the GPS locations recorded at each site by the different project groups. This map will also be useful to understand the changes in photo points suggested in Appendix 2. The photo sites were replicated best when they are located close to a fixed point. The GPS readings have a margin of error of around 5m so a fixed location enables student to better locate the camera position. In the map some photos have been taken away from the true site location, this is usually because the site or view has been blocked by objects moved to the site

temporarily. Future photo points should therefore be located on or near permanent features.

Each year a previous report has been supplied to students to help them locate photo points and replicate the photos. The report supplied has changed over the years and was not necessarily a report from the previous year. This is why attempts by students to include new photo points and different perspectives have not been replicated consistently in successive years. In the future a standardised photo sheet should be provided each year and reviewed annually according to the recommendations made by students. This will be especially important if any changes are made to the photo sites as a result of this critique.

1.2.4. Analysis of Results

As mentioned in section 1.1.1 on page 3 the analysis of photos is done on a qualitative basis, comparing photos to previous years by sight. Attempts to analyse the photos using quantitative methods have been unsuccessful. There is a major issue that has been identified annually by students but which has not received any attention by either Gateway Antarctica or AntNZ. This is the lack of a photo database with high quality, original photos from all previous years. In many years students have not had access even to the previous years' photos to make comparisons. Where they have had access to other years, photo quality has been poor and so results have been limited. Maintenance of a photo database requires little effort by AntNZ and Gateway Antarctica and would quickly add value to the results of the photo monitoring project. Future photos should be submitted along with the students' reports and where possible, previous years' photos collected from students who are still in contact with Gateway Antarctica and AntNZ.

AntNZ will also receive better quality results if it clarifies what changes to look for in photos. Previously students have noted changes to buildings and storage; however the students should be encouraged to look for changes in vehicle tracking and any soil displacement or discolouration. This would more accurately identify the footprint of Scott Base and track any changes between years.

1.2.5. Summary of Recommendations

In its current form the photo monitoring survey is providing limited useful information to AntNZ. The photos provide a good record of Scott Base facilities over time but do not

provide full coverage of the Scott Base vicinity and its disturbance footprint. The changes needed to better identify the cumulative changes to the Scott Base footprint are;

- Creation of a database with high quality, original photographs taken by students.
- Inclusion of new photo points and perspectives looking 'outward' from Scott Base.
- Instruction sheet provided to students with updated photo locations at identifiable locations and a clear description of what changes to look out for.
- Annual update by staff member of photo database, instruction sheet and compilation spreadsheet.

2. Visual Assessment of Ground Disturbance

2.1. Compilation of data

2.1.1. Report history

Visual assessment of ground disturbances has been undertaken at Scott Base in various forms since 2005. The project aims to estimate the level and extent of ground disturbance around Scott Base, and eventually, monitor any change over time. A simple visual assessment method, outlined by Campbell *et al.,* (1993) is used to benchmark the extent and intensity of impacts. This method is used successfully at a range of sites in the Ross Sea region to assess cumulative impacts of human activity and site recovery over time.

From 2005/06 to 2007/08 the visual assessment took place behind Scott Base near the entrance to the Crater Hill track, past the pipeline adjacent to the road to McMurdo. Data was available for six of these sites, although two did not include GPS points and could not be located on the GIS map. This project was not undertaken in 2008/09 but in 2009/10 was reinstated with a focus on the Scott Base vicinity. Over the last four years data has been collected for 99 quadrats along 11 transects located around Scott Base. The data has been recorded and sorted logically for each year which has made compilation of data generally straightforward.

2.1.2. Methods

To compile the data for the visual assessment project the previous years' reports were gathered into a database. The reports for 2005/06 were not available and a two were missing from 2006/07. Data describing the location of transects and quadrates assessed by each group was then collected and stored in a spreadsheet. In many cases there were no GPS co-ordinates marking the location of transects or quadrates and some GPS co-ordinates were incorrectly recorded. Location of these transects were instead estimated as

accurately as possible from cross referencing the provided description of the locations with Google Earth.

The disturbance data recorded for each quadrate was collected and ordered by year, group, transect and distance along the transect. There were 13 variables assessed for each quadrat and a total of 105 quadrates assessed. This resulted in a lot of information available for analysis. Within the scope of this project it was decided that an overall disturbance score would be calculated for each quadrate. This figure was an average of the scores given to each criterion, this resulted in a disturbance scale from 0-3, where 0 is site with no disturbance observed and 3 is a heavily disturbed area. Ten of the 13 variables were included in the calculation of these scores. 'Visibly disturbed area' and 'extent of ground tracking' were omitted because they are an assessment of the wider areas surrounding the quadrats. 'Extent of recovery of previously occupied sites' was also excluded because this criteria was poorly understood by observers and the validity of the observations questionable (see report critique for further information).

The data was the digitised using GIS software. Locations of transects were plotted on one layer and a representation of each quadrate area and its associated disturbance score formed the basis for another. The resulting maps (see appendices 4, 5 and 6) show the spatial distribution of ground disturbance around Scott Base for the last 7 years. These layers can be manipulated to show quadrates studied each year or quadrates of certain disturbance levels. In the future more data can be added to track changes over time.

2.1.3. Results

The data collected as a part of this projects suits representation through GIS mapping. The hypothesis for this project is that ground disturbance decreases with distance from Scott Base. Previous reports have relied on graphing their data to show changes over distance. This has provided limited results as the transects have not radiated out from Scott base into unused areas. Many have crossed into high traffic areas and some are fully situated within high traffic areas. The predicted decrease in disturbance scores over distance was therefore not seen in results.

Plotting these disturbances on a map makes it easy to recognise where transects cross high traffic areas. On the maps in appendix 4 and 5 the predicted trends emerge from the data. Quadrats located in high traffic areas close to Scott Base and along the roads are the most

heavily disturbed and with disturbance decreasing in less used areas. The most disturbed area is to the north-east of the HFC where all vehicle traffic going to, or past Scott Base is channelled. The storage area at the back of Scott Base is less disturbed, as would be expected, because although there is a lot of activity in the area, it is not constant as experienced around the HFC. Along the front of Scott Base the level of disturbance is lower. This area sees some vehicle traffic near the front transition but otherwise disturbances are only created by foot traffic. The map suggests that constant foot traffic is less disturbing than the infrequent vehicle traffic and movement of equipment experienced around the back of Scott Base.

PCAS students have collected data for this project in different locations each year apart from 2011/12 (see appendix 6). Temporal changes in disturbances can therefore not be identified. The 2011/12 project replicated a transect from the previous year however the transect was located in an already disturbed area and little change was recorded. There has been enough quality data collected over the last four years to provide an adequate baseline. Comparisons between this and future monitoring data will highlight any temporal trends and show the cumulative nature of disturbance in the Scott Base vicinity.

2.2. Project Critique

2.2.1. Project design

The visual assessment of ground disturbance project is modelled from the monitoring project established by Campbell *et al.,* in 1993. This monitoring technique is simple, effective and can capture the cumulative impacts of disturbance. The aims of the project are clearly outlined in the project outline supplied to PCAS students. However, there are some slight differences between the aims of the PCAS project and the monitoring carried out by Campbell *et al.,*. These have caused minor issues in the collection and analysis of data for this project. Campbell *et al.,* used this method to assess the ground disturbance in small, briefly used areas such as a scientific field party campsite. Campbell *et al.,* also assumed that the area assessed had been left to recover between monitoring events. In contrast, PCAS uses the method to monitor larger, comparatively high traffic areas that are subject to on-going disturbance. The different design of the project is not currently reflected in the data collection method and suggested changes to the collection sheet are further explained and outlined in section 2.2.3.

2.2.2. Preparation and materials

There is little preparation needed for this project before the students travel south. As with the photo monitoring project the materials needed (tape measure, GPS unit) are supplied by the University and the cameras used to photograph interesting features are the students' own.

The paper outlining the monitoring method by Campbell *et al.,* is a useful resource and should be read before departure. The paper however is difficult to access, it is not available as an online journal through the University's web portal and there is only one copy of the journal available in the library. It is unlikely that students have taken the effort to check out this book and read the article but it provides a good explanation of the methods and rationale of the study. It is recommended that AntNZ provide the digital copy of this paper (which has been scanned and handed in with this report) to all future students carrying out this project. Students that take the time to read the paper will better understand the criteria being assessed and the quality of information collected will improve. When researching for this report it was found that, along with Campbell *et al.,* many other papers referenced in the project outline document are not readily available online for students. This highlights the need for Gateway Antarctica and AntNZ to thoroughly review and update the projects and associated documents.

The GPS co-ordinates provided by the students as a part of this project varied in accuracy and format. The resulting co-ordinates were difficult to collate and plot in ArcGIS. It is recommended that students receive basic training with the GPS before travelling to Antarctica. Students should also be encouraged to provide detailed descriptions of the location of their transects such as start and endpoints, length and bearing. It will also be useful it they locate the starting points near, or at, identifiable permanent features around Scott Base. This will allow future students relocate transects and resample the area for comparison over time.

2.2.3. Data collection

The data collection sheet outlined by Campbell *et al.,* and provided for use by students is simple and easy to use. However as suggested in section 2.2.1 the sheet needs some minor changes to improve the quality of data collected. Certain criteria should be excluded from future data collection and others need further clarification. The criteria are each examined briefly below and an updated collection sheet is included in Appendix 7.

Disturbed surface stones

This records the number of displaced rocks within the study site, where changes in the colour of rocks indicate that they have been moved. A better description of what a disturbed stone looks like should be included in the project outline or on the data sheet. The quantifiable description for each disturbance level (e.g. >25 disturbed stones receives a 'high' disturbance score 3) gives a clear classification method.

Stone impressions

This criterion records the impressions left in the ground after removal of stones. The criterion is self-explanatory and clear classification is given, no change recommended.

Boot imprints

This records the presence and distinctness of mark left on the ground by foot traffic. It is self-explanatory, but no clear classification is given. It is recommended that instead of classifying disturbance by the 'age' of footprints (e.g. fresh or indistinct), classes should be based on the quantity of footprints (e.g., high >25, medium 25-10, low <10, negligible 0)

Visibly disturbed area

This criterion applies to the wider area that the plot was in. As Campbell *et al.,* designed the project for smaller areas (e.g. a campsite) it was expected that this criterion make an estimation of the total area disturbed by human activity. This is not applicable to the visual assessment project as the total disturbed area of Scott Base is far more than 100m^2. This variable should therefore be excluded from future projects.

Surface colour difference

Here the level of contrast between disturbed and non-disturbed soil is measured. Campbell *et al.,* intended this variable to be measured with Mansell soil colour charts. These are not available to PCAS students and so there should be further explanation and clearer classification for this criterion. Students should look for disturbed soil and compare the colour against that of undisturbed soils. To help the students quantify differences the project outline should include photos examples of soil contrast to match their sample to.

Surface impression

This criterion measures surface indentations made by foreign objects such as drums, sleds and vehicles. There has been confusion in the past as to what is included in this variable, with vehicle tracks more often assessed under 'ground tracking'. To ensure consistency of the data the explanation should explain which object impressions are included and exclude tracking from vehicles. The classification should also be quantifiable.

Ground tracking

Tracks made by repeated foot traffic are assessed in this criterion. PCAS students have generally extended this from footpaths, to foot and vehicle tracking. Since many of the areas around Scott Base are subject to frequent traffic this criterion would be better measured using percentage of tracked area inside the quadrate (e.g. high >60% of area tracked, medium 20-60% tracked, low <20% tracked, negligible 0%).

Extent of ground tracking

This criterion is another that looks beyond the boundaries of the quadrat being assessed and is of limited usefulness as tracking around Scott Base is far more than 100m. This variable should also be excluded from future projects.

Foreign objects

The criterion is self-explanatory however classification of disturbance level should be given (e.g. high >10 items smaller than a pencil or >5 items larger than a pencil, medium 5-10 small items or 2-5 large items, low <5 small items or <2 large items, negligible 0 items).

Fuel spills

This criterion is self-explanatory and clear classification is given, no change recommended.

Biological disturbance

Here an assessment is made of the disturbance to plant communities. This is a difficult variable for students to measure and has caused confusion in the past. It is suggested that the variable be changed to an assessment of the likelihood of establishment or survival of a plant community of the area. The classification of disturbance would be as follows. High, area is subject to constant disturbance and the survival of plant species is very unlikely. Medium, area is subject to moderate disturbance and plant species would only be able to survive in small or sheltered areas within the quadrat. Low, the quadrat is subject to low

human activity and plant species could survive in the majority of the quadrat. Negligible, plant species would be able to survive anywhere within this quadrate and would be subject to only rare disturbances.

Disturbance intensity
This is an overall assessment of disturbance in the assessment area. This criterion is self-explanatory and clear classification is given, no change recommended.

Extent of recovery of previously occupied sites
This is another confusing criterion. Around Scott Base many areas are subject to constant disturbances and there is no 'recovery' in these areas. This is in contrast to the areas studied by Campbell *et al.,* which had not been disturbed for many years between monitoring events. It is recommended that this criterion be excluded from future reports.

2.2.4. Analysis of data

Students completing this project have had difficulty in the past meaningfully analysing their data. Many have created some form of overall disturbance score and have attempted to plot these using graphs to show disturbance trends over distance. No analysis could be made comparing disturbance over time because students were not provided with locations of previous transects and could therefore not resample any areas. The exception to this the 2011/12 group who resampled a transect from the previous year.

GIS mapping is the best tool to display the data for this project. However this software is generally beyond the scope and ability of students participating in this project. To get better results the project outline should give a better explanation of where to locate good transect sites where students are likely to see trends over time and space with basic analysis techniques (e.g. using graphs). Over the last 7 years the groups performing the visual disturbance assessment have randomly selected the locations for their transects and then assessed quadrats at set distances along the line. The outline should encourage students to resample a mixture previous years' transects and create new transects that radiate out from high traffic areas around Scott Base. Students should also be encouraged to choose these new transects in re-locatable sites.

Useful information will also be created if the GIS layers created as a part of this report is updated annually or at some point in the future and re-analysed. This could be performed

by a staff member of by a PCAS student for an individual report. With more data digitised into GIS better quality analysis can be performed to identify spatial and temporal trends in disturbances around Scott Base. This will be effective in tracking the cumulative effects of ground disturbances.

2.3. Summary of Recommendations

The data currently collected as a part of this project is not useful in its raw form. GIS analysis of this data however shows the project has real potential to effectively monitor cumulative disturbance around Scott Base. The changes needed to better monitor disturbance are;

- Supply of relevant research papers and maps to students participating in the project.
- A clarified data collection sheet with relevant criteria.
- Explanation of where transects should be located to gather useful information showing spatial trends.
- Continued GIS analysis of data collected.
- Annual update of data compilation spreadsheet created as a part of this report.

Conclusion

Both projects reviewed as a part of this report should be continued in the future by PCAS students. However each project requires changes in design in order to provide sound, useful information to AntNZ. Generally these changes will update the projects to a modernised format. The photo points should be updated to look 'outward' from Scott Base rather than 'in' toward areas that are already heavily disturbed. The visual assessment should include GIS analysis where possible as this is the best tool to display data.

Both projects also require attention by a member of staff at AntNZ of Gateway Antarctica to ensure data is updated and stored correctly and to organise materials for the next years' students. If this is performed annually it will not be a hard task and should take a maximum of one day to complete.

The last recommendation is that the Gateway Antarctica and AntNZ increase their communication with each other regarding these projects. This will encourage the exchange of information, results and recommendations that AntNZ can implement within their environmental management programme to fulfil their regulatory obligations.

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Appendix 1: Criteria for evaluating monitoring programmes

The following criteria for evaluating monitoring programmes is sourced from Kennicutt, *et al.,* (1996, p.37) and has been considered when critiquing the photo monitoring and visual disturbance assessment projects.

12.1 Evaluation of Monitoring Programs for Continuous Improvement

Environmental monitoring should be periodically reviewed by individual national programs, and the results of such reviews shared amongst programs for mutual benefit. It is recommended that review and critical evaluation focus on each of three phases of the monitoring activity: data collection, data analysis, and use of results in management decisions.

The sampling program's activities should be reviewed to ascertain that:

(i) the original design of locations, times, replications and measured variables is being followed consistently. If costs, operational difficulties, changing technologies, etc. are limiting the intended design, appropriate changes must be put in place;

(ii) the quality of the data is as originally specified;

(iii) once analysis has begun, data collection should also be reviewed to determine if the design is inadequate or excessive based on the objectives; and

(iv) changes in the hypothesis may be required as new insights or new activities and/or technologies occur.

12.2 Use of Results in Management Decisions

Data collection and analyses are intended to provide decision-makers with a sound scientific information from which environmental management decisions are made. Therefore, review every few years should consider these aspects:

(i) do the data and the results of the monitoring provide managers with the information envisioned in original designs? If not, adjustments must be made;

(ii) has management's use of the data resulted in a measurable decrease in human impact?; and

(iii) the management value of long-term information may be much greater than short-term. (Program modification for short-term benefit must be considered with caution.)

Appendix 2: Review of fixed photo point sites

Site	Perspective	Recommended Changes
1a	Towards the Hillary Field Centre	This sit could be moved further back toward the NE to take in a wider view of the storage area.
1b	Towards Castle Hill	This perspective should aim to show the NW edge of the storage area and include as much of the view between the back transition and yellow McMurdo/Scott Base sign as possible.
2a	To the East of the Hillary Field Centre	This site could be moved north onto the road to McMurdo to capture the entire back storage area.
2b	To the West of the Hillary Field Centre	This view should remain at this site but look directly west toward the water tanks.
3a	Towards Scott Base from the North	No change recommended.
3b	Towards the Ross Island Wind Farm	No change recommended.
4a	Towards Q Hut from G Mast in the antenna area	No change recommended.
4b	Towards Castle Hill from the antenna area	Move this point NW to be situated along the walking track, looking back NE toward Scott Base.
5a	Towards the TAE Hut from the yellow drum	No change recommended.
6a	Towards the Scott Base dining room from the visitors' hitching rail	No change recommended.
6b	Towards the Wet Lab and the visitors' hitching rail	This point should be discontinued as the wet lab is in the centre of the photo and minimal ground is seen.
7a	Towards the hangar	The hangar is in the direct line of sight. Point could be moved to the veranda of the maintenance building looking over vehicle hitching posts and refuelling area.
7b	Towards the flag pole from the back of the workshop	This point should be discontinued as the maintenance building is in the centre of the photo and minimal ground is seen.
8	From HFC window toward wanagans storage	No change recommended.

New sites	Location and perspective
9	From the power house looking NW out the back of Scott Base vicinity.
10	From the administration deck looking out over the front of Scoot Base and the front transition.

Appendix 7: Updated data collection sheet

Criteria:	Assessment: High	Medium	Low	Negligible
Disturbed surface stones Number of displaced rocks within the study site	> 25	25-10	< 10	None visible
Stone impressions Impressions left in the ground after removal of stones	Fresh, sharp edged	Distinct, slightly rounded	Shallow indentations	None visible
Boot imprints	>25 footprints	10-25 footprints	<10	None visible
Surface colour difference Level of contrast between disturbed and non-disturbed soil	Strong contrast	Moderate contrast	Weak contrast	None visible
Surface impressions Surface indentations made by foreign objects (other than vehicles)	>60% of quadrat covered by impressions	20-60%	<20%	None visible
Ground tracking Extent of quadrat covered by vehicle tracks	>60% of quadrat covered by tracks	20-60%	<20%	Not visible
Foreign objects	>10 items smaller than a pencil or >5 items larger than a pencil	5-10 small items or 2-5 large items	<5 small items or <2 large items	None
Fuel spills	Very obvious	Visible	Faintly distinguished	None
Biological disturbance Likelihood of establishment or survival of a plant community of the area	Quadrat is subject to constant disturbance and the survival of plant species is very unlikely	Quadrat is subject to moderate disturbance and plant species would only be able to survive in small or sheltered areas within the quadrat	Quadrat is subject to low human activity and plant species could survive in the majority of the quadrat	Plant species would be able to survive anywhere within this quadrate and would be subject to only rare disturbances
Disturbance intensity Overall assessment of disturbance in the assessment quadrat	Disturbed and very obvious	Clearly visible disturbance	Weakly distinguished	Disturbance not visible