Environmental health on Australian bases in the Antarctic and sub-Antarctic

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Introduction

Australia has three permanent scientific stations in Antarctica – Casey, Mawson and Davis - and a permanent station on Macquarie Island in the sub-Antarctic. These stations are manned year round with populations varying from as few as 14 over the winter months to over 60 in summer. Summer personnel may spend only a couple of months at a station whereas wintering groups may spend as long as seventeen months before being relieved, although twelve months is more usual.

A station will consist of a station leader, chef, doctor, meteorology observers and a meteorology technician, communications people, and trades people. There may also be a varying number of scientists, students and volunteer field assistants.

The main purpose of the stations is to support science. Currently on Macquarie Island, there are ongoing research and monitoring projects on elephant seals, fur seals, albatrosses and petrels. Other projects include those examining the effect of climate change on vegetation and invertebrates and their potential usefulness as a guide to future climate change.

Personnel and supplies arrive by ship, the voyage from Hobart to Mawson taking about twelve days by the most direct route. During the winter months, the sea ice thickens and extensive shipping becomes impossible. Macquarie Island by contrast is always potentially accessible by ship, being only three days sailing away from Hobart. However, there are often periods of six or more months between ships over the winter.

Life and work in the Antarctic and sub-Antarctic is unique in many ways and presents some unusual environmental challenges to health.

Life in a cold environment

Working in the cold is challenging. At Macquarie Island temperatures vary from a few degrees below zero to as high as 11°C. On the Australian Antarctic stations, summer temperatures can reach a few degrees above zero. At Davis in 1998 the lowest temperature recorded was -42°C (-43°F).

Heat is lost through conduction, convection, radiation and evaporation. Environmental factors such as wind speed, humidity and temperature, clothing used, level of activity and individual factors are all important in predicting the effect of cold on people. Cold stress may result in discomfort, peripheral cooling or general body cooling and effects mental and physical performance (Holmer 2000). Peripheral cooling causes a decrease of dexterity and can increase the risk of accidents. A finger temperature of 15°C can result in decreased performance and pain and at 7°C, severe pain and numbness develop (Holmer 2000). Local effects of cold include frostbite, frostnip, immersion foot and chilblains (Williams 1993). Severe peripheral cold injury can lead to permanent disability and an increased likelihood of experiencing future injury.

General body cooling results in discomfort initially. This can be a distracting factor, decreasing concentration and reaction times. Cooling effects muscle function, increasing the risk of strains and sprains (Holmer 2000). Hypothermia occurs when heat losses are greater than heat production and the core body temperature drops below 35°C. It is associated with clumsiness, lack of judgement, and poor memory. At core temperatures below 30°C there may be cardiac arrhythmias and death. Sudden death may be precipitated by exposure to cold in individuals with undiagnosed cardiac disease.

Recognising risk factors for cold related injuries or injuries related to decreased functioning in the cold is an important step in preventing them. Among the risk factors are fatigue, hunger, inactivity, poor fitness, alcohol and drug use, increased age, endocrine factors, anorexia, burns, other illnesses and ignorance. Factors that can prevent cold injury include acclimatisation, training, vigorous activity, adequate rest and good nutrition. Early recognition and treatment of symptoms can mitigate cold injury (Conway et al 1998).

Strategies to avoid cold related injuries include pre-employment health assessment of expeditioners, education and the provision of protective clothing. In the pre-employment assessment, attention is paid

to any cardiovascular or respiratory problems that may be exacerbated by the cold as well as any other conditions that may predispose someone to cold injury. All expeditioners over 55 are required to pass an exercise stress test. Before going south, lectures are given on cold injury and hypothermia with emphasis placed on early warning signs, prevention and first aid.

The Antarctic Division provides clothing for all expeditioners. This consists of many layers with a windproof outer garment. Unfortunately, much of this clothing is bulky and awkward, especially for smaller expeditioners who are not yet well catered for. With the increase in the number of female expeditioners this is changing. For female expeditioners 'female urinary devices' are also supplied, to prevent toileting related freezing injuries! Equipment like quads (4-wheel motorcycles) is modified to have heated handlebars and enclosing mitts.

Currently the Antarctic Division, in collaboration with the US Army Research Institute of Environmental Medicine, is conducting research into cold acclimatisation. This, like acclimatisation to heat, can develop within ten days, with a decrease in the shivering response and decrease in discomfort. In the longer term, there can be local acclimatisation in the hands, with improved circulation to them – 'fisherman's hands'. There is less cold-induced vasoconstriction of blood vessels supplying the hands and so greater heat loss from them, but dexterity is maintained (Rintamaki 2000).

The research involves looking at changes in levels of catecholamines, neuropeptides, aldosterone and various immunoglobulins in over-wintering expeditioners. In 2000, before departure for Antarctica, cold chamber sessions with expeditioners were carried out to get base-line parameters. These cold chamber sessions were repeated on their return. The data from these experiments are still being analysed.

Surprisingly, cold related injuries are uncommon on Australian Antarctic bases. The majority are trivial injuries such as frost nip and chilblains and are most often associated with recreational activities such as skiing or riding quads or skidoos (Lugg 2000). There have only been a few cases of frostbite, but some of these have led to significant disability. Hypothermia has resulted in a number of near misses over the years and a few fatalities on Australian Antarctic stations. These cases have occurred due to either poor judgement or rapid weather changes without having survival equipment. Another cold related issue is carbon monoxide poisoning (11). This can be an issue in field huts if vents become iced up. Every hut has an electronic carbon monoxide detector with audible alarm as well as 'DeadStop' detectors that display a colour change.

Everyone is field trained to avoid these problems and people are only allowed into the field once it is considered safe. Stations have defined limits, beyond which, on the continent, it is forbidden to travel alone. If travelling outside of station limits survival equipment and a VHF radio must be carried. An intentions board is kept, so that at any time it is possible to see if someone is off station and if they are over-due to return. There are also nightly radio skeds. On Macquarie Island, solo travel is allowed, but as well as carrying a radio we also carry a VHF beacon.

UV and ozone depletion

Total ozone observations in the 1970s showed a thinning in total ozone over the Antarctic. In 1985 the ozone hole was first reported, and every year since 1988 there have been large holes during the austral spring over Antarctica (Roy et al 1994). High levels of UV exposure are likely to cause several long-term health effects including skin cancer, cataracts, and pterygiums. It has also been found to cause a decrease in cellular-immunity. Potentially decreased immunity may cause effects such as increased severity of infections, less effective vaccinations and possibly an increase in non-Hodgkin's lymphoma (De Gruijl and van den Leun 2000). Snow blindness is a short-term effect. Surprisingly only a few cases have been reported in the last few years (Lugg 2000). Expeditioners are made aware of the risks of snow blindness and sunburn before departing Australia and sunglasses and goggles are provided as well as sunscreen. There has been research at Casey on the potential effect of an increase of UV on marine ecosystems. If species such as krill are affected there could be catastrophic effects on animals further up the food chain.

Extremes of day length

Over the summer on the Antarctic stations there is continuous daylight. This causes sleep disturbances – 'big eye' - for most people to a varying degree and can affect their ability to work (Wood et al 1999). Over the winter the converse is true with only a few hours of dusk in the middle of the day. This can lead to sub-syndromal seasonal affective disorder, involving fatigue, sleep disorders, irritability and

social withdrawal (Palinkas and Houseal 2000). Most expeditioners report these symptoms around mid-winter.

Water

The station water at Macquarie Island comes from a creek running into a small dam at the top of Gadget's gully (Gadget having been Mawson's dog). This is then piped to the station where it is stored in two 50,000-litre tanks. Water from these then passes through a filter and UV sterilising system before being piped to individual buildings. The doctor conducts tests for turbidity, conductivity, total dissolved solids and pH monthly. It is also incubated in special media for twenty-four hours to check for the presence of coliforms. If these are found the sample is checked for fluorescence, this being an indicator of *Escherichia coli*. If these are found, as happens occasionally when there is low rainfall, the dam is then flushed and cleaned and the water tanks chlorinated.

In the field water is collected from the hut roofs into a water tank.

Over the years there have been occasional instances of presumed water related illness although generally not severe. The source of contamination is likely to be dead rabbits, birds and rats and their excreta in the creek feeding the dam. On the Antarctic continent, water is less likely to be contaminated with biological material. Water at Davis comes from a tarn near the station. The water is quite saline, being more saline than seawater towards the bottom, and is run through a reverse osmosis plant. The tarn freezes over winter and water is restricted to that stored in tanks.

Sewage

On Macquarie Island there is only minimal processing of sewage. It is macerated and then pumped into Garden Cove, just off station. On the plateau, faeces are bagged and carried to the coast where they are liberated into the sea.

On the Antarctic continent sewage is processed more thoroughly before being discharged. Each base has a sewage processing plant. The sewage is piped into a primary holding tank. From there it passes into a sedimentation tank and then weaves past a set of aeration wheels. It then flows into a final holding tank before being pumped out to sea. The sediment is returned to Australia where it goes into landfill.

The doctor is responsible for measuring the suspended solids and BOD and checking that they meet recommended guidelines. The waste product treatment specifications allow for a suspended solids range of 0-30 mg/l although figures of 300 mg/l have occurred at times. Unfortunately, the growth of the Antarctic stations has overtaken the capacity of the sewage processing plants and sometimes over the summer sewage is only macerated before being discharged. The Antarctic division is in the process of upgrading the facilities at Davis.

For those working in the field on the continent, faeces are collected in a bag and incinerated once back on station. There are usually designated urination posts near field huts or else people urinate into tide cracks in the sea ice. 'Grey water' such as dishwashing water is either poured into tide cracks or into drums that are eventually returned to Australia.

Currently all the stations are in the process of phasing out old cleaning agents and replacing them with 'greener' phosphate free biodegradable alternatives such as 'Simple Green'. However, there are still large stocks of old products to be consumed, the prospect of transferring old stock by helicopter onto a ship for disposal in Australia not being an attractive alternative. Some phosphate containing products, such as laundry powder, are still being supplied.

Food and nutrition

Food becomes a social focus and every base has a chef. Generally, there is only one major resupply per year and so food brought in then has to last all year. Fresh produce has to be checked for pests to avoid inadvertent introductions. Certain fresh foods cannot be brought into Macquarie Island at all, such as mushrooms and *Brassica* such as cabbage since Macquarie has its own cabbage species. Potatoes can only be brought in if they have been pre scrubbed. Eggs are allowed, but any egg waste must be burnt, and it is forbidden to take eggs into the field. This is due to the theoretical risk of Newcastle virus to local penguin populations. Studies at Mawson and Davis base have found that penguins have antibodies to this virus. It is not yet clear if this was introduced by people or always existed in the penguin population.

After some months the diet consists mainly of frozen foods. Potatoes and onions last well, but the only other fresh produce is from hydroponics. Hydroponics is limited in what it can grow, some herbs such as mint being forbidden although it can usually be relied upon to provide a slow stream of lettuce leaves and cucumbers. On the Antarctic continent, where the ambient temperature in winter is less than –15C, large amounts of fuel is required to heat and light hydroponics. One year at Casey base we roughly estimated the production cost of tomatoes at $1000 per kilogram – we only produced one tomato. It is argued that the importance of fresh produce in keeping up morale outweighs the expense of the exercise.

Alcohol consumption is accepted as being part of Antarctic life. Its extent and relevance to health issues and accidents is largely anecdotal. Alcohol related accidents are reported although I suspect the tendency is for patients and doctors to under-report the role of alcohol in accidents due to a fear of repercussions or of jeopardising future compensation claims. The Antarctic divisions attitude towards alcohol is changing. Up until 1998 there was an alcohol ration given to expeditioners. That has since gone the way of the cigarettes, with only the chocolate ration remaining. Expeditioners now have to pay for all their own alcohol, or drink home brew. Supplies are sent down which expeditioners can buy. However, there are limits set on how much suppliers can stock.

Waste management

Attempts are made at waste minimisation, with some things supplied in bulk such as cleaning fluids. It is especially important to try to minimise non-burnable waste as it is usually transferred to the ship by helicopter, before being returned to Australia. This is an expensive process, and takes up valuable helicopter time. However, many things such as shampoo are still supplied in individual, non-reusable containers. There could be improvement in this area.

Waste is separated into different categories – burnable rubbish, HDPE and PTE plastics, bond paper, different colours of glass, aluminium, steel and other non burnable rubbish. Tasmania has limited recycling facilities but currently does recycle HDPE, PTE, aluminium, bond paper and glass. Unfortunately, if there is contamination of the glass, the entire cage pallet may be rejected and so much of our efforts are in vain. Steel tins from station are also rejected, many of them being too rusty to be desirable. Another problem is that we store steel tins crushed flat, to create fewer helicopter loads. Apparently this does not allow enough aeration of the steel during the recycling process. Food wastes, non bond paper and cardboard are incinerated, as are sharps, medical waste and some expired pharmaceuticals. Non-recyclable wastes are returned to Australia for further processing as necessary and generally end up in landfill.

Stations have not always had such a structured waste management policy in the past. Things used to be ‘sea iced’ – put on the sea ice, destined to float away when the pack broke up in summer. There is still a large disused dump near Casey station. This has become an area of much study. Many of the drums there are full of unidentified substances and some are so corroded that any attempt to move them is likely to cause spills and more environmental damage. It is no longer considered acceptable to leave any waste in the Antarctic or sub-Antarctic. When a temporary base was set up at Heard Island in 2000/2001 everything was removed at the end of the season.

Pests

John Cumpston, an Antarctic veteran, commented on the pest situation in 1968. Macquarie Island was first discovered by the *Perseverance*, a fur-sealing vessel, on 11 July 1810. Dogs were brought in by early sealer gangs to hunt birds and were already a pest, killing young seals by 1915. An article published on 15th April 1815 in the *Sydney Gazette* discussed the decline in fur seal populations and potential for recovery.

> *“This prospect is, however, totally obliterated by the ravages committed on the younger seal by innumerable wild dogs bred from those unthinkingly left on the island by the first gangs employed upon it.”*

Rats and cats were also early introductions. Other animals, such as wekas, were introduced to supplement the sealers diet. In 1891, at the inquiry into the loss of the *Kakanui*, William Elder said:

> *“The men always used the tongues of sea elephants and in the season the men used the sea eggs very liberally. I procured and sent to the islands some French rabbits in 1879 or 1880 and I know there are millions of rabbits there now. There were none there before*

I sent them down. I sent goats down but they interfered with the sea-elephants and the men killed them."

Only the cats, dogs, goats and wekas have been eradicated, the last cat having been shot in July 2000 after an eradication program involving trapping and spot lighting. Currently there are rat and rabbit control programs. Rat bait stations are placed near petrel breeding sites and on isolated rock stacks. The rabbits cause significant erosion and inadvertently destroy many petrel and albatross nest sites. Myxomatosis is regularly spread around the island in an attempt to control the rabbits.

Currently a lot of attention is being focused on Campbell Island, a New Zealand controlled sub-Antarctic island that is a similar size to Macquarie Island. During the winter of 2001 they had a huge poison drop in an attempt to eradicate the rats and rabbits. If this is successful it will be a powerful argument for raising funds for a similar project on Macquarie Island.

Other introduced species include spiders, aphids, slugs, snails, a fish moth, an amphipod and a beetle. Most of these have been introduced on food. More research is needed to find out if these are 'pests' as such. There is one weevil like insect, of the genus Anobiidae that is found in flour, but it is really only a pest on station.

The Antarctic stations are more fortunate in that the climate is too inhospitable for most alien species to be able to live or breed outside of buildings. Even house dust mites are unable to proliferate, due to the low humidity (Siebers et al 1999). There have been reports of a grass having been found growing outside an abandoned Russian base in the Larsemann hills. However conditions were too extreme for it to survive to form seed. It was probably introduced on the boots of expeditioners. It is now standard for expeditioners and tourists to check all of their equipment for seeds and to wash their boots in antiseptic before disembarking. Ships are prohibited from discharging ballast water. Tourism remains a concern, especially on Macquarie Island where introduced species could gain a foothold.

Conclusion

I have mainly discussed issues relating directly to the Antarctic and sub Antarctic. However, many of the health issues are the same as would be found in Australia. Although there are more work related injuries than injuries attributable to the external environment, most of these are trivial (Lugg 1997). There are more consultations for medical conditions than for injuries, the majority of these being no different from those seen in medical practice in Australia. In a ten-year period only 42% of consultations were for injuries (Lugg 2000). This is in part due to the careful screening, training and preparation of expeditioners before coming south and their respect for a potentially hostile environment.

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