Financial costs of conducting science in the Arctic: examples from seabird research

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Abstract: Research in remote locations is more expensive than similar activities at sites with easier access, but these costs have rarely been compared. Using examples from seabird research, we show that conducting research in the Arctic is typically eight times more expensive than pursuing similar studies at a southern location. The differences in costs are related principally to the much higher expenses of travel and shipping (typically 4–10× higher for Arctic work), as well as the good practice of meaningful engagement with northern communities (4%–25% of project costs). Although there is some variation in costs among Arctic countries, we hope that the consistent pattern of relatively higher Arctic costs allows policy-makers and funding agencies to better plan for research support, especially for this region that is experiencing rapid environmental change.

Key words: research expenses, travel, community consultation.

Résumé : La recherche réalisée en régions éloignées est plus onéreuse que des activités similaires sur des sites plus accessibles, mais ces coûts ont rarement été comparés. À partir d’exemples issus de la recherche sur les oiseaux marins, nous démontrons qu’effectuer des recherches dans l’Arctique est habituellement huit fois plus coûteux que de faire des études similaires dans une région plus au sud. Les différences de coûts sont reliées principalement à des dépenses de voyage et d’expédition beaucoup plus élevées (généralement 4 à 10 fois plus élevées pour le travail en Arctique), autant qu’à la pratique d’engagement véritable avec les communautés septentrionales (4% à 25% des coûts du projet). Bien qu’il y ait une variation des coûts entre les pays arctiques, nous espérons que la tendance constante de coûts relativement plus élevés en Arctique permette aux décideurs politiques et aux organismes de financement de mieux planifier le soutien à la recherche, particulièrement pour cette région qui connaît un changement environnemental rapide. [Traduit par la Rédaction]

Mots-clés : dépenses de recherche, voyage, consultation communautaire.

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Introduction

Over the past several decades there has been increasing recognition that anthropogenic activities have substantial negative consequences for the environment (e.g., Carson 1962). Prominent, global environmental issues like acid rain (Likens et al. 1996), climate change (Parmesan and Yohe 2003), and international management or depletion of wildlife stocks (e.g., Myers and Worm 2003; Hunter et al. 2010) have become commonplace in news stories. Concerns focusing on these issues have fueled the growth of environmental science, as well as national and international legislation aimed at protecting our environment (e.g., Karr 1990; Forsyth 2004). Gathering the necessary data to answer questions related to the issues of how human activities affect landscapes and ecosystems takes time and money; investment in science can be an expensive but important business (Lubchenco 1998).

While it seems intuitive that conducting a project in a remote area is likely more expensive than conducting similar research near a city or region with local infrastructure, the actual differences in such costs are rarely reported. This appears to be the case with conducting research in the Arctic, a remote region that has been a hotbed for various forms of environmental science for the past four decades (Aksnes et al. 2016).

The fact that conducting scientific research in the Arctic is “expensive” has been known for some time (e.g., Savile 1963; Wright 1990; NSERC 2000; Lambden et al. 2006). There have been intermittent, circumpolar efforts through International Polar Years (IPYs; Barr and Lüdecke 2010) to obtain additional, short-term funding for scientific work, and these have provided some legacy benefits, but few long term increases in research investment. In Canada, the extra costs of working in the Arctic have been recognized by the federal government, which has supported specific, short term, Arctic-focused research [e.g., IPY (Ferguson et al. 2012); ArcticNet (ArcticNet 2015)], but also long-term commitments through research and logistics funding programs in various departments (e.g., Northern Research Supplement, Polar Continental Shelf Program, Canadian High Arctic Research Station; Government of Canada 2015a, 2015b, 2017a, 2017b, 2018a). These departments grant financial or in-kind support specifically to offset the extra costs of working in the Arctic, although many scientists continue to report that the funds available specifically for logistics are insufficient to cover the true costs of working at higher latitudes (but see additional investments made by the Canadian federal government in 2018; Government of Canada 2018b). Despite information on these various programs, the actual, additional cost of conducting research in the Arctic is elusive.

For those scientists thinking of starting work in the Arctic, and indeed for the future of Arctic research itself, this is a key issue. At a time when investment in Arctic research is being lauded internationally (e.g., Council of Canadian Academies 2008; Emmerson and Lahn 2012), the ability to initiate or continue a program in that region merits careful consideration. The difference in costs of working in the Arctic compared with working farther south remains apparently unknown. In fact, nearly 20 years ago, England et al. (1998, p. 184) stated, “… we are unaware of any comparative cost-benefit studies of Arctic versus southern research.”

In this paper, we provide an analysis of the costs of conducting research in the Arctic compared with doing similar work in southern regions. We developed a simple research protocol to conduct field work on seabirds, and then we determined the costs of doing that work at different sites in the high Arctic (~north of 70°N), the low Arctic, and places in the temperate south. Our main examples are from North America, but we provide data on studies from other countries to extend our analysis.
Materials and methods

We used our experience at several Arctic field research sites, as well as those in the south, to develop a protocol for a field program (below) and the associated costs of undertaking that work, based on our knowledge of costs in 2016. In Canada, we modeled costs to work at Prince Leopold Island, Nunavut [Fig. 1 Canada high Arctic (CAN-HA); 74°N, 90°W; high Arctic; Gaston et al. 2005], Digges Sound, Nunavut [Canada low Arctic (CAN-LA); 62°33′N, 77°43′W; low Arctic; Gaston et al. 2013], Gannet Islands, Newfoundland, and Labrador [Canada low Arctic/south (CAN-LA/S); 53°56′N, 56°32′W; low Arctic; Pratte et al. 2017], and Machias Seal Island, New Brunswick [Canada USA south (CAN/USA-S); 44°30′N, 67°06′W; south; Diamond and Devlin 2003]. For Norway, we compared work in Barentsøya, Svalbard [Norway high Arctic (NOR-HA); 78°24′N, 21°32′E; high Arctic; Lucia et al. 2016] versus the Norwegian mainland [Norway south (NOR-S); Tromsø, 69°39′N, 018°57′E; south], and for Greenland we compared costs of working in northern Upernavik [Greenland high Arctic (GRE-HA); 73°43′N, 56°37′W; high Arctic; Frederiksen et al. 2014] and Nuuk [Greenland low Arctic (GRE-LA); 64°10′N, 51°53′W; low Arctic; Merkel and Mosbech 2008]. Note that the costs of working in low Arctic Greenland or Norway would be greater if a site more remote than Nuuk or Tromsø, respectively, were used. We also chose a site in the Aleutian Islands, Alaska [USA low Arctic (USA-LA); 51°45′N, 178°45′W; low Arctic; Major et al. 2017] for a US perspective, using the Machias Seal Island site as our comparison for a southern location.

For our budgeting scenario, we planned the costs required to operate a field research camp for 4 weeks with three people (the lead researcher and two volunteers; this avoided cost issues related to pay scales), set to monitor the breeding success of seabirds (similar to Gaston et al. 2005; Frederiksen et al. 2014; Lucia et al. 2016). We assumed that the site was a new location for the research team, such that there would not be food or fuel there already, but that a cabin would be there if that was required for safety. We let each researcher determine whether they bought food supplies locally or shipped those from the south as

![Fig. 1. Total project costs (US$) of the same seabird research program conducted in different locations, comparing Arctic to southern sites. Abbreviations as follows: CAN-HA, Canada high Arctic; CAN-LA, Canada low Arctic; CAN-LA/S, Canada low Arctic/south; CAN/USA-S, Canada USA south; USA-LA, USA low Arctic; NOR-HA, Norway high Arctic; NOR-S, Norway south; GRE-HA, Greenland high Arctic; GRE-LA, Greenland low Arctic.](image-url)
appropriate to each site. We also assumed that the team would already own basic, essential research supplies (sleeping bags, cooking equipment, optics, and recording gear), but that if special equipment was required (e.g., kerosene heaters, firearms for protection from polar bears *Ursus maritimus*), those would need to be purchased. Furthermore, we assumed that these supplies were located at each researcher’s institution, and thus if shipping was required to the field site, those costs were to be calculated. All calculations were made based on previous spending data at each of these sites for several years and were initially tabulated in the 2016 currency of each country, and then converted to US dollar values for standard comparison (at exchange rates from October 2016). Hence, all values reported are in US$.

For Canadian research, consultation and/or engagement (e.g., local hiring) with Arctic communities generates mutually beneficial understanding of Arctic ecosystems (Gilchrist et al. 2005; Mallory et al. 2006), can provide important training and employment opportunities for northerners, and may be required for permitting. Thus, we conduct project-specific consultations in local communities in most years as part of our northern seabird research programs. These usually are undertaken in advance of a field season and require an extra trip to the Arctic. We note that for many Arctic projects in any of the countries, researchers include simpler community consultations where possible at the start or end of their field work, to minimize overall costs.

In Canada, we have also engaged with high school and college students, as well as the public, through community workshop education programs (e.g., Provencher et al. 2013). These programs have been an important component of our overall research engagement and communication plan, and require considerable logistical coordination with local schools, teachers, sometimes school boards, and often specific time to write grants for this type of outreach. For this reason, we also provided costs of conducting a community workshop on our research in the high and low Arctic. We based these calculations on two researchers travelling to the two northern sites for 5 days to conduct a 2-day community workshop. The workshop costs included shipping of supplies, honoraria for two Inuit elders to participate, and for Inuktitut translators to take part in these sessions. We also included costs for local hunters to collect wildlife that are dissected as part of the workshops. Finally, we included the costs of a program assessment aimed at evaluating the effectiveness of this outreach program (once every 5 years; costs amortized per year), as assessment is a critical component to understanding and improving any communication tool (e.g., Makoul et al. 2007). Lastly, we included the cost of hosting a simple community social event, which is more conducive to discussions and conversations with a wide range of community members.

**Results**

The cost of conducting the proposed seabird research project ranged from US$3 792 to $51 376 (Table 1; October 2016 US$). The two most expensive locations to conduct the basic seabird research were high Arctic Canada and high Arctic Norway (Svalbard; Fig. 1). However, adding the cost of holding a community workshop, the Canadian high Arctic research increased to $71 270.

Comparing expenses for working at Arctic locations within a country to a southern site within the same country, it was 7.8× (range 3.5–13.6; n = 6) costlier to work in the Arctic. The greatest difference was in high Arctic Canada, where costs were 13.6 times greater than conducting the same work in the Bay of Fundy of Nova Scotia, Canada (18.8 times more with a community workshop). The expenses of accommodation and travel were both significantly higher in Arctic (n = 6) versus southern (n = 3) sites (Mann–Whitney tests, both $U = 18, p = 0.02$), whereas all other comparisons of expense categories were not significant, although we note that our sample sizes were small and thus statistical tests must be interpreted cautiously.
The proportional breakdown of costs differed whether working in the Arctic or southern sites. For Arctic work, the greatest proportion of project costs went to travel, whereas the greatest proportion of costs for southern work was field supplies (Fig. 2). There were essentially no costs associated with consultation for southern work, as much of that can be done at prearranged community meetings, often undertaken as day trips from institutions, and thus costs are relatively minor (e.g., meals). In contrast, consultation for Arctic work represented ~10% of Arctic field research costs (~$2 100–$10 000) in all countries, because it included airfare and accommodation (as meetings are remote from home institutions) as well as honoraria for local Arctic community attendees (Table 1; excluding holding a

| Activity               | Canada HA | Canada LA | Canada/US LA | USA HA | USA LA | Greenland HA | Greenland LA | Norway HA | Norway LA |
|------------------------|-----------|-----------|--------------|--------|--------|--------------|--------------|----------|----------|
| Consultation           |           |           |              |        |        |              |              |          |          |
| Travel                 | 5092      | 1900      | 0            | 0      | 0      | 2100         | 1040         | 10184    | 3800     |
| Accommodation          | 380       | 380       | 0            | 0      | 0      | 4800         | 0            | 228     | 228      |
| Honoraria              | 0         | 0         | 0            | 0      | 0      | 0            | 0            | 114     | 114      |
| Per diem rate          |           |           |              |        |        |              |              | 1150    | 1150     |
| Program evaluation     |           |           |              |        |        |              |              | 1150    | 1150     |
| Social event for       |           |           |              |        |        |              |              | 608     | 380      |
| Community              |           |           |              |        |        |              |              |         |          |
| Permits                | 0         | 0         | 0            | 0      | 0      | 0            | 0            | 780     | 780      |
| Field supplies         |           |           |              |        |        |              |              |          |          |
| Fuel                   | 0         | 152       | 152          | 0      | 380    | 150          | 150          | 390     | 0        |
| Heater                 | 380       | 304       | 0            | 129    | 300    | 300          | 260          | 0       | 0        |
| Firearms               | 760       | 760       | 0            | 0      | 1800   | 1800         | 1690         | 0       | 0        |
| Ammunition             | 152       | 152       | 0            | 150    | 150    | 260          | 0            | 0       | 0        |
| Bear fence             | 2280      | 2280      | 0            | 300    | 0      | 650          | 0            | 0       | 0        |
| General supplies       | 5700      |           |              |        |        |              |              |          |          |
| Food                   | 3192      | 3040      | 2660         | 1596   | 1915   | 6300         | 6300         | 1300    | 1040     |
| Shipping               |           |           |              |        |        |              |              |          |          |
| Domestic north         | 608       | 2519      | 380          | 0      | 0      | 1050         | 260          | 130     | 760      |
| Arctic flights         | 1824      | 0         | 760          | 0      | 0      | 390          | 0            | 0       | 0        |
| Domestic south         | 456       | 0         | 0            | 0      | 600    | 0            | 0            | 0       | 0        |
| Arctic flights         | 1368      | 0         | 0            | 0      | 0      | 0            | 0            | 0       | 0        |
| Local help             |           |           |              |        |        |              |              |          |          |
| Guide/contract         | 0         | 0         | 0            | 0      | 0      | 0            | 0            | 3800    | 3800     |
| Camp assistant         | 0         | 0         | 0            | 0      | 0      | 0            | 0            | 0       | 0        |
| Trainee                | 4256      | 4256      | 0            | 0      | 0      | 0            | 0            | 10400   | 7800     |
| Rentals                |           |           |              |        |        |              |              |          |          |
| Truck                  | 38        | 608       | 0            | 304    | 1064   | 0            | 910          | 910     | 0        |
| All-terrain vehicle    | 760       | 0         | 0            | 0      | 0      | 0            | 0            | 0       | 0        |
| Snow machine           | 0         | 0         | 0            | 0      | 0      | 0            | 0            | 0       | 0        |
| Boat                   | 0         | 912       | 0            | 0      | 0      | 0            | 0            | 0       | 0        |
| Accommodation          |           |           |              |        |        |              |              |          |          |
| Base/staging facility  | 2280      | 2736      | 912          | 752    | 1824   | 1650         | 260          | 650     | 0        |
| In transit             | 0         | 912       | 0            | 0      | 0      | 0            | 0            | 0       | 0        |
| Travel to site         |           |           |              |        |        |              |              |          |          |
| Domestic to base/staging| 15276    | 9120      | 3468         | 0      | 7296   | 6300         | 1950         | 1300    |          |
| Local charter          | 11400     | 14262     | 2280         | 1140   | 22800  | 9000         | 1500         | 12000   | 130      |
| Communications         | 304       | 304       | 304          | 76     | 3192   | 750          | 750          | 3380    | 0        |
| Total                  | 51376     | 47408     | 14592        | 3792   | 35408  | 37950        | 10950        | 51350   | 12740    |

Note: Categories of costs are detailed in Methods, but include consultation (with indigenous communities), obtaining permits, field supplies, shipping from southern locations, local hires for field assistance (separate from local charters to get to/from field sites), rentals for equipment, accommodation at staging sites prior to field work, travel to site from staging location to field site, and communications.

The proportional breakdown of costs differed whether working in the Arctic or southern sites. For Arctic work, the greatest proportion of project costs went to travel, whereas the greatest proportion of costs for southern work was field supplies (Fig. 2). There were essentially no costs associated with consultation for southern work, as much of that can be done at prearranged community meetings, often undertaken as day trips from institutions, and thus costs are relatively minor (e.g., meals). In contrast, consultation for Arctic work represented ~10% of Arctic field research costs (~$2 100–$10 000) in all countries, because it included airfare and accommodation (as meetings are remote from home institutions) as well as honoraria for local Arctic community attendees (Table 1; excluding holding a
workshop). We stress that these costs and proportions must be considered relative to total costs; for example, the cost of providing food (daily allowances) for work in Greenland was more expensive than the entire project expenses in the Bay of Fundy (Table 1).

The costs of hosting a 2-day, community workshop in Arctic Canada (∼$13 000–$20 000) were greater than running the entire project in other locations (Table 1). It was 54% more expensive to hold an educational workshop in high Arctic Canada than in low Arctic Canada (Table 1), almost completely due to the higher costs of airfare.

**Discussion**

Across the four countries, our analysis suggests that it is approximately 8× more expensive to conduct a project in the Arctic (up to 19× more, depending on location) than to conduct the same project in southern, temperate regions, consistent with previous qualitative reports (e.g., NSERC 2000). There are some obvious reasons why it is more expensive to work in the Arctic. For example, in Canada in 2016, it cost approximately twice as much to ship 100 kg of gear from Ottawa to the high Arctic as it did to ship it anywhere else in southern Canada, based on posted cargo rates (Air Canada 2017; First Air 2017). At the same time, the lack of availability of many items in Arctic communities (e.g., various types of food supplies) required that overall shipping weight was greater for Arctic work; in other words, not only is it more expensive per unit mass but also more must be shipped for the project, further compounding expenses. Similarly, it is much more expensive to fly on northern airlines. In 2017, a 4300 km return flight from Halifax to Vancouver (southern Canada) in late June cost approximately $650, whereas a 4500 km return flight from Halifax to Ottawa to Resolute Bay cost $6000. This pattern is mirrored in other Arctic countries, but to a much lesser extent. For instance, it cost approximately $1000 to fly from Denmark to Greenland, but $1500 to fly from the low Arctic to high Arctic within Greenland (Air Greenland 2017).

Research in Canada is most expensive due to primarily aircraft-based access to sites (rather than ship-based access), as well as the need for consultation with and hiring from northern communities near research sites (note that community engagement efforts are
supported by all levels of government in the Canadian Arctic but require adequate funding to be conducted properly. In particular, in some Arctic locations and for some projects, consultation and collaboration with northern communities or organizations are essential to successful and meaningful research programs. In our Canadian work this has provided clear, mutual benefits (see Gilchrist et al. 2005; Mallory et al. 2006; Provencher et al. 2013, 2016 for examples), but achieving these successes was only possible with considerable time spent writing proposals to acquire extra resources required to cover these outreach expenses. In the case of holding a complete workshop (Provencher et al. 2013), the costs can be considerable (half of a typical researcher’s annual budget; below).

With the recognized (but generally not quantified) extra expenses of Arctic research, many countries have made some additional funds available compared with funding available for work in the south (e.g., Interact 2017, Svalbard Environmental Protection Fund for Norway/Governor of Svalbard 2017; North Pacific Research Board 2017; US NSF Office of Polar Programs 2017, Canadian programs outlined above). If we consider research in Canada in 2016, the average Natural Sciences and Engineering Research Council (NSERC) core research funding grant for an established ecological researcher was about US$30 000 (Government of Canada 2016), and successful applicants could acquire an additional ~$30 000 from a NSERC Northern Research Supplement and Polar Continental Shelf Program support (Government of Canada 2015a, 2015b; additional funds available only for Arctic logistic costs of travel, charter, or equipment). Given the costs we present in Table 1, this means that for an “average”, established researcher to undertake a project in the Canadian Arctic, effectively all of their core research grant would have to be applied to that one project, whereas a researcher doing the same work but in a southern location could theoretically conduct about five similar projects for the same core grant. Early career researchers tend to get less initial core research support (~75% of established researchers; Government of Canada 2016), and thus they may receive insufficient funding to realistically attempt Arctic research at all, unless they collaborate.

Why conduct research in the Arctic, when you can do more work for less money in the south? For some research questions, the Arctic is the only place where the work can be done. This certainly applies to topics like the effects of climate change on Arctic wildlife (Ferguson et al. 2012) or on northern glaciers, permafrost or sea ice (e.g., Hinzman et al. 2005; Comiso et al. 2008), and the concomitant impacts on diverse territorial and national issues like industrial development and infrastructure, and planning for adaptation and resilience. Moreover, many government scientists have a mandate to work in the Arctic, for reasons ranging from ensuring safe shipping (e.g., Smith and Stephenson 2013) to understanding environmental threats (e.g., Chan et al. 2013), and from monitoring internationally important wildlife populations (e.g., Armitage et al. 2011) to fulfilling reporting obligations under international conventions (e.g., Muir and de Wit 2010). However, for researchers not so constrained by mandate, or simply interested in the Arctic region, the question may become increasingly difficult to answer.

Scientific research costs money, and we have shown here that Arctic research is more expensive than many other locations, and for some prohibitively so. In an era of more focused research funding and the need to produce products quickly to be competitive (e.g., Kelly and Jennions 2006; van Dalen and Henkens 2012), it may become difficult to generate sufficient funds to initiate or continue Arctic projects in the coming decades unless new funding realities are enacted (e.g., Research Council of Norway 2017). Changes in Arctic ecosystems will continue to have local and global consequences, both positive (e.g., industrial opportunities) and negative (e.g., reductions in habitat for pagophilic biota), and understanding the implications of decisions that influence these consequences will only be possible with credible scientific data from research and monitoring. We hope
government policies and funding agencies can use the analyses we provide here, as well as other sources of data, for decisions on funding allocations, especially for funding important ongoing and new research in the Arctic.

Conflicts of interest
The authors have no conflicts of interest to report.

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