Arctic Science

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Long-term monitoring of Arctic birds at the East Bay Island Field Station, within the Qaqsauqtuuq Migratory Bird Sanctuary, 1996–2023

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Abstract

Northern common eider ducks (*Somateria mollissima borealis,* Linnaeus, 1758) are harvested throughout their range and represent an important resource of eggs, meat, and feather down. In the 1990s, there was growing Indigenous and international concern that eiders nesting in Arctic Canada were in decline. In response, Environment and Climate Change Canada (ECCC) established a field station on a small uninhabited island in East Bay, Southampton Island (64°01′N, 81°47′W), with the intention of developing a long-term study of eider demography that could inform harvest management. Throughout the nearly three-decade duration of the East Bay Island Field Station, field logistics revolved around regional sea ice conditions and how to maintain reliable transportation and access to the island. Despite these challenges, the gradual improvement of the field station facilitated a growing breadth of research as new issues emerged, many of which were unforeseen. Here, we provide an overview of the 28 years of research, including studies on the impacts of harvest, avian disease, contaminant levels and parasitology, details of bird migration, ecological trade-offs, and predator-prey dynamics. The breadth of these research topics reflects the diversity of expertise contributed by numerous university collaborators and graduate students, as well as Inuit ingenuity and Indigenous ecological knowledge that contributed to all stages of the research program.

Key words: ecological monitoring, Arctic, long-term, sea ducks, polar bear

1. Introduction

The northern common eider duck (*Somateria mollissima borealis;* mitiq in Inuktitut) is a waterfowl species harvested throughout much of its range for its eggs, meat, and feather down (Goudie et al. 2020). Eiders nesting along coastlines of northern Hudson Bay, Hudson Strait, and Baffin Island, Nunavut, are known to be under several pressures, including growing industrial marine shipping in the region, increased nest predation by polar bears (Smith et al. 2010; Iverson et al. 2014; Dey et al. 2017), disease outbreaks (Iverson et al. 2016*b*), mortality from both fisheries by-catch and harvest on their wintering grounds in West Greenland and Atlantic Canada (Merkel 2004*b*; Merkel et al. 2022), and changes in climate that may affect local ice dynamics and food availability (Jean-Gagnon et al. 2018).

Even as far back as the 1990s, there was growing Indigenous and international concern that northern common eider ducks nesting in Arctic Canada were in decline (CAFF 1997), perhaps due to overharvest on their wintering grounds in West Greenland and Atlantic Canada (Merkel 2004*b*). In response, Environment and Climate Change Canada (ECCC) established a modest field research station in 1996 on a small island in East Bay, Southampton Island (Salliq, 64°01′N, 81°47′W), that supported the largest known eider duck colony in the Canadian Arctic (estimated between 4000 and 6000 breeding pairs, Abraham and Ankney 1986), with the intention of developing a long-term study of eider demography to help assess the sustainability of winter harvest levels. More specifically, the original goal was to develop a bird banding program and related mark-recapture survival study that would inform harvest regulations in both Greenland and Canada. In the years that followed, the data on survival and reproductive rates generated by the field studies on East Bay Island contributed to demographic modelling as intended (Gilliland et al. 2009), which subsequently led to changes in harvest regulations that greatly reduced winter eider duck mortality in West Greenland (Merkel 2010).

Following those initial achievements, many other research topics were pursued at the East Bay Island Field Station and on a growing number of bird species affected by changing environmental conditions, regionally and in the North Atlantic, where many Arctic marine bird species overwinter. Simply put, the presence of an established field station in this remote location provided researchers with the ability to quickly investigate environmental topics as they emerged, many of which would have been otherwise missed. In fact, several of the most important scientific discoveries at this site occurred opportunistically and on topics that were entirely unforeseen when the project was first initiated (e.g., a sudden avian disease epidemic). Diverse research was undertaken, including the effects of harvest, avian disease, migration, contaminant levels, parasitology, and cascading impacts of climate change, including higher rates of polar bear (*Ursus maritimus*) depredation of eider nests. The logistics and infrastructure of the field station also provided the rare opportunity to study other species in detail such as snow buntings (*Plectrophenax nivalis*; an Arctic passerine) and herring gulls at the northern limit of their breeding range (*Larus smithsoniansus*).

Growing the scope of research in response to emerging issues required that the breadth of research expertise needed to be expanded. Over the years, numerous university collaborators and associated graduate students contributed diverse expertise on a wide variety of topics including demographic modelling, disease pathology and parasitology, anthropological ecology, avian physiology, behavioural ecology, genomics, and contaminants, just to name a few. Indeed, over the course of the 28-year East Bay Island program, 16 university professors and 41 graduate students (originating from 14 universities), as well as several research institutions (i.e., the Greenland Institute of Natural Resources; the Biodiversity Research Institute, Maine, USA; the Canadian Cooperative Wildlife Health Centre, Saskatchewan, Canada; Aarhus University, Copenhagen, Denmark), made important, timely, and innovative contributions.

Here, we report how and why the East Bay Island Field Station was established, the challenges that were overcome to start and maintain the program for nearly 30 years, and how an array of research methods was developed to address new and emerging issues, including the growth and integration of Inuit ecological knowledge. Key published research findings generated by the program are reviewed, and how wild birds responded to changing environmental conditions over time, research that was only possible through the collection and analyses of the long-term datasets generated on the island by the decades of challenging fieldwork. Throughout the paper, we emphasize how both Inuit ingenuity and ecological knowledge contributed to all stages of the research program including the identification of several important research topics that were undertaken. Related to this, we highlight recent efforts by our group to grow Inuit participation in environmental monitoring through the recent establishment of the Inuit Field Training Program.

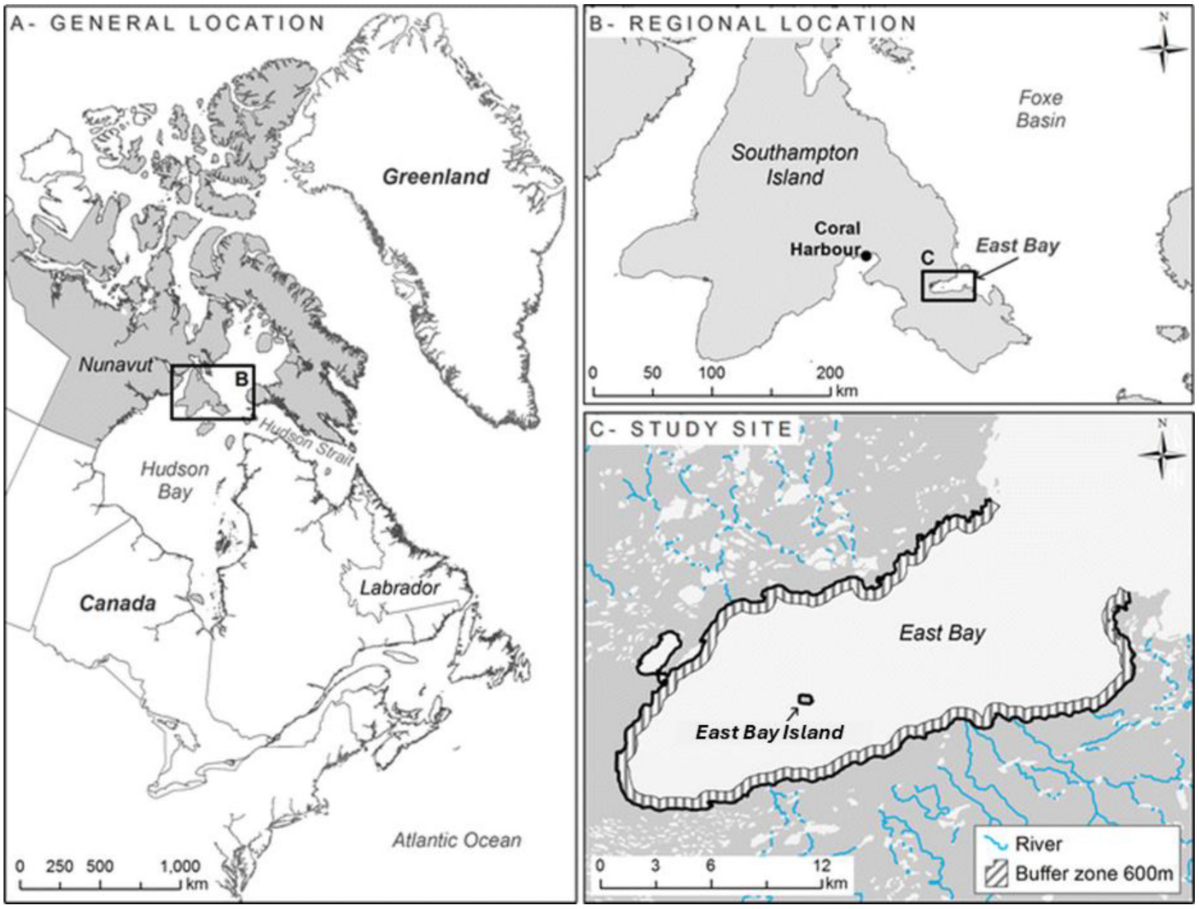
Finally, we conclude by explaining how the increase in polar bear activity that has occurred on the island resulted in the continuous decline of nesting eider ducks (due to a decade of reproductive failure caused by nest predation) and has led to an increasing risk of dangerous bear encounters for field personnel. In recent years, risks to safety have necessitated that the field staff leave the island in late June by helicopter before key, long-term data can be collected in July and August as it once was. Collectively, the worsening "bear situation", in which data acquisition has been truncated while risk to personnel from bear encounters has increased, sadly necessitated the responsible end of field operations at the East Bay Island Field Station in 2024, and we discuss the implications.

2. History of the East Bay Island Field Station

2.1. Historical context of the East Bay region

The geographical, Indigenous, and historical research context of Southampton (Salliq) Island has been recently reviewed (e.g., MacNearney et al. 2025, this volume). Briefly, archaeological evidence from Southampton Island suggests that Late Paleo-Inuit were present in the area to around 2000 years ago (Collins 1957), and that Early Inuit (Sallirmuit, Inuit from Southampton Island) inhabited the region by the early 14th century, supported by the rich regional diversity and abundance of terrestrial and marine mammals, fish, and birds (Clark 1980). Sadly, the Sallirmuit were decimated by disease after the construction of a whaling post on Southampton Island in 1897, with the few remaining survivors relocated to Naujaat in 1902 (Bird 1953). The island was gradually repopulated with Inuit, with many originating from northern Quebec where strong family ties remain. Inuit were relocated to the island by ship (N. Nakoolak, personal communication, 2025), in part to support both a Hudson's Bay Company trading post located at the present location of the hamlet of Coral Harbour (Salliq), and a large World War II air force base built in 1941 (now decommissioned). The air base was used as a staging point to ferry military aircraft to Europe via Greenland during the war and was located at the current location of the regional airport, 16 km west of Coral Harbour. Although the air base is considered a protected, historical site (Archaeological Ordinances), the hazardous waste left behind by the military is still being managed and removed by the Canadian Government. Today, approximately 1035 people live in the hamlet of Coral Harbour (N 64°08′, W 89°09′), which is the only community on Southampton Island. This population is predominantly Inuit (≥85%; Statistics-Canada 2021).

Fig. 1. Location of the East Bay Island Field Station within the Canadian Arctic.

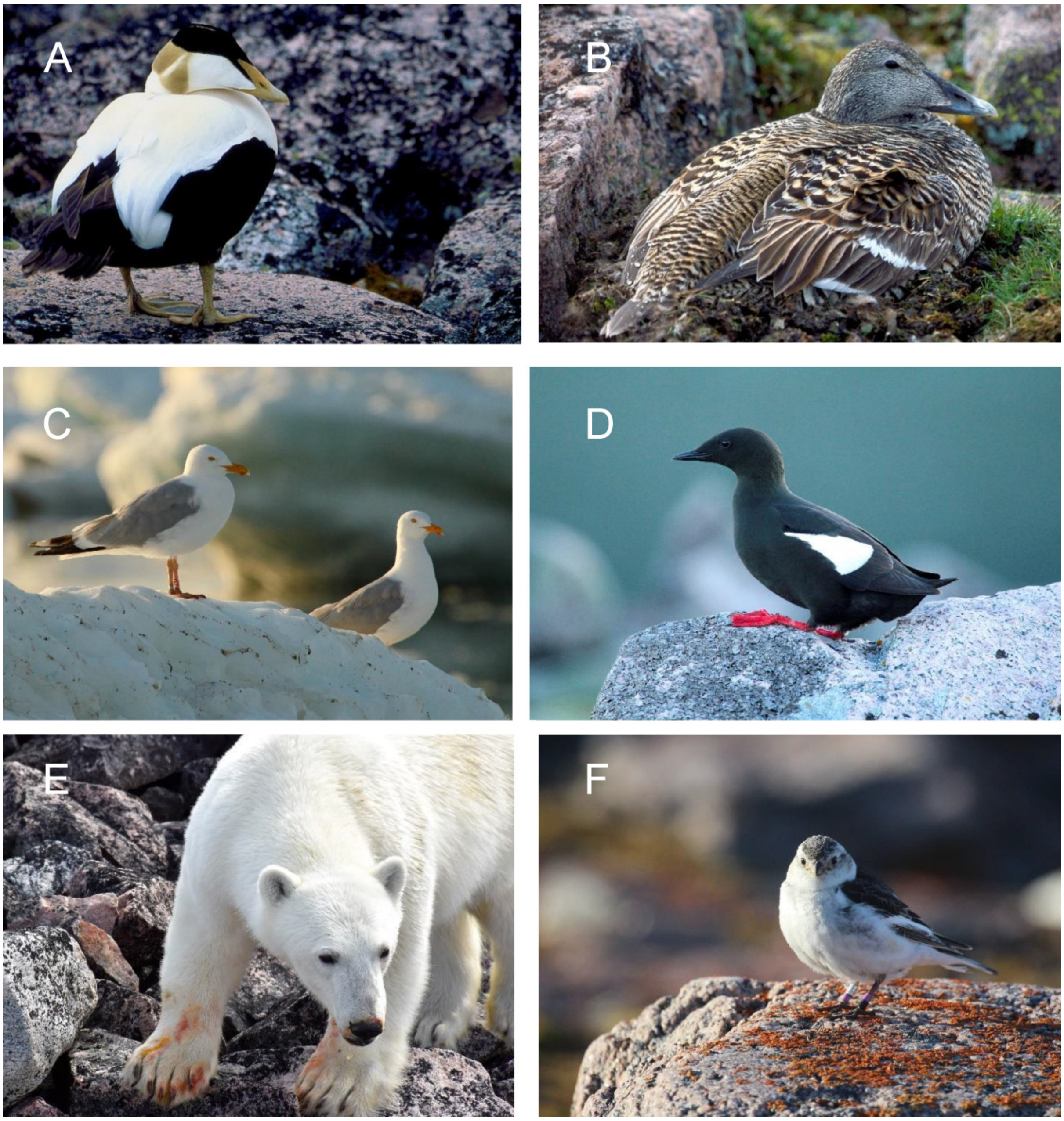


Extensive biological explorations of Southampton Island have been conducted by ornithologists since the early 1900s, and to a degree rarely achieved elsewhere in Arctic Canada. The earliest published information regarding bird species on Southampton Island was collected during the 1903–1904 expedition on the D.G.S Neptune by the ship's naturalist, Andrew Halckett (Halckett 1904). Since that time, expeditions have explored Southampton Island extensively with biologists often living and travelling with Inuit families for months at a time (Sutton 1931). Ornithological explorations were undertaken in 1929 and 1930 by George Sutton and a team of Inuit (Sutton 1931, 1932), and later by R. Bray in 1936 and 1937 (Bray and Manning 1943), Tom Barry and Graham Cooch in the 1950s (Cooch and Barry 1957), Ken Ross in the 1970s (Parker and Ross 1973), and Ken and Diana Abraham in the 1980s (Abraham and Ankney 1986, see below).

The efforts of Barry and Cooch culminated in the creation of two migratory bird sanctuaries (MBSs) established to protect snow goose breeding colonies from possible disturbance and/or potential development in the area (East Bay and Harry Gibbons MBSs, now Qaqsauqtuuq and Ikkattuaq MBSs). One of the original bird sanctuaries was named after the Inuit guide and interpreter, Harry Gibbons Unainnuk (c. 1900–1954). He and his family assisted many scientists in their studies of geese from the 1930s to the 1950s, including Barry and Cooch themselves (Cooch and Barry 1957). More recently, in 2015, both migratory bird sanctuaries on Southampton Island underwent official name changes to recognize the Inuktitut (i.e., Inuit language) place names of the two areas. In Inuktitut, Ikkattuaq refers to "the flat shallow area", describing the extensive tidal flats where the Boas River flows into the Bay of God's Mercy, whereas Qaqsauqtuuq means "place of many loons" in reference to the abundance of red-throated loons (*Gavia stellata*) that nest and stage there prior to their southward fall migration.

The East Bay Island Research Station lies within the Qaqsauqtuuq MBS (Fig. 1). The sanctuary encompasses 1124 km^2 located 50 km east of Coral Harbour and is centered around the marine waters of East Bay, a 50 km-long inlet extending west from Foxe Channel. In addition to this formal designation as a Federal Migratory Bird Sanctuary, the diverse avifauna of the area (Fig. 2), has resulted in its designation as an Important Bird Area in Canada (NU023; IBA Canada 2004), an Important Area for Birds in Nunavut (Site 16; ECCC 2012), and a Key Terrestrial (NU Site 44; Latour et al. 2008) and Marine (NU Site 24; Mallory and Fontaine 2004) Habitat Site for Migratory Birds in Nunavut. The coastal region has also been identified by the Sea Duck Key Habitat Sites Atlas as an internationally important habitat for sea duck conservation, and for eiders specifically (Sea Duck Joint Venture Key Sites Atlas 2022).

Fig. 2. Photos of the wildlife species researched in detail at the East Bay Island Field Station, including (A) common eider drake (male), (B) common eider hen (female), (C) herring gull, (D) black guillemot, (E) polar bear, and (F) snow bunting (photos A, B, C, D, and F by H. G. Gilchrist. Photo E by E. Richardson).



2.2. Responding to emerging conservation issues

In the 1990s, concern was growing, both nationally and internationally, that northern common eider ducks were in decline, possibly due to unsustainable harvest on their wintering grounds (CAFF Circumpolar Eider Conservation Strategy 1997). This was also of regional significance in Nunavut, because the common eider duck has a longstanding cultural significance for Inuit who have developed a broad ecological understanding of the species (Nakashima 1991; Henri 2007). Common eiders (Mitiq) continue to be a source of meat, eggs, and feather down for Inuit who harvest eiders annually (Henri 2012; Henri et al. 2018).

In response, the Northern Region of ECCC granted 2 years of initial funding to pilot a banding program of common eider ducks like those already ongoing for thick-billed murres (e.g., Coats Island, Patterson et al. 2024) and geese (e.g., Karrak Lake, Alisauskas et al. 2024; Bylot Island, Gauthier et al. 2023). Such a demographic study, in which birds were banded, released back into the wild, and then resighted/recaptured in subsequent years, was intended to generate estimates of their adult survival rates (see additional details below regarding banding and use of colour markers). This was intended to help inform whether harvest levels were sustainable. Such a study would also identify migration routes of common eiders nesting in Arctic Canada and confirm regions of their harvest from band returns.

The first step was to identify a site that supported a sufficiently large breeding population of eiders. Inuit ecological knowledge, archeological evidence, and field reports provided by biologists were all consulted. All corroborated that a large eider colony occurred on a small, low relief, offshore island found in East Bay, Southampton Island, (64°00′N, 82°30′W) that Inuit called, Qikiqtakuluk, meaning «nesting place for eiders».

A biological field team that had been studying gulls, geese, and Arctic Terns in East Bay, visited the island in July 1980, guided by Toomasie Nakoolak from Coral Harbour. They had walked across the sea ice from their temporary research camp located on the south coast of East Bay (K. Abraham, personal communication, 2024), and approximated that "between 3900 and 5900 active eider nests were present" (Abraham and Ankney 1986). They also noted the presence of numerous archaeological features such as tent rings, stone fox traps, and stone food caches. Some caches still contained eider duck bones, which suggested that the island had been frequently visited and seasonally inhabited by Inuit in the past, and that the island had been an important and reliable nesting site and harvesting location of eiders for centuries (K. Abraham, pers. com., 1995).

Observations from aerial surveys provided further evidence that the island in East Bay supported a sufficiently large eider population to warrant a demographic study (Gaston et al. 1986). In their extensive aerial survey of large birds across Foxe Basin and northern Hudson Bay, Gaston et al. (1983) reported that most common eiders observed from the air "were associated with colonies found on small offshore islands". They confirmed that while most eider colonies "supported less than 750 pairs", the island in East Bay "supported several thousands of birds", and was the largest that they had detected.

Both Inuit perspectives and published reports concurred that the island in East Bay apparently supported the largest northern common eider duck nesting colony in the Canadian Arctic. Additional written notes were provided by K. Abraham to H. Grant Gilchrist (HGG) in 1995, further detailing KA's visit to the island. In April 1996, Josiah Nakoolak (JN), Jimmie Nakoolak, and HGG travelled to the remote island by dog team for several days and confirmed that the 900 m × 500 m island hosted a large eider colony, was suitable for establishing a small research camp that the landfast sea ice was smooth enough to allow a plane to land nearby on skis, but that the island lacked a freshwater drinking source.

2.3. Early establishment of the East Bay Island Field Station

The unique challenges of establishing a field research station on a remote offshore island in the Arctic became clear the very first day the field team arrived onsite on 10 June 1996. The crew had planned for the pilot to land the plane on the ice of East Bay and drop them off near the island. Unfortunately, meltwater had already pooled on the surface of the ice by the time they had arrived, preventing the plane from landing safely. This necessitated its 3 h return to Iqaluit, on Baffin Island, to switch the landing gear from skis to wheels. Luckily, the fair weather the following day permitted the group to return, this time landing on a small gravel beach on the south shore of the mainland. The next three days were spent by the team pulling sleds loaded with food, equipment, and banding supplies across the wet sea ice and over to the island (6 km).

The challenges experienced during the first field season had shown that the dynamics of the sea ice surrounding the island would dominate the planning of research and camp logistics going forward. Planes could only reliably land on the ice during the last weeks of May and early days of June, necessitating that most of the food, freight, and people had to arrive while planes could still land safely on the ice near camp (Fig. 3). Departure from the island was just as challenging. In the early years, people would leave the island by walking out over the ice in late June carrying their own personal gear or by boating out after the ice break-up in late July and early August. Between the time when the sea ice was no longer safe to walk on, and after the ice had cleared out of the bay enough to permit boating, the field crews were stranded on the island and could not be resupplied for up to 20 days (2011 field season). Although there were several small, shallow ponds found on the island, the water was contaminated by bird guano and was not safe to drink.

In time, the project acquired a reliable snowmobile and qamutiik sled, which greatly enhanced the movement of gear, people, and barrels of drinking water into camp, and was essential for the evacuation of people to Coral Harbour in the rare case of an emergency. Each May, JN would also use the snowmobile to travel from Coral Harbour out to East Bay in advance of "plane day" to demarcate a landing strip on the ice to assist the pilots. The station was equipped with a VHF radio to communicate daily with the nearby (7 km) East Bay Mainland Field Station (MacNearney et al. 2025), and satellite phones were used to coordinate incoming and outbound flights. Weather was monitored on the island using a mast-mounted Davis Pro weather station.

2.4. Improvements required to meet changing needs

Over the course of the project, the timing of ice break-up became increasingly unpredictable and walking over the ice and/or boating consequently became much more dangerous. To reduce risk, ECCC and federal partners at the Polar Continental Shelf Program, Natural Resources Canada (NRCan), arranged to have a helicopter extract the field crew from the island each year and fly them the short distance to the mainland. There, they had temporary accommodation in the Mainland Camp (MacNearney et al. 2025, this volume), until they were flown back to Iqaluit by Twin Otter.

Early during the project, spring snowstorms, below zero temperatures, and dramatic rain events were endured by field teams living in nylon dome tents (Fig. 3); the living conditions were recorded for posterity in the 1997 daily camp log

Fig. 3. Photos of the East Bay Island Field station over time (1996–2023), including (A) tent camp in 1998, (B) tent camp in 2002, (C) plane having landed on sea ice near East Bay Island in 2022, (D) interior of the sleeping cabin, and (E) sleeping, laboratory, and kitchen cabins in 2023 (photos by H. G. Gilchrist).

with one word: "Adverse". These living conditions combined with the risks of occasional polar bear encounters prompted the construction of a wooden 4 × 5 m sleeping cabin by ECCC in 2000. Construction was funded by a federal infrastructure grant intended to improve worker safety. The cabin accommodated eight people and greatly improved living and safety conditions (Fig. 3), while the rest of the camp at the time still consisted of three canvas tents used for food storage, as a kitchen and dining area, and as a laboratory i.e., blood centrifuging, eider duck dissections, and surgical implantation of satellite transmitters used to track eider migration conducted in 2001, 2003, 2012, and 2013 (Mosbech et al. 2006; Fast et al. 2011; Fig. 4). As the program continued and the diversity of topics under study expanded, the size of the summer field crews grew. This necessitated the construction of a second, small, plywood "over-flow" sleeping cabin (2008),

Fig. 4. Photos of East Bay Island Research methods, including (A) opening the eider duck banding net, (B) extracting a king eider duck from the net, (C) banding a snow bunting, (D) reading eider bands from an observation blind, (E) surgically implanting a satellite transmitter into an anesthetized eider duck, and (F) centrifuging blood samples in the lab cabin (photos by H. G. Gilchrist).

soon followed by a 4 × 8 m building that served as a laboratory, affectionately called the "*Labin*" (Fig. 4). Finally, a 4 × 9 m kitchen cabin was constructed in 2019.

A solar power system was mounted on the roof of the lab cabin in 2013 providing electricity for lights, freezers, operation of scientific equipment, and to charge batteries. This was funded by the Federal Arctic Research Infrastructure Fund of Polar Knowledge Canada (POLAR). Once the solar system was in place, generators were used only as back-up and to power tools. In response to the growing interactions with polar bears on the island each year, a 9000 V electric fence, powered by the solar power system, was constructed around the camp's perimeter in 2017 by professional contractor Jeff Marley (Margo Supplies Ltd., Fig. 3). All staff members on the island carried handheld radios and shotguns when they left the bear fence perimeter to work, necessitating that all field staff acquire a Federal Possession and Acquisition Firearms License, and complete additional firearms training provided by ECCC in Ottawa prior to each field season.

The East Bay Island program was typically (and intentionally) staffed by a diversity of field personnel with varying skills and prior experience. High turnover between years was

Table 1. Attributes of the East Bay Island Field Station, 1996–2023.

Field station features	
Organisation that created the station	Canadian Wildlife Service (now part of ECCC)
Organisation that maintains the site (2023)	Environment and climate change Canada
Location	64°01′N, 81°47′W
Distance to the nearest community	45 km (Coral Harbour, NU)
Number of permanent buildings	4
Number of people supported at one time	10–12
Camp equipment	Propane stove, electric freezer, sat phone
Camp power	Solar system, two portable generators
Key considerations for camp	Island too small to land fixed wing aircraft
	High polar bear (*Ursus maritimus*) encounters
	Helicopter support required to extract field team
	No drinkable fresh water on the island
Collaborating organisations	Environment and Climate Change Canada
	Carleton University
	University of Windsor
	Trent University
	University of Guelph
	University of Saskatchewan
	Simon Fraser University
	University of New Brunswick
	Queen's University
	Dalhousie University
	University of Michigan State
	Oxford University
	University of Quebec, Rimouski
	Acadia University
	Aarhus University
	Biodiversity Research Institute
	Canadian Wildlife Health Cooperative
	Greenland Institute of Natural Resources
	Sea Duck Joint Venture
	Circumpolar Seabird Working Group
Focal species for monitoring	Common Eider
	Herring Gull
	Snow Bunting
	Polar Bear
Ancillary species monitored	Black guillemot
	King eider duck
Environment Canada Field Technicians	Maureen Kay (1996–1999, 2006)
	Myra Robertson (2000–2005)
	Bonnie Fournier (2003)
	Michelle Bacchi (2007)
	Amie Black (2008–2013)
	Mike Janssen (2012–2018)
	Christie Macdonald (2017)
	Jake Russel-Mercier (2015–2017)
	Catherine Geoffroy (2018)
	Bronwyn Harkness (2019)
	Maisey Roach-Krajewski (2023)
	Holly Hennin (2019-present)
Thesis students and Post Doctoral Fellows (PDF)	Grace Bottitta (MSc, Trent University, 1998)
	Sarah Jamieson (MSc, U. of New Brunswick, 2000)
	Karel Allard (PhD, U. of New Brunswick, 2000)
	Joel Bety (PDF, Simon Fraser U., 2001)

Table 1. (*concluded*).

Field station features	
	Kerrith McKay (MSc, U of Guelph, 2001)
	Peter Fast (MSc, U of Saskatchewan, 2002)
	Laura McKinnon (MSc, U of Michigan State, 2002)
	Isabel Buttler (MSc, Carleton U, 2007)
	Dominique Henri (MSc 2006, PhD, Oxford U, 2007)
	Lisha Berzins (MSc, Trent U., 2006).
	Edith Senechal (MSc, U. Quebec, Rimouski, 2006)
	Oliver Love (PDF, Simon Fraser U., 2007)
	Sebastien Descamps (PDF, Carleton U., 2007)
	Samuel Iverson (PhD, Carleton U, 2009)
	Christie Macdonald (MSc, U of Windsor, 2010)
	Sarah Baldo (MSc, U of Windsor, 2010)
	Sarah Guindre-Parker (MSc, U of Windsor, 2010)
	N. Jane Harms (PhD, U of Saskatchewan, 2010)
	Holly Hennin (PhD, U of Windsor, 2010)
	Jennifer Provencher (PhD, Carleton U, 2010)
	Pierre Lagegneux (PDF, UQAR, 2012)
	Frankie Jean-Gagnon (MSc, UQAR, 2013)
	Rolanda Steenweg (PhD, Dalhousie U, 2013)
	Nik Clyde (MSc, Carleton U, 2015)
	Sean Power (MSc, U of Windsor, 2015)
	Christine Anderson (MSc, Acadia U., 2015)
	Jacintha Van Dijk (PDF, Carleton U., 2015)
	Cody Dey (PDF, U of Windsor, 2015)
	Holly Hennin (PDF, U of Windsor, 2016)
	Kyle Parkinson (MSc, U of Windsor, 2017)
	Patrick Jagielski (MSc, U of Windsor, 2017)
	Reyd Smith (MSc, U of Windsor, 2018)
	Erica Geldart (MSc, U of Windsor, 2018)
	Andrew Barnas (PDF, U of Windsor, 2020)
	Erika Nissen (MSc, U of Windsor, 2020)
	Duncan Wright (MSc, U of Windsor, 2022)
	Alysha Riquer (MSc, U of Windsor, 2022)
	Rebecca Jardine (MSc, U of Windsor, 2022)
	Emily MacDonald (MSc, U of Windsor, 2022)
	Shay Kroeze (PhD, Queen's University, 2023)
	Kerry Roe (MSc, Queen's University, 2023)
	Jacob Peterson-Galema (MSc, U of Windsor, 2024)

also common because, as is typical of many long-term programs, field crews consisted of many early-career scientists, seasonal field technicians, and graduate students (the latter of whom predictably left the program following their thesis completion, Table 1) This posed challenges when trying to ensure that field workers consistently followed established research, safety, and data entry protocols. To address this, the Principal Investigators wrote a Field Manual that was sent to field staff prior to each field season. Printed copies were also available in camp for reference. The Manual listed emergency response numbers and field safety protocols and then went on to review field preparation (e.g., what to bring and what would be provided), behavioral expectations and responsibilities of staff, aspects of logistical planning, required camp maintenance, and a detailed easy-to-follow description of all research methods. Over the course of 28 years, the Field Manual was regularly updated as new research projects were initiated and others were completed. Two additional field manuals were written specifically to address polar bear safety (written by MJ) and data management (see below, written by IB).

3. Development of monitoring programs

A foundational element of the eider study was the establishment of a long-term banding and mark-resight program. Additionally, new capture techniques (see below) enabled the project to take numerous physical measurements of eiders and to collect biological samples (e.g., blood samples, blood smears, feathers, and swabs) immediately upon their arrival to their breeding grounds, prior to egg laying. Capturing birds prior to laying enabled novel research of within-season physiology and how it related to factors such as breeding propensity, nest initiation date, nest success, predation, and environmental conditions (e.g., snow, ice, and water temperature). These diverse research elements were predicated on the development of several new capture and monitoring techniques reviewed below.

Research permits were applied for and acquired annually, including Nunavut Wildlife Research (WL-000159 to WL-2023-010), Animal Care Approval (2002PNR008 to 24GG26), Canadian Wildlife Service Wildlife Research in Nunavut (NunSCI-02-04 to SC-NR-2024-NU-002), and Access to Inuit Owned Lands (VX15N07). The research program followed the codes and ethics of the Wildlife Animal Care Committee guidelines, Environment and Climate Change Canada.

3.1. Eider banding

The project developed a new sea duck capture technique, much like the mist net systems used to capture small passerines, but on a much larger scale. The team suspended 60 m long salmon fishing nets, attached with metal shower curtain rings, to a steel cable raised above the ground by two metal poles (Fig. 4). The cable was drawn tight using a winch that enabled the team to raise and lower the net when needed and close it at the end of the banding sessions. Both common and king eider (*Somateria spectabilis*) ducks were caught in these large "flight nets" as they flew over the nesting colony before they initiated egg-laying, although king eiders were caught more infrequently. The timing of this approach minimized the risk of nest abandonment by eider hens because they were captured before most eider ducks had laid. Once extracted from the nets, individual eiders were banded with Incoloy metal bands as well as unique colour alpha-numeric Darvic bands so that they could be individually identified from a distance after release, while on migration, or when harvested on wintering grounds in either west Greenland or Atlantic Canada. During the years of the study (1996–2023), 8738 adult common eider ducks were banded.

From 2002 onward, plastic colour nasal tags were also applied to the bills of hens with suture material that intentionally degraded with time. In this way, nasal tags fell off prior to the bird's fall migration. Colour nasal tag combinations helped identify individual hens when their colour leg bands were concealed under them while incubating. Morphological and physiological measures of nasal-tagged hens were also taken at the time of capture so such parameters could be further related to their timing of arrival at the colony and their reproductive effort following their release back into the wild (Hennin et al. 2015).

The project attempted to establish a known-aged, banded eider population to help understand population dynamics, and to do so required that many ducklings had to be banded each year. As in other eider colonies (Goudie et al. 2020), departing broods of ducklings were accompanied to sea by several adult eider hens within hours after hatch. Even on the low-relief island, there was an obvious flow of ducklings downhill as they walked from nesting areas down towards the margins of the island and out to sea. Taking advantage of this "flow", ducklings were captured by applying the concept of a fish weir to trap ducklings and their accompanying adult hens as they left the island. At three locations on the island, small stone walls were constructed that funneled departing broods into wire box traps on the shoreline. While in the traps, ducklings were protected from predation by herring gulls as they awaited banding.

This passive capture technique allowed for the banding, weighing, and measuring of many ducklings, as well as hens (many of whom had been captured earlier in the field season; see above). The date of departure, body measurements (mass and tarsus length), and banding location of each duckling were recorded. Ducklings were banded with a custom-made, Incoloy waterfowl duckling band filled with plasticine (Descamps et al. 2011). The plasticine prevented the large band from slipping off the legs of small ducklings and eventually eroded as the duckling grew. Overall, 2339 eider ducklings were banded over the course of the study. This effort was most effective in the early years when there was strong reproductive success, and prior to the years of annual nest failure generated by polar bear predation (see below).

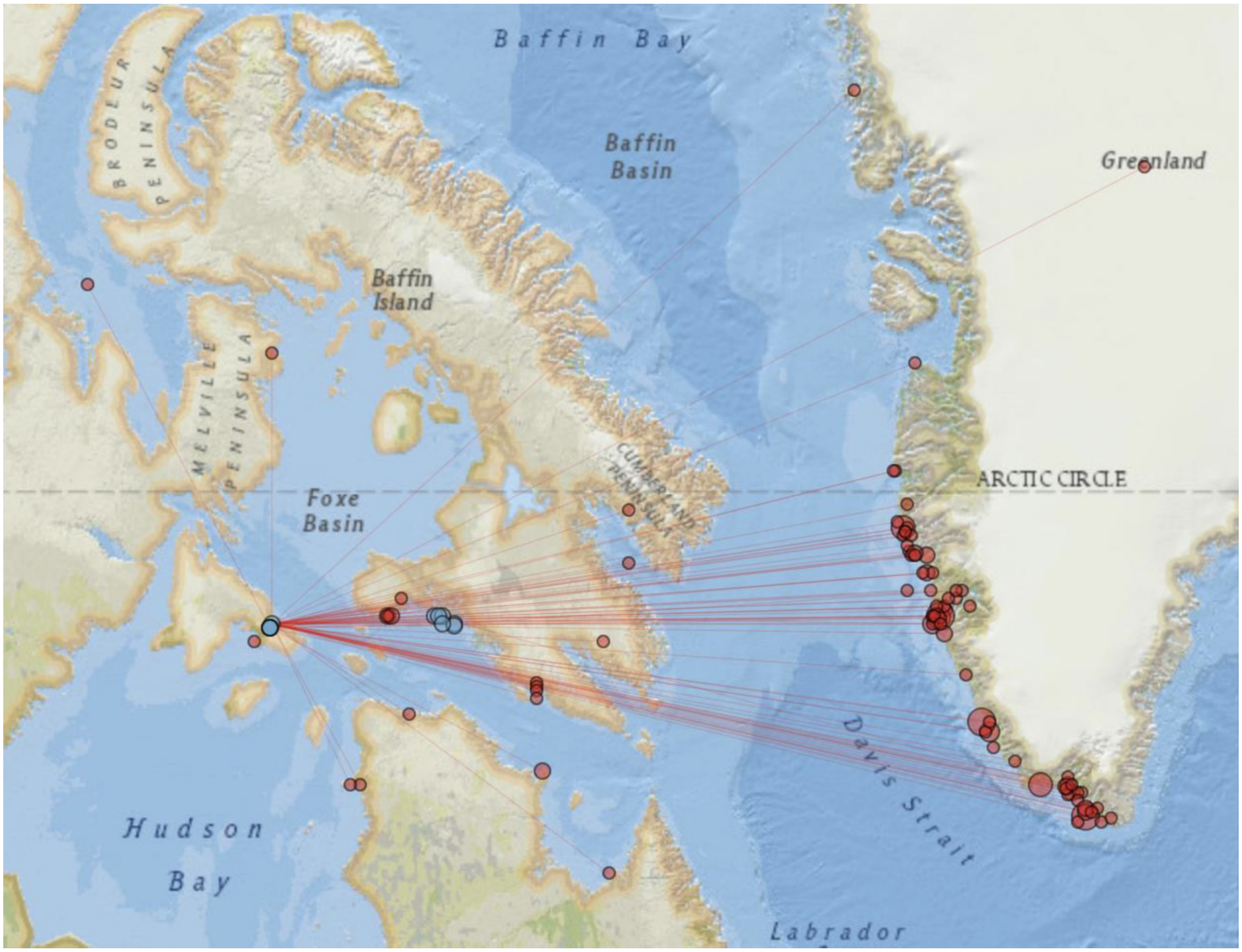
3.2. Band reading and daily counts of permanent eider nesting plots

Efforts were made to resight all banded eider ducks. Following net-banding in June, eiders were released and efforts made to re-sight them on the island in the subsequent months and years. Recognizing that the field team would be devoting hours to this effort, wooden observation blinds were constructed on the island to provide concealment from wildlife and protection from inclement weather (Fig. 4). Each blind was accessed by staff crawling on their hands and knees through canvas access tunnels so that they could enter and leave the blinds without disturbing the colony. One blind was situated to intentionally overlook a 3 ha pond on which eiders landed and loitered on its margins (particularly during the period of early colony arrival). This blind location provided ideal opportunities to read their alpha-numeric bands using spotting scopes (termed, "Main Pond Band Reading", Figs. 4 and 8). Other blinds were located overlooking long-term study plots, in which the arrival, nest initiation date, nest site fidelity, recruitment, and nest outcome were monitored twice daily until nests failed, or eggs hatched, and ducklings departed the colony.

3.3. Sampling for contaminants, parasites, genetics, disease, and physiological markers

The annual efforts to capture and band common eiders in support of demographic mark-resight studies, also provided the opportunity to collect biological samples and conduct experimental studies rarely achieved among wild bird populations, including parasite treatments, hormonal implantation, and body condition manipulation. The fact that eiders were captured prior to their nest initiation, rather than on their

Fig. 5. (*a*) Location of eider ducks banded at East Bay Island recovered in Nunavut, Nunavik, and west Greenland through harvest or mortality caused though by-catch in coastal fishing gear (Basemap: Leaflet Provided StreetMap). (*b*) Location of eider ducks banded at East Bay Island recovered in eastern North America primarily through harvest (Basemap: Leaflet Provided StreetMap).



nests following clutch completion, also provided a unique research opportunity at this site. Individual reproductive strategies of wild birds could be related to variable levels of parasite burden (Provencher et al. 2017), contaminants (Wayland et al. 2003; Provencher et al. 2016*a*), physiology (Descamps et al. 2011), hormone levels (Legagneux et al. 2013; Harms et al. 2015; Hennin et al. 2016), emerging infectious diseases (Descamps et al. 2009), as well as oceanic conditions both in the North Atlantic (Love et al. 2010; Guéry et al. 2017, 2019), and locally (Love et al. 2010; Jean-Gagnon et al. 2018). Biological sampling at East Bay Island also generated a long-term database of multiple physiological traits of individual eiders including how hormone levels mediated reproductive timing and investment (Hennin et al. 2015, 2019).

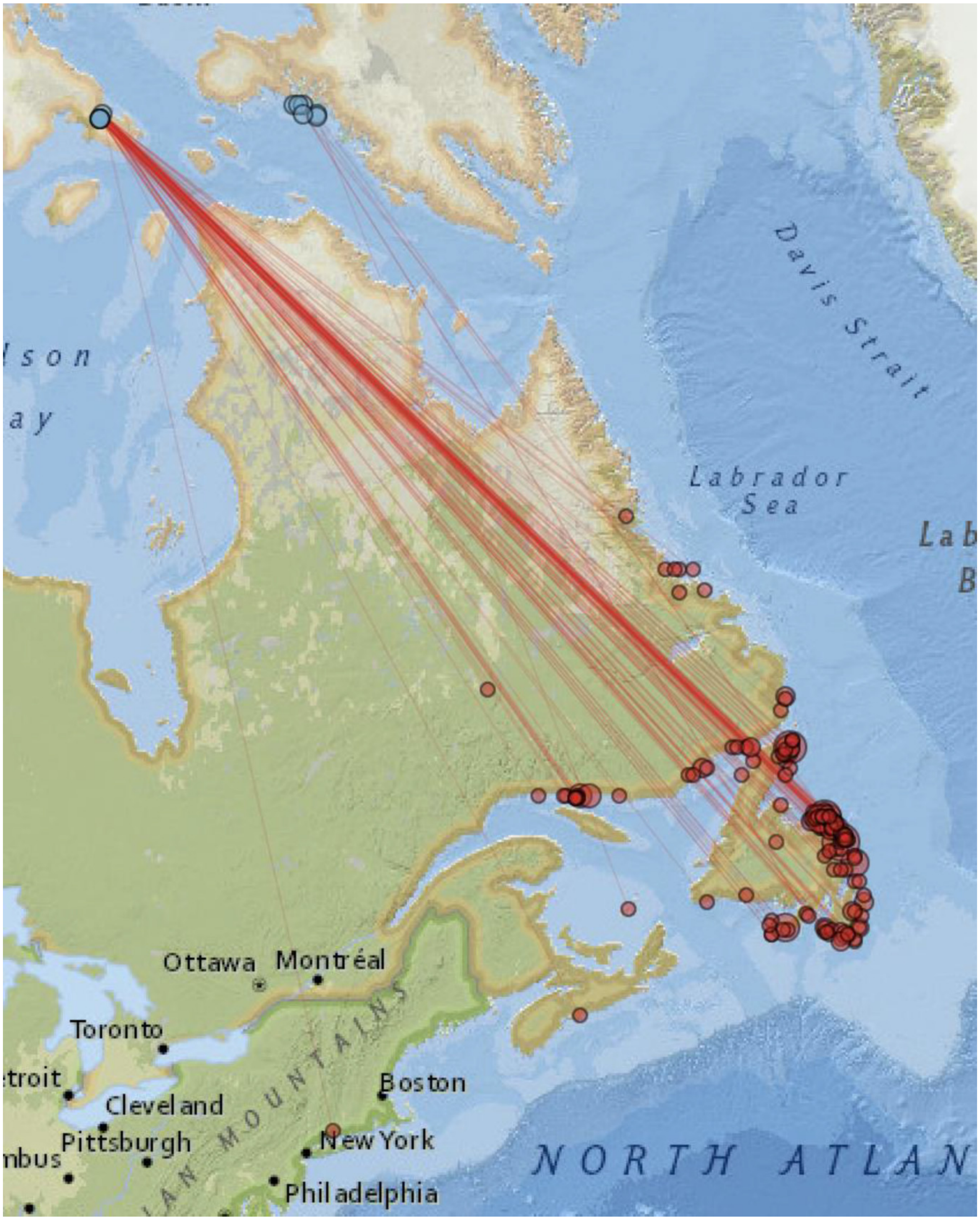
3.3.1. Contaminants and parasites

Infrequently, a small number of eiders were collected for dissection (<15 per year) to examine organ size, energy reserves, and morphology. This provided an additional opportunity to examine eiders for contaminants and parasite burdens. Concentrations of trace elements such as cadmium, mercury, and selenium were examined in livers, kidneys, and blood of dissected birds (Wayland et al. 2001), and experimentally in relation to stress response, immune function, body condition, and reproductive stage (Wayland et al. 2002, 2003, 2005; Provencher et al. 2017). Eiders collected and dissected also provided the opportunity to assess parasite burden in relation to sex, age, migratory behaviour, and breeding propensity (Provencher et al. 2017; Vestbo et al. 2019).

3.3.2. Genetics

Blood samples collected from female eiders during the banding process were examined to explore the presence of kin-based sociality while breeding. Molecular markers were used to genetically characterize female social groups at

Fig. 5. (*concluded*).



arrival, nesting, and when departing the colony with ducklings (McKinnon et al. 2006).

3.3.3. Disease

When eiders were captured at the banding nets, cloacal and tracheal swabs were collected to monitor the pathogen dynamics at the site. During an avian cholera epidemic that began on East Bay Island in 2005 and 2006 (see below), biological sampling intensified so that both swab and blood samples were taken from the same individuals upon their arrival to the island and just prior to laying. This enabled the team to assess pathological aspects of the avian cholera outbreak as it unfolded, and eventually why mortality levels at the colony declined over time (Fig. 9). Mortality rates could be assessed in relation to acquired herd immunity, the proportion of birds previously infected, and variation in annual colony size (Iverson et al. 2016*a*; Van Dijk et al. 2021).

Fig. 6. Number of nesting female common eider ducks (as an index of colony size) and field days spent on the island, both in relation to year.

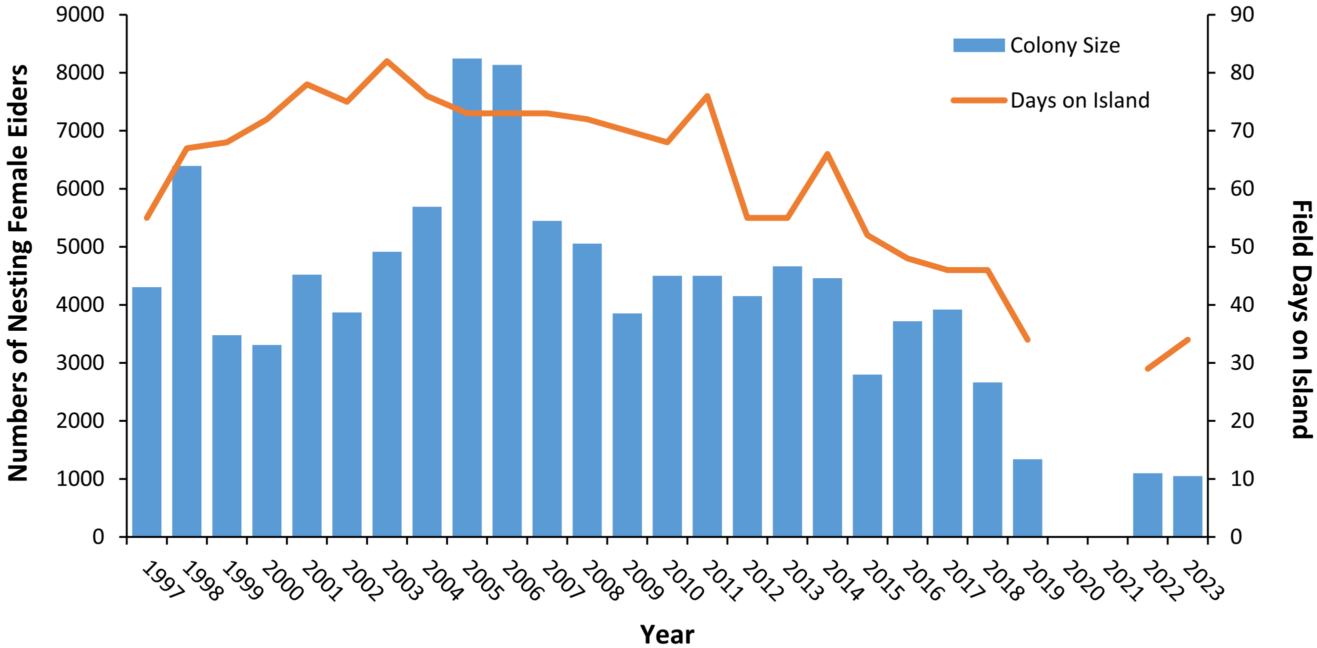
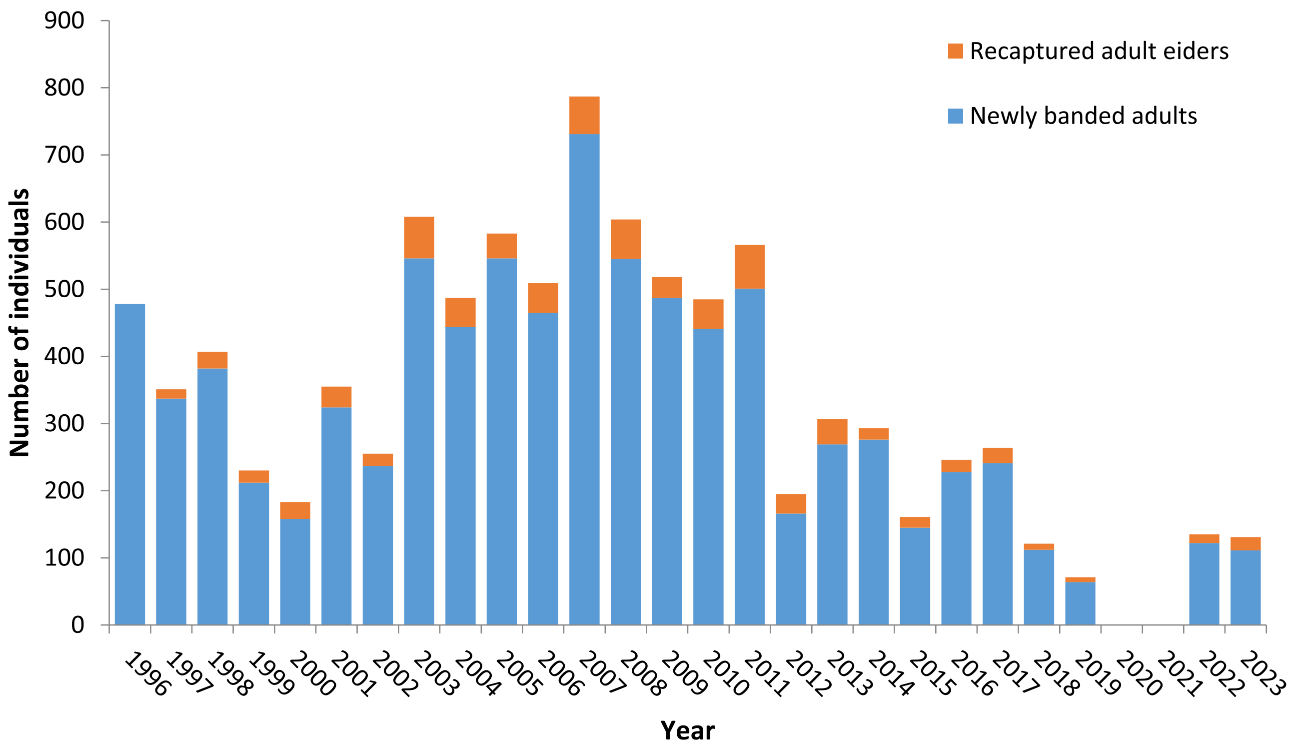


Fig. 7. The number of new eider ducks banded and/or recaptured on East Bay Island in relation to the year.



3.3.4. Physiological markers

Feathers collected from eiders at banding were examined for corticosterone concentrations (CORT) to examine hormonal activity (baseline and stress-induced) during the period of feather growth which occurred the fall before feathers were collected (Goudie et al. 2020). One tail feather (second lateral right feather) was plucked from each individual and stored in an envelope in a dark and dry place until laboratory analyses.

Toe-clippings taken from both male and female common eiders at capture were analyzed for stable isotopes, allowing individuals to be assigned to one of two overwintering

Fig. 8. Number of eider duck bands recorded annually on East Bay Island in relation to year.

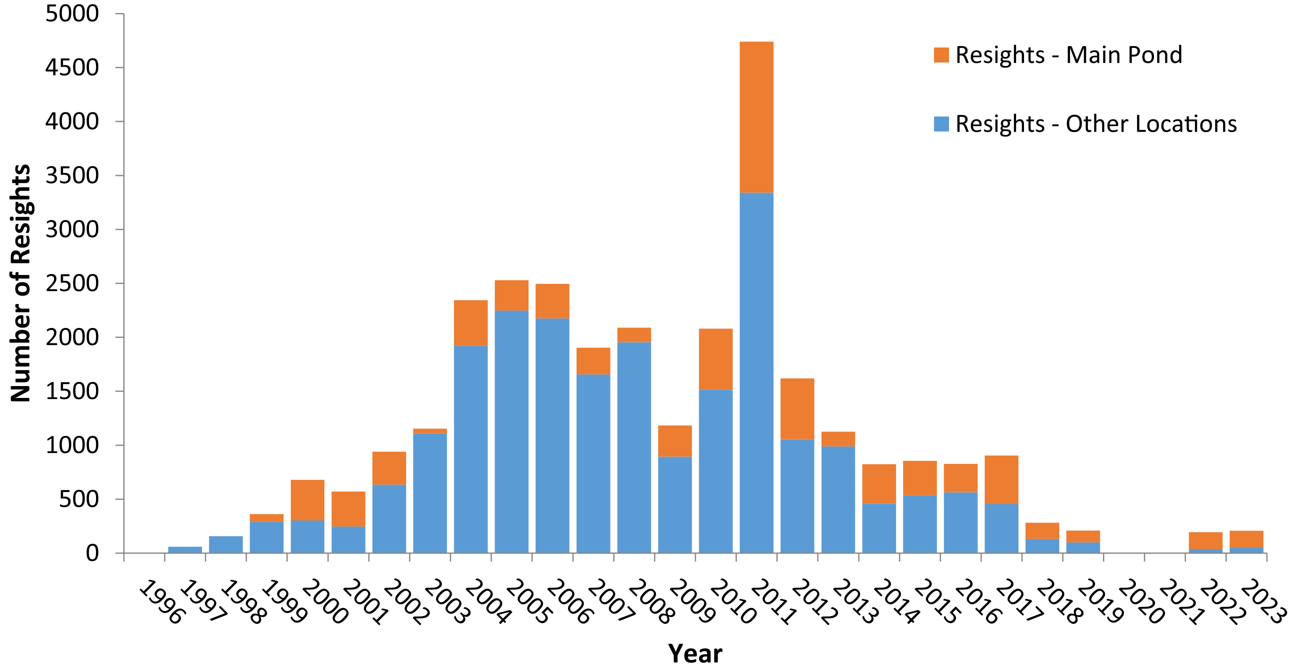
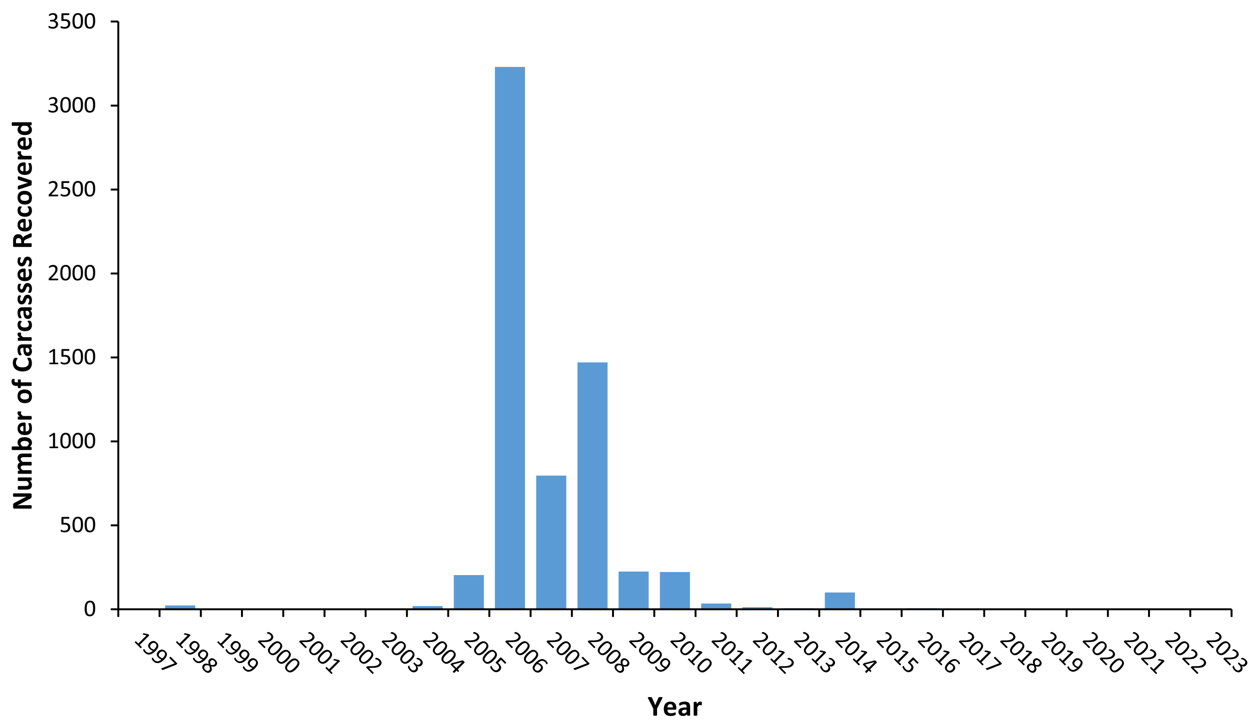


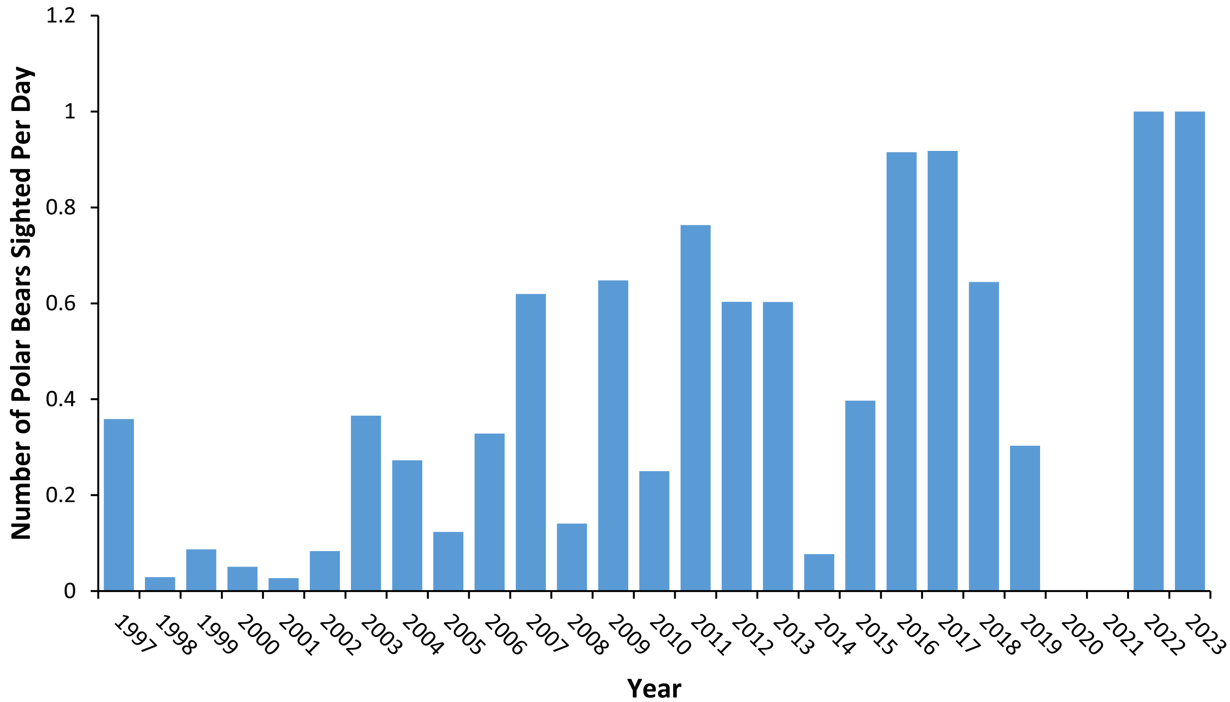
Fig. 9. Number of eider ducks recovered dead on East Bay Island from Avian Cholera in relation to year.



locations: Greenland or off the coast of Newfoundland and Labrador (Steenweg et al. 2017). Implementing the use of stable isotopes from both claws/toe clippings and blood samples demonstrated that the time when pairs were formed varied based upon their wintering location (Steenweg et al. 2017).

Blood sampling was first included in our capture protocols in 2001 with the aim of obtaining plasma to measure triglycerides and vitellogenin, as indicators of reproductive decisions made by female eiders. For example, triglycerides, when corrected for body mass, can indicate the rate at which a bird is fattening, and vitellogenin is a protein hormone that

Fig. 10. The number of polar bears observed per day of camp operations in relation to the year.



birds only produce when they are recruiting follicles in anticipation of egg laying (reviewed in Hennin et al. 2015). Using these traits, it was possible to discern true pre-laying females from those that were already recruiting follicles (Hennin et al. 2015).

From 2006 to 2023 (excluding 2020 and 2021 due to Covid-19), 1 mL of blood (<1% total blood volume as outlined in Canadian Council of Animal Care guidelines) was collected. Blood was collected within 3 min after the birds being captured in the flight nets to obtain baseline corticosterone samples (i.e., not representative of stress levels). Importantly, this also provided us with ∼0.5 mL of plasma from each female to assay a suite of relevant physiological traits (e.g., baseline corticosterone and triglycerides; Hennin et al. 2015, 2016). Males were sampled as well from 2015 to 2017. With the deployment of nasal tags on females, often prior to laying, East Bay Island Program presented a unique opportunity to capture and biologically sample individual females at the nets with minimal disturbance, release them, and subsequently relate their reproductive decisions to their prior physiological state at capture.

3.4. Vertebrate biodiversity

Since the inception of the program, birds and mammals observed on, or adjacent to, the island were recorded as part of a "daily species log". Field staff convened in camp at the end of each workday and discussed the species that they had observed and to derive estimates of the numbers seen. In this way, the program confirmed the list of avian and mammalian species that reproduced on the island annually, visited regularly, or were considered occasional visitors or vagrants (Table 2). This historical record of species occurrence and abundance also provided information on the timing of arrival of wildlife to the island in relation to the year and environmental conditions.

3.5. Polar bear daily occurrence and new behavioral studies using aerial drones

Polar bears were frequently encountered while conducting field studies on East Bay Island (Fig. 10). Many bears passed by the island without incident, travelling on the sea ice in a consistent direction from southwest to northeast, suggesting that an annual overland migration of bears occurred in June as they travelled from Fisher and Evans Straits across southern Southampton Island, through East Bay, and onward towards the floe edge in Foxe Channel. This is a view shared by the Aiviq Hunters and Trappers Organization (HTO) of Coral Harbour. Occasionally, bears arrived onto the island itself, where they slept, ate eider duck eggs (see bear research below), and/or investigated camp. The daily occurrence of bears, as well as their body condition, was recorded each day across all the years in our daily log, and this long-term information provided the opportunity to quantify the relationship between bear encounter rate and the seasonal timing of sea ice break-up in the region (Iverson et al. 2014). As bear occurrences on the island increased over the years of the project, their impact on nesting eiders and herring gulls grew. In response, the project expanded in 2016 to study the predator-prey relationships of bears, eider ducks, and herring gulls by video-graphing their behavioral interactions from above using aerial drones flown by students and technicians operating from within the safety of the electrified bear fence (e.g., Jagielski et al. 2022; Barnas et al. 2024). Bear monitoring expanded to include trail cameras (n = 20–38 per year)

Table 2. List of species observed at East Bay Island (F: frequently, O: occasionally, R: rarely).

Common name	Scientific name	Status
Mammals		
Bowhead whale	*Balaena mysticetus*	R
Beluga	*Delphinapterus leucas*	O
Polar bear	*Ursus maritimus*	F
Atlantic walrus	*Odobenus rosmarus*	O
Bearded seal	*Erignathus barbatus*	F
Ringed seal	*Pusa hispida*	F
Caribou	*Rangifer tarandrus*	F
Arctic fox	*Vulpes lagopus*	F
Ermine	*Mustela erminea*	R
Northern Collared Lemming	*Dicrostonyx groenlandicus*	O
Birds		
Red-throated Loon	*Gavia stellata*	B
Pacific Loon	*Gavia pacifica*	F
Common Loon	*Gavia immer*	O
Yellow-billed Loon	*Gavia adamsii*	R
Greater White-fronted Goose	*Anser albifrons*	O
Snow Goose	*Chen caerulescens*	F
Ross' Goose	*Chen rossii*	F
Canada Goose	*Branta canadensis*	F
Cackling Goose	*Branta hutchinsii*	B
Brant	*Branta bernicla*	B
Tundra Swan	*Cygnus columbianus*	F
Eurasian Wigeon	*Anas penelope*	R
American Wigeon	*Anas americana*	O
Northern Shoveler	*Anas clypeata*	R
Northern Pintail	*Anas acuta*	F
Green-winged Teal	*Anas crecca*	O
Redhead	*Aythya americana*	R
Steller's Eider	*Somateria fischeri*	R
King Eider	*Somateria spectabilis*	B
Common Eider	*Somateria mollissima*	B
Long-tailed Duck	*Clangula hyemalis*	F
Bufflehead	*Bucephala albeola*	R
Common Goldeneye	*Bucephala clangula*	R
Common Merganser	*Mergus merganser*	R
Red-breasted Merganser	*Mergus serrator*	B
Ruddy Shelduck	*Tadorna feruginea*	R
Rough-legged Hawk	*Buteo lagopus*	O
Merlin	*Falco columbarius*	R
Gyrfalcon	*Falco rusticolus*	O
Peregrine Falcon	*Falco peregrinus*	F
Willow Ptarmigan	*Lagopus lagopus*	R
Rock Ptarmigan	*Lagopus mutus*	B
Sandhill Crane	*Grus canadensis*	F
Black-bellied Plover	*Pluvialis squatarola*	F
American Golden Plover	*Pluvialis dominica*	F
Semipalmated Plover	*Charadrius semipalmatus*	F
Lesser Yellowlegs	*Tringa flavipes*	R
Solitary Sandpiper	*Tringa solitaria*	R

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Table 2. (*continued*).

Common name	Scientific name	Status
Willet	*Tringa semipalmata*	R
Spotted Sandpiper	*Actitis macularia*	R
Whimbrel	*Numenius phaeopus*	O
Ruddy Turnstone	*Arenaria interpres*	F
Red Knot	*Calidris canutus*	O
Sanderling	*Calidris alba*	O
Semipalmated Sandpiper	*Calidris pusilla*	F
Least Sandpiper	*Calidris minutilla*	O
White-rumped Sandpiper	*Calidris fuscicollis*	F
Baird's Sandpiper	*Calidris bairdii*	O
Pectoral Sandpiper	*Calidris melanotos*	O
Purple Sandpiper	*Calidris maritima*	F
Dunlin	*Calidris alpina*	F
Stilt Sandpiper	*Calidris himantopus*	R
Red-necked Phalarope	*Phalaropus lobatus*	O
Red Phalarope	*Phalaropus fulicaria*	F
Pomarine Jaeger	*Stercorarius pomarinus*	O
Parasitic Jaeger	*Stercorarius parasiticus*	F
Long-tailed Jaeger	*Stercorarius longicaudus*	O
Franklin's Gull	*Larus pipixcan*	R
Ring-billed Gull	*Larus delawarensis*	R
Herring Gull	*Larus argentatus*	B
Thayer's Gull	*Larus thayeri*	O
Iceland Gull	*Larus glaucoides*	O
Lesser Black-backed Gull	*Larus fuscus*	R
Glaucous Gull	*Larus hyperboreus*	F
Great Black-backed Gull	*Larus marinus*	O
Sabine's Gull	*Xema sabini*	F
Arctic Tern	*Sterna paradisaea*	F
Slaty-backed Gull	*Larus schistisagus*	R
Thick-billed Murre	*Uria iomvia*	R
Black Guillemot	*Cepphus grylle*	B
Snowy Owl	*Nyctea scandiaca*	O
Short-eared Owl	*Asio flammeus*	O
Common Raven	*Corvus corax*	F
Horned Lark	*Eremophila alpestris*	F
Tree Swallow	*Tachycineta bicolor*	R
Bank Swallow	*Riparia riparia*	R
Barn Swallow	*Hirundo rustica*	R
Northern Wheatear	*Oenanthe oenanthe*	R
American Pipit	*Anthus rubescens*	F
Myrtle Warbler	*Setophaga coronata coronata*	R
Yellow-rumped Warbler	*Setophaga coronata*	O
Palm Warbler	*Dendroica palmarum*	R
Blackpoll Warbler	*Dendroica striata*	R
Northern Waterthrush	*Seiurus noveboracensis*	R
Wilson's Warbler	*Wilsonia pusilla*	R
Savannah Sparrow	*Passerculus sandwichensis*	O
Lincoln's Sparrow	*Melospiza lincolnii*	R
White-throated Sparrow	*Zonotrichia albicollis*	R
Harris' Sparrow	*Zonotrichia querula*	R
White-crowned Sparrow	*Zonotrichia leucophrys*	O
Slate-colored Junco	*Junco hyemalis hyemalis*	R

Table 2. (*concluded*).

Common name	Scientific name	Status
Dark-eyed Junco	*Junco hyemalis*	R
Lapland Longspur	*Calcarius lapponicus*	F
Snow Bunting	*Plectrophenax nivalis*	B
Common Redpoll	*Carduelis flammea*	O
Hoary Redpoll	*Carduelis hornemanni*	R

mounted to either observation blinds or stand-alone wooden posts to track bear movement on the island and quantify the concomitant heart-rate response of nesting eiders (Geldart et al. 2023).

3.6. Recent development of methods used to monitor eider nests remotely

To help offset the disruption of long-term nest-plot monitoring caused by bears during the later years of the study, and the resulting inability to visually monitor breeding females throughout incubation, the program expanded on previous approaches to monitor eider nest activity remotely and non-invasively (Bottitta et al. 2002; Fast et al. 2007; Provencher et al. 2017). Beginning in 2019, trail cameras, heart rate monitoring devices, and temperature loggers were deployed each year in late June to monitor a sample of nests into incubation. Several of these devices were specifically engineered for the project by Chris Harris, OPL, and CADS at the University of Windsor. Using these devices in combination, eider nest attendance and their response to weather and polar bear activity could be monitored remotely (Geldart et al. 2022, 2023; Simone et al. 2022; MacDonald 2024), and all while the field team had safely left the island to avoid bear encounters. The monitoring equipment and related memory cards were subsequently retrieved by a small team that returned to the island by helicopter for a day in late July each year.

Drones were also used to survey the eider colony in 2022, 2023, and 2024 by aerial transects, when it was confirmed that incubating females could be reliably detected visually from high-resolution video footage, despite how camouflaged they were when sitting on the nest. Drone surveys were also possible because there was no tall vegetation on EBI that could conceal eiders from above, and that eiders did not respond to drones passing over them (Geldart et al. 2022).

3.7. Studies of snow buntings

East Bay Island is characterized by an abundance of granite rock piles which provide ideal nesting habitat for snow buntings, which construct their nests within rock crevices (Montgomerie and Lyon 2020). In addition, several freshwater ponds are present on the island which generate an abundance of arthropods that provide snow buntings with a reliable and accessible food source. Due to the high density of breeding pairs and the relative ease with which nests can be found and monitored, snow buntings were studied at the East Bay Island Field Station from 2007 to 2023 (MacDonald et al. 2012; McKinnon et al. 2016). Each year, male and female buntings were caught with walk-in and Potter traps baited with mixed seed from their migratory arrival (late May) until breeding (mid-June). All breeding pairs were banded annually with a unique combination of three coloured leg bands and an aluminum federal band (size 1B) to facilitate the subsequent identification of individuals and breeding pairs. Birds were released within 20 min, and after release, the identities of breeding pairs were confirmed using spotting scopes and, more recently, with digital cameras and telephoto lenses. Additionally, the breeding territories of all pairs were mapped and then intensively searched to locate nests. Nests were closely monitored each year to obtain the lay date of the first egg laid, as well as the clutch size from 2007 to 2019 and 2022 to 2023. Breeding success data (e.g., fledgling body weight and size, number) were collected from 2007 to 2014 (remotely with timelapse cameras in 2022/23) during final nest visits when nestlings were on average, 8 days of age (i.e., 3–4 days before fledging to ensure nestlings did not fledge prematurely; Guindre-Parker et al. 2013). All nestlings were counted, banded and weighed, and the wing and minimum tarsus length of each nestling were taken, with a total of 896 adults and 313 chicks banded between 2007 and 2023.

3.8. Data management

During the first 11 years of the project and prior to 2008, all banding and morphology data had been entered into separate *Microsoft (MS) Excel* files. The diverse information collected on eider ducks often included multiple indices within a single year, as well as multiple years of banding information, reproductive outcomes, morphological traits, and physiological metrics of the same individual duck. Multiple Excel files soon became cumbersome and inefficient as the complexity of the data grew. This warranted that a relational database was developed so that information relating to individual birds and across multiple years of their lifetime could be linked and reliably updated.

Dr. Andre R. Breton (ARB; Insight Database Design and Consulting) was enlisted to build a relational database using *Microsoft Access 2007*, which was the software supported by the Canadian Government at the time. ARB and E. Isabel Buttler (EIB) worked closely together to customize the design of the East Bay Island Eider Capture-Mark-Recapture Database and to incorporate morphological and physiological measures for many individual eider ducks. Laboratory results obtained from physiological samples taken from eiders were also uploaded to the database, which included information on the methods of laboratory analysis as well as where samples were stored and archived.

Over the course of 3 years, the database design and functionality were intensively improved upon. The value of the new database was immediately apparent when data errors existing within the historical data were identified for the first time and easily corrected. In addition, a new user-friendly data-entry interface was designed for students and summer staff, as well as an associated data-entry manual written by EIB to offer step-by-step instructions to ensure accurate data entry even by inexperienced, first-time users. This interface greatly reduced data-entry errors in several ways. It prevented summer field staff from altering data terms, column headings, acronyms, or other "fixed" data entry approaches whether intentionally or unintentionally. Erroneous band resightings were drastically reduced by the need to first find that a banded individual actually existed within the database before a subsequent resight/contact of that bird could be entered. Finally, the computerized data entry forms were intentionally structured in such a way as to mirror the order and set-up of field notebooks used by staff in the field (e.g., the order of information to be entered).

To maintain data integrity for the East Bay Island program, a permanent data manager was hired in 2011 to present (EIB). The value of this position to support this long-term study cannot be overstated. EIB was intimately familiar with the field procedures at East Bay Island (Buttler et al. 2011) and had been overseeing the data collection for four seasons following the completion of her own graduate student thesis. Each year, field data were entered into the computer database by summer field staff while they were still up north and before they had dispersed. Once data had been entered using the data entry forms, EIB subsequently ran built-in, permanent "house-cleaning queries" to address common data entry errors and to highlight any data in need of correction. Annual review and compilation of data by EIB each fall prevented data drift as the data manager could provide immediate feedback on the data quality immediately following each field season. EIB and the team could also identify how the implementation of protocols could be improved upon. This ongoing approach was extremely useful for a long-term research program such as this, because research topics were surprisingly dynamic over time as new research opportunities emerged while others ended. In addition to maintaining data quality, the data manager also facilitated researchers and their students by efficiently querying the database on their behalf and providing them with datasets tailored to meet their specific research questions. This allowed science teams, and especially graduate students, to focus their efforts on data analysis and writing rather than on data gathering, entry, forensics, and proofing.

4. Key findings from long-term studies at East Bay Island Field Station

4.1. Population ecology, distribution, migration, and harvest of common eiders

Eider banding efforts at East Bay Island Field Station quickly provided new insights into the migratory links between Arctic Canada, Atlantic Canada, and west Greenland. Over 11 077 common eiders (4735 females, 4093 males, and 2211 as ducklings) and 578 king eiders (268 females and 305 males) were banded in total (1996–2023). Band reporting from hunters began within months of the first fall migration in 1996. Bands were reported by hunters in Nunavut (16), Greenland (104) (Fig. 5*a*), Newfoundland, Labrador, and Saint Pierre et Miquelon (167), Quebec (35), Nova Scotia (1), and Connecticut (1), between 1996 and 2023. These initial findings suggested substantial harvest of eiders breeding in Canada during winter in both west Greenland and Atlantic Canada (Fig. 5*b*). At this time, spectacled eider ducks (Petersen et al. 1995), as well as king and common eiders (Dickson et al. 2012), were being surgically implanted with satellite transmitters in Alaska and in the western Canadian Arctic. These pioneering studies revolutionized the study of eider duck migration (Petersen et al. 1995; Dickson et al. 2012). This prompted the East Bay Island project to conduct a similar satellite telemetry project through an international funding and research collaboration between Denmark, Greenland, and Canada to explore migratory connections between breeding and wintering areas in greater detail (2001, 2003, 2012–2013, Merkel et al. 2002). Thus, East Bay was among the first projects of its kind to track sea ducks by surgically implanting satellite tracking devices into birds and releasing them back into the wild (Mosbech et al. 2006). Results indicated that some eiders migrated through Hudson Strait and south along the Labrador and Newfoundland coasts to winter in Atlantic Canada as expected. However, 69% ($n = 25$) crossed Davis Strait to winter in southwest Greenland and returned in spring to breed in Canada. Similarly, seven of eight eiders implanted along the Greenland coast in winter crossed the Davis Strait into Arctic Canada in spring to breed (Mosbech et al. 2006). Thus, the detailed findings generated through satellite tracking of eiders between Canada and West Greenland substantiated the general patterns of migration previously suggested by band recoveries.

There was concern that eider ducks were being heavily hunted in winter, and further, that many eiders were shot and crippled but not retrieved by hunters (termed "crippling loss"). To investigate this, eiders were caught alive at the banding nets and X-rayed in the field at East Bay Island in 1997 and 1998 (B. Barrow), and of 252 eiders examined, 61 (24%) had lead shot pellets embedded in their tissues (with a mean of 1.7 pellets per bird; Hicklin and Barrow 2004). Similarly, of northern common eiders X-rayed on their wintering grounds in West Greenland, 29% of adult birds carried embedded shot, including 13% of first winter birds and 16% of immature birds carried shot (Falk et al. 2006). This high proportion of the eider population having been previously wounded by shooting (whether sampled during summer in Canada or during winter in Greenland), suggested intense hunting pressure of eiders. Concerns in west Greenland were further substantiated by a review of winter eider harvest levels (Merkel 2004*a*) and an 81% decline in the regional common eider nesting populations detected there over a 40-year period (Merkel 2004*b*).

With this new information, it was possible to explore the sustainability of harvest levels (Gilliland et al. 2009). Estimates of wintering population, harvest levels, and migratory connectivity were integrated into a population simulation model to investigate the sustainability of the reported harvest, which consisted of two wintering areas in Greenland and Atlantic Canada, and three breeding populations (i.e., eiders that bred in Greenland and wintered in Greenland, eiders that bred in Canada and wintered in Greenland, and eiders that bred in Canada and wintered in Canada). The model indicated that the harvest in Atlantic Canada was sustainable, but barely so (6500 females in the recreational harvest and 1200 in the indigenous harvest; Gilliland). In contrast, the annual winter harvest of 55 000–70 000 eiders reported in Greenland between 1993 and 2000 was considered not sustainable. Moreover, harvest occurring in late winter likely had a greater impact on populations than harvest in early winter, as it was more likely additive rather than compensatory later in the season (Gilliland et al. 2009).

This prompted efforts to shorten hunting seasons and to reduce winter mortality. Following extensive international consultation that included the participation of Inuit travelling from Nunavut, Canada to Greenland, new harvest regulations were successfully instituted in West Greenland in 2001 (Anon 2001). A shortened hunting season reduced winter mortality by two-thirds (Merkel 2010), and eider populations began to recover in both Greenland and Canada in the following years (Merkel 2010). The resulting strong population increase marks this as one of the most successful international conservation efforts of marine birds in the circumpolar Arctic.

Interestingly, the historical impact of winter harvest on eider duck populations was also implicated in findings generated from the analysis of pond sediment cores collected at eider duck colonies found along the south coast of Baffin Island, 200 km east of East Bay (Duda et al. 2018; Hargan et al. 2019; Clyde et al 2021). Sediment cores provided demographic insights over a timescale of roughly 500 years and revealed dramatic declines in the nutrient input of eider ducks on islands, and presumably eider populations, occurred during the turn of the 20th century (around 1900); the same period when firearms, ammunition, and powerboats were introduced and extensively adopted by hunters in west Greenland (Hargan et al. 2019).

The long-term monitoring of breeding success and mark-resight program at East Bay also provided unique research opportunities to examine changes in eider demography and population dynamics (Fig. 7). More specifically, the long-term mark-resight data from East Bay enabled the assessment of the impact of avian cholera on eider mortality (Descamps et al. 2009), as well as colony persistence (Descamps et al. 2012; *see "Pathogens" section below*). These long-term data also confirmed the importance of environmental conditions on the wintering grounds in the North Atlantic and how they affected eider duck life history (Guéry et al. 2017, 2019). Long-term time series on vital rates are rare for Arctic breeding birds but are necessary to understand the impact of changing environmental conditions on their populations. The 28 years of data on northern common eiders and other species generated at East Bay Island thus represents a rare tool to understand, and ideally predict, the consequences of a rapidly changing Arctic. This is notable given that long-term ecological and environmental studies (LTEES) are necessary to understand the regulation and function of ecological communities over time (Magurran et al. 2010). In fact, long-term studies have been found to contribute disproportionately to advancing ecology and informing environmental policy (Hughes et al. 2017) and their influence grows the longer they operate (Nichols and Williams 2006; Hughes et al. 2017).

4.2. Reproductive ecology of eiders

Both satellite telemetry and isotopic studies indicated that eiders breeding at East Bay Island overwintered either along the west coast of Greenland or along coasts of Newfoundland and Labrador (Mosbech et al. 2006; Steenweg et al. 2017*a*, 2017*b*; Fig. 7). These two regions are often exposed to opposite wintering conditions as a function of the North Atlantic Oscillation (Guéry et al. 2019). Eiders often arrived at East Bay in different body conditions, reflecting weather conditions experienced during the fall (Legagneux et al. 2013; Harms et al. 2015) and/or winter (Descamps et al. 2011). Pre-laying body condition is a key parameter that integrates prior environmental conditions and impact reproductive investment in eiders (Descamps et al. 2011; Harms et al. 2015; Hennin et al. 2016, 2018, 2019; Legagneux et al. 2013). Specifically, body condition is directly related to the amount of endogenous reserves available for reproduction investment (egg production and incubation). When fat stores fall below a critical threshold, birds may decide to skip a breeding event, a common strategy in long-lived species (Jean-Gagnon et al. 2018; Legagneux et al. 2013; Grandmont et al. 2023).

Blood samples collected from female eiders during the banding process were examined to explore the presence of kin-based sociality while breeding. Molecular markers were used to genetically characterize female social groups and this confirmed high levels of relatedness between females arriving together to the colony following migration, between females nesting adjacent to one another within the colony, and between groups of females departing the colony with ducklings (McKinnon et al. 2006). This provided the first genetically confirmed evidence of strong female kin-based social groups forming among common eiders as early as colony arrival and nest site selection (McKinnon et al. 2006).

At arrival at the breeding area, eider hens must obtain a minimum body mass of 2000 g to lay eggs (typically 4 eggs at EBI) and subsequently incubate their clutch for 21–24 d without feeding (Bottitta et al. 2002, 2003). They achieve this through a combination of stored fat resources carried with them during spring migration, and by accruing energy at arrival by foraging on local marine prey (Sénéchal et al. 2011; Steenweg et al. 2022). After laying the clutch, females also had to retain enough somatic stores to complete their 24 d incubation fast or risk nest abandonment (Bottitta et al. 2003). Therefore, both arrival condition and the ability of females to quickly access local resources enabled female eiders to build up fat necessary for egg laying and subsequent fasting during incubation. Warmer spring temperatures in the area of

Southampton Island predicted earlier ice-free conditions at East Bay (particularly at river mouths), and in turn, higher breeding propensity and earlier laying by eiders (Love et al. 2010; Jean-Gagnon et al. 2018). By contrast, experimental reductions in food availability, mimicking poor environmental conditions at arrival, reduced breeding propensity, independent of how close females were to laying (Legagneux et al. 2013). Further, lay dates that timed duckling hatching just prior to ice-free conditions in the waters around East Bay Island in July resulted in the highest rates of subsequent female recruitment into the breeding population (Love et al. 2010). Collectively, these findings indicate how weather conditions during the winter as well as local sea ice conditions that eiders face upon arrival to breeding areas (which influenced access to regional prey sources), both influenced the timing and reproductive decisions (e.g., pre-laying, laying, incubation duration, and brood departure) of common eider ducks as well as the survival of ducklings into adulthood.

In addition to environmental constraints, individual-based differences appear to generate further variation in reproductive investment and output. Heavier females lay earlier and produce larger clutches (Descamps et al. 2011). Physiological studies examining underlying mechanisms (reviewed in Hennin et al. 2015) revealed that female eiders may have a unique strategy of early protein recruitment to initiate egg production, nearly two weeks before they initiate rapid follicle growth and begin depositing fats to their eggs (Hennin et al. 2015). Further, individual variation in energetic demand increases foraging effort and the transition from somatic fattening to egg development, respectively (Hennin et al. 2015; Hennin et al. 2016), and importantly, variation in these traits was found not to be driven by environmental factors (Steenweg et al. 2015). Females that were able to physiologically fatten more quickly were found to have diverse diets (Parkinson et al. 2022), laid the earliest with the shortest delay after arrival, and had the largest clutches (Hennin et al. 2016, 2018). Female eiders that were able to elevate their physiological energetic demand had higher reproductive success without impacting their survival (Hennin et al. 2016). Finally, levels of feather stress hormones were not affected by prior reproductive investment nor by pre-breeding (spring) body condition prior to the molting period but were likely affected by weather conditions during moult (Legagneux et al. 2013) and had dramatic cascading influences on reproduction during an avian cholera outbreak (Harms et al. 2015). High feather CORT levels were associated with lower body condition and reproductive success and consequently lower survival during an avian cholera outbreak (Harms et al. 2015). This work showed that information from nondestructive sampling of feathers had the potential to track ecological carry-over effects of environmental stress across seasons.

Taken together, this entire body of work, which spanned nearly 20 years, has contributed understanding to how environmental and individual (physiological) mechanisms interact to drive the timing of reproduction and the seasonal decline in clutch size and illustrates the importance of accounting for breeding stage when analyzing and interpreting reproductive data.

4.3. Contaminants, parasites, and pathogens of common eiders

4.3.1. Contaminants

There is a long history of studying contaminants in migratory birds that nest in the Canadian Arctic (*reviewed in*, Mallory and Braune 2012; Bianchini et al. 2022), and the East Bay Island Field Station has contributed to this ongoing suite of programs since its inception in 1996 (Mallory et al. 2004). Quantifying essential and nonessential trace elements in eiders have been the focus of most of the work, including levels of mercury, cadmium, and other elements across geographic ranges (Wayland et al. 2001; Wayland et al. 2005; Mallory et al. 2017; Bianchini et al. 2022), and in relation to reproductive stage (Wayland et al. 2002). Beyond documenting which contaminants were present in the birds nesting on EBI, there have been several studies that have examined the role of contaminants in determining a variety of health metrics. Several immune metrics were found to vary in relation to mercury, cadmium, and selenium in eiders, but levels differed significantly between years, perhaps because the physiological conditions of eiders also vary from year to year (Wayland et al. 2002; Provencher et al. 2016*a*). Further work has also shown how foraging ecology, weather patterns, and mercury burdens can affect reproductive hormones and phenology (Smith et al. 2022, 2023).

4.3.2. Parasites

Endoparasites are known to have significant impacts on wild birds, and the nesting eiders at East Bay have been examined for parasites to explore ecological patterns, particularly related to helminths (Provencher et al. 2016*b*; Tourangeau et al. 2019). The number and accessibility of nesting eiders on East Bay Island facilitated experimental dosing studies that examined the relationship between contaminants and parasites, showing that parasites and contaminants can have interactive effects on eider health (Provencher et al. 2017; Morrill et al. 2019). More specifically, individual eiders that hosted large internal parasite communities had reduced exposure to contaminants such as mercury and lead, apparently because parasites absorb and clear contaminants from eider tissues (Provencher et al. 2017). Based upon banding and related mark-recapture studies at East Bay Island, these patterns appeared to provide a long-term benefit to eider survival when intestinal parasites are present and particularly among individuals exposed to mercury and lead (Provencher et al. 2017; Morrill et al. 2019).

4.3.3. Pathogens

One study using samples from East Bay examined the fungal diversity on common eider feathers (Robicheau et al. 2019). This study examined fungi on bird feathers from several regions in Nunavut but detected one of the strongly keratinolytic fungi (*Neosetophoma samarorum*) on the common eiders sampled at East Bay. Importantly, keratinolytic ability is a known pathogenicity factor in fungi, which has led to additional questions about how these fungi affect the health of the eiders carrying these species.

Several pathogens have been assessed at the East Bay Island colony. Avian influenza viruses (AIV) have been examined at East Bay Island over the last decade. Between the years 2007 and 2011, eider ducks tested for AIV antibodies showed between 9% and 82% seroconversion via blood sampling and 0%–6% positive for active AIV infections via oral and cloacal swabbing (Provencher et al. in prep). This demonstrates that the eiders at East Bay Island experience varying levels of exposure to AIV from year to year. Most of the common forms detected were of low pathogenic avian influenza and contributed information on how ducks may act as reservoirs of AIV (Hall et al. 2015).

More recently, the outbreak of Highly Pathogenic Avian Influenza (HPAI) in North America motivated the expansion of biological sampling of eiders nesting on EBI as part of a national wild bird surveillance program (Giacinti et al. 2024). A total of 90 king eiders and common eiders were tested at EBI in 2022, all of which were found to be negative for both low-path AIV and HPAI. Given the previously known interannual variation in AIVs detected in eiders at East Bay Island, this 1 year is not enough to confirm trends per se, but did demonstrate that the species exhibited high variation of this pathogen across its range in Canada in 2022 (Giacinti et al. 2024; McLaughlin et al. 2025).

The largest body of work on pathogens at East Bay Island focused on avian cholera, which is a contagious disease caused by the bacterium, *Pasteurella multocida*. Avian cholera was first detected in eiders at East Bay in 2005 (Iverson et al. 2016*b*). In the first few years, the mortality levels at the colony were extremely high, with over 3000 females found/counted dead on the island in 2006 alone (i.e., roughly 37% of the nesting female eider population that summer, Fig. 6). Mortality was recorded by the field teams on the island during all breeding seasons (Fig. 9), leading to estimates that the colony was approximately 56% of the size it was prior to the avian cholera outbreak between the years 2006 and 2009 (Iverson et al. 2016*b*). During the epidemic, research expanded to study how eiders at both the individual and population level responded to the outbreak. Buttler et al. (2011) showed that holding times beyond 30 min during banding exacerbated mortality during the cholera epidemic, and thus showed the importance of minimizing restraint time in wild birds. The stress during moult influenced the reproductive success and survival of the eiders breeding on EBI, but only during the years of the cholera outbreak (Harms et al. 2015). Cholera had differential impacts on individual eiders so that those hens arriving earliest to the colony and that laid the largest clutches were more likely to succumb to the disease (Descamps et al. 2009). An early modelling exercise that integrated both survival and reproductive rates of common eiders breeding on East Bay Island, indicated that the eider colony would not persist beyond 10 years, if the epidemic did not abate or "fade out" (Descamps et al. 2012).

Importantly, ongoing monitoring at the site that lasted more than a decade beyond the initial pathogen outbreak. This allowed research of the full disease cycle at the colony—from initial mortality events in 2005 to the end of the outbreak in 2012 when detections of the disease and mortality ended. This enabled the project to examine what drove the end of the outbreak, which was determined to be herd immunity to the pathogen as antibodies built up in the surviving individuals (van Dijk et al. 2021). Further studies focused on the cholera outbreak in eiders in the larger region around East Bay Island and the development of a disease surveillance network of Inuit communities (Iverson et al. 2016*a*, 2016*b*; Henri et al. 2018). Collectively, this rare research opportunity, in which a wild bird population was studied during an epidemic quantified the impacts of disease on reproduction, physiological metrics, and survival. New research using stored/archived blood and serum samples has been initiated to examine the genetic diversity and genomic health of the eiders before, during, and after the epidemic to explore what may have predisposed some eiders to survive the initial onset of the disease at the colony when many did not. This also highlights the value of mid- and long-term monitoring studies, which can assess unforeseen global and/or local environmental changes by adopting approaches similar to before-and-after control-impact (BACI) designs (Underwood 1994).

4.4. Ecological studies of herring gulls

Behavioral studies of predators and prey in the wild are often difficult to conduct because of the challenges associated with quantifying and then testing key parameters derived from theoretical models (Abrams 2020). This is especially true of multi-species systems where trophic interactions are complex and within habitats where observations are hindered by dense vegetation, low densities of the species, and periods of darkness. East Bay Island proved ideal to study sources of temporal and spatial variation of predator-prey interactions occurring between herring gulls and common eider ducks. Long daylight hours, unobstructed views at close range, inter- and intra-specific interactions, and the fact that many individual birds of both species were easily identified by their unique colour alpha-numeric bands contributed to the studies.

From 1999 to 2003, the foraging behavior of herring gulls depredating common eider eggs and ducklings was studied, and particularly how rates of gull foraging activity and success varied with wind, temperature, tide height, solar radiation, eider reproductive phenology, and eider nesting densities (Allard and Gilchrist 2002; Allard 2006). Gulls began consuming eggs as they became available and ended exploitation of eggs, and turned their attention to ducklings upon the onset of colony departure of ducklings. Herring gulls did not force incubating hens off their nests as glaucous gulls (*Larus hyperboreus*) and common ravens (*Corvus corax*) can do, but instead, took eggs only from unattended nests. Consequently, herring gulls within the colony foraged most intensively, and were most successful during early egg laying when hen nest attendance was sporadic (Bottitta et al. 2003) and eggs poorly concealed (Fast et al. 2010), and when eider ducklings left the island to sea accompanied by hens (Allard 2006). At colony departure, large waves generated by storms often separated ducklings from their family groups, and were easily taken by gulls hovering above them.

Apparent survival was estimated for adult herring gulls nesting within two distinct breeding habitats found within East Bay (Allard et al. 2006). The first subpopulation nested directly on East Bay Island at high densities, and the second nested widely dispersed along the wet, coastal tundra of Southampton Island. Gulls nesting on the island aggressively defended their foraging territories and particularly against nonresident gulls that occasionally visited the island (Allard 2006). Program Mark was used to analyze capture-mark-resight (CMR) data obtained from 62 adults captured between 1998 and 2002: 47 and 15 nesting on the island and mainland, respectively. There was no statistical difference detected in survival rates between the two nearby nesting populations, and the overall estimate of annual adult survival was 0.87 ($\pm$0.03 SE). This remains the only known survival estimate produced for adult herring gulls at the northern limit of their North American breeding range and falls within the range of values reported for the species (Allard et al. 2006). Similarly, the herring gulls nesting at East Bay Island were not found to be morphologically distinguishable from other herring gull populations found across eastern North America (Robertson et al. 2016).

Where the herring gulls at East Bay were found to be different ecologically, was related to their migratory behaviour and choice of wintering locations, which differed markedly from those herring gulls breeding elsewhere in Atlantic Canada and the Great Lakes (Anderson et al. 2019, 2020). The variability in the migration strategies of herring gulls was evaluated by tracking the long-distance migrants of East Bay, and three populations of short-distance migrants breeding in Atlantic Canada, using global positioning system (GPS) tracking devices. The directness of their migration routes, overall migration speed, travel speed, and use of stopovers were compared (Anderson et al. 2019). Gulls breeding at East Bay migrated long distances to overwinter in the Gulf of Mexico, traveling more than four times farther than the short-distance migrants breeding in Atlantic Canada and the Great Lakes (Anderson et al. 2020). Gulls from East Bay also spent most of the winter in marine habitats while the other populations used a wider variety of habitats, including urban areas (Anderson et al. 2019). Individual gulls from East Bay appeared to be consistent in their migratory strategies between years, and most followed coastal migration routes (Anderson et al. 2020; Baak et al. 2021). By contrast, gulls breeding in Atlantic Canada wintered primarily along the Atlantic coast of the United States between the State of North New Jersey in the south and the province of Nova Scotia, Canada in the north (Anderson et al. 2019, 2020; Baak et al. 2021).

The eggs of herring gulls nesting on East Bay Island have been collected annually since 2009 and examined for contaminants as part of Canada's Chemicals Management Plan (Gewurtz et al. 2016). East Bay is the only Arctic sampling location of herring gulls within the Canadian monitoring program and has therefore contributed greatly to studies of spatial and temporal trends and particularly when compared to herring gulls nesting in the Great Lakes region of southern Canada. Some contaminant levels are higher among herring gulls nesting in urban areas such as perfluorooctane sulfonic acids (PFCs), whereas several chemicals were surprisingly high in the eggs of herring gulls collected at East Bay (e.g., perfluoroalkyl carboxylic acids (PFCAs)) suggesting very different pathways of exposure (Gewurtz et al. 2016). PFCAs are part of the PFAS group of "forever chemicals" that are used in a variety of industry and commercial applications and are the focus of recent bans domestically and internationally because of their persistence and bioaccumulation. Most Arctic birds are thought to pick these up in the south during winter. It is likely that the herring gulls nesting at East Bay have higher exposure of some of these compounds, in relation to their Great Lake and Atlantic counterparts, because of their time spent in heavy industrial regions coastally in the Gulf of Mexico, and often at the mouth of the highly polluted Mississippi River (Anderson et al. 2019).

Recent analyses of herring gull eggs, including those collected at East Bay, are currently examining a suite of additional contaminants listed under the Stockholm Convention (United Nations Treaty Collection 2001). Preliminary analyses have demonstrated considerable inter-annual variation in contaminant burdens among gulls, and particularly across the geographic range of sampling in Canada (Vanderlip et al. *in prep*). This work highlights the importance of having remote locations like East Bay Island contribute to these chemical monitoring programs because they help assess how chemicals travel and persist in the environment both temporally and geographically.

4.5. Ecological studies of snow buntings

East Bay Island supports one of the highest nesting densities ever recorded for snow buntings (70 pairs/km^2; O.P. Love unpublished data), which made East Bay Island an ideal location to study sexual selection, mate choice, demography, reproductive ecology, and migration of buntings.

Male snow buntings arrive on the breeding grounds in late May and early June. They begin establishing territories and attracting mates when females arrive in early June (Riquier 2024). Males use multiple song modalities to signal their reproductive quality through their individually distinct, multi-syllable songs (Baldo et al. 2015). At East Bay Island, males were found to have a single song type rather than a complex repertoire, and that male song was comprised of multiple syllables, with syllable-sharing occurring across males. Songs varied distinctly between males that potentially facilitated individual recognition (Baldo et al. 2014). Interestingly, song performance was not linked to reproductive parameters; however, oxidative stress from increased singing for mate attraction may present a physiological cost that prevents low-quality males from being able to produce high-quality signals (i.e., songs; Baldo et al. 2015).

In terms of plumage signaling, the size of the black alula on the plain white wing of males was shown to signal physiological health (immunoglobulin Y, oxidative stress) and positively predicted the number of offspring produced (Guindre-Parker et al. 2013*a*, 2014). Additionally, melanin-based plumage reflectance was also related to important territory features known to enhance fledgling success as % rock cover for nesting habitat (Guindre-Parker et al. 2013*a*), and predicted a male's ability to defend its territory. Collectively, these visual traits apparently acted as inter-sexual signals (Guindre-Parker et al. 2013*b*). Male snow buntings that defended higher-quality territories experienced an oxidative stress, as did males that provisioned offspring at a high rate (Guindre-Parker et al. 2013*a*). This body of work suggests that oxidative stress may be a mechanism that impacts reproductive parameters and that variation in these traits is communicated through signals of individual quality (e.g., song and plumage coloration).

Long-term demographic studies at East Bay Island showed that buntings returned to breed at a high rate each year (Macdonald et al. 2012). This enabled the project to deploy geolocator tracking devices on adult snow buntings and then retrieve them the following year. The data generated by geolocators demonstrated that Snow buntings from East Bay exhibited strong migratory connectivity to the western North America wintering range, whereas recoveries of birds banded in Greenland and/or eastern North America indicated that they typically wintered in Eastern Canada (Macdonald et al. 2012). This revealed that snow buntings have a parallel migration system, in which Hudson Bay acts as a migratory divide for eastern and western snow bunting populations (Macdonald et al. 2012). When examining variation in migration behavior, hatch-year birds typically departed northern Hudson Bay before adults, and adult males departed before females during fall migration (McKinnon et al. 2016). In contrast, during spring migration, males often departed northward to the breeding grounds first, but only days before females arrived (McKinnon et al. 2016). In terms of wintering behavior, a higher proportion of males occurred at wintering sites that experienced harsher weather (i.e., colder temperatures, greater snowfall, and snow depth), likely because they could tolerate conditions due to their larger body sizes that are known to enhance thermoregulation (Macdonald et al. 2015). Further, females very often tended to carry more fat than males, perhaps indicating that they inhabited lower quality habitats and maintained more fat stores as an energetic buffer (Macdonald et al. 2015). Collectively, these studies have helped to explore migratory routes, connectivity, and underlying drivers in migratory and wintering behavior of an Arctic passerine, the snow bunting.

Recent work examining the impacts of climate on buntings breeding at East Bay Island revealed that females use fine-scale temperature cues to time their laying (Riquier 2024) and that lay dates are both population- and individually-responsive to warming springs (Riquier 2024). Importantly, laying decisions that mismatch chick energy demand with the timing of arthropod emergence on the island dramatically reduced breeding success, and these mismatches are occurring more often (Riquier 2024). Buntings can start to overheat, and therefore face performance and fitness consequences at only 12 °C (O'Connor et al. 2022). Finally, females worked harder to feed their chicks than males (i.e., more provisioning trips to the nest (Jardine 2024; Riquier 2024)), placing females closer to overheating than males, although there is significant plasticity in these responses leaving hope for responses to climate change (Jardine 2024). Collectively, the 15 years dedicated to studying snow bunting territoriality, migration, and reproductive decisions at East Bay Island quantified the phenological flexibility of an Arctic songbird to a level rarely achieved.

4.6. Ecological studies of polar bears

A growing issue for several species of ground-nesting birds in the Arctic has been the impact of polar bears depredating their eggs (Rockwell and Gormezano 2009;Smith et al. 2010; Iverson et al. 2014; Prop et al. 2015). In northern Hudson Bay and Hudson Strait for example, northerners have broadly reported that polar bears are arriving onto eider nesting islands earlier than previously (i.e., reports communicated to HGG during in-person, community meetings). Perhaps their early arrival onto islands reflects that sea ice is breaking up 3–4 weeks earlier in the region in many years, thereby constraining their access to seals, their preferred prey (Iverson et al. 2014; Dey et al. 2017). In support of this, a review of field camp logs which listed the daily presence of bears encountered on East Bay Island (and on nearby Coats Island as well), was strongly related to years of early sea ice break-up in the region (Iverson et al. 2014). This suggests that bears moved onto land earlier, and interacted with ground-nesting birds more, during those years when their ice platform to hunt seals had deteriorated early (Iverson et al. 2014). However, the caloric intake of bird eggs is apparently insufficient to meet the daily energetic needs of polar bears in summer (Dey et al. 2017; Jagielski et al. 2021*b*).

Foraging theory predicts that bears should linger on the islands supporting the largest number of eider nests, simply as they slow their movements taking advantage of high prey density (Abrams 2020). Over time and driven by successive years of reproductive failure, eider ducks should respond in turn by redistributing themselves, and nest on more islands at lower densities, thereby making it more energetically costly and time consuming for bears to search and depredate their nests (Dey et al. 2017, 2018). This is a working hypothesis and one not yet borne out by data. Given the evolutionary development of the extremely high breeding site fidelity demonstrated by female common eiders (Goudie et al. 2020; Clyde et al 2021), any redistribution predicated on nest failure would be a very slow process. Based upon extensive coastal surveys of over 250 islands along the south coast of Baffin Island, roughly 100 km to the east of East Bay Island, there has been no strong evidence that eider colonies are declining and/or redistributing themselves in response to bears as predicted (Dey et al. 2020).

By contrast, the eider colony on East Bay Island is in dramatic decline, even though mortality from avian cholera has abated (Van Dijk et al. 2021). Colony decline does not appear to be a result of female mortality, but from hens remaining alive and dispersing to nest elsewhere. In support of this, Inuit from Coral Harbour have reported that some banded female eiders, who have been banded at the East Bay Island colony, are now nesting on an island in an inland lake found

Fig. 11. A polar bear walking freely onto East Bay Island (photo by E. Richardson).

6 km from Coral Harbour in an apparent predator refuge maintained by human activities (JN, pers com).

Since 2011 (Fig. 10), the dangerous presence of polar bears on the island has severely disrupted long-term monitoring and research efforts of birds and necessitated that the camp was protected by a 9000-volt electric fence. Team members also left the island altogether in early July, since 2011 (Fig. 6), prior to the peak of bear activities. The removal of field staff in early July therefore disrupted the long-term study of common eiders, herring gulls, and snow buntings. This was very discouraging at the time, until we realized the rare research opportunity that had presented itself. The bears were attracted to the colony and foraged freely and unencumbered (Fig. 11), and the existing cabins and electric bear fence had the potential to support a small team to live and work safely on the island from within the fenced perimeter. In 2016, 2017, and 2024, a "bear team" flew onto the island in early July on the same helicopter that extracted the "eider team", with the goal of video-graphing foraging polar bears using aerial drones.

Drones effectively filmed bears and eiders and did not disturb either species, apparently because the alarm calls of herring gulls attacking the polar bears drowned out the sound of drones entirely (Jagielski et al. 2022; Geldart et al. 2022). Video analysis showed that bears were not efficient predators of eggs because they did not adjust their search behavior in response to the density of nests either spatially or temporally, as the season progressed (Jagielski et al. 2021*a*). Bears consumed eggs at a decelerating rate as they depleted the colony (Jagielski et al. 2021*a*, 2021*b*, 2022). In fact, many bears remained on the island in search of eggs several days after most had been eaten, and energetic calculations showed that these bears were losing more energy per day than they gained (Jagielski et al. 2021*b*). Many eider eggs were also ingested by herring gulls who took advantage of the unattended eggs left exposed when eider hens flushed from their nests in response to approaching bears (Barnas et al. 2022, 2024; Geldart et al. 2023). Collectively, the aerial drone photography of foraging bears and the response of the birds that they were depredating (Simone et al. 2022), generated among the most detailed and comprehensive data of polar bear foraging ecology and energetics in summer.

5. Community involvement and inuit knowledge in research

5.1. Community involvement

Since the first considerations to establish the East Bay Island Field Station, Inuit perspectives were sought out and valued. HGG and JN first met with the community to gauge support and seek practical advice in 1996. This meeting was by invitation and in response to local concerns at the time that regional eider populations were in decline, and growing uncertainty about the role of winter harvest on shared eider populations. The Aiviit Hunters and Trappers Organization (HTO) of Coral Harbour supported the expansion of eider research in Hudson Bay and Hudson Strait and specifically encouraged the establishment of a field research station at East Bay Island, where they knew a large eider duck colony existed. HTO board members encouraged that an overland reconnaissance trip be undertaken to the island in April 1996 to help the team prepare for the first field expedition planned for later that summer. Local Inuit knowledge of the island, the nearby coastal tundra of East Bay, and the surrounding sea ice helped successfully launch the first field season and grow the program in the years to follow.

As the field research program unfolded, annual meetings continued to be held in Coral Harbour each winter. This provided the opportunity for information to be shared, any concerns addressed, and opportunities identified. Annual in-person meetings also strengthened the pursuit of shared interests which, as the HTO relayed, enhanced approval of required land use and research permits by the community. As just one example, the HTO expressed concerns that shorebirds breeding on Southampton Island were in decline. In response, HGG initiated the East Bay Mainland Field Research Station in 1997 with collaborator Erica Nol (Trent University), to study shorebird demography and ecology (MacNearney et al. 2025). While in town, researchers also regularly delivered presentations to school children and several of the students went on to work at the East Bay Island and Mainland field stations as adults in the decades that followed.

The Aiviit HTO and community of Coral Harbour also expressed appreciation that several national and international conservation issues affecting "their" birds, but occurring beyond Nunavut were monitored in support of their regional interests (e.g., harvest, disease, levels of contaminants). As one example, the efforts of ECCC, the Greenland Institute of Natural Resources, the Self-Government of Greenland, Aarhus University, and partners through the Arctic Council helped to enact new harvest regulations in Greenland that greatly reduced winter harvest mortality of eiders (Merkel 2010). This was appreciated by Canadian Inuit harvesting the same, shared eider population.

The Aiviit HTO and the community stated that hiring local people should be a continuing priority of the East Bay Island Program and that "not everyone at the camp should come up from the south". Everyone agreed. However, all recognized that the limited space capacity in the field camp as well as the shortened field season over the last decade (now measured in weeks and not months, *see above*) constrained the number of Inuit participants each summer as well as limited the depth and duration of their experience. More needed to be done, so ECCC, Natural Resources Canada, and the community of Coral Harbour worked together to initiate and co-deliver the *Inuit Field Training Program* (IFTP). It was a new initiative intended to enhance Inuit capacity and leadership of environmental studies as well as connect Inuit youth with opportunities for employment in the field of environmental monitoring in Nunavut. First delivered in 2018, the IFTP has now expanded to two locations each summer with each co-delivered by two Inuit mentors and two scientists, who engage up to eight Inuit youth participants all while living together in a remote research field camp. The topics covered include practical field skills, sampling techniques, wildlife identification, safety, teamwork, and an overview of possible work and learning opportunities in Nunavut. The IFTP has expanded to other sites, but one continues to be delivered in collaboration with the Aiviit HTO at the East Bay Mainland Research Station (MacNearny 2025, *this volume*) each summer.

During nearly 30 years of partnering with Inuit communities, the East Bay Island Program garnered considerable practical experience related to gathering and documenting Inuit knowledge, delivering training programs, Inuit hiring, and communicating results to northern communities. A priority of the program has been to publish "lessons learned", with the intention of supporting the efforts of other long-term studies to grow Inuit involvement. Published accounts recognized the value of Inuit knowledge in conservation efforts of seabirds (Gilchrist et al. 2005; Martin et al. 2025), and provided recommendations on how best to disseminate information to communities (Henri et al. 2020), establish Indigenous networks to detect and monitor environmental change (Iverson et al. 2016*a*; Henri et al. 2018, 2020), engage Inuit youth in environmental research (Henri et al. 2022), and identify and overcome institutional biases that continue to present challenges to hiring Indigenous peoples living in remote communities (Richard et al. 2023).

5.2. Inuit knowledge

Over the course of the EBI Program, Inuit knowledge helped identify emerging issues affecting breeding sea ducks and seabirds on several occasions on Southampton Island and in the Hudson Strait area (Gilchrist et al. 2005; Henri et al. 2020). The emergence of avian cholera among northern common eider duck populations was first detected by Inuit living in northern Quebec (Gaston, personal communication) and later at East Bay Island (Iverson et al. 2016*b*). This initiated new studies in which Inuit knowledge of avian disease was gathered to confirm that avian cholera was a new and emerging disease among common eider ducks, rather than a sporadic occurrence that had previously affected eiders in the region (Henri et al. 2018). Avian cholera had also been detected among snow geese nesting on Southampton Island, and prior to the outbreak affecting common eider ducks (K. Abraham, pers. com). During expanded field work to assess the geographic spread of avian cholera among eider ducks in Hudson Strait and northern Hudson Bay (conducted by joint teams of biologists and Inuit; Iverson et al. 2016*a*, 2016*b*), Inuit expressed concerns that polar bears were having a growing impact on colonial-nesting birds and particularly on nesting eider ducks (Iverson et al. 2014; Dey et al. 2018). Inuit from Kimmirut, Kinngait, Coral Harbour, and Sanikiluaq all reported that bears were moving onto nesting islands earlier, marauding bird colonies, and that this growing impact of bears might be due to reduced sea ice in the region. Inuit knowledge helped identify emerging ecological issues and direct field research efforts. On multiple occasions, Inuit partners (e.g., the Aiviit HTO) contributed written support letters which helped raise additional funding to address priorities identified by Nunavut and Nunavik communities (e.g., Nunavut Wildlife Research Trust, NSERC, Mitacs).

Inuit ecological knowledge continues to help monitor the occurrence of avian disease and rates of polar bear predation among eider and seabird colonies not only at East Bay, Southampton Island, but more broadly throughout Nunavut and Nunavik (Iverson et al. 2016*a*; Henri et al. 2018, 2020; Tomaselli et al. 2022). A particularly rich source of information is contributed annually by Inuit living in the communities of Coral Harbour, Kinggait, Kimmirut, Iqaluit, Sanikiluaq, and Ivujivik (Nunavik), whose residents regularly visit eider duck colonies in summer and harvest eiders during both their spring and fall migrations.

6. Direct contributions from research and monitoring to policy

Common eider ducks are an important harvested resource throughout their circumpolar range for their eggs, meat, and feather down (Merkel and Barry 2008). Growing recognition of the need to manage declining eider populations internationally, and the fact that eiders are a resource shared by Arctic countries, led the Circumpolar Seabird Working Group of the Arctic Council to prepare the Circumpolar Eider Conservation Strategy and Action Plan in 1997 (CAFF 1997). The plan encouraged studies that examined harvest, mortality in commercial fisheries, contaminant levels, and factors affecting eider reproduction (CAFF-Circumpolar Seabird Working Group, 1997). The Eider Conservation Strategy went on to list specific action items, several of which served to direct eider duck research at the East Bay Island Field Station throughout the years of the project.

An early key objective of the East Bay Island Program was to estimate rates of adult eider survival through banding and mark-resight efforts and to estimate rates of annual eider reproductive success through plot monitoring. This information contributed to an international demographic modelling that found that the Greenland winter harvest was not sustainable and that the eider hunt in Newfoundland barely was. This prompted efforts to shorten hunting seasons and to reduce winter mortality (Merkel 2010), marking this as one of the most successful international conservation efforts of marine birds in the circumpolar Arctic.

The East Bay Island Program was among the first to document how changing environmental conditions, driven by climate change (i.e., reduced sea ice conditions during spring in northern Hudson Bay confirmed through satellite imaging), had altered the timing and extent of a natural predator-prey system (Smith et al. 2010; Iverson et al. 2014). These published results were highlighted in early reports summarizing the emerging impacts of climate change in the circumpolar Arctic, including the Arctic Biodiversity Assessment (2013) and the Status of the Arctic Marine Biodiversity Report (2017).

7. Future monitoring prospects: the need to strategically shift program direction

The Qaqsauqtuuq Migratory Bird Sanctuary (formerly, East Bay MBS) was established to protect nesting snow geese (Cooch and Barry 1957). Fortuitously, the small offshore island in the Bay fell within the Sanctuary and is now co-managed by the Irniurviit Area Co-Management Committee (ECCC 2020), which requires that research and land use permits must be acquired for anyone intending to visit the island itself.

After nearly three decades of research conducted at the East Bay Island Field Station, the research program accomplished a lot and much more than had been originally planned. First established in 1996 to study adult survival rates of eider ducks in relation to winter harvest mortality, the program went on to publish findings on eider migration (Mosbech et al. 2006), contaminants, parasitology, disease, predation influences of climate, Inuit ecological knowledge, and how physiological traits, including hormones influence reproductive investment. Other species that co-occurred on the island were also studied in detail, including herring gulls, snow buntings, and polar bears. In addition to published findings and influence on conservation policy, the program trained multiple cohorts of Arctic scientists (41 graduate students and postdoctoral fellows from 14 universities), as well as Inuit from Coral Harbour, many of whom continue to examine long term ecological trends of changing Arctic ecosystems.

One of the most striking ecological changes to occur on East Bay Island was the increasing presence of polar bears now arriving earlier during the eider incubation period for egg predation in many years (Fig. 10). Although this provided new research opportunities to study the inter-specific interactions of bears and birds in detail (e.g., Jagielski et al. 2022; Barnas et al. 2024), the consistent predation and often complete destruction of the colony has resulted in nearly no duckling recruitment into the breeding population for nearly 10 consecutive years, resulting in a continuous decline in colony size (Fig. 6). The project responded to the risks of increasing polar bear activity on the island by intentionally shortening the research season and safely removing field staff from the island by helicopter in late June/early July each year (beginning in 2014). Although the shorter field season reduced encounters between polar bears and field workers as intended, it made it challenging to collect key long-term data from the eider colony, such as laying dates, nesting distribution, timing of nest failure, and adult survival, all of which had been the foundation of the research program for so many years. As just one example, it was no longer possible to quantify the survival rates of eider hens because it became impossible to discern whether the absence of individual hens from the island represented their mortality or instead that hens were alive and went undetected because they had emigrated away from the colony to breed in response to more than a decade of reproductive failure caused by bears.

These developments also came at a time when the costs of Arctic research continued to rise (Mallory et al. 2018), placing significant financial pressure on the program and its collaborators. Collectively, these issues generated a challenging situation, in which the costs and safety risks associated with maintaining the program grew, while the amount and diversity of data collected each year declined. As a result, the delivery of the East Bay Island program was no longer commensurate with the priorities of ECCC. So, after 28 years, the difficult decision was made that the 2024 field season was the final year of the East Bay Island Field Station.

The closure of the East Bay Island Field Station in 2024 generated new opportunities to redirect research into other areas of the Eastern Arctic that can better address issues related to eider duck conservation and management. As one example, a long-term eider project was re-initiated in 2024 along the south coast of Baffin Island in partnership with the Aiviq HTO in Kinngait, the Nunavut Wildlife Management Board, and the Sea Duck Joint Venture. First initiated by G. Cooch in the 1950s (Cooch 1965), the intent of the surveys is to understand how the density and distribution of common eiders nesting on coastal islands has changed over nearly 70 years. While using the wealth of knowledge on eider ecology and polar-bear foraging patterns generated on East Bay Island, these surveys will also help inform a related social-science project concurrently examining how changes in eider colony abundance and polar bear distribution may influence the socioeconomics of eider harvesting by Inuit living in the community of Kinngait.

7.1. Postscript—the legacy of the East Bay Island Field Station

In addition to the measurable scientific productivity generated over the years, another key contribution of the long-term East Bay Island Field Station has been that it provided a venue to promote leadership development for 100s of young people. Most of the participants at East Bay were early in their career when they participated, and many have since expressed that their early experiences at this remote Arctic location had a lasting impact on them. Working on the island was very humbling but helped them build trust in their abilities to work things out, troubleshoot scientific methods and logistical challenges, and to work and live closely with others from diverse backgrounds. Several alumni have gone on professionally to become university professors, government scientists, journalists, and leaders in both nongovernment conservation and Indigenous organizations. Their collective achievements after leaving the East Bay Program have been outstanding, and once again, largely unforeseen when the field station was first established in 1996. We argue that long-term studies such as this, and the training and leadership opportunities they generate for young people, help contribute to a growing community of conservationists whose efforts and positive impacts on conservation will likely exceed that of the Field Station itself.

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The authors declare there are no competing interests.

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