Parasites and Pollution:
Why Both Matter to Marine Bird Conservation in the North

by Jennifer F. Provencher

INTRODUCTION

WILD ANIMALS ARE EXPOSED TO A NUMBER OF factors that can affect both individuals and populations. Habitat and food availability, disease, parasites, and environmental pollutants all have the potential to influence their health and reproductive success (Heinz, 1975; Hudson, 1986; Descamps et al., 2012; Vincenzi et al., 2013). Knowledge of how biotic and abiotic factors, such as parasites and contaminants, can jointly influence individual reproduction is crucial to understanding what drives changes in individual health and populations; thus, it has a bearing on appropriate evidence-based wildlife conservation and management options (Wayland et al., 2002; Reed et al., 2008).

Mercury (Hg) is of particular interest because of its known negative impacts on organisms and the increasing levels detected recently in the Canadian Arctic (Rigét et al., 2011). Mercury is a trace metal that is found naturally in the environment, but it is also released through the burning of fossil fuels and other industrial processes (Munthe et al., 2011). It is estimated that approximately 65% of global airborne Hg emissions originate in Asia (Munthe et al., 2011). Large atmospheric depositions of Hg occur in northern North America because global circulation patterns carry gaseous Hg across the Pacific (Jaffe et al., 2005). As a result, Hg concentrations in some regions of the Canadian Arctic continue to rise even though Hg emissions have been reduced in North America (Munthe et al., 2011; Rigét et al., 2011).

Most of the Hg deposited from atmospheric sources into the terrestrial, aquatic, and marine ecosystems is in the form of gaseous elemental Hg. Once elemental Hg is deposited, methylmercury (MeHg) is formed by bacterial methylation in both freshwater and marine environments (Barkay et al., 2011; Lehnherr et al., 2011). Methylmercury is then accumulated and biomagnified through the food chain, and high concentrations occur within the tissues of organisms at upper trophic levels (Campbell et al., 2005).

Increased burdens of MeHg have been found to influence animal health and reproduction, and MeHg is considered toxic (Dietz et al., 2013). For example, MeHg can act as an enzyme inhibitor and may irreversibly disrupt a number of metabolic processes (Hoffman et al., 2002). Methylmercury exposure can also cause oxidative cellular injury, in which it disrupts receptor signaling pathways associated with the endocrine system and thereby disrupts gene regulation of the body's protective mechanisms (Ung et al., 2010). Thus, Hg not only causes direct damage to cells, but also can have an indirect effect on metabolic pathways, leaving cells open to damage from other chemicals as well. These physiological disruptions at the cellular level can manifest in a number of ways, including sensory disturbances and loss of muscle coordination (Liu et al., 2012).

In captive populations of birds, high Hg exposure has been associated with lower reproductive efforts, increased deformities in developing young, and behavioral changes (Heinz, 1979; Braune et al., 2012). In wild birds, increased levels of Hg have also been linked with neurological changes, reduced reproduction, and decreased fat stores (Wayland et al., 2002; Burgess and Meyer, 2008; Scheuhammer et al., 2008), all of which indicate a decline in fitness. Collectively, these changes can not only affect individuals of a species, but also have the potential, in highly polluted areas, to affect species at the population level. A model using Hg burdens among free-living Common Loons (*Gavia immer*) in highly polluted areas of eastern North America found that Hg was likely having an impact on local loon populations by lowering their reproductive efforts (Meyer, 2005).

In addition to environmental pollutants such as Hg, parasites can also affect wildlife species. Parasites are naturally a part of every ecosystem, and by definition ultimately compete with hosts for resources (Hatcher and Dunn, 2011). Parasites can thus either cause hosts to have reduced reserves, or impose the need for hosts to acquire more resources in order to compensate for the nutrient drain (Hatcher and Dunn, 2011). Captive populations have demonstrated that parasites can have a range of negative effects on avian hosts. Breeding American Kestrels (*Falco sparverius*) experimentally infected with nematodes (*Trichinella pseudospiralis*) were found to have a decline in flying activity and an increase in stress behaviours such as gaping and scratching (Saumier et al., 1991). Parasites can influence reproductive success as well as affecting individual health. For example, nematodes (*Trichostrongylus tenius*) have been found to reduce fecundity of female Red Grouse (*Lagopus lagopus scoticus*), which can lead to population regulation (Hudson and Dobson, 1991).

Parasites do not act on host condition and health in isolation, but are also influenced by other external factors, such as pollutants. Parasites and contaminants can lead to a decline in host health and reproduction independently of each other, but when both are present, their interactions may be complex (Marcogliese and Pietrock, 2011; Minguez et al., 2012). Either parasites or contaminants can alter immune functions and thus influence how a host is affected by the other. A host exposed to parasites typically mounts an immune response, which may be energetically costly (reviewed by Bulté et al., 2012). In turn, the presence of parasites, which can interfere with the host's immune response, can change how a host responds to contaminant exposure (Marcogliese and Pietrock, 2011).

In addition to changes in immunity, parasites may affect host contaminant uptake and retention. Parasites may alter the energy budget of a host, and this in turn can cause either an increase or a decrease in metabolic or foraging rates, or both (Bergey et al., 2002). This change in foraging may increase or decrease a host's exposure to trophically transmitted contaminants such as Hg. Within the host, several species of intestinal helminths have also been shown to absorb contaminants such as trace metals (Bergey et al., 2002; Robinson et al., 2010; Jankovska et al., 2012), and some absorb them at even higher rates than their hosts (Nachev et al., 2010; Brázová et al., 2012). Where contaminants are sequestered by parasites, helminths may provide a protective advantage to the host. Such interactions are difficult to predict, but it is important to understand their influence on survival and reproduction.

RESEARCH DIRECTIONS

Some studies have focused on how the presence of parasites and contaminants, together and separately, affects host health, condition, or reproductive success. Gammarid amphipods infected with an acanthocephalan parasite survived longer than uninfected individuals when experimentally exposed to metal contamination, suggesting that the presence of parasites compensates or blocks the negative effects of cadmium exposure (Gismondi et al., 2012). In a wild population of Glaucous Gulls (*Larus hyperboreus*) that were exposed naturally to both parasites and high levels of organochlorines, untreated males had reduced nest success compared to those who were treated for intestinal parasites (Bustnes et al., 2006). Thus, exposure to both parasites and pollution can have an additive or synergistic interaction, with a negative net effect on reproduction. Although our knowledge of the interactions between parasites and contaminants within hosts is growing, in general there has been little research on how these relationships influence host condition and reproduction in free-ranging animals.

The northern Common Eider (*Somateria mollissima*, hereafter referred to as eider duck) is a particularly useful model species for examining factors that affect breeding ecology. Eider ducks are well studied in the circumpolar Arctic, and they are relatively easy to mark, track, and monitor over time while they are breeding. In northern Hudson Bay, Canada, eider duck breeding ecology has been intensively studied in relation to reproductive tradeoffs and optimal reproductive strategies as they relate to individual and parental characteristics (Descamps et al., 2009, 2011; Love et al., 2010). Importantly, eider ducks have also been examined previously for parasitism and contaminant levels (Wayland et al., 2001; Mallory et al., 2004). In adult eider ducks, high Hg levels have been associated with both reduced abdominal fat stores and increased intensity

FIG. 1. Jennifer Provencher interacting with local hunters in Cape Dorset, Nunavut, during spring migration (image courtesy of Sam Iverson).

of nematodes (Wayland et al., 2001). Wayland et al. (2008) found that wild King Eider ducks (*Somateria spectabilis*) that carried higher levels of Hg had a lower probability of being recaptured the following year, suggesting a reduced survival rate in those birds. Although eider duck body condition is known to be affected by both contaminants and parasites, how these two factors together might influence reproductive effort is unclear.

OBJECTIVES AND METHODS

To investigate questions about how mercury and intestinal parasites affect marine birds, and specifically eider ducks, I am using a combination of observational and experimental approaches. My research first examines mercury and parasite burdens found in migrating eider ducks as they arrive in Hudson Strait after overwintering in Greenland and Newfoundland. I worked with local hunters in Cape Dorset, Nunavut, during their annual spring eider duck harvest in 2011 and 2012 (Fig. 1). Using a large sample of birds collected during this collaboration, I will investigate how parasites and Hg are associated in eider ducks and relate each to the body condition of individual birds. My first objective also entails investigating whether a sex bias in both Hg and parasitism occurs in eider ducks, as a proxy of understanding how these two factors may affect sexes differentially. My second objective is to examine how parasites and Hg relate to arrival condition in female eider ducks during migration, a time of low body condition and high energetic stress.

My thesis research will next focus on the relationship between mercury and intestinal parasites among female eiders breeding at East Bay Island, Nunavut (Fig. 2). Each year approximately 500 eiders are banded as they arrive on the island to breed. All birds caught are banded. In 2013, female eiders also received a temporary nasal tag, which

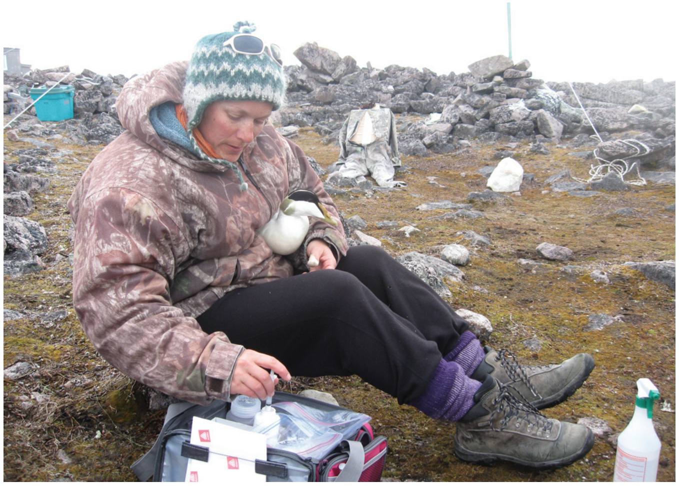

FIG. 2. The author working with a male Common Eider on East Bay Island, Nunavut (image courtesy of Holly Hennin).

helps us to monitor marked individuals and quantify metrics associated with their breeding and reproduction. Taking advantage of this annual capture and banding program at East Bay Island, I use an experimental approach to study how the variation in breeding propensity and productivity is related to Hg burdens, both in the presence and in the absence of gastro-intestinal parasites. Tagged females caught at the East Bay Island banding station will be given either an oral anti-parasite treatment (PANACUR; active ingredient fenbendazole) or a placebo treatment (water). At the same time, a small blood sample will be taken to assess female Hg burdens. The females will then be released and monitored to quantify their breeding. This experimental study will allow me to compare metrics of reproduction of females with varying levels of naturally occurring Hg while manipulating parasites in a treatment group of birds. Plans are underway to carry out another year of experimental manipulation at East Bay Island in 2014.

PRELIMINARY RESULTS

In the spring of 2011 and 2012, I worked with local hunters in Cape Dorset, Nunavut, and collected 242 eider ducks as they arrived in the area of their spring migration. Dissection and processing of these birds were completed through collaboration with the Nunavut Arctic College in Iqaluit (Provencher et al., 2013) and at the National Wildlife Research Centre of Environment Canada. After dissection of birds, each gastro-intestinal tract was slit open lengthwise and examined for parasites. Parasite enumeration and identification were then completed for each individual bird. In addition, breast muscle tissue was removed from each bird using chemically clean procedures. Breast muscle tissue was later homogenized and submitted for Hg and stable isotope (δN and δC) laboratory analysis so that Hg concentration and parasite presence and intensity could be documented and related to each other statistically.

During the breeding season of 2013, I worked with the team on East Bay Island, Nunavut, to capture, tag, and experimentally treat 134 female eider ducks as they arrived on the island. Nasal-tagged females were then monitored for nest initiation date, clutch size, number of eggs hatched, and number of ducklings that fledged and departed the island. In addition, temperature and light loggers placed in 35 eider duck nests enabled me to monitor nest attendance of the female, which included the number and length of her absences from the nest. Analysis of these data is currently underway.

SIGNIFICANCE

The conservation of wildlife is of broad interest in Canada, especially in the North, where many species are hunted. These important species can signal changes in the ecosystem that raise research questions (Brook et al., 2009; Braune et al., 2010). The relationships between parasites, contaminants, and individual condition also become particularly important in environments such as polar ecosystems, where these external factors are known to be changing. Global models currently predict that Arctic ecosystems will undergo rapid changes in the coming decades. The International Panel on Climate Change (IPCC) has predicted that climatic changes will occur most rapidly in the Arctic region over the next 80 years: increasing temperatures and declining snow cover are expected throughout the region (IPCC, 2007). As a result of warming climatic conditions, new and more abundant parasites are predicted to be a growing risk for Arctic biota (Brooks and Hoberg, 2007). At the same time, endemic parasites may experience shifts in survival and host availability because of changes to food webs, some of which have already been observed in the North with the reduction of sea ice (Davidson et al., 2011; Provencher et al., 2012). Pollutant levels in the Arctic are changing, as well as climatic conditions. Mercury (Hg) is now of particular concern for Arctic ecosystems (AMAP, 2011), and despite declines in Hg production in North America, Hg concentrations detected in some Arctic wildlife species in Canada continue to increase (Rigét et al., 2011). In light of the ongoing and expected changes to environments in Canada's North, understanding how parasites and contaminants interact to influence reproduction in wildlife is crucial to predicting potential changes in wildlife populations.

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