Comparative Immunology, Microbiology and Infectious Diseases xxx (2012) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Comparative Immunology, Microbiology and Infectious Diseases

journal homepage: www.elsevier.com/locate/cimid

Avian wildlife as sentinels of ecosystem health

Judit E.G. Smits [a,*], Kimberly J. Fernie [b,1]

[a] TRW 2D20, Ecosystem & Public Health, Faculty of Veterinary Medicine, University of Calgary, 3280 Hospital Drive NW, Calgary, Alberta, Canada T2N 4Z6
[b] Ecotoxicology and Wildlife Health Division, Wildlife and Landscape Science Directorate, Science and Technology Branch, Environment Canada, 867 Lakeshore Road, Burlington, Ontario, Canada L7R 4A6

ARTICLE INFO

Article history:
Received 2 May 2012
Received in revised form
19 November 2012
Accepted 24 November 2012

Keywords:
Avian bioindicators
Sentinel species
Nonlethal bioindicators
Ecosystem health
Biomarkers of contaminant exposure

ABSTRACT

Birds have been widely used as sentinels of ecosystem health reflecting changes in habitat quality, increased incidence of disease, and exposure to and effects of chemical contaminants. Numerous studies addressing these issues focus on the breeding period, since hormonal, behavioural, reproductive, and developmental aspects of the health can be observed over a relatively short time-span. Many body systems within individuals are tightly integrated and interdependent, and can be affected by contaminant chemicals, disease, and habitat changes in complex ways. Animals higher in the food web will reflect cumulative effects of multiple stressors. Such features make birds ideal indicators for assessing environmental health in areas of environmental concern. Five case studies are presented, highlighting the use of different species which have provided insight into ecosystem sustainability, including (i) the consequences of anthropogenic disturbances of sagebrush habitat on the greater northern sage grouse *Centrocercus urophasianus*; (ii) the high prevalence of disease in very specific passerine species in the Canary Islands closely paralleling deterioration of formerly productive desert habitat and ensuing interspecific stressors; (iii) fractures, abnormal bone structure, and associated biochemical aberrations in nestling storks exposed to acidic tailings mud from a dyke rupture at an iron pyrite mine near Sevilla, Spain; (iv) newly presented data demonstrating biochemical changes in nestling peregrine falcons *Falco peregrinus* and associations with exposure to major chemical classes in the Great Lakes Basin of Canada; and (v) the variability in responses of tree swallows *Tachycineta bicolor* to contaminants, biological and meteorological challenges when breeding in the Athabasca oil sands.

1. Introduction

Studying native fauna in environments that have been changed or damaged through anthropogenic activities provides relevant information about the viability and balance of that ecosystem. It is valuable that such work is conducted by a group of collaborating scientists with complementary expertise to facilitate concurrent studies of animals inhabiting different levels in the food chain and which represent terrestrial and aquatic ecosystems. It is well recognized that the health and reproductive success of upper trophic-level animals is a reflection of their environment. Apart from the quantity and quality of the food supplied by their immediate environment, air, water and soil borne pollutants also contribute to, or compromise the fitness and long term survival of wild populations.

Avifauna are readily visible components of normal ecosystems which, in many parts of the world, are monitored with variable intensity, and population numbers are recorded by bird banding societies. These data indirectly reflect the cumulative integrated effects of contaminants through their trophic relationships. This is

* Corresponding author. Tel.: +1 403 210 7407; fax: +1 403 210 9740.
E-mail addresses: jegsmits@ucalgary.ca, judit.smits@ucalgary.ca (J.E.G. Smits), kim.fernie@ec.gc.ca (K.J. Fernie).
[1] Tel.: +1 905 336 4843.

0147-9571/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.cimid.2012.11.007

especially true on their breeding grounds, since hormonal, behavioural, reproductive, and developmental aspects of the health of wildlife can be observed over a relatively short time-span. Such features make birds ideal indicator species for assessing the environmental health of areas of concern [1–5].

This paper will present specific case studies that demonstrate the utility and sensitivity of birds as indicators of the health of the ecosystems which they inhabit. Since the impetus for wildlife studies often includes conservation, it is well known that one of the greatest threats to wild species is the fragmentation and disruption of the ecosystems/environments on which they depend. The first two cases are compelling examples of birds being sensitive sentinels of ecosystem health in habitats disturbed by anthropogenic activities, but that are unrelated to contaminants. We consider the implications of our findings to individuals or populations. We suggest practical processes in designing and carrying out research to answer questions of how to detect biological impacts of environmental changes, whether they are degradation or pollutant related.

2. Habitat disturbance and population effects

In one example of native birds being sensitive sentinels of the anthropogenic disturbance of an ecosystem, greater northern sage grouse *Centrocercus urophasianus urophasianus* ('sage grouse' hereafter) in Canada exist at the northern extent of their range in North America with the remaining small populations restricted to southeastern Alberta and southwestern Saskatchewan. This iconic prairie bird depends entirely upon sagebrush for food and shelter making it a sensitive and vulnerable sentinel of ecosystem health. In Canada, it is the silver sagebrush *Artemisia cana* on native prairie that provides the necessary habitat for this grouse. This species of sagebrush provides a somewhat sparser cover than the big sagebrush *Artemisia ridentate*, which is the major habitat for the grouse in the range used by these birds in the northwestern plains of the United States of America [6].

Large tracks of the sagebrush habitat (70–80%) historically used by the birds in Alberta and Saskatchewan have been changed into cropland over the past 30 years [7]. As well, native range has been improved for grazing cattle through seeding with forage plants. Habitat has also been lost and fragmented especially through industrial development requiring roads and industrial infrastructure. The rangeland used for extensive grazing of cattle has been a long-time practice and remains the major classification of land in Montana that currently has stable and relatively large populations of sage grouse. The impacts of light to moderate cattle grazing on sage grouse habitat has been seen to positively influence use by the birds, whereas overgrazing or higher density livestock use results in trampled eggs and deteriorating habitat [8].

There have been different pressures on the areas used by the birds, but the greatest and strongest associations with their precipitous declines have been oil and gas development which began most intensively in the 1980s [9]. Besides direct impacts of human and vehicular activity, the roads and infrastructure have changed the predator–prey balance in favour of the predators. In one study of 117 radio-marked sage grouse, predation was reported as the most common cause of death being responsible for 83% of deaths in adult males and 53% in adult females, with most mortality occurring in the spring and summer [10]. Carnivores such as coyotes and foxes make use of roadways for ready access to areas where the birds traditionally raise their offspring. Large raptors are efficient predators of the birds, especially of the chicks. Raptors have benefited from fence and power lines, poles and tower-like infrastructure components of oil pump jack stations, for perching and hunting [11–13]. Research has documented declines in the greater sage grouse in areas of increasing oil and gas activity, and has demonstrated avoidance of infrastructure by males and by nesting and brooding females [13]. Remaining sagebrush habitat has been degraded by heavy cattle grazing, hydrological alterations, changes in natural fire frequency and, subsequently, proliferation of invasive species. Only 6% of the historic range of sage grouse in Canada is currently occupied and the continental range has been reduced by 44% [14].

This near-disappearance of an iconic prairie bird provides a compelling indication of the value of native wild birds as indicators of ecosystem health and sustainability. With the concurrent efforts of university researchers, government wildlife and agricultural agencies, plus cooperation from the energy sector in the affected areas, there will be a continued opportunity to study this species and its population trend as indicators of the re-establishment of a healthy, resilient, ecosystem.

3. Habitat disturbance and disease

In another case, passerines were sentinels of compromised habitats through the dramatic species specific prevalence of disease. The Spanish Canary Islands off the northwestern coast of Africa are primarily comprised of delicate, desert steppe habitat. Fuerteventura and Lanzarote are two of these islands on which studies have been conducted into the ecology and conservation of several species of passerines, as well as columbiformes [15] and vultures [16]. A study was carried out over 2 years, during which approximately 800 passerines were caught and banded [17]. Five species were caught; Spanish sparrows *Passer hispaniolensis* ($n = 128$), trumpeter finches *Bucanetes githagineus amantum* ($n = 228$), Canary Island stonechats *Saxicola dacotiae* ($n = 3$), Berthelot's pipit *Anthus berthelotti*, ($n = 139$) and the short-toed lark *Calandrella rufescens polatzeki* ($n = 395$). Except for some of the pipits from Lanzarote, all species were caught in the same mist nets and/or on the same premises. A remarkably high proportion had exuberant lesions on the legs, toes and occasionally the face. Using light microscopy and transmission electron microscopy, avian pox virus was confirmed, with follow-up PCR further identifying two newly described poxviruses infecting these passerines. Of the birds with completely or partially missing toes or nails, 75 of these 80 animals also had proliferative, pox-like lesions strongly suggestive that the pox infection was responsible for the missing digits [17].

Please cite this article in press as: Smits JEG, Fernie KJ. Avian wildlife as sentinels of ecosystem health. Comp Immunol Microbiol Infect Dis (2012), http://dx.doi.org/10.1016/j.cimid.2012.11.007