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Waterbirds as bioindicators of wetland heavy metal pollution

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Abstract

As highly developing urbanized and industrialized processes, wetland ecosystems are subject to natural and man-induced change through physical, chemical and energetic processes. Heavy metal pollution situation is more serious increasingly, water birds whose life history is in wetlands are at high risk both lethal and sub-lethal effects, as their body burdens increase. It is costly and time-consuming to determine environmental quality by examining concentrations of metals in very many organisms, thus indicator species and indicator tissues must be selected. Biological monitoring is thought to be satisfactory way to quantify heavy metal abundance and bioavailability. Waterbirds populations may serve as sentinel species for natural and man-made toxicological problems in the environment.

We discussed the impacts of heavy metal polltion on the water birds in wetland ecosystems, and summaried the researches of waterbirds were used for bioindicators, especially in recent 10 years. As different parts of birds can be used to investigated the heavy metal pollution of wetland systems. We discussed the advantages and disadvantages of them, as well as water birds as monitors of the wetland quality changes in this paper.

Keywords: waterbirds, heavy metal, bioindicator, wetlands pollution

1. Introduction

An exponential increase in industrial and urban activities in the late nineteenth century has led to extensive environmental pollution worldwide [1]. Heavy metals contamination is a great concern at global, regional and local level [2] and influence the functional and structural integrity of an ecosystem [3]. Heavy metal pollution in wetlands not only deteriorates the water quality, which has negative influence on the hydrophytes and animals directly or indirectly, also makes a decline in the range of many bird species, leading the biodiversity in wetlands decrease. Organisms that live in wetland systems can bio-accumulate organic and certain inorganic substances over time, and are at risk from both lethal and sub-lethal effects, as their body burdens increase [4]. Maintaining healthy ecosystems that can protect the well-being of organisms living within them, including humans, requires not only environmental planning and management, but also knowledge of how stressors vary in the environment [5]. Increasingly it is necessary to understand the fate and effect of chemicals to assess the health of ecosystems and to provide early warning of changes in the environment that might indicate adverse effects [6]. Biomonitors are usually

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selected to complement physical monitoring, but may in some instances provide the only available means of monitoring [7]. Birds in many cases appear to be more sensitive to environmental contaminants than other vertebrates [8]. Waterbirds populations may serve as sentinel species for natural and man-made toxicological problems in the environment. Since 1971, the herring gull (*Larus argentatus*) has been used as a sentinel species for monitoring the levels of mercury in the Great Lakes ecosystem [9].

2. Heavy metal effect on water birds

Waterbirds suffer severe health impairment or death when subjected to high concentrations of some heavy metals. In birds, the possible consequences of exposure to sub-lethal concentrations of heavy metals for individuals are (1) reproductive dysfunction; (2) increased susceptibility to disease; and (3) behavioral changes [10]. At the population level, water pollutionmakes the species suffering server impaired damage and declining dramatically, even disappeared, followed by their distribution changing. Studies have shown that heavy metals can also have an influence on the reproduction and general health of some birds [11,12]. Contaminants such as cadmium, mercury, and selenium have been shown to adversely affect the condition of birds by reducing their growth or body weight [13].

Egg of waterbirds exposure to heavy metals may have an impact on early growth and nestling survival [14]. The effects of chromium, lead and cadmium were studied on the embryogenesis, hatching success and viability of the mallard [15] and the results showed that each heavy metal (Cr, Pb, Cd) proved to have adverse effects on the embryonic development, hatching and viability of the mallard.

3. Waterbirds as indicator of heavy metal pollution in wetland system

3.1 Internal tissues and blood as monitoring units.

Internal tissues, especially soft tissues are broadly used for bioindictor in many researches; one or several tissues of muscle, liver, kidney, spleen, heart, lung, as well as fat, blood, brain and bone are usually used to investigate the concentrations of heavy metals in the environment. There are content and concentration differences of the same metal element in different tissues of a species, so it's essential to measure different tissuesfor the popution level evaluation. . Mean values for THg in muscle, brain and bone of Western Alaskan water birds were investigated, and in the species studied are unlikely to cause adverse reproductive or behavioral effects in the birds [10]. Goodale et al.(2008) studied the mercury in several foraging birds using egg and blood, indicated that some of them were effective bioindicators of Hg of the Gulf of Maine [11]. Cid et al. (2009) measured Pb and Cd in bone, pectoralis muscle, liver, gonad, and brain of three bird species representative of the Embalse La Florida ecosystem[12].

3.2 Egg as monitoring units.

Waterbirds' eggs were used a lot as biomonitor to detect heavy metals' concentration or its temporal-spatial trends as they are easier to obtain and can be saved for a long period compared with soft tissues and nestlings. They are not as much be influenced by types, parts and ages as feathers. Variability in contamination due to trophic levels varying interspecifically is well known. Additionally, intraspecific variations based on differing fat content, age, and size of matrix objects occur in adults. In eggs of sea birds, those aspects are less significant making them excellent for monitoring marine pollution [13]. Metal levels in eggs can often be used as an indicator of exposure and of potential effects [14]. Eggs are a good indicator of local exposure, since most birds in tropical and temperate regions spend many weeks on the breeding grounds before they lay eggs, acquiring sufficient resources (and thus heavy metals) locally to produce the eggs [6], and eggs have a highly consistent composition which do not change in size and composition

during both the day and year.
Mora's research results show that a proportion of many inorganic elements accumulate in the eggshell and that the potential effects on the proper structure and functioning of the eggshell should not be ignored [15]. Dauwe *et al*. (2004) noticed that eggs from the two most polluted sites had significantly less spermatozoa on the perivitelline layer than eggs from the least polluted site [16]. Pereira *et al*. (2009) monitored Gannet (*Morus bassanus*) eggs from Bass Rock (North Sea) and Ailsa Craig (eastern Atlantic) for total mercury (1974–2004) through egg contents, and found there was spatial variation in both the absolute concentrations and temporal trends for Hg residues in gannet eggs [17]. Dipper（*Cinclus cinclus*）eggs was collected for analyzing the trends of Mercury content during 1990–1999 of in south-west Ireland [18].

3.3 Feather as monitoring units.

The use of feathers has been suggested as non-destructive means of assessing the contamination of heavy metals [19]. There are several advantages for feather as monitoring units, first, they are easy to obtain and can be observed for a long period, so feather is useful for long-term study; second, when large number of samples are needed, it has few damages to the population's survival and reproduction of waterbirds as eggs and nestlings do. However, there are still some factors that make the using of feather to monitor water quality disputable; the results may be influenced by feather types and the location of body parts besides the common variation existing in other monitoring units. Guo *et al.* (2001) studied the level and distribution of mercury in feathers of birds, and found that the distributions of Hg in different types of feather and different parts for the same feather are distinct [20]. Down and contour feather are used more for heavy metal researches, Burger and Gochfeld (2000) examined Albatross Chicks feathers from Midway Atoll and results suggested that both species have higher levels in their down than in their contour feathers [21]. Malik and Zeb (2009) analyzed the concentrations of several heavy metals in the feathers of cattle egret (*Bubulcus ibis*) from three breeding colonies in Pakistan, and the results suggested that the feathers of cattle egret could be used as a bio-monitor of the local heavy metals contamination [19].

3.4 Nestlings as monitoring units.

Compared with adults, nestlings can reflect the level of local pollutants better; in addition, they are easier to be obtained as the fight ability of them has not been fully developed. The problem for nestlings as monitoring units is how to make sure of their day old, because differences exist between different day old nestlings. Wemel *et al*. (1996) examined five trace elements in soft tissues and feathers of Kittiwake nestlings from the Island of Helgoland, North Sea, their results showed that the tissue distribution of metals was similar in all age classes and demonstrated that particularly older chicks (26 days old) were reliable bioindicators of mercury and cadmium contaminations [22]. However, trace element distribution in nestlings may be influenced by excretion, varying degrees of tissue growth and/or metal contamination of the ingested food. Eggs and nestlings were collected for investigating the mercury contamination of little terns (*Sterna albifrons*) breeding at the western Baltic Sea from 1978 to 1996 [13].

4. Advantages and disadvantages of water birds as biomonitor

A number of advantages and disadvantages of birds as biomonitors can be noted. As bird is high in the food chain, they may be particularly suitable as monitors of any signal that accumulates through the chain, but they may also be sensitive to many diverse factors affecting the food chain.

Advantages: Birds are abundant, widely distributed and, in some cases, long-lived. Not only can birds monitor local food webs, but also, if they are migratory they can be used to compare exposure in different regions [23].

One of the most compelling reasons for using birds as biomonitors is quite pragmatic. It is that they are relatively easy to study and that large amounts of data have already been gathered for bird populations. Coastal birds are good bioindicators because they reveal current environmental exposure and respond relatively rapidly to contamination events [24].

Disadvantages: In migratory birds, exposure to contaminants throughout the course of a year is determined by their migration patterns which can extend across entire hemispheres as the birds migrate between breeding and wintering grounds. Dietary composition may vary within the breeding range of individual species of birds [25-27] and since prey may be differentially contaminated depending, for example, on trophic level, dietary choices may contribute to spatial variation of contaminant levels found in the birds [27]. So migratory habits can render birds much less suitable as biomonitors because individuals may differ in their migrations to an uncertain extent and make it difficult to determine the spatial scale they represent. A similar problem of buffering may be evident at behavioral and physiological levels of buffering may render birds less satisfactory as biomonitors than lower animals. For example, birds are able to regulate tissue concentrations of many metals, and body reserves of fat, to a much greater extent than invertebrates can, and so birds may less readily reflect environmental stresses.

Besides these, the differences existing in water birds, such as sex, age, tissues and species, make it difficult to establish a consistent standard for environment evaluation. Burger (2007) reviewed 43 studies of metals in vertebrates, found that females had higher levels in 30 cases where there were significant differences (and males were higher in only 14 cases) [28]. Nonetheless, females often have higher levels, suggesting that the mechanism of excretion into eggs and eggshells is not as effective as once assumed, or that uptake is greater [28]. Wemel et al. found that some heavy metals in soft tissues and feathers of Kittiwake nestlings were low in hatchlings and increased with age of the nestlings [22].

Measuring heavy metal concentrations in birds is useful, however, in many cases it may not be sufficient because stress caused by exposure to heavy metals can be both direct and indirect (e.g. decreased amount of food).

5. Summary:

There has been sufficient information available to conclude that significance and impact of the presence of heavy metal pollutants in the wetland environment influenced the survival and reproduction of water birds, for instance, thinner eggshell, lower incubate rate and higher mortality rate. Heavy metal contents investigations and compares, as well as their period temporal and spatial trends in different species with distinct monitoring unitswere developed so many all over the world. However, there still has not developed a standard to confirm the threshold of each heavy metal suitable for most waterbirds. Most of the reports on heavy metal concentration associated with adverse effects were educed in laboratory. As damages of heavy metal to waterbirds are often associated with other pollutants in nature, it's difficult to judge whether the behavioral or physiological changes of birds living in wetland systems are caused by heavy metals and which kind of heavy metal. Besides these, as the factors that influence the concentration of heavy metals are so many, it is necessary to establish an evaluation criterion of pollution levels that result from different monitoring units.

Waterbirds was useful as bioindicator of wetland heavy metal pollution, however, which kind of body parts was chosen might influenced the results. Most heavy metal concentration investigations were developed in a small spatial scale so far, and researches on the whole global wetland systems are still lack, a large-scale environment risk assessment cannot be performed for these data's absent.

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