

# Paramount roles of wild birds as bioindicators of contamination

## Abstract

This review aims to give all-inclusive précis of key roles of wild birds as bioindicators of contamination using theoretical and empirical evidence provided in different literature and its influence on conservation. Over the years wild birds have been used as bioindicators of contamination globally. Are wild birds suitable for measuring heavy metal pollution? Bioindicators are species used to appraise the health conditions of the environment and they are capable of determining the environmental integrity if their functions and populations are put into consideration. Birds are good indicators because they are very easy to detect and their presence is easy to observe in any environment or if the habitat does not fulfill the ecological requirements, as they are equipped with the ability of flight so that they will leave the environment. Apart from that, in classification individual species are easy to identify with their wide distribution. Heavy metals are essential elements for organisms but may be toxic with high level, affecting productive function and behavioural features and equally heavy metals can easily be accumulated and biomagnified through food or food web. Therefore, using birds as bioindicators is a function of properties of interest and resources available for ecological evaluation which promotes conservation of bird species for impending generation.

**Keywords:** bioindicator, wild birds, contamination, environment, heavy metals, taxa

Volume 2 Issue 6 - 2017

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**Received:** November 17, 2017 | **Published:** December 29, 2017

## Introduction

Bioindicators are species used to appraise the health conditions of the environment or ecosystem and they are capable of determining the environmental integrity using their functions and populations. In preserving and managing the natural surroundings, it is imperative to monitor the condition of many components of the ecological unit. Under normal circumstance, conservation advocates would be more interested to examine all properties of concern within a natural ecosystem<sup>1</sup> resources required for ecological evaluation are usually limited coupled with vast nature of natural ecosystem. Due to this constrain only an undersized fraction of these properties are usually examined. In most cases physical, chemical or biological properties that indicate the status of un-sample parameters of the environment may be monitored in the absence of all-inclusive data on entire ecosystems by conservation advocates. Thereby stimulating selection of individual species or groups of species to serve as biological indicators. For example black-headed oriole with a conservation status of least concern may be selected. However, the population seems to be decreasing due to habitat loss and other factors.<sup>2</sup> The condition of ecosystems can be measured using characteristics, such as presence or absence, abundance, density, mortality rate and breeding success<sup>1</sup> of wild birds. Apart from that, the status of other taxa, the presence and impacts of stressors on birds and patterns of biological diversity may also be put into consideration. Therefore, bird diversity is an indicator of species richness of natural ecosystem.

According to Carignan & Villard,<sup>3</sup> Chambers<sup>1</sup> the ovenbird *Seiurus aurocapillus*, is a good indicator of closed-canopy, mature forests with a sparse understory. This simply means the presence or absence of the said species is considered to be a good indicator of the presence or absence of closed-canopy, mature forests with a sparse understory. Due to the associated relationship over time, ovenbird can be used to measure the level of deforestation and habitat destruction. If the term

indicator is properly examined, it simply refers to value and level, with a clear indication of occurrence of a factor under consideration and they are normally developed within the perspective of basic frameworks of application in the course of evaluation of natural ecosystem. The basic components of an indicator comprises of parameter derived from combinations of more than a few parameters which provide essential information about the frequency of occurrence of evaluated resources with the aim of quantifying it present properties in time and space to determine its effects on the environment, health conditions of the population, ecosystem structure and the productivity.<sup>4</sup> Therefore, it is imperative for conservation managers to spot the measurable parameters required to support sustainability of a given population. Therefore, this review aims to give all-inclusive précis of key roles of wild birds as bioindicators of contamination using theoretical and empirical evidence provided in different literature and its effects on conservation. Over the years, ecologists have used wild birds as indices for heavy metal pollution, were the birds able to measure the effects of heavy metal concentration in the environment. Over the years, surrogate species have been used in ecology and conservation science to determine the association of plants and animals in a specific geographical locality.<sup>3</sup> Similarly, conservation biologists have used target species as desirable shortcuts for proper understanding and better management of ecosystems<sup>5</sup> due to natural difficulty and poor scientific resources. Indicators are group into different Categories namely; composition indicators, ecological indicators, biodiversity indicators, keystone species, umbrella species, focal species, flagship species and vulnerable species.

## Composition indicators

These include both community and ecosystem composition.<sup>6</sup> It has been predicted that climate change could be responsible for a major change in forest composition and migration of bird species due to a large correlation between climatic conditions and bird population

changes.<sup>7</sup> Therefore, birds are considered as pioneer indicators for changes related to global warming as a result of their rapid response to temperature changes.

Composition indicators are very susceptible to environmental pressure as a factor. This factor in most cases stimulates the effect of these stress factors on biota<sup>5</sup> and the resultant effect is a product of the response of at least a subset of other taxa occurring naturally in that habitat. Species and taxa are usually used to identify habitat of wild birds based on the dynamics of ecosystem. In some cases, species differences may prevent wild birds from becoming an excellent substitute towards response to environmental stress. For example village weaver *Ploceus cucullatus* are composite indicator of cultivation of cereals, such as rice, maize and guinea corn because their activities increase with the increased in rainfall which is associated with planting of grains.

### Ecological indicators

This term general refers to response of bird species to exposure, habitat response, and stressor indicators. Wild bird's requirements are specific. For example; food, temperature, rainfall, conducive habitat, season of the year and abundant vegetation cover. Therefore, their presence indicates a satisfied environment. Bird species are very sensitive to well-known environmental strain factors and they are usually capable of demonstrating the effect of these strain factors on biota, and the effect of the response on a subset of other taxa present in the habitat.<sup>8</sup>

### Biodiversity indicators

A biodiversity indicator is a group of taxa (e.g. genus, tribe, family or order, or a selected group of species from a range of higher taxa), or functional group, the diversity of which reflects<sup>1</sup> some measure of the diversity. For example; character richness, species richness and level of endemism in a specific habitat. Biodiversity indicators demonstrate the diversity of other taxa within a given habitat.

### Keystone species

Keystone species can be defined as species that have excessively large effect on other species in an ecosystem irrespective of their small abundance. Examples of keystone species are keystone predators, keystone food resource, keystone modifiers, keystone mutualists and keystone diseases.<sup>5,6</sup> Keystone species play a similar role in many ecological communities by maintaining the structure and integrity of the community.<sup>9</sup> Without keystone species the ecosystem will cease to exist together. Oil palm can be considered to be keystone indicators because it provides habitat for village weaver *Ploceus cucullatus* because the leaves are used in building nest. Apart from that, hummingbirds are also known as keystone mutualists because they influence the persistence of quite a lot of plant species through pollination.<sup>9</sup> An intact and continuous forest with high count of *Acacia campylacantha*, *Anogeissus leiocarpa* and *Kigellia africana* which lovebirds preferred perching on, best breeding ground due to many holes on the boles and coupled with availability of food resources are keystone host that supports more birds.<sup>10</sup> Desert environments, palm and fig trees in tropical forests are called keystone hosts because they provide habitat for a variety of bird species.<sup>9</sup> Keystone preys are species that can maintain their numbers despite being preyed upon, therefore controlling the density of a predator.<sup>9</sup>

### Umbrella species

Umbrella species can be defined as species which their careful

protection preserves the habitats and species within<sup>6</sup> but these habitats and species would not be significantly distorted by the loss of the umbrella species. It can also be defined as species whose conservation gives protection to a large number of naturally co-occurring species. This simply means, the conservation of umbrella species promotes the conservation of other species within the same habitat. Although there is uncertainty regarding the effectiveness of single umbrella species in conservation biology, the use of multiple species can enhance the effectiveness of this tool.<sup>11</sup> However, large areas of habitat are required to maintain viable populations. Although, less demanding spatial habitat requirements will also be protected along the line without necessary setting up new conservation strategies.

### Focal species

This can be defined as species basically identified as being most sensitive to a threat in a changing environment and careful protection preserves the habitats and species within.<sup>5</sup> Focal species are use to identify the appropriate spatial and functional parameters that must be present in an environment thereby promoting sustenance of the biota. Based on the definition given above, focal species are in consonance with umbrella species.

### Flagship

Flagship species are charismatic species that easily attract public support for<sup>1</sup> fund raising and awareness creation. Flagship species can be defined as popular, charismatic species that serve as symbols and rallying points for major conservation initiatives.<sup>5</sup> The feature of charisma, actually necessary for a flagship species is responsible for its restrictions as bioindicators because, essential areas for biodiversity conservation may be deficient in charismatic megafauna. Receptively, however, current research suggests that the flagship perception may be more flexible and responsive to a diversity of social, cultural, scientific and political dimensions<sup>12</sup> that might extend beyond the traditional model.

### Vulnerable species

Vulnerable or endangered species are target species, mainly if they are endemic to a specific study locality. However, vulnerable species are generally not good indicators,<sup>13,14</sup> but in process of selection there, it needs to be clearly stated that these species are selected as targets due to their endangered status, independent of any use they might have such as indicators, keystone, umbrella or any other above mentioned category. One species can fall under several different categories.<sup>5</sup>

### Environmental indicators

These are species that indicate the presence or intensity of stressors in the environment. Five types of pollution indicator species were identified by Chambers:<sup>1</sup>

- i. **Sentinels:** These are very sensitive species introduced into a mark environment to offer early-warning symptoms of the incidence of pollution in the ecosystem.
- ii. **Detectors:** These are also species that are endemic to a specific locality showing measurable reaction to a modified environment, for example, changes in behaviour, mortality or age-class structure. Apart from that, the species are expected to exhibit a sharp respond to changes in environmental conditions.
- iii. **Exploiters:** These are species that are capable of indicating pollution in the environment using their presence as a function. The survival of exploiter species is a function of their ability to

utilized polluted environment. Therefore, they often flourish in disturbed or polluted areas based on the fact that, competitors cannot persevere in the distorted environment.

- iv. **Accumulators:** These are species that build up pollutants in considerable amount in their body tissue such as liver, kidney, lungs, skin and feathers.

### Bioassay organisms

These are species use in laboratory evaluation to spot the concentration of pollutants to determine contaminant toxicity.

### Bio-indicator species

These are species that are capable of responding to little environmental changes. For example, the North American species kirtland's warbler *Dendroica kirtlandii* has been projected as a marker of global warming.<sup>1</sup>

### Site-type indicator species

These are species that are capable of serving as a marker of occurrence of specific environmental conditions, such as certain rock, soil types and habitat elements.

### Recovery indicator species

These are species used to measure the recovery rate of an ecosystem.<sup>15</sup> For example, the success of any habitat restoration programs can be measured using birds as recovery indicator.<sup>16</sup>

### Management indicator species

Management indicator species shows the impact of management regimes on biota. For example, removal of woody vegetation which decreases the numbers of woodland predators thereby makes the habitat more productive and attractive to many communities of grassland-nesting birds<sup>17</sup> such as common waxbill and sparrow weaver.

### Pollution indicator species

These are species that are capable of indicating the effects of pollutants on the biotic environment.<sup>15</sup> They also recognized keystone species and dominant species in their debate of the indicator species concept. The defining characteristics of these species make them attractive targets for environmental monitoring.

### Dominant species

These are species that embraces a large proportion of the biomass and may be numerically dominant in an ecosystem.<sup>1,15</sup>

## Advantages of using birds as indicator species

Over time good indicators of the general environmental conditions are attributed to birds. Although their ability to directly and rapidly bring about changes in ecosystem properties coupled with the impacts of such changes on other taxa still exist with reservation.<sup>18,19</sup> The positive benefits of using birds as indicator species are:

- i. They are very easy to detect and their presence is easy to observe in the environment.
- ii. They also publicizes their presence using their call, bright colour and numerous species are diurnal.<sup>18</sup>
- iii. They have a well treated classification and individual species are easy to identify directly in the field.<sup>19</sup>

- iv. Birds are widely distributed and occupy a broad range of habitat types and ecological niches.<sup>1</sup>
- v. The distribution, abundance, habitat preference, biology, ecology and life history of birds are well known.<sup>19</sup>
- vi. Birds exist near the top of the food chain thereby making them to be sensitive to changes at lower levels of the food chain and environmental contaminants concentration.<sup>1,18</sup>
- vii. A lot of bird species are considered to be agents of pollination and dispersers of seeds of crop plants thereby maintaining the ecosystems.<sup>1</sup>

## Disadvantages of using birds as indicator species

Some of the attributes of birds can either be useful or harmful which is a function of spatial and temporal scales coupled with the main purpose of observation:

- i. Birds watch can be carried out on large broad spectrum because birds are mobile. Thereby making it easy for researchers to attribute their reaction to specific changes in environmental conditions.<sup>19</sup>
- ii. The mobile nature of bird species is exceedingly different from other terrestrial animals and their resource utilization occurs in three-dimensional space compared to other animals, thereby resulting to inaccurate responses to environmental alteration.<sup>1</sup>
- iii. They also have ability to send warning signals after long term exposure using generation times but, they are not reliable when used as indicator of short- term environmental instability.<sup>19</sup>
- iv. Secondary or tertiary alteration in component of stressors equally affects birds thereby, reducing their worth as a bioindicator.
- v. In some cases, a number of opportunist birds may create confusion in environmental monitoring by responding absolutely to dreadful conditions in the environment at first.<sup>19</sup> This may prevent ecologist from chosen birds as indicator.
- vi. They also have behavioural and physiological traits that make them less sensitive to ecosystem changes compared to other animals. For example, birds can regulate fat stores and metal concentrations in their body tissues to a much greater degree than invertebrates.<sup>1</sup> If this so, why do ecologists use birds as biological indicators?

## Functions of birds as an indicator

Bioindicators are species used to appraise the health conditions of the environment or ecosystem and they are usually capable of determining the environmental integrity using their functions and populations.<sup>1,3</sup> Birds in particular are usually affected by indiscriminate deforestation which is a function of conversion of forest land to a crop land, firewood collection, logging of trees for timber, production of charcoal and wild fires which render birds homeless.<sup>20</sup> The exposure of bare ground to erosion as a result of intense farming is capable of introducing contaminants, such as pesticides, herbicide and fertilizer residue into stagnant water in form of surface runoff. Pollutants, such as salts, nutrients like phosphorus and nitrogen, and pesticide residue can be found in this runoff.<sup>21</sup> Pesticide can contaminate the soil, water and air and an increase in the use of pesticides decrease the availability of arthropod prey and weeds<sup>22,23</sup> for bird species.



Similarly, bird species have equally shown substantial population decline due to range contraction in agroecosystems, which have been linked to the intensification of agriculture as well<sup>24,25</sup> as the effects of pollutants have been reviewed by Fuller<sup>26</sup> and Newton.<sup>27</sup> A number of studies have explored how regular pollutants destructively affect bird populations for instance, the increased use of pesticides and inorganic fertilizers<sup>27,28</sup> increases food production but with an increased in the level of contaminants in agricultural landscape. Apart from that, it is also considered to be a serious hazard capable of affecting breeding performance and local survival of bird.<sup>29,30</sup> Although the toxicology effects of pollutants are now more pronounced in recent time than ever, but basic evidence for the prospective side effects that changes community structure with promising pollutants, along with the propelling links between specific species and their functional-guild in terms of biotic responses remains limited.<sup>31</sup>

Over time, birds have extensively been used as biomonitors of environmental contamination with persistent organic pollutants.<sup>32-34</sup> Conventionally, birds have also been used to monitor ecological processes, such as food web structure and the dynamics,<sup>35</sup> ecosystem health,<sup>36</sup> forest and agricultural management,<sup>37</sup> and the response of biological systems to climate change.<sup>36</sup> In a few occasions, the benefit of using popular and accessible species gives room for a precise recognition of the physiological mechanism linking population-level response to the ecological process under study<sup>36,38</sup> especially when the level of contaminant in the environment is put into consideration for example in Benue State, Nigeria that is more of an agrarian state. If birds are critically examined, as an important component of biotic community,<sup>39</sup> which are capable of responding quickly to change in habitat and environmental fluctuation some contaminants could be detected in them. Metal distributions in abiotic and biotic systems require precise examination to evaluate the impact on ecosystems. Wildlife studies of exposure and effect could be challenging, but the results are more complete than evaluation of only metal concentrations. Birds are good sentinel species because they are observable, sensitive to toxicants, and live in different trophic positions.<sup>40</sup>

Thus, birds are considered to be good bioindicators of an agroecosystems quality, productivity, and stability and often have correlation with their habitats.<sup>41</sup> They have also been used as surrogates for assessing the impact of habitat changes<sup>42,23</sup> due the change in agricultural practices. The presence of contaminant in avian species provides basic information for determining factors stimulating population fluctuation of bird species in addition to loss of habitat, poaching, diseases, predators and prey relationship in terms of population interactions,<sup>44</sup> provided they are done in accordance to basic scientific principles.<sup>20</sup> Cropland is one of the three major ecosystems in the world, providing irreplaceable ecological functions and economic values.<sup>45,46</sup> However, cropland ecosystem has been increasingly affected by heavy metals. Heavy metals enter cropland ecosystem through natural and anthropogenic ways, including hydrological processes, natural erosion, atmospheric deposition, and agricultural non-point source pollution, industrial activities<sup>46,47</sup> through irrigation activities and surface runoff.

## Effects of heavy metals on bird species

Some heavy metals are essential elements for organisms but may be toxic with high level, affecting productive function and behavioral features<sup>46</sup> and heavy metals can be accumulated and biomagnified through the food chain or food web in avian species. Heavy metals enter bird species through direct inhalation, ingestion and dermal contact absorption, resulting in potential risk to wildlife.<sup>46,48</sup>

Arsenic and its compounds are carcinogenic to organisms.<sup>49</sup> Lead can cause lead poisoning and damage to the nervous system and immune function.<sup>46</sup> Cadmium may reduce reproduction and growth performance of birds. Ingestion of even trace quantities of Cadmium can affect the physiology and health of bird species.<sup>46</sup>

Methylmercury can be bioaccumulated and biomagnified through the food chain, and chronic dietary exposure to small concentrations can impair reproduction of bird.<sup>50,51</sup> Moreover, feces can accumulate heavy metals at higher concentrations than diet items.<sup>46</sup> As a result, pollutant may be transferred to another place through feces of migrants.<sup>47</sup> Heavy metal exposure risk to birds in cropland and wetland ecosystem is an international issue<sup>52</sup> today. An established home range area can be compared with soil concentration data, and resulting patterns may provide evidence of exposure and uptake. For example, if a bird exclusively selects foraging sites near or in contamination “hotspots,” it may be subjected to greater risk than if it forages evenly across its home range.<sup>53</sup>

Conversely, birds whose nests are located in heavily contaminated areas, yet whose foraging efforts are allocated to non-contaminated regions are not necessarily at great risk, and may manifest only minor effects on productivity. Studies have also indicated that contaminant concentrations in soils and subsequent diets within foraging areas of birds were associated with residue levels in target tissues.<sup>31,53</sup> Some studies in the past used distribution and nesting success of birds as indicators of contaminant uptake across a diverse landscape gradient.<sup>54</sup> Resident birds that forage in a finite home range where heavy metal concentrations may bioaccumulate in the food web can represent local contamination in a heterogeneous environment.<sup>53</sup> Nestlings are very effective at reflecting chronic exposure in the breeding area because of their vulnerable life stage and high association between the food quantity they are given during growth and body burden.<sup>54</sup>

It was reported that chromium concentration in mallard duck produced adverse effects in embryo development, viability and hatching.<sup>55</sup> Chromium is necessary in organisms at certain amounts but becomes harmful when in excess or above the required threshold level of 50mg/kg in wild birds as recommended by WHO.<sup>56</sup> The possible noticeable effects of mercury in birds are decreased egg weight, fertility, and hatchability. Increase in kidney lesions, brain lesions, skeletal deformities; reduced clutch size, poor hatchability, poor embryonic growth, behavioural change and neurologic signs of weakness and inadequate coordination in wild birds.<sup>57</sup> It has also been demonstrated that the occurrence of deformities increases rapidly when selenium concentrations in fish eggs are greater than 10mg/kg.<sup>58</sup> Consistent evidence of teratogenesis and reproductive failure has been observed in whole-body of fish with selenium concentration greater than 15mg/kg<sup>58</sup> and this may be applicable to wild birds. Although, anthropogenic activities and other environmental contaminants has been demonstrated to have significant affect on wild birds,<sup>59,60</sup> lead is one of the most toxic metals known, affecting the renal, gastrointestinal, reproductive, central and peripheral nervous systems, as well as the biosynthesis of wildlife.<sup>60,61</sup> The basic effects of arsenic in birds have been reported such as teratogenic effects in birds. Arsenate could be teratogenic in the offspring of brooding birds. Equally too, arsenic has been shown to be capable of causing chromosome damage in bone marrow cells of birds as well.<sup>31,62</sup> The mechanism of arsenic genotoxicity is not clear, although several mechanisms have been proposed, including reactive oxygen species and the inhibition of deoxyribonucleic acid (DNA) repair.<sup>31,62,63</sup> In a study of the potential of arsenic compounds to act as promoters, a significant increase in the incidence of kidney tumours was observed

in male birds.<sup>31,62</sup> Cadmium is capable of causing kidney damage<sup>64</sup> in population of wild birds. Cadmium may also enter the environment mainly through the ground, because it is found in manures and pesticides.

## Conclusion and recommendations

Birds are good indicators because they are very easy to detect and their presence is easy to observe in any environment. Apart from that, in classification individual species are well treated coupled their wide distribution. They also exist near the top of the food chain thereby making them to be sensitive to changes at lower levels of the food chain and environmental contaminants concentration. Some heavy metals may be toxic with high level, affecting productive function and behavioural characteristics, presence of lead may stimulate lead poisoning thereby resulting to poor immune function and damage of nervous system. Cadmium equally has the ability to bring about reduce reproduction and growth performance of birds. Apart from that, methylmercury can also impair reproduction of bird resulting to decreased egg weight, fertility, and hatchability. The above effects of heavy metals in bird species are easily noticeable once the permissible limit of a specific heavy metal is exceeded. Hence, wild birds are excellent indicators of heavy metal pollution in the environment.

Using birds as bioindicator is a function of properties of interest and resources available for ecological evaluation which promotes conservation of bird species for generation yet unborn. Therefore, it is essential to examine prospective mechanism by which heavy metals may be responsible for establishment of diseases in wild birds. This will definitely promote conservation of bird species more importantly species that are endangered and threaten.

## Acknowledgments

None.

## Conflict of interest

The author declares no conflict of interest.

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