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SUGGESTED GUIDELINES FOR USE OF AVIAN SPECIES AS BIOMONITORS

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Abstract. An animal's suitability as a biomonitor of environmental change can be determined by biological, reproductive and ecological characteristics determined at the class, order and species level. The animal's habitat where the research is to be performed and the form, function and structure of the environmental change being studied within that habitat also determines suitability. Non-threatened populations of large, non-migratory, long-lived, seasonally-breeding tertiary avian predators, whose dietary preferences are narrow and known, can be useful as monitors of environmental chemical contaminants. If chemicals are being monitored, a quantifiable endpoint effect must be demonstrated in the species, or a similar species under experimental laboratory conditions. Logistical and economic issues as well as public and regulatory authority acceptance should also be considered when assessing the suitability of a species as a biomonitor.

Keywords: avian, biomonitor, environmental contaminants, guidelines

1. Introduction

The use of mammals, birds, reptiles, amphibians and invertebrates as monitors of the potential effects of chemicals in the environment is well documented (Burger and Peakall, 1995; Jefree *et al*., 2001). There appear fewer publications providing guidance in establishing the suitability of avian species as biomonitors (Burger and Peakall, 1995; Gragnaniello *et al*., 2001). An animal has characteristics defined at the class, order, genus and species level that should be considered when assessing its suitability as a biomonitor species. A characteristic at the class level is birds molt their feathers and this uniquely avian tissue is useful as an indicator of whole body concentrations of certain heavy metals (Burger, 1993). A characteristic at the genus level is the predominantly piscivorous diet of many *Haliaeetus* genus eagles that allows for the determination of the origin of tissue concentrations of pollutants (Helander *et al*., 1982; Bowerman *et al*., 2003; Hollamby *et al*., 2004d). As well as biological, physiological, behavioural and reproductive characteristics of the biomonitor species, knowledge of ecological structure and function, and form and cycling of the chemical (or change) within the environment being examined, is required (Douthwaite, 1992; Jefree *et al.*, 2001). The objective of this communication is to describe the characteristics of a successful avian biomonitor and what factors should be considered when selecting a species for this role.

2. Suggested Characteristics of a Avian Biomonitor

The following suggested characteristics of an avian biomonitor were established from the work of others (International Joint Commission, 1985; Burger and Peakall, 1995; State of the Lakes Ecosystem Conference, SOLEC 1998; Gragnaniello *et al.*, 2001), and our observations during project planning for an ecotoxicological study of African fish eagles (*Haliaeetus vocifer*) and marabou storks (*Leptoptilos crumeniferus*) in Uganda (Hollamby *et al.*, 2004a,b,c,d). The resultant list is one view of the ideal requirements for a biomonitoring program utilizing avian species. It is highly unlikely that any species or program could meet all of the following guidelines and it is likely the relative importance of each guideline will vary between projects with different monitoring objectives. However, consideration of each factor listed should help researchers focus their project design by determining the limitations and advantages of a particular species in a biomonitoring role and whether project objectives can be met through that species.

Suggested characteristics and factors when selecting an avian biomonitor are:

1. The population of the species must be large enough such that sampling will not adversely affect the population.
2. The species body size should be large enough so that sample volume is adequate to meet analysis requirements.
3. The species should be long lived.
4. Size, age and sex differences within the species can be documented.
5. Size, age and sex variation in bioaccumulation of the chemical within the species can be documented.
6. The species must have a specimen that can be sampled, in the correct quantity at a suitable body site, in which there is a correlation between concentrations found and concentrations known to cause a specific endpoint effect.
7. The specimen chosen for sampling must be able to be stored from the time of sampling until analysis in a manner that will not affect the analysis or results.
8. The biology of the species should be characterized such that changes can be monitored.
9. The species should be capable of being monitored over a number of seasons or biological cycles.

10. The species should be non-migratory and non-nomadic, at least for the part of their life cycle when sampling occurs, so as tissue concentrations of chemicals are an indication of local environmental contamination.
11. The diet of the species can be determined for the environment under examination and must be relatively consistent within and between environments under study.
12. Species foraging range must be known, if local point source determinations are required.
13. The species reproductive cycle in the study area is known, and reproductive success (number of young reared) and productivity (number of young hatched) able to be determined quantitatively.
14. If bioaccumulation of the chemical is to be studied, the species should occupy a high trophic level in the food chain.
15. The species should be able to tolerate a range of concentrations of the chemical under examination.
16. Exposure routes for the chemical in the species concerned need to be documented.
17. A chemical's quantifiable endpoint effects must be demonstrated in the species, or a similar species under experimental laboratory conditions.
18. Knowledge of the chemicals to be examined, their localized usage, their activity and reactions in the environment under examination can be documented.
19. The species can be sampled cost effectively and with relative ease, in the environment under examination.
20. Public and regulatory acceptance of the species as a biomonitor and the sampling methods utilized should be established.

3. Discussion

While many of the suggested characteristics of an avian biomonitor may appear obvious, nuances should be considered when applying them to a specific situation. African fish eagles are exposed to certain persistent organic pollutants and mercury by eating fish, with bioaccummulation and biomagnification increasing contaminant concentration with increasing trophic level. African fish eagles feed on a variety of fish with detritivorous cichlid species, such as Nile tilapia (*Oreochromis niloticus)* comprising a large portion of the diet (Stewart *et al*., 1997). However, fish eagle diet may vary between sampling locations and even between individual birds (Brown, 1980). Observations of prey remains at nests in Murchison Falls (Hollamby, 2003) indicate tiger fish (*Hydrocynus forsaklii*), a carnivorous species forms a large percentage of the fish eagle diet in this location. In other areas, multiple observations have shown that some fish eagles are largely orniphagous (Brown, 1980). In locations where carnivorous fish species are the main prey items, this would add another trophic level to the food chain that may result in exposure of fish eagles to higher chemical concentrations through bioaccumulation. Such dietary variation between locations may complicate comparisons of chemical effects on indicator species if intraspecific dietary variation is not investigated (Bearhop *et al.*, 2000). Analysis of stable isotopes of nitrogen and carbon from feathers and other tissues permit the monitoring of trophic status over time or between sampling sites (Furness and Camphuysen, 1997). Not only sampling site variability needs to be accounted for when developing a project design. Feather heavy metal concentrations can show inter and intra clutch variability among nestlings as Janssens *et al.*, 2002 demonstrated with great tits (*Parus major*). These examples highlight the importance of characterizing the local biology of the species so that spatial and temporal changes in the biology of a species across its distribution can be accounted for.

Non-migratory and non-nomadic species are useful biomonitors as tissue concentrations of chemicals are an indication of local environmental contamination. However, this does not preclude the use of migratory species for specific biomonitoring roles. The majority of urban marabou storks in Uganda's capital, Kampala undertake seasonal, mainly north south migrations within Uganda, coinciding with rainfall seasonality (Pomeroy, 1977). Therefore concentrations of chemical residues in adult marabou stork tissues may not be wholly due to local exposure. This problem is partially overcome by sampling nestlings. Marabou storks have a well-defined breeding season and are communal nesters. Multiple nests can occur in a single tree. Marabou storks have an extremely long fledging period, with first flights out of the nest occurring at 110–115 days (Hancock *et al.*, 1992). During this long nestling period, when they are unable to fly, marabou storks are relatively easy to sample. Once the location of a colony is known, multiple nests in a single tree can facilitate rapid sampling of individuals. Nesting trees are often used for many years making estimations of population reproductive parameters easier to assess (Pomeroy, 1978). Marabou storks highlight how a species may be suitable for a specific role as a biomonitor. For the marabou stork this could involve comparisons of nestlings from urban and rural colonies as indicators of contaminant concentrations at these sites. Thoughtful project design in assessing the potential of the study species for the specific biomonitoring role proposed is therefore critical.

The type of tissue used for biomonitoring studies is critical. Feathers are an excellent, non-invasive tissue to sample for chemicals that are largely endogenously derived, such as mercury (Burger, 1993; Hollamby *et al.*, 2004d). Feather mercury concentrations can vary depending on the order the sampled feather has in the sequence of the molt cycle with body contour feathers showing the least variation in mercury content (Furness *et al.* 1986). Bearhop *et al.*, 2000, when examining seabird colonies points out that down feathers can only indicate contamination over the weeks that they are growing whereas blood probably reflects contaminant concentration over the whole breeding season. Another factor when determining appropriate tissue type is what tissue other studies have used so comparisons can be made or evidence of correlation of tissue concentrations for the chemical being studied can be documented. For example, laboratory and field studies have shown that DDE residues in blood plasma are highly correlated with DDE concentration in the brain, the rate of DDE exposure, and the amount of DDE in eggs of free-living birds of prey (Henny and Meeker, 1981). Finally, logistical constraints may affect what tissue type is most suitable for a specific project. Can the tissue be appropriately processed, transported and stored without affecting the analysis? This becomes increasingly important when samples are taken in remote locations or in countries that may have minimal or no in situ capacity to conduct the required analyses.

Establishing the sex of birds sampled can be important as gender specific differences in weight and contaminant excretion routes can lead to sex specific variation in contaminant concentrations Becker *et al*., 2002, found that female Gentoo penguins *Pygoscelis papua*, had lower mercury body feather concentrations than males and attributed this to likely excretion of mercury into eggs. Avian sex in non-ratite species can easily be determined with almost 100% accuracy by DNA analysis of feathers or blood (Griffiths *et al*., 1998).

A chemical's quantifiable endpoint effects must be demonstrated in the species, or a similar species under experimental laboratory conditions. For example, the effects of mercury and many persistent organic pollutants on a variety of avian species have been well documented in field and laboratory settings (Borg *et al*., 1970; Lincer, 1975; Henny and Meeker, 1981; Eisler, 1987; Blus *et al*., 1996). However, the variation in species biology, analytical methods, tissues examined and reporting of results can make comparisons between studies difficult. In addition, knowledge of the chemicals to be examined, their localized usage and their activity and reactions in the environment under study should be documented. This documentation can be difficult in developing countries where records may be absent, minimal, scattered, poorly verifiable or not readily available. Researchers conducting biomonitoring in such countries should, in addition to publishing their findings, endeavor to leave adequate documentation of their results with the appropriate in situ licensing or regulatory authority. An example of the activity and reaction of a chemical being variable in different environments is the higher rates of dissipation of organochlorine compounds in tropical compared to temperate climates (Wiktelius and Edwards, 1997; Hartley and Douthwaite, 1994).

Lack of defined seasonality to breeding cycles of many tropical avian species means a biomonitoring program in these areas ideally needs to have the logistical capacity to sample over extended periods. Any monitoring program needs to establish breeding patterns of the indicator species at the specific study site, rather than relying on data extrapolated from other areas as local and seasonal variations may occur (Sumba, 1986; Brown, 1980). Productivity (the number of chicks per nest) and success (the number of chicks fledged per nest) are reproductive parameters that need to be assessed over a number of seasons to determine the effects of environmentally persistent contaminants on a population (Elliot *et al*., 1998). Therefore, biomonitoring programs with a goal of establishing trends should have the capacity to sample the same region over a number of years.

Physical and logistical constraints can limit the usefulness of a biomonitor species. Marabou storks are difficult to band due to the excretion of urates on their legs that prevents adequate band visualization (Pomeroy, 1975). Adult marabou storks are also highly intelligent and wary, making capture for sampling purposes difficult (Pomeroy and Woodford, 1976). An adequate wild population size is also essential for any biological sampling program and is preferable to sampling of captive populations, which has become necessary for some species, such as the Spanish imperial eagle (*Aquila adalberti*) (Garcia-Montijano *et al*., 2002).

Public and regulatory acceptance of a biomonitoring project is essential for its success. Communicating the objectives, necessity for, and individual animal welfare aspects of the biomonitoring program to the public is integral to achieving this acceptance. This may mean liaising with landowners for permission to sample when nests occur on private property. It may also involve communication with a conservation agency/regulatory authority to help the agency differentiate between the objectives of conservation projects working on a vulnerable or endangered species and a biomonitoring program sampling a relatively abundant species.

Consideration of the characteristics that determine a species suitability as a biomonitor should form an integral part of any project design. Thoughtful assessment of the limitations and advantages of a species as a biomonitor will ultimately improve the soundness of the conclusions that can be drawn from subsequent research involving that species and its environment.

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