BIOMONITORING OF TERRESTRIAL VERTEBRATES IN ATLANTIC COAST ESTUARIES: UTILITY AND VULNERABILITY INDICES

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Abstract

As part of the Biomonitoring of Environmental Status and Trends program of USGS, the threat of contaminants to terrestrial vertebrates residing in or near coastal estuarine ecosystems is being evaluated by data synthesis and field activities. As one objective, the relative utility of various wildlife species for contaminant monitoring in estuaries on the Atlantic Coast is being evaluated. Two sets of indices have been developed to assist decision makers in risk assessment of persistent organic pollutant, cholinesterase-inhibiting pesticide, mercury, lead shot, and petroleum crude oil contamination. The "Utility Index" ranks terrestrial vertebrate species as potential biomonitors of these chemicals based upon a species' exposure potential, geographic occurrence, ease of collection, and history of use in contaminant monitoring. The "Vulnerability Index" evaluates the threat of these contaminants to populations by incorporating exposure potential, individual sensitivity, and population resilience. Though several indices have previously ranked the vulnerability of birds to oil releases, there has been little effort to create comparable tools for other contaminants, nor to address the exposure of other terrestrial vertebrates to these threats. For 25 species commonly found in estuarine habitat that were ranked for the Atlantic Coast, high ranks for vulnerability were not necessarily predictive of utility, and vice versa. For example, gulls and terns tended to have high utility and low vulnerability ranks across chemical classes due to their abundance and life history characteristics, while the bald eagle and brown pelican each scored in the top five of several vulnerability indices and generally ranked low in utility. Fish-eating birds such as cormorants, ospreys, and herons ranked high for utility for both mercury and persistent organic pollutants, suggesting the value in joint monitoring of these contaminants.

Introduction

Terrestrial vertebrates are an important group of species to monitor due to their value to man as trust species for hunting and recreational activities, their role in the ecosystem, and their ability to accumulate large concentrations of pesticides as a result of high trophic position. Recent analyses of terrestrial vertebrate contaminant exposure and effects data on the Atlantic Coast have revealed a lack of temporally and spatially replicated data in this region, and have identified gaps for which future monitoring efforts should be prioritized. The indices presented here have been used to rank twenty-five terrestrial vertebrates commonly found in estuaries on the Atlantic Coast for their vulnerability to contaminants and their utility in monitoring pollution in Atlantic Coast estuaries. These analyses can be utilized in the creation of a wide-scale monitoring program for this region, or indices can be used by resources managers in the creation of local monitoring programs.

Methods

- Two indices were developed as tools to rank terrestrial vertebrate species:
  - The *Utility Index* ranks the suitability of a species as a biomonitor of exposure to a contaminant.
  - The *Vulnerability Index* ranks susceptibility of populations upon exposure.
- Indices were developed for 5 contaminants or contaminant classes:
  - Persistent Organic Pollutants (POPs)
  - Mercury
  - Cholinesterase (ChE)-Inhibiting Pesticides
  - Lead Shot
  - Crude Petroleum Oil
- 25 species (21 birds, 2 mammals, and 2 reptiles) found in or near estuarine habitat were selected to rank based upon documented or suspected contaminant exposure and effects, as valued or protected natural resources, or as representatives of certain taxonomic groups:

❖ American Oystercatcher (AMOY)
❖ Bald Eagle (BAEA)
❖ Black Duck (BLDU)
❖ Black Skimmer (BLSK)
❖ Black-Crowned Night-Heron (BCNH)
❖ Brown Pelican (BRPE)
❖ Clapper Rail (CLRA)
❖ Common Tern (COTE)
❖ Diamondback Terrapin (DBTE)
❖ Double-Crested Cormorant (DCCO)
❖ Great Blue Heron (GBHE)
❖ Greater Scaup (GRSC)
❖ Gull-Billed Tern (GBTE)
❖ Herring Gull (HEGU)
❖ Laughing Gull (LAGU)
❖ Mink (MINK)
❖ Muskrat (MUSK)
❖ Mute Swan (MUSW)
❖ Osprey (OSPR)
❖ Ruddy Duck (RUDU)
❖ Snapping Turtle (SNTU)
❖ Snowy Egret (SNEG)
❖ Tree Swallow (TRSW)
❖ Tricolored Heron (TRHE)
❖ Willet (WILL)

Conclusions

- Rankings presented apply only to terrestrial vertebrates residing in Atlantic Coast estuaries, and only when considering the entire coast as the intended study area. However, the indices are designed to be generic, and thus may be utilized in their present format to rank any species in any habitat.
- In general, high ranks for vulnerability were not necessarily predictive of utility, and vice versa.
- Though birds are overwhelmingly used for terrestrial vertebrates contaminant monitoring, mammals and reptiles consistently ranked among the top species as biomonitors of environmental pollution.
- Inter-species sensitivity is often poorly elucidated, and hinders the assessment of vulnerability. Some species, such as the turtles, ranked high in vulnerability as a precautionary measure due to the paucity of contaminant exposure and effects data available.

Results and Discussion

Sample: MERCURY UTILITY INDEX

A. EXPOSURE POTENTIAL
1. Primary Dietary Preference
10—Fish
8—Terrestrial vertebrates or aquatic invertebrates
6—Both vegetation and animals (aquatic omnivore)
4—Both vegetation and animals (terrestrial omnivore)
1—Vegetation

2. Longevity
5—Long-lived (>15 years)
3—5-15 years
1—Short-lived (<5 years)

3. Use of industrial or urbanized areas, and areas vulnerable to acid precipitation
5—Readily inhabits or forages in these areas
3—Will occasionally utilize these areas
1—Avoids these areas

B. GEOGRAPHIC OCCURRENCE
1. Range
5—Present throughout entire study area
4—Present throughout more than half of study area
3—Present throughout about half of study area
2—Present throughout less than half of study area
1—Present in small part of study area only

2. Residency
5—Year-round resident (does not migrate)
4—Migrates within study area
3—Migrates beyond study area (present breeding season)
2—Migrates beyond study area (present winter season)
1—Present during migration only

C. EASE OF COLLECTION
1.Social structure
5—Highly colonial or gregarious
3—Semi-colonial or semi-gregarious
1—Solitary

2. Accessibility of sampling unit
5—Individuals or nests are easily accessible
3—Individuals or nests are moderately accessible
1—Individuals or nests are difficult to access

3. Ease of capture
5—Low mobility (e.g., nestbound young or eggs available)
3—Moderate mobility (e.g., independently-foraging young)
1—High mobility (e.g., mobile adults available only)

4. Abundance in study area
5—Abundant (Numerous in suitable habitat)
4—Common (Certain to be in suitable habitat)
3—Uncommon (Presence is expected, but not a certainty)
2—Occasional (Presence is possible, but not expected)
1—Rare (Not normally present)

5. Federal or state management status in study area
5—Not protected or managed
4—Protected
3—Threatened
1—Endangered

D. QUANTITY OF EXISTING EXPOSURE AND EFFECTS DATA
5—Substantial data
3—Some data
1—Very little data

Sample: MERCURY VULNERABILITY INDEX

A. EXPOSURE POTENTIAL
Primary Dietary Preference
10—Fish
8—Terrestrial vertebrates or aquatic invertebrates
6—Both aquatic vegetation and animals (aquatic omnivore)
4—Both vegetation and animals (terrestrial omnivore)
1—Vegetation

2. Use of industrial or urbanized areas, and areas vulnerable to acid precipitation
5—Readily inhabits or forages in these areas
3—Will occasionally utilize these areas
1—Avoids these areas

3. Longevity
5—Long-lived (>15 years)
3—5-15 years
1—Short-lived (<5 years)

4. Residency
5—Year-round resident (does not migrate)
4—Migrates within study area
3—Migrates beyond study area (present breeding season)
2—Migrates beyond study area (present winter season)
1—Present during migration only

5. Social structure
5—Highly colonial or gregarious
3—Semi-colonial or semi-gregarious
1—Solitary

6. Range
5—Present in small part of study area only
4—Present throughout less than half of study area
3—Present throughout about half of study area
2—Present throughout more than half of study area
1—Present throughout entire study area

B. SENSITIVITY

1. Molt
5—Does not molt
3—Molts infrequently (interval of complete molt ≥1year)
1—Molts frequently (complete molt > once a year)

C. RESILIENCE OF POPULATION

1. Abundance in study area
5—Rare (Not normally present)
4—Occasional (Presence is possible, but not expected)
3—Uncommon (Presence expected, but not a certainty)
2—Common (Certain to be in suitable habitat)
1—Abundant (Numerous in suitable habitat)

2. Distribution outside of study area
5—endemic to study area
3—present outside of study area, but not abundant
1—abundant outside of study area

3. Reproductive potential
5—Low (1-2 offspring per year)
3—Moderate (3-4 offspring per year)
1—High (>4 offspring per year)

4. Age at first breeding
5—6+ years
4—5 years
3—4 years
2—3 years
1—1-2 years

Mercury Utility Index Score =

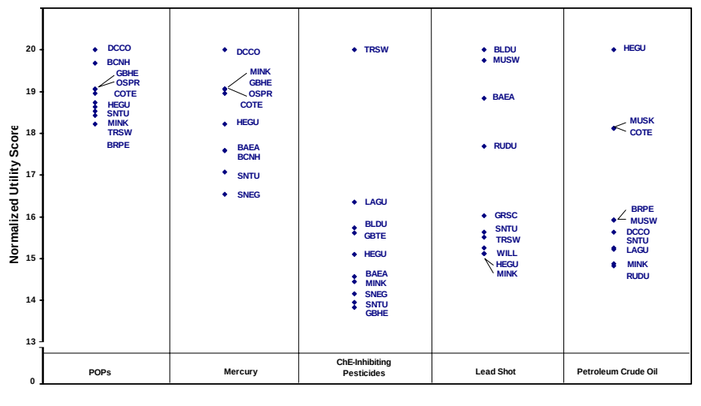
(Exposure Potential) + (Geographic Occurrence) + (Ease of Collection) + (Quantity of Existing Data)

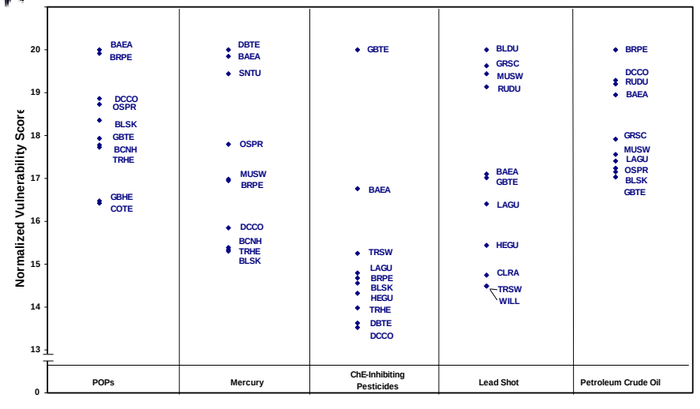
$$\frac{(A1 + A2 + A3)}{4} + \frac{(B1 + B2)}{2} + \frac{(C1 + C2 + C3 + C4 + C5)}{5} + (D)$$

Mercury Vulnerability Index Score =

$$2\,(\text{Exposure Potential}) + (\text{Sensitivity}) + (\text{Resilience of Population})$$

$$\frac{2\,(A1 + A2 + A3 + A4 + A5 + A6)}{7} + (B1) + \frac{(C1 + C2 + C3 + C4)}{4}$$





Relative scores of the 10 highest ranked species for biomonitoring utility and vulnerability to persistent organic pollutants, mercury, cholinesterase-inhibiting pesticides, lead shot, and crude petroleum oil in Atlantic Coast estuaries. Scores were normalized to a maximum of 20, and ties are represented by connecting lines.