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Charismatic or Abundant Species Are Not Always Good Indicators for Monitoring Biodiversity & Ecosystem Changes

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Abstract: Many selected populations from plants and animals have been frequently used as indicators species for monitoring ecological changes and ecosystems dynamics overtime, giving early warning signs for possible deviations in ecosystems, and allowing for measuring performance of management interventions. However, there is recent criticism and discussion among the environmental scientists and mangers about the pitfalls of the approach. This article aims at reviewing limitations & challenges of selecting and using indicator species in monitoring biodiversity & ecosystem changes. Particular objectives are (1) outlining and briefly discussing common challenges and limitations, (2) pointing out ways for overcoming limitations mentioned including list of best signs that must be observed and considered when identifying indicator species for monitoring ecological changes, and finally (3) providing a path for future research work needed in this topic. Literature review showed that criticism and limitations are including subjectivity and vague justifications in selecting single or group of indicators, methodological challenges during data collection, and lack of knowledge about responses of such indicators to future climate change and subsequent impacts on their effectiveness in ecological monitoring schemes. In conclusion, the best indicator species should have among others; known responses to disturbances, quickly indicate changes and cause-and-effects relationships in ecological state variables, has a stable population in space and time, and easily detected and measured. Finally, future work needed in this topic should be directed towards: (1) assessing and increasing the effectiveness of the indicators; (2) understanding the limitations of indicators including their sensitivity to anticipated climatic changes; (3) which taxonomic groups are better for which monitoring purpose; and (4) lastly, finding better quantitative multimetrics indices to assess the efficiency of the indicators.

Keywords: Ecosystem Changes, Ecological Monitoring, Indicator Species, Limitations of Indicators Species

1. Introduction

Recent reports such as [23] have indicated that climatic changes (e.g. flooding or drought events) will continue to increase worldwide, causing more serious ecological changes such as land degradation, biodiversity loss, and spread of invasive species. Spellerberg [45] viewed these ecological changes as changes that occur in the state and trend of the ecosystems (i.e. biotic or abiotic (or both) components) at relatively longer time scales (e.g. years) due to human or natural stressors. Regardless of the reasons for these changes, however, there is global need for environmental conservation planning based on enough amount of information (i.e. data) about variables driving natural ecosystem dynamics. In fact, these ecosystem-state variables are considered best descriptors (indicators) of the ecosystem’s departures from the norms or natural range of variability as vital concept in the management and conservation of natural resources [7, 38, 40].

Nevertheless, ecologists and conservation biologists have long-standing debates and challenges regarding identification and use of the state variables (hereafter ecological indicators) to monitor these ecological changes [3, 11]. For instance, many selected populations from plants and animals have been frequently applied by ecologists as indicators species for monitoring ecological changes and ecosystems dynamics overtime, giving early warning signs for possible deviations in ecosystems, and allowing for measuring performance of management interventions [11, 40, 41, 43]. [1, 2, 3, 41] suggested that the success of the Indicator Species (IS) method relays on the fact that living organisms are best at reflecting changes in their local environment and habitat. These indicators species are evaluated at population levels through presence/absence, relative abundance, reproductive success and survival rates; or it could be community measurements like composition, diversity, and trophic structure, or any combinations [21, 24].

Despite many plants, animals and microbes have been successfully utilized as indicators for monitoring ecological changes [e.g. 5, 12, 15, 25, 34, 43], however, Siddig et al [41] reported that there is recent criticism and discussion among the environmental scientists and mangers about the pitfalls of the approach.

This short review aims at briefly; (1) *outlining and commenting on some of the potential limitations that may hamper the successful use and application of a certain indicator species, and* (2) *pointing out ways for overcoming limitations and some thoughts for future directions including recommendations about the best characteristics and signs of effective indicators species as stated in the literature.*

2. Criticism and Challenges of Selecting and Using Indicator Species

Despite the intuitiveness of the method, still there some issues and limitations around selection and use of indicator species which have not yet been resolved (figure 1).

First, selection of certain indicator species in ecological monitoring process is largely subjective and mostly relay on vague justifications. Lindenmayer and Likens [30] confirmed that the selected indicators are mostly based on: (1) conservation status [48]; (2) socio-economic pressure or even personal desire that always has been skewed towards charismatic species [22]; and (3) species' local fidelity and abundance [10].

Second, as stated in [35, 30], that the approach also experienced lack of relevancy to desired monitoring goals in which the indicator is going to be used. In another word and as indicated in [32, 31], there is a vague and generalized relationship between the indicators and desired environmental contexts (e.g. ecosystem health, environmental quality and ecological risk assessment).

Third, abundant species is not always good indicator. Most monitoring programs have been using indicators species' abundance as the sole criterion to support the conclusions about the ecosystem changes [8, 10, 33]. However, this abundance adopted in the conclusions could be confounded with detectability factors, for example. Another point raised by Lindenmayer and Likens in [30] is weather this abundance really comes out of metapopulation of the indicators species [17, 18, 29] rather than just dominance in couple local sites which assures that there is enough dispersal (perhaps re-colonization) to maintain long-term dynamic of the population, thus permanent indication. For instance, in the literature there are many studies focused on the use of macroinvertbrates communities as indicators of wetlands health, but rarely have provided rigorous justifications to this other than their abundance, for example [10].

Forth, local biological interactions have not been accounted for. As matter of fact that never changes in a single population indicator from plants, mammals, birds, amphibians or invertebrates reflects reliably the whole complexity of the habitat or ecosystem conditions that they live in [31]. Moreover, [36, 44] argued that biological interactions at the community level (e.g. predation/parasitism) could also greatly influence estimates of abundance and distribution of indicators species, in addition to their effects on some behavioral aspects.

Fifth, methodological difficulties related to detectability of the indicators themselves. Cairns and Pratt in [3] reviewed the effects of different aspects those related to sampling operations and sources of errors during the implementations of the monitoring scheme. All these points are actually making a lot of sense when it comes to the example of having logistical difficulties to sample community data at enough area, lack of well identification of some species sampled due to inexperienced investigator, or even occurrence of some outliers and false recordings (i.e. NAs) on the data sheet that all of which can yield significant errors in the data thus erroneous conclusions eventually.

Sixth, the sensitivity to scale makes inferences difficult as issues of scale is a foundation stone in almost all ecological measurements [28]. Of course use of indicators in monitoring ecological changes is affected by the spatiotemporal scale. On the other hand use of indicators taxa is thought to be sensitive to specific populations, ecosystems or landscape characteristics which makes the possibilities of inferences beyond these scales difficult [19, 20, 40]. The illustrative case of this is the argument of [26] who proved the failure of using small mammals as indicators for assessing forest ecosystem health in Washington State, US, in reverse to conclusion that has been made earlier about their success in Ontario, Canada by [39].

Seventh and finally, climate change effects are unclear on indicators and their effectiveness in monitoring such ecological changes [46]. Interestingly, [16] gave general insights about the biology of climate change with special attention to influences on timing of some classical events (i.e. phonology). For example if the indicators are based on measurements of a fecundity of some vernal pools amphibians, we have to think twice on this since several studies [e.g. 14] showed that the effects of hydroperiods on a breeding ponds have already existed due to climate changes [see also 13, 27].

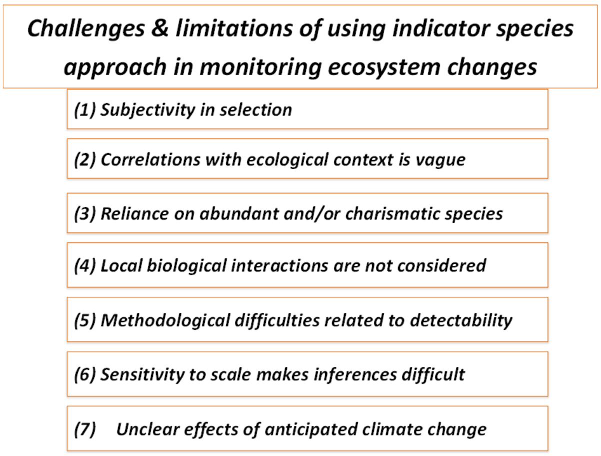

Figure 1. *Limitations and challenges of identifying and using indicator species for monitoring ecological changes.*

3. Conclusions and Future Directions

Application of indicators species as proxy to detect ecosystem changes is vital and needed at this era where so many environmental challenges have been threatening ecosystems. The literature proved that this approach has wide array of applications that can range from biodiversity assessments, habitat management, and agricultural productivity to ecotoxicology investigations. For overcoming limitations mentioned above (figure 1), a multi-criteria must be used in selection and use of indicators.

As presented in [41] characteristics and signs of the effective indicators species that must be observed and considered when identifying indicator species form on it orang ecological changes that should not only have known responses to natural and anthropogenic disturbances and a known range of variability of these responses, but also (1) strongly and immediately reflect cause and effects relationships in ecosystem changes; (2) predict the management interventions and/or alteration; (3) integrate as much as possible the key environmental features (e.g. vegetation type and climate conditions) but also give information about unmeasured variables; (4) have low variability in abundance in space and time and a stable population structure (e.g. sex ratio); (5) be easy to detect and measure in terms of logistics and accessibility; and (6) be socially relevant and of value to local communities. Also look at [37, 3, 4, 7, 47], and [9] for more information on characteristics and signs of the effective indicators species.

Finally, future work needed in this topic should be directed towards: (1) assessing and increasing the effectiveness of the indicators; (2) understanding the limitations of indicators including their sensitivity to anticipated climatic changes; (3) which taxonomic groups are better for which monitoring purpose; and (4) lastly, finding better quantitative multimetrics indices to assess the efficiency of the indicators.

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