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Fish as Ecological Health Indicators of Freshwater Ecosystems

Sajina A. M.[1*], Deepa Sudheesan[1], Lohith Kumar, K.[1] and Sandhya K. M.[2]

[1]ICAR- Central Inland Fisheries Research Institute, Barrackpore, Kolkata, West Bengal (700 120), India

[2]ICAR- Central Institute of Fisheries Technology, Matsyapuri, Kochi, Kerala (682 029), India

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Corresponding Author

Sajina A. M.

e-mail: sajnaali2000@gmail.com

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Abstract

Aquatic ecosystems, especially freshwater resources, face many anthropogenic stressors such as pollution, habitat destruction, flow alterations etc leading to impairment in ecological health of the systems. Conservationists need ecological indicators showing the level of alterations or impairment for decision making in managing these important resources. Fish are widely used as sentinel species to evaluate ecological health and are excellent indicators of overall health of aquatic systems they inhabit. This article focuses on briefing some reliable and useful approaches in assessing the ecosystem health in which fishes are used as indicator organism. Many of those approaches need to be refined for each geographical area and type of water body for use as effective biological monitoring tool.

Introduction

Freshwater ecosystems form hotspots of biodiversity because they contain very huge numbers of species, despite occupying a very small fraction of entire terrestrial surface. Despite they provide extremely important services to human welfare, freshwater ecosystems such as rivers and lakes belong to some of the most intensively human influenced ecosystems on Earth, which is an unfortunate consequence of industrialization, urbanization and general societal activity. Once stressed and degraded, these ecosystems have become incapable of supplying services to the same level as in the past and their capacity to sustain economic activity and human health is, therefore, being reduced. Agricultural runoff, urban wastewater and discharge of untreated sewage form important sources of pollutants and nutrients in the aquatic systems. Despite the present efforts for pollution abatement in freshwater ecosystems, there are many cases of severe accumulation of industrial pollutants in these systems. Assessment of ecosystem health is a prerequisite and integral part of conservation programmes aiming ecosystem restoration. Present article focuses on topics such as concepts of ecosystem/ ecological health, ecological indictors, advantages of fish as ecological indicator, brief account on various approaches of using fish for ecosystem health assessment and some case studies of large scale ecological assessment projects using fishes.

What is Ecosystem Health/ Ecological Health?

Ecosystem health is a terminology used to illustrate the state or condition of an ecosystem. This metaphor encompasses two dimensions- ecological integrity and the human dimension. Earlier times, changing environments were mostly due to natural causes whereas today human

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E-mail: *bioticapublications@gmail.com*

activities dominates over natural causes. This shifting balance of drivers behind changing environment from natural reasons to human activities caused the last century especially the last few decades to witness the evolution of concepts of ecosystem health and ecological indicators. The concept of ecosystem health has infused into the environmental management, the public domain, and also to the current scientific and legislative lexicon.

Ecological Indicator

An ecological indicator is an organism (or a part of an organism or a community of organisms) that contains information on the ecological health of the environment. There are many ecological indicators developed based on structural, functional, and system-level aspects for assessment, diagnosis and prognosis of aquatic ecosystem health. Among the various aquatic ecosystem health indicators, biological indicators holds great implications in comparison to physico-chemical, habitat and flow indicators because biological responses are assumed to integrate the independent and interactive effects of various stressors, which makes them very robust indicators of ecosystem condition. Most commonly used aquatic organisms as biological indicators in freshwater ecosystems include algae, macrophytes, macro-invertebrate and fish.

Advantages of Fish as Indicator of Ecosystem

Fish is one of the most popular indicator organism used in ecological assessments as they reflect watershed conditions. There are many complimentary attributes of fishes making them a powerful tool in assessing aquatic environments that had been explained by many researchers.

• Fishes are sensitive to most forms of human disturbance and they reflect cumulative effects of multiple types of anthropogenic disturbances.

• It is relatively easy to identify fish species due to their much known details as in taxonomy, ecological requirements and life history traits, hence easier, cheaper and more precise assessment.

• Fishes mostly occupy high trophic levels, integrating effects of complex and varied stressors on their prey.

• Fishes, as a group, cover all trophic levels and hence can be used as indicators over wide temporal and spatial ranges.

• Many fish species have high longevity enabling detection of disturbances over a long time frame.

• The sensitivity to disturbances of many fishes and their responses to environmental stressors are well studied and well documented.

• Fishes occupy a variety of habitats and ecological niches and operate over a variety of spatial scales. Many species have very narrow range of habitat requirements and thus reflect predictable responses to anthropogenic changes in habitat.

• Reduced growth and low recruitment of fishes which indicate stress can easily be assessed.

• Fishes are important economic resources which attracts greater public concern. They are of great interest to persons concerned about losses in biological diversity. Hence, with fishes as indicators, it is easy to convey the cause effect relationships to stakeholders beyond the scientific community.

Apart from these advantages, some authors have pointed out some disadvantages too in using fishes in ecological assessments, which include:

• **Manpower requirement:** A large crew is required to arrange proper sampling of fish communities.

• **Migratory nature:** The movement of migratory fishes may provide misleading data.

• **Sampling bias:** All sampling methods for fishes (electro fishing, seining *etc*.) have associated biases.

Approaches of using Fish as Indicators of Ecosystem Health

Most common approaches of using fish as ecological indicator for assessing the ecosystem health are broadly classified into six categories, *viz.,* (i) Indicator taxa/guilds, (ii) Health assessment index, (iii) Fluctuating asymmetry, (iv) indices of diversity, richness and/or evenness, (v) multivariate methods, and (vi) the Index of Biotic integrity-IBI.

1. Indicator Taxa/ Guilds

The basic concept behind use of indicator taxa is that certain taxa become abundant in degraded waters owing to their tolerance and certain taxa disappear from degraded system as they are intolerant. This approach is most useful especially when only presence-absence data is available. The challenging and subjective part of the approach lies in selecting indicator taxa or categorizing taxa as tolerant and intolerant. Based on the type of association with environmental degradation or anthropogenic stress, the indicator species could be positive or negative. If a species is found to be considerably more frequent in a comparatively undisturbed area, it could be considered as a 'positive' indicator of ecological integrity whereas if it is found to be notably more frequent in a more disturbed area, it could be considered as a 'negative' indicator of ecological integrity. In practice, investigators generally select indicator taxa or guilds empirically on the basis of their declining or increasing abundance or distribution with environmental degradation rather than on the basis of experimental tests of sensitivity to specific stressors.

2. Health Assessment Index

Among organismic and necropsy/ autopsy based approaches, Health Assessment Index (HAI) is one of the most popular quantitative methods. It is a quantitative index developed by Adam *et al*. (1993). HAI is an extension of the preceding field necropsy system and Adam *et al*. (1993) refined it to HAI through assigning numerical values to index variables based on the degree of severity or damage incurred by an organ or tissue from environmental stressors. The higher the HAI score for an individual fish or a population being appraised, the poorer the health profile of the fish or the population in that particular aquatic system. HAI has been proven to be a simple and inexpensive means of rapidly assessing general fish health in field conditions as it permits statistical comparisons to be made among data sets. The index takes account of post mortem, blood and parasite data and has been broadly used to assess the general health status of fish populations in a wide range of aquatic system, especially reservoirs and rivers. HAI, though introduced as a quantitative health assessment method for rapid evaluation of fish condition in the field, it has proven its efficacy as long-term biological monitoring tool in many aquatic systems.

3. Fluctuating Asymmetry

Fluctuating asymmetry is a particular form of biological asymmetry, characterized by small random deviations from perfect symmetry. The concept that environmental and genetic stress may increase the levels of fluctuating asymmetry in individuals and populations makes fluctuating asymmetry a prospective tool for biomonitoring efforts and conservation biology. The inability of an organism to withstand random perturbations during its development has been proposed as a potential early indicator of stress. The fundamental basis for the study of fluctuating asymmetry is that symmetry is the ideal state of bilaterally paired traits. Interest in fluctuating asymmetry originated because of its potential for measuring population-level stress.

Fluctuating asymmetry has been extensively applied as a bioindicator and it is a quantitative biomarker for detecting individual and population stress caused by physicochemical contaminants during the developmental process as well as natural disturbances that can lower the number of population of distinct fish. In the case of a polluted ecosystem, fishes were observed to have high fluctuating asymmetry that lives in stressful environments considering they have to compensate stress by requiring energy.

4. Indices of Diversity, Richness and/or Evenness

Environmental degradation, in general, changes diverse communities consisting of many species with relatively equal abundance to simple assemblages dominated by a few species. Though very old concept, concept of species richness remains to be the most commonly used approach of measuring ecological communities. The three attributes of communities, species richness, diversity and evenness, have been widely used to analyze community structure and environmental degradation of aquatic ecosystems. Results of laboratory and field studies repeatedly show that changes in diversity do not provide reliable indications of changes in the degree of ecosystem impact. Methods have been developed to ameliorate some deficiencies of diversity indices such as species replacement and longitudinal changes in species richness, yet on comparison to other approaches for biological integrity of fish communities, their performance is not at par.

5. Multivariate Methods

The methods under this approach include similarity and dissimilarity indices and other multivariate statistical procedures such as cluster analysis, discriminant analysis, factor analysis, canonical correspondence analysis *etc*. The similarity and dissimilarity indices compare the amount of overlap in species composition or relative abundance and can be used to indicate biological integrity by comparing sample of interest with reference conditions. These analyses are most effective when samples are compared to relatively pristine and highly degraded reference sites. The Jaccard similarity index and Bray Curtis Similarity Index and are widely used for presence-absence data whereas the percentage similarity coefficient is used for quantitative data.

6. Index of Biotic Integrity (IBI)

The IBI is a quantitative biological tool developed by Karr (1981) based on the attributes of stream fish communities with a strong ecological foundation that integrates attributes from several levels of ecosystem organization. The core principle of IBI is to detect divergence from biological integrity, the product of regional evolutionary and biogeographic processes- divergence attributable to human actions. Biotic integrity is defined as “the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region” (Karr and Dudley, 1981).

IBI is a multimetric index and hence with the ability to integrate information from individual, population, community, zoogeographic and ecosystem levels into an ecologically based index of quality of an aquatic ecosystem. A metric or biological attribute is some feature or characteristic of the biotic assemblage that reflects ambient conditions, especially the influence of human actions. Hence selection of suitable metrics is crucial to the development of all MMIs including IBI. IBI is more often applied for integrated ecological health assessment of stream/ river ecosystems. It has been modified and many versions have been developed for regional applications.

Conclusion

Most developed countries have incorporated biological criteria or standards based on fish communities for ecological health assessment of freshwater systems, as European Fish Index have been adopted through legislation of the Water Framework Directive for European aquatic systems. In developing countries like India, there exists very limited bio-monitoring components and it is of paramount importance to identify more useful and reliable approaches to assess aquatic resource conditions of such countries and initiatives are to be taken to implement and incorporate it into their water resource management and protection programmes.

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