Prominent Biological Indicators : Do we have in India?

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Indicators are signs that act as signals to tell us something is changing. Everyday experienced and the simplest indicators are traffic signals with green, yellow and red lights. The biological indicators obviously point out about the presence, condition and numbers of types of living organisms or species at community or ecosystem level. These organisms provide important information about the health of our ecosystems. Studying these indicators as a way of evaluating the health of a body of water is called biological assessment. The parallel to the assessment of human health is obvious. We go to doctor to get diagnosis and hopefully initiate treatment to bring us back to normal or healthy conditions. Doctors will apply several indicators such as pulse, blood pressure sugar in blood & urine etc to assess and diagnose the disease. The assessment of health of ecosystem is similar. We observe that an ecosystem is not healthy and ask what is wrong? And what can be done for bringing it back to normal? To answer these questions ecologists try to diagnose by certain biological, or more precisely, ecological indicators.

Often quoted and the most effective indicator was from a book, *Silent Spring* written by Rachel Carlson way back in 1962 that revealed want of birds' chirping, twittering and singing in North America during spring. It was an indicator of widespread pesticide pollution that killed several insect species; but the unscrupulous eradication of insects by the pollution was sensed cumulatively by the absence of birds. Primarily, biological indicators are species that can be used to assess the diversity of organisms (biodiversity) in the environment (in a particular ecosystem) and monitor the health of an ecosystem. The basic aim of use of bio-indicators is to warn about emerging catastrophes at an early stage. One simple example is the presence of "lichens" which indicates good quality of air in the pristine environment around us, while its absence would point out urban polluted air owing to emission of several obnoxious gases (SO_2, NO_x etc). Similarly, Tubifex worms indicate oxygen-poor and stagnant water unfit to drink while dwindling species of fish and amphibians in our aquatic environment indicates presence of pesticides. Recently, some parts of Karnataka and Kerala in India recorded abnormal fall in population of damsel fly and dragon fly which can be considered as prominent indicators of Endosulphan which is a banned pesticide in Europe and its impact was not investigated in India before it grabbed media attention when a doctor practicing in one of the villages noticed large number of cancerous abnormalities among his patients. These insects were the first creatures wiped out by pesticide use. If an ecologist or nature lover had detected the change, use of the pesticides and cancer among the people could have been averted. These are the simplest or qualitative indicators of change which can be easily understood by the layman and scientifically justifiable. Policy makers also look for such simplistic indicators that have great public appeal and impact.

The indicators should be based on who will be using the information from the indicators. There are generally three possible users, each with different information needs. They are: 1) technical experts and science advisors, 2) policy-makers, decision makers and resource managers, and 3) general public and media. The technical experts and scientists will be interested in detailed and complex indicators which should have scientific validity, sensitivity, responsiveness and have data available on past conditions. The policy-makers and resource managers will be concerned with indicators that are directly related to evaluating policies and objectives. They require their indicators to be sensitive, responsive and cost-effective and have meaning for public awareness. Finally, the general public responds to indicators that have clear and simple messages and are meaningful to them.

Bio-indicators are any biological species or group of species whose function, population, or status can reveal what degree of ecosystem integrity is present. They include species, biological communities and processes which are used to assess the quality of the environment and how it changes over time. Changes in the environment are often attributed to anthropogenic disturbances (*e.g.,* pollution, land use changes, habitat degradation) or natural stressors (e.g., global warming, drought, cold, cyclone etc), although anthropogenic stressors form the primary focus of bio-indicator research.

Macro-invertebrates are useful and convenient indicators of the ecological health of a water body or river. They are almost always present, and are easy to sample and identify. The sensitivity of the range of macro-invertebrates found will enable an objective judgement of the ecological condition to be made. In Australia, the SIGNAL method has been developed and is used by researchers and community *Waterwatch* groups to monitor water health. In the United States, the Environmental Protection Agency (EPA) has published *Rapid Bioassessment Protocols,* based on macro-invertebrates, as well as periphyton and fish. These protocols are used by many federal, state and local government agencies to design bio-surveys for assessment of water quality. The species identification procedures are conducted in the field without the use of specialized equipment and the techniques. In South Africa, the Southern African Scoring System (SASS) method was developed as a rapid bio-assessment technique, based on benthic macro-invertebrates and used for the assessment of water quality in Southern African rivers.

The widespread development and application of biological indicators has occurred primarily since the 1960s. Over the years, range of biological indicators has expanded to assist us in studying all types of environments using every major taxonomic group. The idea to apply an assessment of ecosystem health in environmental management emerged in the late 1980s. Therefore, these are more commonly called ecological health indicators. The advanced scientific indicators are not only qualitative but also quantitative which point out the degree of disturbance and damage to the ecosystem. They are expressed numerically as indices of integrity, stability, resilience, diversity and complexity of components of an ecosystem.

However, at this juncture it is better to distinguish between indicator species and the '*bio-accumulative indicator species*' used in pollution/toxicological studies. The bio-accumulative indicator species whose appearance and dominance is associated with deteriorating environment have high tolerance as compared to less resistant species. To understand degree of organic pollution Bellan (1967) used polychaete based index while Bellan and Santini (1981) used amphipod based index. Roberts *et al*. (1998) have proposed an index based on macrofauna species that accounts for ratio of species abundance in control and stressed areas. More recently, AMBI index uses species classification as tool for detecting pollution (Borja *et al*., 2000). This index has been considered useful for application in European Water Framework in coastal and estuarine ecosystems.

In marine and coastal ecosystem, vegetation of green algae *Ulva, Enteromorpha, Cladophora, Chaetomorpha* and red algae *Gracilaria*, *Porphyra* and *Corallina* is considered indicator of pollution while *Fucus* and *Laminaria* belonging to Pheophyta as well as all submerged marine Spermatophytae which are sensitive to any kind of pollution are indicators of good quality water. Most of the ecosystems are complex with multiple component species. Using a single or isolated species as indicator for a complex system is dangerous therefore, attributes of many species of the ecosystem are taken together to have a single indicator. This is a reductionist approach in which a single indicator is set which can be used easily understood for management of a resource in an ecosystem. In marine fisheries earlier indicators were based on the fish assessments of single species stocks and no consideration was given to the ecosystem for judging the impacts. It is increasingly realized now that changes in ecosystem could be due to ecological as well as exploitation parameters on in combination of both. In this situation a single indicator of fishery in balance (FIB) has been computed by taking in to consideration different ecological groups of exploited marine fishes and their mean trophic levels.

The ecological indicators applied today can be classified on eight levels from reductionist to holistic indicators (Jorgensen *et al*., 2010).

Level 1 covers presence or absence of specific species as shown by damsel fly and dragon fly in Karnataka and Kerala. The best known type of indicator is the 'Saprobien system' (Hynes, 1971) which classifies streams based on degree of pollution as shown by the presence of different species as indicators species.

Level 2 uses ratios between classes of organisms.

Level 3 is based on concentration of chemical compounds e.g. in eutrophication, PCB and heavy metal contamination.

Level 4 applies concentration of entire tropic level as indicators e.g. high concentration phytoplankton as indicator of eutrophication of lakes. Similarly, high fish biomass or good number of bird species are indicators of good water quality and healthy forest respectively.

Level 5 uses rates as indicators; for instance, primary production ($g/m^2/d$) determination is used as an indicator for eutrophication. Similarly, annual growth of trees is used as indicator of healthy forest and conversely high mortality in a population can be used as an indicator of unhealthy environment.

Level 6 covers composite indicators such as ratios of respiration/biomass, respiration/production, production/biomass and primary producers/consumers. However, these ratios are also used to indicate whether an ecosystem is in early stages of development or in a mature state.

Level 7 encompasses holistic indicators such as resistance, resilience, buffer capacity, biodiversity, connectivity of the ecological network and turnover of carbon, nitrogen etc. It is known that high resistance, high resilience, high buffer capacity, high biodiversity and high connectivity of the networks are indicators of a healthy ecosystem.

Level 8 indicators are thermodynamic variables which may be called as super holistic indicators. Such indicators are exergy, emergy, entropy production and mass and/or energy retention time. Ecological benefits (services & utilities) belong to this level.

Many policy and management bodies with an interest in aquatic or marine systems have endorsed indicator-based approaches to management (FAO, 2002; World Bank, 2002). In all cases, the agencies note that ecosystems are so complex and unpredictable that suites of indicators are needed to give an adequate picture of their state. In fact, it is often noted that suites of indicators are needed for each dimension of sustainability: ecological, social, economic, and institutional (Charles, 2001; FAO, 2003). Indicators now have a prominent and legitimate role in monitoring, assessing, and understanding ecosystem status, impacts of human activities, and effectiveness of management measures in achieving objectives, and they have a growing role in rule-based decision-making. Recently work on the state of global biodiversity (Butchart *et al*., 2010) compiled 31 indicators to substantiate biodiversity loss at 3 levels namely state, pressure and response. Most indicators of the state of biodiversity covering species, population trends, extinction risks, habitat extent and community composition showed decline whereas those of pressure such as resource consumption, invasive alien species, overexploitation and climate change showed increase.

This symposium will open vistas to set indicators at species, community and ecosystem levels at local, state and national levels so that policy makers will be sensitized to save our environment and biodiversity.