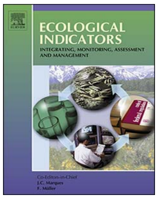
Ecological Indicators 80 (2017) 163–173

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind



Original Article

Indicators and assessment of ecosystem health of Bakreswar reservoir, India: An approach through network analysis

Arnab Banerjee[a], Moitreyee Chakrabarty[b], Nabyendu Rakshit[a], Joyita Mukherjee[a], Santanu Ray[a,*]

[a] Ecological Modelling Laboratory, Department of Zoology, Visva-Bharati University, Santiniketan, 731235, West Bengal, India
[b] Department of Conservation Biology, Durgapur Government College, Jawahar Lal Nehru Road, Amarabati Colony, Durgapur, West Bengal, 713214, India

ARTICLE INFO

Keywords:
Food web
Ecopath with ecosim
Ecosystem indices
Robustness
Exergy
Aquatic ecosystem
West Bengal

ABSTRACT

Artificial water bodies like reservoirs are unique in sense that they encompass hybrid characters of both lakes and streams. Detailed study of reservoir ecosystem is necessary in order to understand and evaluate the health of such systems. A universal characteristic of any ecosystem is its ability to counter stress conditions and this ability is termed robustness which signifies the systems sustainability. Exergy or eco-exergy, measuring the amount of stored workable energy in the system is another important descriptor of an ecosystem. Both robustness and eco-exergy are good indicators of ecosystem health and also they are dependent on the magnitude and type of the inflicted stress. Robustness of Bakreswar reservoir system has been studied here following hypothetical perturbation scenarios that represent possible real situations of eutrophication (nutrient loading) and over-fishing. Quite a few descriptive ecosystem indices have also been considered for the current study including Total System Throughflow (*TST*), Finn Cycling Index (*FCI*), Redundancy (*R*), Ascendancy (*A*), Developmental capacity (*C*), Total Primary Production to Total Respiration ratio (*TPP/TR*), Total Primary Production to Total Biomass Ratio (*TPP/TB*), detritivory to herbivory ratio and also the Exergy of the system. It is concluded from this study that the Bakreswar reservoir is a moderately stable ecosystem with fair maturity level and is able to withstand stress for a reasonable extent. The network indices revealed that variation in robustness of the system is related more with fish biomass perturbation scenario rather than that for the autotroph biomass perturbations. This is confirmed by the network indices as well as the change in the system exergy values which shows more variation in the fish biomass scenario.

1. Introduction

Quantification of ecosystem health does not follow any direct methods, though the concept has been realized by researchers since long back from the 1940s. From the propositions of various scientists it can be summarized that any system that has a good organization and autonomy, may continue to persist even after undergoing stress conditions (Costanza, 1998, 1992; Costanza and Mageau, 1999) and these systems can be identified as healthy and sustainable (Haskell et al., 1992; Sampson et al., 1994; Woodley et al., 1993). Direct and indirect anthropogenic impacts like overfishing, deforestation, habitat expansion (Chapin et al., 2000; Karr and Chu, 1998; Myers and Knoll, 2001) and also natural causes including common problems like organic pollution, eutrophication, increased rates of nitrate contamination, acidification of water body, increased salinization, increased turbidity etc. (Straškraba and Tundisi, 1999), any ecosystem can at any point of time face stress which may affect the system organization and functioning.

In order to find reliable indicators of the ecosystem health many ecosystem indices gives acceptable results. These indices are applicable following construction of food-web models for the concerned ecosystems that represent trophic structure based on a ‘who eats whom’ relationship. The component species are represented as *nodes* in the network and the corresponding flow of matter and energy between them are represented as *arcs*. Construction of such network considerable reduces the difficulties related to unavailability or scarcity of information (data) (Allen, 1971; Christensen and Pauly, 1993; Likens, 1985). Of the various ecosystem indices that are available (Ulanowicz, 1986) system Robustness and the system Exergy values are considered more descriptive as compared to others when assessing the system health.

Recovery of a system from its perturbed state is in relation to the robustness of the same. Either 1) the system can endure perturbations and may continue functioning in its previous stature (Holling and

---

* Corresponding author at: Ecological Modelling Laboratory, Department of Zoology, Visva-Bharati, Santiniketan, 731235, India.
E-mail addresses: arnab.banerjee@visva-bharati.ac.in (A. Banerjee), miotreyeebanerjee@gmail.com (M. Chakrabarty), nabyendurakshit@gmail.com (N. Rakshit), joyitamukherjee07@gmail.com (J. Mukherjee), sray@visva-bharati.ac.in, santanu_5@yahoo.com (S. Ray).

http://dx.doi.org/10.1016/j.ecolind.2017.05.021
Received 6 April 2017; Received in revised form 4 May 2017; Accepted 7 May 2017
Available online 15 May 2017
1470-160X/ © 2017 Elsevier Ltd. All rights reserved.

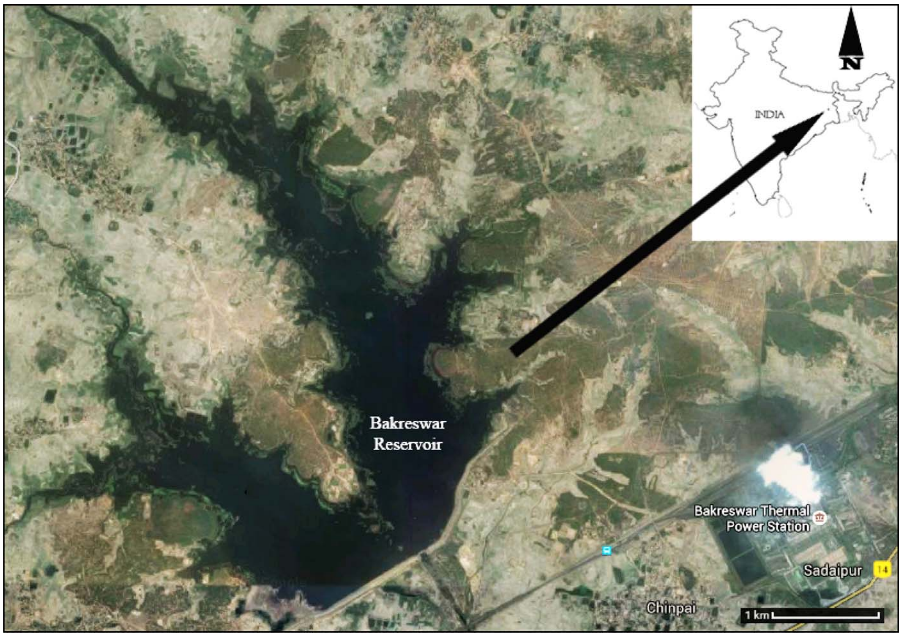


Fig. 1. Satellite map of Bakreswar reservoir (source: Google maps).

Gunderson, 2002) or 2) they can sustain some components despite the unfavourable conditions (Carlson and Doyle, 2002) or 3) they might even come back from their perturbed state (provided that the change is not up to the mark of 'irreversible') owing to their flexibility i.e. they can resist the change due to their resilience (Levin and Lubchenco, 2008). It can be stated that the resilience of a system varies with its robustness and the more is the robustness of a system, more is the capability of the same to recover from stress (Fath, 2015; Kharrazi et al., 2013). According to Ulanowicz (1986), the robustness of any system can be quantified from the above aspects combining the principles of both information theory and network analysis. Network analysis allows the examination of food webs (Ulanowicz, 2009a) and any perturbation in the system occurring during stress can be reflected in that (Costanza and Mageau, 1999; Ulanowicz, 1997).

An important aspect of any ecosystem is the amount of workable energy that is stored in the system – in the various living components of it. This strength – termed as Exergy (also eco-exergy) (Jørgensen, 1981; Jørgensen and Mejer, 1979) is a concept having its base in thermodynamics and assumes that the maximum possible value is feasible when the system shows maximum distance from thermodynamic equilibrium (Jeppesen et al., 1997; Jørgensen, 2007, 1999, 1992a,b, 1982; Jørgensen et al., 2005). Exergy is one of the most important goal function of an ecosystem reflecting the total energy of the constituent components that ensures the continuous operation of the same (Zhang et al., 2003) and thus can be considered a good indicator of the systems' status. Exergy varies among the different organisms following their genetic complexity and more complex organisms tend to have more exergy in comparison to simpler forms.

It is evident from previous studies (Goerner et al., 2009) that as the efficiency of the ecosystem increases, its ability to recover from stress decreases due to increase in specialization of the flows of matter and energy between the constituent components. Conversely, more redundancy of the system hinders it from functioning optimally (Kharrazi et al., 2013; Ulanowicz, 2009a,b, 1986; Ulanowicz and Kay, 1991). A balance between the efficiency and resilience allows a system to function optimally (Ulanowicz et al., 2009) with resilience playing a greater role in the stability of the system (Goerner et al., 2009). As shown previously by various authors (Goerner et al., 2009; Ulanowicz et al., 2009), optimal functioning of an ecosystem lies within a 'window of vitality'; a zone where a system is most potent. Thus it becomes necessary to study the ecosystems from this point of view to ascertain their functioning and estimating their robustness; or in other words to check if the system is 'healthy' (Costanza and Mageau, 1999; Fath, 2015).

Artificially created reservoir ecosystems are no exception from these situations. The ever increasing need of freshwater supplies and the constant uprising of industries feed the necessity of building these artificial water bodies by impounding running water of rivers (Kennedy, 1999; Straškraba and Tundisi, 1999). Bakreswar reservoir is a system that serves most of the purposes of any other similar ecosystems including supply of fresh water to the Bakreswar Thermal power plant and also to the adjacent villages, providing some means of economic support via fishing. Previous studies on the Bakreswar reservoir food web (Banerjee et al., 2016) indicates that it is a moderately mature ecosystem but is vulnerable to anthropogenic activities like pollution, eutrophication, overfishing and other similar activities. Overexploitation of commercially important fishes may deplete the system and may cause shifting of system functionality beyond the point of recovery (Kennish, 2002). Similarly, eutrophication is also another major concern which may be caused due to nutrient loading (Micheli, 1999). These conditions can come into play due to anthropogenic activities (Straškraba and Tundisi, 1999) and may lead to series of related events on the whole system (Sala et al., 1998).

The current study aims at assessing ecosystem health of the Bakreswar reservoir food web. Various ecological network analysis indices (for example total system throughflow, Finn cycling index, ascendancy, etc.) along with the robustness and system exergy values for this reservoir are used as ecological indicators to identify the responses of the reservoir relating to hypothetical conditions of stress following eutrophication and overfishing and also possible stocking related to fishery. The objective of the study is to find out how much is the ecosystem capable of maintaining its structure following perturbation i.e. how healthy is the Bakreswar reservoir ecosystem?

2. Material and methods

2.1. Study site

The current study is carried out at the Bakreswar Reservoir (Fig. 1) situated in the district of Birbhum (lat. 23° 50.519′ N; long. 87° 24.612′ E) which was built in 1999 by the dam raised on Bakreswar River (BKTPS, 2012). Located about 3 kilometres from the Bakreswar

Download English Version:

https://daneshyari.com/en/article/5741378

Download Persian Version:

https://daneshyari.com/article/5741378

Daneshyari.com