Analyzing the Behavior of Benthic Fish Foraging in Shallow Lake as an Indicator of Ecosystem Health

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The main goal of this study is to look at how a fish that lives on the bottom eats in shallow lakes to see how healthy the ecosystem is. In this study, we argue that the way benthic fish hunt for food could be used to figure out how healthy shallow lake ecosystems are right now. In shallow lakes, the water may change from clear to cloudy, with sediment resuspension caused by benthivores eating benthic invertebrates. The giving-up-density (GUD) of benthic fish foraging in experimental patches may affect shallow lake ecosystems. GUD predicted bream's maximum height, indicating that short-term behaviour predicted long-term growth. Benthic fish differed across adjacent rich and poor patched but not between micropatches inside the same feeding patch. Benthic fish forage between our patch dimension and the tiny patch scale.Even though they are just a first step, the methods presented here should help estimate the likelihood of environmental state transitions and find the right steps to take to stop them.

Keywords: shallow lake, Environmental variables, Benthic environment, Feeding strategy, benthivorous fish, foraging behaviour, patch use behaviour

1. INTRODUCTION

Foraging is one of the most important things animals do to stay healthy. Conventional theory says that the best way to find food is to maximise the rate of energy gain over time(MacArthur)(Pyke, 1984)(Stephens, 1986). Many models are based on the idea that animals can make the best decisions about food because they know everything about their environment. The marginal value theory(Charnov, 1976)says that animals should leave patches at the same rate they stop harvesting. This means that animals know their reinforcing the fact intake rate and can judge the quality of their current patch right away. This last idea isn't true, especially for hunters who look in different places for hidden prey. Instead, animals may use basic methods, such as spending the same amount of time on each patch of food, no matter how much food is there, or judging the patch's quality based on samples of food found there.

Underwater acoustic systems, like single-beam, dual-beam, split-beam, and multi-beam echo sounders, as well as acoustic cameras are often used to keep an eye on fish and other objects in saltwater and freshwater surroundings(Moursund, 2003)(Graham, 2004)(Simmonds, 2005 (Holmes, 2006 (Stanton, 2012) (Rudstam, 2012). In recent years, improvements in acoustic technology, deployment methods, and analysis software have made this survey method more effective(Koslow, 2009) (Godo, 2014)(Martignac, 2015). These systems can be used in either mobile study mode or fixed survey mode, depending on how they are set up. A common way to figure out how many fish are in mid-water is to use mobile survey systems with a transducer on the hull that points down. A big benefit of this survey method is that it can take samples from a lot of places quickly and often. Systems that operate in a stationary survey mode and use fixed-

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location and side-looking sonar techniques can collect information with time scales of seconds or sub-seconds to find, count, track, and identify demersal and benthic fish. Because DIDSON had a wider field of view than other sonars, a high spatial resolution, and a high frame carrier frequency (Belcher, 2001)(Martignac, 2015), it was used in a lot of different studies, especially for estimating and sizing the number of anadromous fish (Boswell, 2008) (Burwen,2010) and watching how fish behaved around fixed (Han, 2009) (Makabe, 2012). Concerning the performance of the acoustic equipment mentioned above, it is important to remember that observations with fine temporal scales (i.e., stationary survey mode) tend to cover a small area, while observations that cover a large area (i.e., mobile survey mode) tend to have coarse or limited temporal scales. Existing acoustic systems can't get around the limitations of underwater communication observations in terms of time-space media attention and resolution for ecological application areas (Godo, 2014).

For ecosystems to work well, we need to be able to accurately identify important drivers and use reliable methods to measure and predict how these drivers will affect the system. Most of the time, people think that natural systems would acclimatise to a gradual change in the environment by slowly changing their state. Small changes in drivers, on the other hand, can sometimes cause abrupt changes between ecology states (Scheffer, 2001). Regime shifts have been seen in both land and water systems, and they can be caused by both external and internal factors, such as climate and trophic interactions (Schmitz, 2006) (Persson, 2007). In a recent paper, Carpenter et al. (2008) gave a number of leading indicators that can be used to predict regime shifts in systems with complicated trophic interactions. Carpenter et al. (2008) used conventional variation, return rates, and variance spectroscopy in phytoplankton abundance to test the utility of regime shift metrics in the context of top predator-induced regime transitions. All of these indicators, though, require frequent sample size and a focus on the response variable at the base of the food web, which is a few trophic levels below the driver. One way to do this would be to make indicators that require less sampling and focus on the driver.

When people and/or their resources can't be seen or measured, behavioural indicators can be used to figure out the state and size of a population. This idea is based on the idea that behavioral genetics is flexible and adaptable and that animals respond in a predictable way to changes in their surroundings like in optimality theory.

By putting together animal behaviour observations and a theoretical foundation, it is possible to figure out how an animal values things like risk and the availability of resources. In this study, we argue that ecosystem health and resilience can be measured using both population monitoring and behavioural indicators. If the way a community works depends on what decisions the members of a single keystone species make, then watching the behaviour and attitude of representatives of that species should give you an idea of how the community is doing and how it works.

We show this with an example from shallow lakes, where the number of certain key players determines the ecosystem's state and how likely it is to change states. Shallow lakes are one of the best examples of ecosystems with different states. They can be clear and dominated by submerged plants, or cloudy and dominated by phytoplankton (Scheffer and van Nes, 2007). Because each state may be stable and kept that way by different feedback processes, it is hard to make changes from one state to another (Scheffer, 2001). So, it is especially important to stop unwanted changes, because biological values could be lost forever, and it would be expensive to bring them back. We argue that keeping an eye on the actions of key players, in this case,

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benthic-feeding fish in shallow lakes, can give first-hand information about the state of an ecosystem. This could then be used to help slow changes in system state and stop bad regime shifts.

1.1 The behavior of benthivorous fishforaging

It is well known that man-made macroinvertebrates habitats help fishing resources and the management of coastal fisheries. There have been a lot of artificial reef projects in more than 50 countries, mostly in Japan, France, the U.S., and Spain (Lindberg and Seaman, 2011). In 1973, Taiwan's government started a long-term plan to build and use artificial islands to increase fishing resources and commercial fishing. Over 220,000 different types of artificial reefs have been put in place at 88 locations over the past almost 40 years (Fishery Administration, Taiwan, 2017). Underwater acoustic devices like side-scan sonar were used to study these artificial reef sites in a systematic way so that an effective administrative and management system could be made (Tian, 2011)(Fishery Administration, Taiwan, 2012).

When there are a lot of food sources on the bottom and the water is clear, benthic fish may use their eyesight to find food on the surface of the silt. As a way to avoid being eaten by predators, many species of benthic macroinvertebrates have developed ways to live in soil particles, such as efficient ways to take in oxygen. So, when there are more fish looking for food, there will be less prey that is easy to see. This will force benthic fish to look for food deeper in the substrate. For some fish, like bream, carp, and gizzard shade, this means filtering through a lot of silt with their gill rakers to get food particles. If food pieces are interred deeper in the sediment, it takes longer for animals to find them (Fig. 3), and more sediment is moved to find each piece of food, which causes more sediment to be stirred up (Zambrano, 2001). When there isn't enough food, there will be a lot of resuspending of particles and a rise in water turbidity.

Several studies show how important fish are as links between habitats on the bottom and in the water(Vadeboncoeur, 2002). To predict where an animal will live, you have to figure out how good each habitat is. But it's hard to measure the availability of resources as seen by foragers. This is especially true in environments with different types of prey, where our measurements of prey density may not be a good indicator of what the fish see as available. Many fish species use both habitats every dayor at different times in their lives (Persson and Bronmark 2002b). Because sediments can either take nutrients away or add them, benthic habitats may have a big effect on the amount of nutrients in a lake.

It is known that fish that feed on the bottom can cause big changes in the trophic state of shallow lakes. By resuspending, large bream affect turbidity and may switch a lake between two stable states. Zambrano (2001) said that these changes would be very bad and would depend a lot on the amount of benthic resources. When benthic fish eat too much of the benthic resource and the number of benthic resources drops, bream must increase their foraging and move it to deeper layers to keep from starving. This makes resuspension much worse and could make shallow lakes go from being clear to being cloudy, which would cause huge losses in ecosystem services and biodiversity. The method used in this study could be used to predict the likelihood of switching, which could then be used to measure the effectiveness of strategies for reducing emissions.

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2. MATERIAL AND METHODS

2.1 Study area

Figure 1: The Kanwar Lake is 16 km from Begusarai, which is the district capital. It is at 25°35' N and 86°10' E in terms of latitude and longitude. It was made by the way the Budhi Gandak River, which flows into the Ganga, wound around. During the monsoon, it joins with other bodies of water to make an area of 7,400 ha, which is bigger than its own area of 2600 ha. In 2009, the Indian Ministry of Environment and Forest put it on a list of lakes of national importance and added it to the National Wetland Conservation Program. The ground is level all over, with an average height of 44 metres above mean sea level. It rains an average of 1100 millimetres per year, mostly during the southwest monsoons from July to September. It's a big part of the lives of people who live nearby. There are more than 41 fish that are good for business (Anon, 2004). Hilsa, Pomphret, Tengra, Salmon, and Catla were caught on a small scale in this lake. In this fishery, people often catch Wallago attu and Rohu (Cirrhinus mrigala). Based on a recent study by Ramakrishna et al. (2002), the lake was split into three main sections for this study. Samples were drawn from the entrance, middle of the lake, and exit blocks (Figure 1).

2.2 Experimental Setup

We took samples of the fish in the lake with NORDIC survey gill nets (Appelberg 2000). From knot to knot, the nets had twelve different mesh sizes that ranged from 5 to 55 mm. Because of variations in lake size and time limits, sample intensities were not the same in all lakes (Table 1). Always judged by how many net nights (CPUE, catch per unit effort). The catch was described by the total catch, the number of benthivores (BPUE, or benthivores per unit effort), the percentage of benthivores, the number of piscivores (PPUE, or piscivores per unit effort), and the percentage of piscivores. We chose the Wallago attu and the Rohu (Cirrhinus mrigala), which are both common in Kanwar Lake, to be fair representation species of the benthic ecosystem. Cirrhinus mrigala and Wallago attu had an average of 2.18 0.29106/mm3 and 2.36 0.36 106/mm3 erythrocytes, respectively.

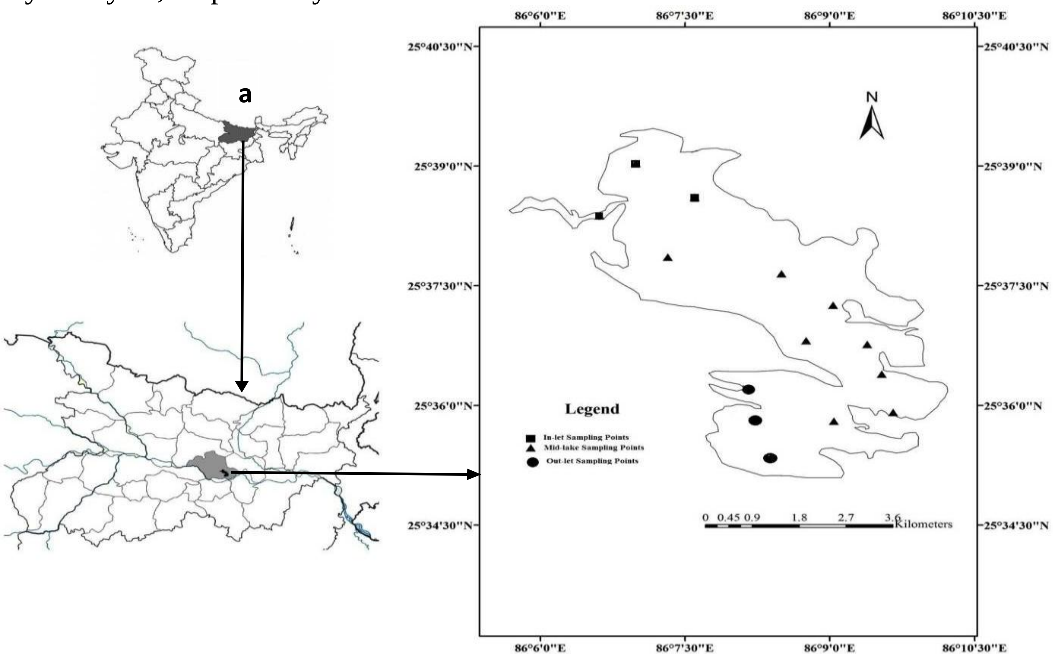

Figure 1: (a) Map of India, (b) Map of Bihar and (c) Study site with sampling locations

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3. DATA ANALYSIS

From the hunters' point of view, GUD showed how good the habitat was, and the amount of food eaten showed how much the patch was used. The normalisation of GUDs as a way to measure the sameness of decommissioning harvest rates is based on the idea that the search within the patch is random (Olsson et al. 2001). But the way the foragers act could change how the resources are spread out in the patch. This could cause the GUD in the rich patch to be higher than in the poor patch, even if the rate of harvesting stops at the same rate in both patches. There may be deviations from a random search if the fish picks up the best and quickest food items first or if stirring by the fish makes it more or less likely that it will find more food. Getting more food from the rich patch is an alternative and reliable way to find out if the search effort was biassed. When more food is started gathering from better food patches than from poorer ones, the forager shows that they can approximate and make adjustments to patch quality.

4. RESULT & DISCUSSION

Figure 2 demonstrates that the primary objective of maintaining shallow lakes should be to maintain an abundance of benthic organisms, notwithstanding the need to monitor the quantity of benthivores. However, it may be difficult to estimate the number of benthos fish in lakes with abundant macrophytes. We'll illustrate this with collected data on the benthos of Lake Kanwar. In a previous section, we discussed how an increase in nutrient loading induced a transition from a clear to a turbid state, and how the system remained in a turbid condition even after the external driver's strength decreased. In the early 1990s, those in charge of the lake tried to clean it up by initiating a trophic cascade that resulted in less phytoplankton through biomanipulation. Over the period of 1.5 years, 80 percent of the lake's bottom-dwelling fish were removed. The summer secchi depth increased from 0.4 m to 1.5 m as the lake became cleaner, as predicted. This indicates that the lake transitioned from being extremely overcast to largely clear (see "shift 2" in Fig. 4). Following biomanipulation, benthic fish consumed more benthos, indicating that this food supply became more prevalent (Persson and Bronmark, 2002).

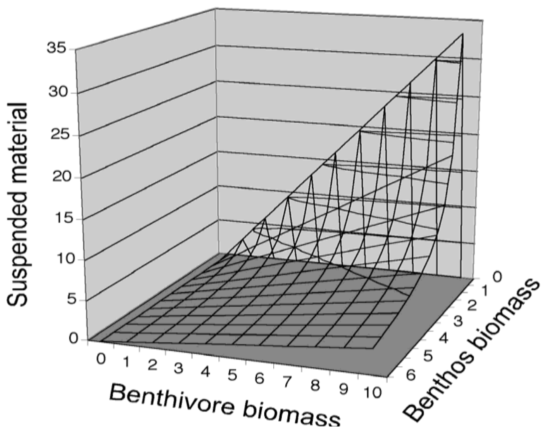

Figure 2 depicts the cumulative effects of benthivore and benthic invertebrate biomass on the quantity of suspended solids in the water, demonstrating a rise in turbidity when benthivore biomass rises or falls.

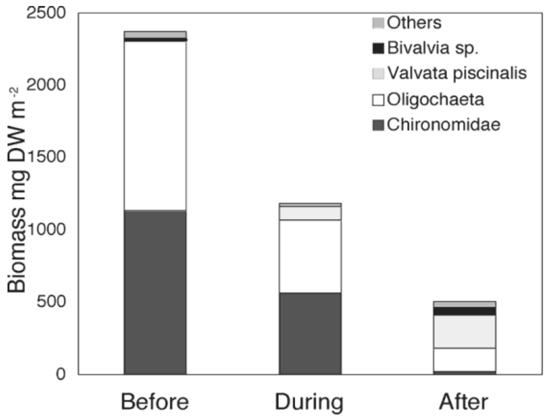

Figure 3 shows the depth-weighted benthos biomass in Lake before, during, and after the mass removal of benthivorous fish. Benthic biomass was decreased even when the benthic predators were eliminated.

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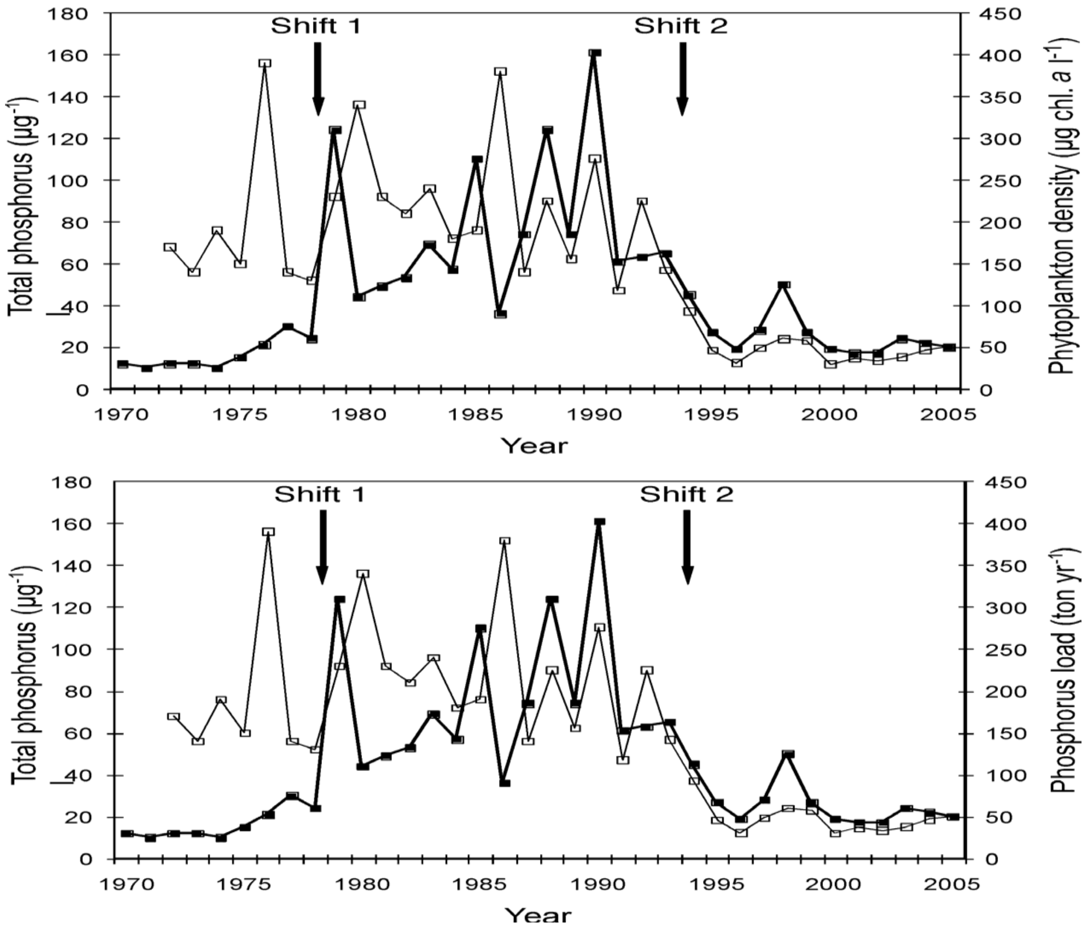

Fig. 4: Changes in the lake's regime.

Benthos samples showed that the total benthos biomass was lower after the biomanipulation (Fig.3). This is likely because sedimentation after phytoplankton blooms no longer fed the growth of benthos in the sediment. Even though the total benthos biomass went down, the number of benthos that eat algae, like mollusks and snails, went up because the clearer water let epiphytic algae move into deeper waters. So, the fact that these types of prey are found in benthos shows that they are not often eaten. This shows that there isn't always a link between plenty and availability.

Table 1 lists behavioural indicators, the data they provide, and the significance of various results. Benthivores leave behind a lot of resources when they leave a patch, and their maximum length is GUD.

Behavioral indicator	**Information**	**Meaning**
GUD	rate of resuspension	A low GUD signifies a higher likelihood of a turbid state.
GUD	ecosystem quality	A low score suggests a greater likelihood of a turbid state.
CurrentGUD/sustainableGUD	departurefromequilibrium	lower current GUD indicates lower stability
GUDrisky/GUDsafe	predator control	A low score indicates greater control and a decreased likelihood of turbid conditions.

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Here, we strongly recommend that observing how herbivores search for food is a superior approach. Several factors may indicate that a system is resistant to change and unlikely to experience regime shifts (Table 1). A large benthos biomass prevents the overexploitation of benthic materials and, ultimately, the re - suspension of sediments. In a cross-system comparison, a high GUD and a large maximum size of benthic predators were both indicative of a healthy habitat (Persson and Stenberg, 2006). Similar findings have been observed in a system. The largest bream in Lake Kanwar, a tiny lake in Bihar that naturally fluctuates from clear to hazy, weighed 1 kilogramme when the water was foggy and 2.4 kilogrammes when the water was clear. In addition, the growth rate of benthic perch increased as foggy conditions cleared. This occurred as a result of more available food sources. These results indicate that hunting behaviour, which is related to size and growth, can be used to detect early environmental changes (Table 1).

Thirdly, the connection between GUD and overall height could assist us determine how environmental changes affect the reliability of a system. In a previous study, Persson and Stenberg (2006) discovered a correlation between the giving up concentration, benthos density, and the overall height of the bream, a typical benthivore. The study demonstrates that the decisions made by benthic fish in the wild reveal both the current environmental quality and their future growth. This is useful information since a change in GUD would indicate a change in environmental quality, which would drive fish to alter their future plans. In Figure 5, the solid line represents a condition in which short-term behavioral decisions and long-term growth possibilities are in equilibrium, whereas the dotted line represents the equilibrium connection in a particular lake. The solid star signifies that the quality of the fish's habitat has improved, allowing the fish to grow larger. However, the open star indicates that the quality of the habitat is deteriorating, which slows the growth of fish. If a significant portion of the population is already larger than the newly estimated maximum size, there is a possibility that the benthic resource is being depleted too rapidly. Thus, a speculative and non-obvious interpretation of "shift 1" in Figure 4 would be to assert that the transition from clear to wet conditions was caused by the fall in productivity, which was caused by the reduction in external phosphorus loading. It is intriguing that expenditures in sewage treatment facilities have led to a significant decrease in phosphorus loading while chlorophyll a concentration has increased.

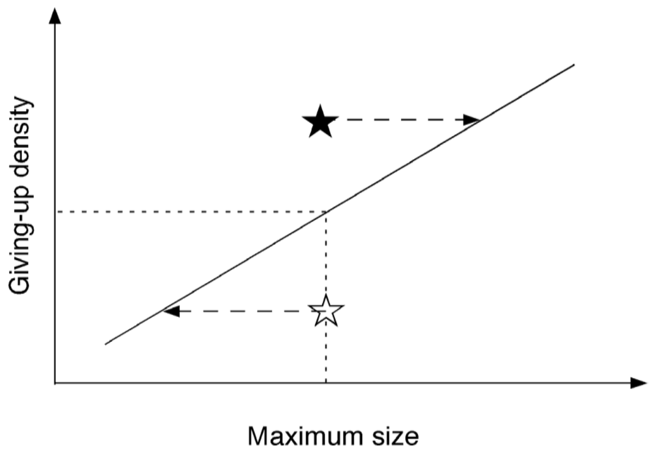

Figure 6 depicts the linear relationship between the maximum size of herbivores and giving-up density (GUD) based on empirical research (Persson and Stenberg, 2006). The straight line thus illustrates the equilibrium relationship between foraging rate and expected growth. Variances

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from the line indicate changes in the system's status that necessitate modifying future predictions. Increased production would suggest a greater GUD (filled star), which would result in improved prospects and a larger maximum size. However, a decreasing GUD would necessitate stricter criteria and a reduced maximum size. There is a risk of overhunting of the benthos resource if a significant proportion of the benthic fish stocks contains individuals that are larger than the size equivalent of the GUD (see Fig. 2).

CONCLUSION

Ecology has placed significant emphasis on ensuring that functions at the individual, community, and community levels are interdependent. Recent research has examined the significance of marine sediments for ecosystem function in lakes.Fish are important because they move around and help connect different habitats.Benthic habitats may also have a big effect on the amount of food in a lake because sediments can both take nutrients away and give them back. The ideas here are a first step toward evaluating the state of a system in a way that takes individual behaviour into account. The suggested set of indicators tells us a lot about the state and stability of a system that shows both gradual and sudden changes. It also makes it easier to predict how likely it is that an ecosystem will change from one state to another and to find ways to stop such changes. Hence, a more thorough analysis would need to find critical threshold levels and turning points. This would require more long-term studies of how behaviour changes in response to changes in the environment both between and within years. Even though it would be hard work, these kinds of studies might give us new information that we don't have much of at the moment, like how a system's susceptibility to changes changes over time.

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