ROLE OF KEYSTONE SPECIES IN AQUATIC ECOSYSTEM

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Introduction

"[Keystone species] importance convinced managers and conservationists alike that the ecological impact of single species matters. That is, in order to manage, understand, and restore ecological assemblages, the roles of individual species have to be understood and considered." – Dr. Robert Pain

A keystone species is a species that has a disproportionately large effect on its environment relative to its abundance. Such species play a critical role in maintaining the structure of an ecological community, affecting many other organisms in an ecosystem and helping to determine the types and numbers of various other species in the community.

The role that a keystone species plays in its ecosystem is analogous to the role of a keystone in an arch. While the keystone is under the least pressure of any of the stones in an arch, the arch still collapses without it. Similarly, an ecosystem may experience a dramatic shift if a keystone species is removed, even though that species was a small part of the ecosystem by measures of biomass or productivity. It has become a very popular concept in conservation biology.

The keystone species concept was coined, in 1969, by the zoologist Robert T. Paine, professor emeritus of the University of Washington, to explain the relationship between *Pisaster ochraceus*, a species of starfish, and *Mytilus californianus*, a species of mussel. In his classic 1966 paper, Dr. Robert Paine described such a system in Makah Bay in Washington State. This led to his 1969 paper where he proposed the keystone species concept. The concept has been very popular in conservation, deployed in a range of contexts and mobilized to engender support for conservation.

Given that there are many historical definitions of the keystone species concept, and without a consensus on its exact definition, a list of examples best illustrates the concept of keystone species.

A classic keystone species is a small predator that prevents a particular herbivorous species from eliminating dominant plant species. Since the prey numbers are low, the keystone predator numbers can be even lower and still be effective. Yet without the predators, the herbivorous prey would explode in numbers, wipe out the dominant plants, and dramatically alter the character of the ecosystem. The exact scenario changes in each example, but the central idea remains that through a chain of interactions, a non-abundant species has an out-sized impact on ecosystem functions.

As was described by Dr. Robert Paine in his classic 1966 paper, some sea stars may prey on sea urchins, mussels, and other shellfish that have no other natural predators. If the sea star is removed from the ecosystem, the mussel population explodes uncontrollably, driving out most other species, while the urchin population annihilates coral reefs.

Similarly, sea otters protect kelp forests from damage by sea urchins. Kelp "roots", called holdfasts, are merely anchors, and not the vast nutrient gathering networks of land plants. Thus the sea urchins only need to eat the roots of the kelp, a tiny fraction of the plant's biomass, to remove it from the ecosystem. These creatures need not be apex predators. Sea stars are prey for sharks, rays, and sea anemones. Sea otters are prey for Orca.

The concept

The term keystone species has enjoyed an enduring popularity in the ecological literature since its introduction by Robert T. Paine in 1969: Paine (1969) was cited in more than 92 publications from 1970 to 1989; an earlier paper (Paine 1966), which introduced the phenomenon of keystone species in intertidal systems but did not use the term, was cited more than 850 times during the same period.

Paine (1966, 1969) noted that experimental removal of some rocky intertidal carnivores (such as the starfish *Pisaster*) led to nearly complete dominance of the substrate by one or two sessile species (mussels), resulting in greatly decreased species diversity. In this and other cases, the importance of the keystone predator derived from two requisites (Paine 1969, Pimm 1980): the predator preferentially ate and controlled the density of a primary consumer, and the consumer was capable of excluding (through competition or predation) other species from the community. Essentially, then, the early connotation was that keystone predators are important because they control the densities of important competitor or predator species. Predators have also been labeled keystone when they control the densities of other types of ecologically significant prey species. For example, sea otters (*Enhydra lutris)* have often been referred to as keystone predators (e.g., Duggins 1980,

Estes and Palmisano 1974) because they limit density of sea urchins (*Strongylocentrotus* spp.), which in turn eat kelp and other fleshy macroalgae that form the basis of a different community than is present in their absence (VanBlaricom and

Estes 1988). Thus, otter removal has community-level influences, by releasing from predation a primary consumer that eats a plant that harbors other organisms.

As used by Paine and other ecologists, there are two hallmarks of keystone species. First, their presence is crucial in maintaining the organization and diversity of their ecological communities. Second, it is implicit that these species are exceptional, relative to the rest of the community, in their importance. Given the assumed importance of keystone species, it is not surprising that biologists have advocated that key or keystone species be special targets in the efforts to maximize biodiversity protection (e.g., Burkey 1989, Frankel and Soule 1981, Soule and Simberloff 1986. Terborgh 1986) and as species in need of priority protection (e.g., Cox *et al.* 1991).

The keystone species play a central and critical role in maintenance of community structure and ecosystem functioning. If an ecosystem can be returned to a state in which the keystone species flourish, then all the other species, which depend on them, will also flourish. The importance of biodiversity in environmental management beside socioeconomic development and well being of human society, has led to the development of various techniques for conservation of ecological diversity. Some simple ways of managing the natural systems should be evolved so as to retain and conserve the identity of a region for a better tomorrow. One of the simplest ways of doing so is by identifying species, which play the key role of holding together the entire biological community or ecosystem. These species are known as 'keystone species' in ecological term.

The central core of keystone concept is that only a few species have uniquely important effect on the community or ecosystem by virtue of their uniquely important traits and attributes. Only those species can be considered as keystone species that had a significant effect on 'time window' of other species. In most of the cases, it is indeed groups of species rather than individual species that assume importance and these species groups could be referred to as the 'keystone groups' or 'functional groups'. Keystone species or 'keystone species groups' play a vital role in maintaining ecosystem and regulating the biodiversity. Loss of vital function, and changes within the ecosystem or community would follow if such species groups are removed from the system. These species are 'responsible' for the existence of an ecosystem of certain type and create possibilities for the development of other types of communities.

Biodiversity within an area can be characterized by measures of species richness, species diversity, taxic diversity, and functional diversity, each highlighting different perspectives. Functional diversity refers to the varieties of functions carried out by different species and groups of species known as functional groups. The population dynamics of keystone species define the pattern of succession of vegetation. Turnover cycles of matter and energy flows in an ecosystem are dominated by the life activity of keystone species, and these activities determine the major shifts in ecosystem structure at the spatial and temporal scales. Population mosaics of keystone species have largest spatial-temporal dimensions, and population mosaics of subordinate species are thereby determined by the keystone species. Keystone species are responsible for the existence of the ecosystem and maintenance of its species diversity. So the biodiversity in any ecosystem can be manipulated by perturbations in such uniquely important species.

A major research challenge for ecologists is to predict which species in the community would become keystone species.

The current level of conceptual understanding of the effects of biodiversity on ecosystem processes is so primitive that at this stage it is possible to recognize the linkages at the level of functional groups only. In any ecosystem there are diverse types of functions performed by different species or species groups. However, no two species or individuals are identical. It may be noted that species diversity within the functional groups or genetic diversity within the species has important ecosystem consequences.

Although certain species have much greater influence than others on an ecosystem structure, not all ecosystems include the same species that exert such pervasive influence on them. In fact most ecosystems are somewhat sensitive to the loss of a few species, though some losses have greater impact on the system than others. Nevertheless, identification of such species, which would function as keystone species in an ecosystem can help in the conservation of that ecosystem. The fact that some species matter more than the others, becomes especially clear in the case of 'keystone species' or 'ecosystem engineers' or 'organisms with high importance value for the community'. These terms may differ in usage, but all refer to those species whose loss or removal results in disproportionately greater impact on the community when compared to the loss of other species. Members of the functional groups maintain and determine the resilience of the ecosystem by spreading a wide range of ecological niches exploited by the component species.

The contribution of individual species toward ecosystem development varies in time and space, and accordingly, not all species are equally important when we look at the community stability and functioning. The community function may be maintained by a species or summed effects of a few species. Some species undoubtedly play more significant role than others in ecosystem function. The varieties of functions that a species can perform are limited and consequently, an increase in species richness also increases functional diversity, producing an increase in ecological stability.

Within a community it is not possible to substitute species for one another, rather there are a good number of combinations of species that can produce similar ecological roles. There is no intrinsically unique level at which biotic diversity affects ecosystem processes. Based upon their ecological roles and the specific ecological niches that they exploit, species can be divided into 'functional groups'. A functional group refers to a group of species, which perform ecologically similar roles in ecosystem processes.

For heuristic purposes, the usages of keystone species is divided into five types. This categorization is not meant to imply mutually exclusive groups or an exhaustive review of the term's application, but rather to show the diversity of keystone effects referred to in the literature

Table 1. Categories of presumed keystones and the effects of their effective removal from a system.

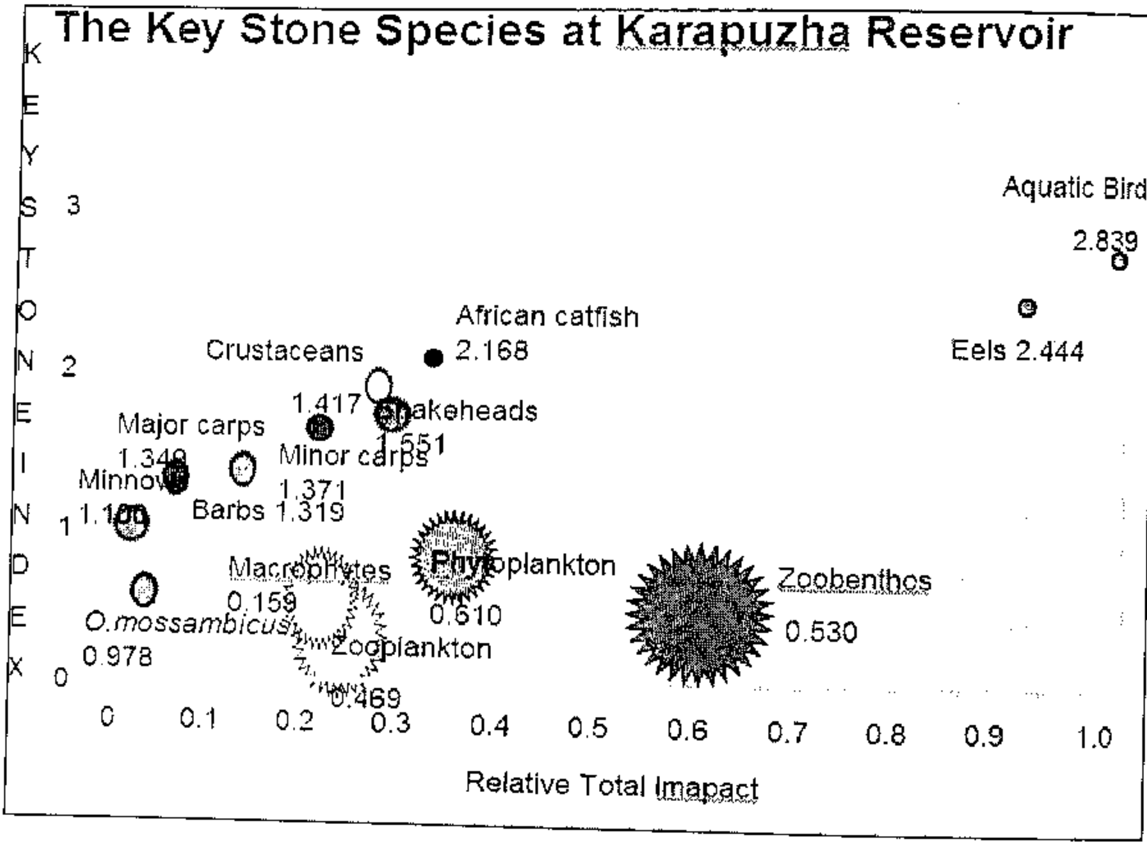
Keystone category	Effect of removal
Predator	Increase in one or several predators/ consumers/competitors, which subsequently extirpates several prey/competitor species
Prey	Other species more sensitive to predation may become extinct; predator populations may crash
Plant	Extirpation of dependent animals, potentially including pollinators and seed dispersers
Link	Failure of reproduction and recruitment in certain plants, with potential subsequent losses
Modifier	Loss of structures/materials that affect habitat type and energy

Determining the Keystone Status of Species

All species are important for the existence of an ecosystem and for the maintenance of its various functions, but as mentioned earlier, all are not equally important. The identification of species and groups of species, which play key role in maintaining the ecosystem stability and resilience by influencing the structure and function of an ecosystem is a stupendous task, and very few attempts have been made in this direction. Since the importance of some species may largely be the consequence of their rich interaction structure, one possible quantitative approach to identify the most influential species is to study their position in the network of interspecific interactions.

We have developed a network structure of the reservoir ecosystem is built using Ecopath with Ecosim software for characterizing the interaction structures of each species. This study was conducted at Karapuzha reservoir, located at Wayanad District of Kerala. In this paper the keystoneness of the functional groups (species or group of species) of food web model of a reservoir ecosystem is examined. The species in this reservoir are assembled into 15 functional groups from Detritus to Aquatic birds. The total system throughput in the reservoir is 30039 t/km2 with a connectance index of 0.277. The system omniovory index is estimated at 0.109. The sum of all detritus flows into detritus is 11268.45 t/km2. The analysis of the mixed trophic impacts presented allows ranking of functional groups by their keystoneness. The keystone index varied from 0.610 for Phytoplankton to 2.839 for aquatic birds. The important result is that keystone species exert their high impact by means of top-down effects, a feature initially suggested being a defining characteristic of keystone species. *Clarias gariepinus* has a very high key stone index at 2.168 which shows how much influence an invasive species has on the food web of this reservoir ecosystem. The study shows that lower biomass species in this reservoir ecosystem are showing very high keystone indices.

Fig. Keystone indices of Karapuzha Reservoir ecosystem.



Conclusion

Management and policy must explicitly consider the complexity of interactions in natural systems Will the extinction of a single species in a community cause the loss of many others? Can we identify a set of species that are so important in determining the ecological functioning of a community that they warrant special conservation efforts? Conserving biodiversity is often a compromise between protecting species, areas, ecosystems or processes .If our goal is to conserve ecosystem structure and maintain a reliable supply of ecosystem services, then identifying and conserving important species will be the only real long-term solution for managing diversity loss, ultimately protecting only the rarest species is only a symptomatic treatment. Paine's tantalizing results should inspire theoreticians to explore the implications of assemblages structured with many weakly interacting species and only a few strong interactors.. The concept has been useful in demonstrating that under certain conditions some species have particularly strong interactions, and we recognize that in recommending the abandonment of a popular and evocative concept there is a danger of making it more .

For further reading.

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