Ecosystem Services as a Pedagogical Perspective for Teaching the Importance of Biodiversity to High School Students

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**Sammanfattning**

Reducing the rate at which biodiversity is presently being lost is one of the challenges for the coming years. Through diverse activities, humankind is currently responsible for the extinction of species worldwide, which has consequences for whole ecosystems. The preservation of biodiversity is not only important for its intrinsic values, but also for its role in maintaining the functioning of ecosystems that provide humans with services that are important for our well-being and safety. As it is a concern for all of humanity there is a demand for education that can develop in students an understanding of the complexity which lies behind the ecosystem services of which they benefit. Including how the disturbance of this complexity will lead to consequences for the whole human world. Current attempts to educate the public has failed to conjure motivation and interest. However, ecological network research create opportunity for understanding the underlying relationships between species, and the use of ecosystem services as a pedagogical perspective offers the possibility to demonstrate the importance of these relationships for ecosystem functioning. In this literature review it is examined how this could benefit environmental education in high school.

**Nyckelord**

Biodiversity, Ecosystem services, Environmental education, Ecological literacy

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Abstract

Reducing the rate at which biodiversity is presently being lost is one of the challenges for the coming years. Through diverse activities, humankind is currently responsible for the extinction of species worldwide, which has consequences for whole ecosystems. The preservation of biodiversity is not only important for its intrinsic values, but also for its role in maintaining the functioning of ecosystems that provide humans with services that are important for our well-being and safety. As it is a concern for all of humanity there is a demand for education that can develop in students an understanding of the complexity which lies behind the ecosystem services of which they benefit. Including how the disturbance of this complexity will lead to consequences for the whole human world. Current attempts to educate the public has failed to conjure motivation and interest. However, ecological network research create opportunity for understanding the underlying relationships between species, and the use of ecosystem services as a pedagogical perspective offers the possibility to demonstrate the importance of these relationships for ecosystem functioning. In this literature review it is examined how this could benefit environmental education in high school.

Key word: Biodiversity, Ecosystem services, Environmental education, Ecological literacy
Introduction

In 2009 Rockström et al. concluded that humanity stands before a number of challenges, there amongst reducing the rate at which biodiversity is currently being lost. It could be argued that extinction is a natural process, however, it is now happening with a 100-1000 times more rapid rate, and humans are already responsible for the extinction of 5-20% of the species in some organismal groups (Trombulak et al., 2004; Chapin III et al., 2000). The rate is of such magnitude that the current loss of biodiversity has been referred to as the sixth mass extinction in Earth’s history (Chapin III et al., 2000). No natural background levels have been of a magnitude higher than this rate (Diaz et al., 2003). Humans are altering the ecosystems through a variety of activities (Hooper et al., 2005; Trombulak et al., 2004). Around 40-50% of the ice-free land surface has been transformed by humans with effects on forests and wetlands (Chapin III et al., 2000), and land-use change is expected to be the greatest cause of loss of biodiversity by 2100. However, humans are also altering the biogeochemical cycles and are simplifying the movement of nonendemic species. Therefore, nitrogen deposition, invasive species and changes in the concentrations of greenhouse gases are also projected to have a great impact on biodiversity in the future (Chapin III et al., 2000). All of these anthropogenic impacts will also increase with the growing human population and will continue to reduce the ecosystems capacity to withstand change (Trombulak et al., 2004; Elmqvist et al., 2003). This in turn will influence the delivery of ecosystem services, such as pollination, erosion control and purification of air and water (Hooper et al., 2005). In other words, benefits that humans acquire from nature and that are important for human well-being by for example providing access to water and safety against environmental change (Boyd & Banzhaf, 2007; Diaz et al., 2006; Box 1). Chapin III et al. (2000) argue that since the extinction of species is an irreversible event it is of special societal concern and, therefore, it should be the option of society to preserve these species when more knowledge of their contributions to human well-being is yet to be attained.

As it is a challenge of current demand it is also an area that should be addressed in education, and teachers have reason to be prepared to engage their students in discussions of all aspects of biodiversity (Miani et al., 2016). Trombulak (2004) suggests that considering the impact that humans are having on the natural world, conservation literacy should be part of education in
all nations. Pyle (2003) conclude that in the background of what we now know, there is no
doubt that people need to have a strong sense of connection to the nature and the natural
processes in order to achieve a functional coexistence between nature and humans. Especially
in the urban surroundings, today’s youth are unaware of the connection between humans and
nature simply because they have no contact with natural processes (Nadkarni, 2004). People’s
perception of the threat to the natural processes are influenced by the magnitude of change
they have actually seen occur, which in the urban areas is minimal (Trombulak et al., 2004).
But it is not only in the urban parts of the world, everywhere humans are losing their sense of
connection to nature without realizing that they are a part of essentially all ecosystems
(Nadkarni, 2004; Redman, Grove & Kuby, 2004). If education cannot achieve a change in public
understanding of biodiversity, then conservation biology will continue to fight a losing battle
(Bride, 2006). Therefore, it is critical for conservation in the future that students are taught a
holistic understanding of environmental threats and an ability to address these threats
through a holistic view (Ardoin & Heimlich, 2013). To achieve that, human activities must be
acknowledged as part of the ecosystems (Schröter et al., 2005). This literature review
examines the use of ecosystem services as a pedagogical perspective for demonstrating the
importance of biodiversity. Including how ecological network research can contribute with an
understanding of how species interaction is a condition for ecosystem functioning.

Education on biodiversity

Surveys that have been conducted to assess the level of public awareness on biodiversity
suggests that education and strategies to inform the public are failing to evoke interest and
motivation for biodiversity conservation (Navarro-Perez & Tidball, 2012). What was also
concluded after the surveys was that strategies are failing to make the general public see the
impact that biological resources have on their lives (Navarro-Perez & Tidball, 2012). According
to Menzel and Bögeholz (2009) this could be due to three matters concerning the concept of
biodiversity. To begin with, the concept itself involves not only species but ecosystems and
genes as well, something that is often overlooked by the public and educators (Navarro-Perez
& Tidball, 2012; Hooper et al., 2005). The genetic diversity of all individuals within a species
represents an important assurance for species response to environmental variation.
(Trombulak et al., 2004), and with the expected climate change it is of importance for species survival (Chapin III et al., 2000). Secondly, the term biodiversity causes learners to have an ecological focus when the reasons for biodiversity loss and its consequences are complex interactions between ethical, economic and social issues (Menzel & Bögelholz, 2009). Finally, since the loss of biodiversity is often exemplified by biodiversity hotspots, that are usually situated in developing countries, it causes the students to conceive it as a local problem when the local situation is often caused by global and regional interactions (Navarro-Perez & Tidball, 2012; Menzel & Bögelholz, 2009). Furthermore, a focus on biodiversity hotspots also threatens to overlook that the loss of biodiversity impacts ecosystems and their services all around the globe, not only in hotspots, as Kareiva and Marvier (2003) points out.

Van Weelie and Wals (2002) concludes that a challenge for educators when teaching about biodiversity is to allow the student to attribute personal meaning to biodiversity by teaching it in a context where the student develops a psychological or physical involvement. Van Weelie and Wals (2002), therefore, present what they call stepping stones for contextualizing biodiversity. One of these steps is determining the pedagogical perspective from which one wishes to proceed. Three perspectives are presented, the nature and self, the ecological literacy and the politics of nature. The politics of nature perspective wishes to illuminate the political side by discussing, for example, the distribution of natural resources, with key ideas such as exploitation and north-south relationships. The nature and self-perspective wishes to create opportunities for experiencing biodiversity with key ideas such as sense of wonder and caring. The ecological literacy perspective wishes to develop in students an ecological literacy by demonstrating the connection that exists between species in an ecosystem, and by illuminating the part of humans in these ecosystems. The key ideas that ought to be included are ecosystems, species inter-relations such as food webs, and human impact. According to Cutter-Mackenzie & Smith (2003) a student has a nominal ecological literacy when he or she is developing an awareness and sensitivity for the significance of natural systems and the consequences human behaviour are having on these systems.
Ecosystem services as a possible ecological literacy perspective

In a report from UNESCO (2002) it is brought forward that very few attempts are made in education to make the link between people’s health and the sustainability of ecosystems, neither are students asked to reflect on the impacts they have on the functioning of ecosystems. However, in research, more links are now being made between biodiversity and ecosystem functioning (Balvanera et al., 2006; Diaz et al., 2006; Hooper et al., 2005), making ecosystem services a possible perspective for teaching the importance of biodiversity.

The loss of biodiversity cause concern for ethical and aesthetic reasons, and it is considered important for the emotional and spiritual value it has for humans, together with nature’s intrinsic values (Hooper et al., 2005; Trombulak et al, 2004). However, Diaz, Fargione, Stuart Chapin III and Tilman (2006) point out that biodiversity also concerns human well-being through the effect it has on the ecosystems providing services to us humans. The diversity of life is affected by the changes humans make on the ecosystems in which they are a part, but it is also clear that the diversity in turn affects the properties of ecosystems and therefore its services (Diaz et al., 2006; Box 1). Ecosystem services are the properties of ecosystems, properties as in materials such as carbon and organic matter and the movement of energy, that directly or indirectly benefits humanity (Hooper et al., 2005). Examples of ecosystem services are the cleansing of air and water, pollination, climate regulation, maintaining of hydrological cycles and atmospheric composition, and storing and cycling of nutrients (Hooper et al., 2005; DeFries et al., 2005). Ecosystem goods are properties of the ecosystem that are already known to have a value, such as food, materials for construction, and medicines (Hooper et al., 2005). That ecosystem services do not have a direct market value has consequently made them less observable and thereby less valued (Barbier et al., 2011). Therefore, attempts to maximize the production of ecosystem goods, such as timber, has unintendingly lead to decreases in ecosystem services, such as flood control (Bennett, Peterson & Gordon, 2009). It is not until recent years that the value of these services has received attention (DeFries et al., 2005; Box 1).
Box 1: Examples of ecosystem services in coastal and estuarine ecosystems

Human population densities are higher at the coasts and more than one third of all the world’s people live in coastal areas where they depend on the services that the coastal ecosystems provide (Barbier et al., 2008). At the same time, human activities are degrading the estuarine and coastal ecosystems on which the coastal populations depend (Barbier et al., 2011). Coral reefs, of which 30% are either lost or degraded, contribute with ecosystem services such as coastal protection, nutrient cycling, and sustenance of fisheries by hosting almost a third of the world’s marine fish species (Barbier et al., 2011; Moberg & Folke, 1999). With coastal protection is meant the buffering of severe weather and waves (Barbier et al., 2009), and the loss of this buffering effect contributed to the extensive damage caused by the tsunami in 2004 and the hurricanes in the Gulf of Mexico in 2005 (Carpenter et al., 2006). Seagrass beds, of which 29% are either lost or degraded, contribute with coastal protection, water purification and erosion control. Salt marshes, of which 50% are lost or degraded, also contribute with coastal protection and erosion control, but also with carbon sequestration (Barbier et al., 2011). Apart from the already mentioned vegetation, mangroves also contribute with coastal protection, erosion control, disruption of freshwater discharge, and habitats for fisheries (Bennett et al., 2009; Moberg & Folke, 1999).

In-between these ecosystems there also exist a connection, by reducing waves and currents, the coral reefs create a physical environment that enable seagrass and mangroves to develop (Bennett et al., 2009; Barbier et al., 2011). At the same time, mangroves and seagrass beds create an environment that has clear water low in nutrients, that benefit the establishment of coral reefs (Moberg & Folke, 1999).

The components of biodiversity, from the genetic diversity to the landscape dimension, may all be important in the provision of ecosystem services and, therefore, there is a need for a better understanding of the properties that maintain the endurance of diverse ecosystems (Diaz et al., 2006; Pascual, Dunne & Levin, 2005). For example, it has been found that an important aspect of biodiversity is that when many components have the same function then the risk of that function to get disrupted is smaller. This also means that a minor species performing a function the same as other components can be important for the stability of that ecosystem (Diaz & Cabido, 2001), in other words, a species with scarce connections to other
species can have rather unpredictable and large effects on the functioning and structure of the ecosystem (Dunne, Williams & Martinez, 2002). Simply knowing that a species is present or not is not enough to know its impact on the ecosystem, because it is the changes in its interactions with other species that alter the effects on ecosystem processes (Chapin III et al., 2000). Brooks et al. (2004) advocates for protecting as many species as possible and that this would be the main goal of conservation. However, Molnar, Marvier and Kareiva (2004) disagree and argue that it is in the assemblages of species in an ecosystem that the value lies and in understanding its ecological role. As Kareiva and Marvier (2003) illustrate, a few species can be important for the delivery of a valuable service by addressing how Canada, with the fewest endemic plant species per area, still resides in the top for the values its ecosystems services per area contribute with. Therefore, changes in the evenness of species, rather than species richness, ought to be given attention since it has important consequences for the ecosystem, previous to a species being threatened to extinction (Chapin III et al., 2000).

It has been suggested that a change in focus, from a species to a network interaction perspective is necessary as to better understand how ecosystems will be affected by coming anthropogenic change (McCann, 2007). McCann (2007) argues that research has focused on diversity and overlooked networks of interactions between organisms that characterize ecosystems. This is in line with a growing field of research that suggest that it is the functional diversity, the value of different species traits, instead of the actual number of species that determine the functioning of the ecosystem (Diaz & Cabido, 2001). A greater understanding of the underlying functions that maintain the diversity of ecosystems is therefore important (Pascual et al., 2005).

Ecological networks

In the ecological literacy perspective Van Weelie and Wals (2002) specifies food webs as a key idea that should be included and underlines that the ecological literacy perspective ought to include an explanation on how species in an ecosystem are connected. One of the goals with ecological network research is understanding the persistence of the complexity in nature and how it affects the functioning of ecosystems (Ings et al., 2009). Therefore, this research has
the possibility to explain the essential functions that preserve the diversity of ecosystems, as pointed out by Pascual et al. (2005).

A food web is perhaps the most known type of the ecological networks and is an illustrative overview describing the feeding relationships between species at different trophic levels (Newman, 2003; Eklöf & Allesina, 2012). However, ecological networks are generally divided into consumer-resource networks, where food webs are included, mutualistic networks, such as plant-pollinator, and competitive networks, in terms of species competing for resources (Eklöf & Allesina, 2012). An ecological network is a representation of the species and the connections between them, the connections are called edges and the items, in this case species, are called nodes (Newman, 2003). The number of nodes will thereby represent species richness and the edges will represent the interactions between them (Eklöf & Allesina, 2012).

All organisms are connected with each other, even though the degree vary (Trombulak et al., 2004), and the interaction between species decide the characteristics of the ecosystem (Chapin III et al., 2000, Box 2). Different trophic interactions, such as predation, parasitism and herbivory, as well as mutualism and competition, can directly influence ecosystem processes through the flow of energy and materials, or indirectly by changing the amount of species or species traits (Chapin III et al., 2000). As previously mentioned, the cycling of nutrients is one important ecosystem service (Hooper et al., 2005), in the case of nitrogen for example, this is mediated by mutualistic interactions between nitrogen-fixing microorganisms and plants (Chapin III et al., 2000). In the same way trophic interactions, where one level can influence both levels above and below, can have large effects on ecosystem processes. For example, in situations when a top predator is in decline, the prey populations increases drastically and consume all the resources, resources that could otherwise offer an ecosystem service to humans (Chapin III et al., 2000, Box 2). Furthermore, human introduction of invasive species in a body of water can for instance cause alterations in food webs by shifting the controlling interactions from the water into the sediments (Chapin III et al., 2000). Both trophic interactions, mutualism and competition also leads to interaction between other species which often has strong effect on the ecosystem (Chapin et al., 2000, Box 2). Säterberg, Sellman and Ebenman (2013) describe how a species can become functionally extinct before its own
survival is threatened, thereby causing the extinction of another species. Of these extinctions there is a comparatively high percentage that are neither consumed by the functionally extinct species, nor a consumer of that species (Säterberg et al., 2013). What was also found is that there is a relation with body mass, making a decreasing large-bodied species more likely to cause the extinction of another species within the food web. Säterberg et al. (2013) conclude that results like these underlines the importance of a more system-oriented approach. Moreover, a species loss from a community has the capacity to cause a cascade of secondary extinctions, as shown by Eklöf and Ebenman (2006). However, this risk decreases with increasing connectance, in other words a complex community is generally less vulnerable to species extinction than a simple one. A likely explanation for this lies in how the consumer have several different preys in a highly connected food web, hence, the loss of one will not cause a great impact (Eklöf & Ebenman, 2006). However, the consequences on the community also depend on the connectivity of the lost species. Generally, if the species that was lost was a lower level primary consumer then this will lead to more secondary extinctions, whereas, a species with less connectivity is likely to cause fewer secondary extinctions (Eklöf & Ebenman, 2006; Christianou & Ebenman, 2005). Christianou and Ebenman (2005) also found that a lost species causes more secondary extinctions if it is uncommon and has strong connections to many consumers. Examples like these from the ecological network research underlines the importance of considering all forms of organisms when trying to understand the impact of biodiversity on the functioning of ecosystems (Chapin III et al., 2000), and such understanding is important for realizing the factors that lies behind ecosystem functioning (Pascal et al., 2005).

One of the limitations with ecological networks lies in combining different kinds of relationships and interactions within one network (Eklöf & Allesina, 2012). Most research is on feeding relationships whereas non-feeding relationships, such as habitat modification, are often excluded (Kéfi et al., 2012). Non-feeding relationships can have consequences for complete communities, for example the engineering of beavers can affect both feeding and survival for other species, and frameworks for including such interactions within networks are only beginning to evolve (Kéfi et al., 2012). When this can be accomplished, the ecological network obtains the capacity to contribute with a holistic view of the interactions of the whole ecological community, even though this will cause the network to be more complex.
Box 2: Examples of the complexity of ecosystem interaction

Maron et al. (2006) examined how the introduction of foxes disrupted nutrient subsidies that was brought from sea to land by seabirds on the Aleutian Islands. When the foxes hunted the seabirds, it resulted in less nutrients being carried to land and thus low phosphorus and nitrogen values in the soils causing changes in plant productivity. The results substantiate that top predators can have influences on the productivity and composition of plants through the complex interactions in ecosystems (Maron et al., 2006).

The overfishing of sea otters by Russian fur traders during the 18th century caused the sea urchins, that are one of the sea otters main food, to expand greatly in number (Estes & Palmisano, 1974; Chapin III et al., 2000). The increase in sea urchin population in turn caused the kelp forests to decrease due to being consumed by the sea urchins more rapidly than when the sea otters where keeping the sea urchin populations at bay (Estes & Palmisano, 1974; Chapin III et al., 2000). Kelp forests are habitat for fish and other marine animals and also work as an effective wave damper in shallow waters, thereby decreasing the beach erosion (Mork, 1996).

The large blue butterfly *Maculinea arion*, that was eradicated in the UK, had several unsuccessful attempts of reintroduction (Thomas, Simcox & Clarke, 2009). It was not until scientists realized the complexity of its interactions that the reintroduction was successful. The larvae of *Maculinea arion* depend on the *Myrmica* ants who carry the larvae into their nests and feed them. The ant itself require open areas for building its nests which depend on rabbits grazing. The rabbits had been declining due to the disease myxomatosis and therefore the extinction of *Maculinea arion* was indirectly caused by rabbit decline (Thomas et al., 2009).

Implications for education

Using ecosystem services as a pedagogical perspective for teaching the importance of biodiversity offers several advantages. Firstly, it will clarify the part of biodiversity in
maintaining the services on which we rely by showing that it is not only in some parts of the world that conservation is important. Everywhere we depend on biodiversity for the health of our ecosystems and hence our own. Secondly, it will illuminate ecosystem services itself as a concept since normally we are only aware of the direct products that nature provides us with in the form of ecosystem goods. Ecosystem services shows the importance of an appreciations for the whole system, and this can bring clarity on how we need the system to function, not only the goods it provides us with. Finally, ecosystem services offer the possibility to move away from an exclusively ecological focus towards a discussion on the complex economic and social considerations. By including the human roll in ecosystems, one can demonstrate both how we depend on ecosystems and also how we alter them, depending on the ecosystem service one chooses for once lesson. For instance, with the findings of this literature review in mind, one could imagine using the previously mentioned examples of the complexity of ecosystem interaction (Box 2) as a theme for constructing a case study. The case study could be as a form of investigation where the students are instructed to investigate what could have caused the following events. In the case of the sea otters, for example, a possible approach could be to inform the students on how one has recorded an increase in coast erosion and that one believes it to be connected to a decrease in kelp vegetation further out. The students would then be asked to search for an explanation. Another way would be to put students in the role of construction planners for a harbour close to housing at the coast. In the same way, a certain amount of information would have to be given, such as the waters are known to be habitat for sea otter, and that the harbour is expected to bring heavy traffic. The students would then be asked to search for possible consequences, in this case sea otter decrease, kelp decrease, and coast erosion, causing the housing to be in the risk zone of erosion.

With more similar examples from the natural world it would be possible to illuminate species connections and consequences of human actions, and with ecological network research starting to include different types of interactions within one network, the ability to predict human impact on complex networks could become reality (Kéfi et al., 2012). The structural complexity of ecological networks can potentially make them hard to understand (Eklöf & Allesina, 2012), however, all students are familiar with a social network, people who interact with each other, making this a possible opening for understanding (Newman, 2003). For example, in a network it is commonly found that if A is connected to B and B is connected to
C, then there is a higher probability that A is also connected to C, which in a social network would mean that your friends friend is probably also your friend (Newman, 2003).

Conclusively, ecosystem services as a pedagogical perspective have the possibility to demonstrate the importance of biodiversity through illustrating the influence of these services on human well-being. For the understanding of ecosystem functioning, ecological network research offer insight on how species interact with each other and how the disturbance of the system can lead to unexpected consequences. Therefore, ecosystem services and ecological networks can contribute to environmental education by furthering the development of ecologically literate students.
References


