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Perspectives on the link between ecosystem services and biodiversity: The assessment of the nursery function

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ABSTRACT

The relationship between biodiversity and each ecosystem service or bundle of ecosystem services (e.g. win–win, win–lose or win–neutral) is an active field of research that requires structured and consistent information. The application of that research for conservation and decision-making can be hampered by the ambiguity found in the definition of the nursery function under the ecosystem service perspective. In this paper, we review how the role of nursery habitats is included in the ecosystem services literature, covering conceptual, biophysical and economic reflections. The role of ecosystems as nurseries is mostly analyzed in coastal environments. The main observation is that there is no consensus on the consideration of the nursery function as a service (e.g. which species or habitats) or on how to assess it (e.g. which indicators or valuation methods). After that review, we analyze three different interpretations given to the nursery function, namely the ecological, conservationist and economic point of view; and we distinguish between different types of assessment that may consider the nursery function.

We conclude that the nursery function can be considered an ecosystem service on its own right when it is linked to a concrete human benefit and not when it is represented with indicators of general biodiversity or ecosystem condition. Thus, the analysis of the delivery of ecosystem services should be differentiated from the analysis of ecological integrity. Only with this distinction science may be able to quantify the link between biodiversity and ecosystem services and policy may be effective in halting biodiversity loss. Similar considerations could apply for other biodiversity constituents that may be treated as ecosystem services.

1. Protecting biodiversity through ecosystem services

Ecosystem services became a policy tool to protect biodiversity mainly as a result of the global strategic plan 2011–2020 of the Convention on Biological Diversity (Aichi biodiversity targets), before scientific consensus about the mutual relationship between ecosystem services and biodiversity was well established. Still today, although there are numerous evidences supporting a positive relationship between biodiversity, ecosystem functions, and the delivery of particular ecosystem services (Egoh et al., 2009, Cardinale, 2011, Isbell et al., 2011, Mace et al., 2012, Harrison et al., 2014), there is not much consensus on what the links are and how they operate (Loreau et al., 2001, Harrison et al., 2014).

Ecosystem services have, by definition, an anthropocentric focus. They are the direct or indirect contributions from ecosystems to human welfare. To consider something as an ecosystem service, this must have human demand or identified beneficiaries (Haines-Young & Potschin, 2013). Nevertheless, it does not mean that ecosystem services promote a utilitarian view of nature; they rather aim at highlighting the processes and outputs from ecosystems that contribute to human well-being and that are usually overlooked, especially in sectors not related with nature conservation or in areas where nature protection is not the first priority.

Biological diversity at species and population levels is closely linked to ecosystem functioning and it is assumed to positively influence the provision of particular ecosystem services across scales (Naeem et al., 1995, Worm et al., 2006, Cardinale et al., 2012). At the same time, biodiversity and ecosystem functioning are influenced by interactions between individuals or species (see Gray et al., 2014 and references therein), which directly rely on habitat availability and condition. For example, the ecosystem services that improve water quality (i.e. water purification) and flow regulation (i.e. flood protection) are enhanced by increases in community and habitat area (Harrison et al., 2014). Biodiversity is also alleged to stabilize the delivery of ecosystem services through time (Tilman, 1996, Chapin et al., 2000, Hooper et al., 2005, Schindler

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et al., 2010) and this is even more demanded in ecosystems that are expected to provide multiple functions (Hector & Bagchi, 2007). Consequently, there is a big concern about the effects of biodiversity loss, not only for the ecosystems, but also for human well-being and livelihood (Hoekstra et al., 2005, Duffy, 2009, Schindler et al., 2010, Treml et al., 2015). In this context where biodiversity is being linked to human well-being, several initiatives promote the ecosystem service approach (e.g. MA, 2005, UNEP, 2007, TEEB, 2010, IPBES in Díaz et al., 2015), which aims at integrating both natural and social systems providing a more comprehensive approach for decision-making.

A major challenge to apply the concepts of ecosystem services in management and decision-making is to have clear assessment frameworks that allow measuring each service and linking them to human well-being. During our involvement in some initiatives that try to operationalize ecosystem services (e.g. MAES, 2014, OpenNESS, 2014, MARS, 2015), several conceptual discrepancies and empirical challenges have arisen when trying to quantify particular ecosystem services. One of the most controversial services is the so-called "maintenance of nursery populations and habitats" in the Common International Classification of Ecosystem Services (CICES, 2015) or "habitats for species" in The Economics of Ecosystems and Biodiversity (TEEB) (see Appendix). The main reasons behind are that, on the one hand, this ecosystem service could be interlinked or correlated with other services that directly rely on it (e.g. fisheries) and, on the other hand, it refers to biodiversity components and ecosystem functions (i.e. nursery function). In this context, our main questions were: Can the nursery function be considered an ecosystem service? If so, how should it be adequately assessed? What are the different options?

This paper presents, first, a short review of existing approaches that analyze the nursery function as an ecosystem service (Section 2); then, a critical analysis of these approaches discussing different perspectives in considering biodiversity components (Section 3); and finally a proposal of specific options to tackle the nursery function in ecosystem service assessments (Section 4).The analysis is especially important when aiming to assess the links between biodiversity and the delivery of ecosystem services.

2. Nursery habitats and the ecosystem service approach

2.1. Definitions and classifications

A nursery can be defined as a habitat that contributes more than the average, compared with other habitats, to the production of individuals of a particular species that recruit to adult populations (Beck et al., 2001). The main factors that facilitate the reproduction and recruitment are density, growth and survival of juveniles, movement to adult habitats, or a combination of those (Beck et al., 2001). In this sense, experimental studies have demonstrated how the nursery function (i.e. the production of individuals that recruit to adult populations per unit area of juvenile habitat *sensu* Beck et al., 2001) decreased with nursery habitat loss (Cheminée et al., 2013).

In an ecosystem service context, it is unclear whether the nursery habitats and function could be regarded as a distinct ecosystem service or as a biodiversity component. For example, The Economics of Ecosystems & Biodiversity foundations (TEEB, 2010) proposed "maintenance of life cycles of migratory species" as an ecosystem service, postulating that when the migratory species have commercial value and reproduce in a certain habitat, that nursery function should be valued by itself (e.g. mangroves used as spawning and nursery areas of fish and crustaceans harvested far away) (Table 1). Still, both TEEB (2010) and MA (2005) state that the so-called habitat or supporting services (such as "habitats for species" or "photosynthesis", see Appendix) are necessary for the production of most of the other ecosystem services and, thus, have only indirect impacts on people. Similarly, even if not so explicit, the CICES description of the "lifecycle maintenance, habitat and gene pool protection" class (which includes pollination and the maintenance of nursery populations and habitats, see Appendix) seems to be restricted to the reproduction and nursery functions that support provisioning services (e.g. pollination as a support to commercial crops) (Haines-Young & Potschin, 2013). Within this classification, the "maintenance of nursery populations and habitats" is an independent service defined as habitats for plant and animal nursery and reproduction. In contrast, the UK National Ecosystem Assessment Follow-on (Turner et al., 2014) states that the nursery function is already valued through the fish that is caught and sold on markets (i.e. through its contribution to fisheries) and, thus, it is not included in the list of final ecosystem services. Instead, it is split between two intermediate services named "larval and gamete supply" and "formation of species habitat".

Other authors include the maintenance of all vegetal and animal populations as well as their resilience among regulating or supporting services (Beaumont et al., 2007, Rönnbäck et al., 2007) which is difficult to detach from biodiversity or ecological integrity. In other cases, the definition of nurseries as ecosystem service remains ambiguous and can be used with different connotations. For example, the service habitat/refugia analyzed by Costanza et al. (1997) included nursery areas for commercial species as well as resting areas for migratory species. It was valued with fish/shrimp market prices, endangered species conservation value and general conservation value. In Salomidi et al. (2012) the service "reproduction & nursery areas" seems to cover by definition all marine species (i.e. the viability of populations), but the examples are mostly linked to commercial species. Some other names referring to the nursery function as an ecosystem service in the literature are: breeding and feeding ground, nursery habitat, habitat provision, refuge or shelter (see Table S2 in Liquete et al., 2013).

Given this variety of opinions about how the nursery function should be defined and classified in an ecosystem services' context, we propose to follow a simplified representation of the ecosystem services' cascade framework (derived from Haines-Young & Potschin, 2010) (Fig. 1). More complete schemes have been developed, for instance, in international initiatives such as Müller et al. (2010), TEEB (2010) or Maes et al. (2013) or other proposals such as Villamagna et al. (2013). Applying this kind of conceptual framework clarifies which compartment of the socio-ecological systems is being analyzed and what is missing to fully characterized, for instance, one ecosystem service. In Fig. 1, ecosystem functions and processes comprise all the biophysical roles that sustain the provision of a specific ecosystem service, thus indicating the natural capacity to provide that service. Ecosystem services (also noted as ecosystem service flows) are the actual contribution of ecosystem components (as goods or services) to human well-being. The benefits and values designate the perception or valuation that human-beings attribute to a specific service. The management and social responses reflect how the political and personal decisions act as drivers of change of the environment, affecting the ecosystems' condition. Biodiversity is the variety of life, including variation among genes, species, ecosystems and habitats.

To move from this conceptual framework to real-world assessments researchers generally use indicators or proxies. Indicators are variables that provide aggregated information on certain phenomena, acting as communication tools that facilitate a simplification of complex processes (Müller & Burkhard, 2012). Proxies are here assumed to be approximations of ecosystem services' indicators when the entire phenomena cannot be quantified; a proxy is thus a figure that can represent the value of an ecosystem service indicator. Depending on the objective of each case study, the proxies or indicators may refer to ecosystem functions and processes,