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Review

Novel tradable instruments in the conservation of coral reefs, based on the coral gardening concept for reef restoration

Baruch Rinkevich

National Institute of Oceanography, Tel Shikmona, P.O. Box 8030, Haifa 31080, Israel

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ABSTRACT

Nearly all coral reefs bordering nations have experienced net losses in reef biodiversity, goods and services, even without considering the ever-developing global change impacts. In response, this overview wishes to reveal through prospects of active reef-restoration, the currently non-marketed or poorly marketed reef services, focusing on a single coral species (*Stylophora pistillata*). It is implied that the integration of equity capitals and other commodification with reef-restoration practices will improve total reef services. Two tiers of market-related activities are defined, the traditional first-tier instruments (valuating costs/gains for extracting tradable goods and services) and novel second-tier instruments (new/expanded monetary tools developed as by-products of reef restoration measures). The emerging new suite of economic mechanisms based on restoration methodologies could be served as an incentive for ecosystem conservation, enhancing the sum values of all services generated by coral reefs, where the same stocks of farmed/transplanted coral colonies will be used as market instruments. I found that active restoration measures disclose 12 classes of second-tier goods and services, which may partly/wholly finance restoration acts, bringing to light reef capitalizations that allow the expansion of markets with products that have not been considered before. The degree to which the second tier of market-related services could buffer coral-reef degradation is still unclear and would vary with different reef types and in various reef restoration scenarios; however, reducing the uncertainty associated with restoration. It is expected that the expansion of markets with the new products and the enhancement of those already existing will be materialized even if reef ecosystems will recover into different statuses.

1. Market-based services in ecosystem biodiversity

Market based valuations of the total goods-and-services provided by environments are common tools used for quantitatively assigning the benefits provided by the ecosystems to human beings, as losses following degradation. Some commonly used instruments, such as harvest quotas, biodiversity offsets/credits, mitigation banking, carbon payment mechanisms such as REDD+ and trade-off measures, have been progressively employed for more than two decades as integral components in conservation policies in a wide range of ecosystems and through diverse policy frameworks (e.g., Boyd and Banzhaf, 2007; McKenney and Kiesecker, 2010; Morrison-Saunders and Pope, 2013; Venter et al., 2013). The ways some of these instruments are being used (Madsen et al., 2010; Venter et al., 2013) is highly controversial. For example, certain offset stratagems, while being criticized for inappropriately employing tools of ecosystem restoration (such investment in the restoration of natural capital; Blignaut et al., 2014; Curran et al., 2014), are often used in ameliorating damages in one area, in exchange for failing biodiversity elsewhere. Additionally, in many cases the major price tags for environmental services are weighed in a simplified way, without considering the costs/benefits accrued to biodiversity and ignore the extra costs incurred by rehabilitating biological phase shifts or completely destructed ecosystems, since a destroyed/phase shifted ecosystem cannot be simply reverted to an earlier status of ecosystem services (Reid, 2010). In contrast to the prevailing notion that market-based services are correctly employed, the international initiative called 'Economics of Ecosystems and Biodiversity' (TEEB, 2009), has indicated that most of the services provided by any specific ecosystem are usually not deliberated when employing conventional macro-economic indicators (such as the GDP), since many of the goods/services are not traded in markets. Thus, it is important to elucidate and analyze the yet unpriced potentially tradable environment-elements, taking

E-mail address: buki@ocean.org.il.

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into account that ecosystem services define up to 90% of the poor rural communities' income, worldwide (Ring et al., 2010).

Past markets have failed to provide efficient allocations for a wide range of ecosystem services (Kroeger and Casey, 2007), in contrast to the wide diversification of ecosystem services, particularly true in low-income country economies (Dasgupta, 2010; Rhyne et al., 2014). Consequently, I wish to contribute by signifying that there are as of yet non-marketed or poorly-marketed elements in the coral reef ecosystems' goods and services that may be explored when employing the scientific discipline of 'active reef restoration' (Rinkevich, 2005a, 2006, 2008, 2014; Shafir and Rinkevich, 2008). I draw attention to the integration of novel economic components within reef restoration practices that may lead to novel trading policy mechanisms.

Coral reefs, while exhibiting exceptional diversity, are highly degraded, exposed to multiple threats, including the prospect of global change impacts (Bruno et al., 2007; Shafir and Rinkevich, 2008). Evidently, these threats directly impact the enormous numbers of animal and algal species associated with coral reef ecosystems (Wilson et al., 2008). Global economy nets benefits from coral reefs reach US$30 billion/y from fisheries and coastal protection and in goods and services, including tourism (Cesar et al., 2003). Despite their notable values, nearly all coral reefs bordering nations have experienced net losses in reef biodiversity, with no pristine reef ecosystem remaining. About 40% of the global coral-reef ecosystem has already been lost, a process galloping forward at 0.5–2% per year (Bruno and Selig, 2007; De'ath et al., 2012), even without considering the ever developing global change impacts that cause enormous economic losses. For example, corals killed by severe bleaching could cost the global economy US$ 83 billion (Cesar et al., 2003).

2. Coral reef restoration

Current best management instruments employed in coral reefs worldwide are often failed to achieve their conservation objectives (e.g., Rinkevich, 2005a, 2008; Miller and Russ, 2014). It is also agreed that these failed management practices will hardly withstand the expected global change impacts on coral reef communities (e.g., bleaching-mediated mass coral mortalities; Rinkevich, 2005a,b, 2008; 2014). It may thus envisaged that the 'reefs of tomorrow' would not necessarily resemble the 'reefs of the past' in terms of species composition, diversity and community composition, as well as in terms of goods and services. Nevertheless, when restored coral reefs may allow the preservation of important ecosystem processes and services that would be lost when present reef systems fail. Restored reefs will also allow the survival of other reef dwelling species that would otherwise become extinct in impacted areas. This rationale is suggested and discussed in terrestrial restoration of forests, parks and reserves (Benito-Garzón et al., 2013; Chauvenet et al., 2013) and is also worth emulating in the coral reef arena (Rinkevich, 2014, 2015).

Active restoration of coral reefs, while still in its infancy and facing a variety of challenges (Rinkevich, 2014), is now capable, in addition of handling a wide range of ecological applications, to restore a variety of societal equity capitals and other social commodification, all intermingled within an unabridged socio-economic perspective (Rinkevich, 2014, 2015). Clearly, any trade policy associated with coral reef restoration should also be based on sound socio-economic considerations. However, there are not, as of yet, any established evaluations for incipient reef-related markets, primarily those directing biodiversity, landscape qualities and trading of coral reef resources. Moreover, priorities for ecosystem-service trading mechanisms (e.g., eco-tourism) are usually selected without considering novel alternatives emerging from reef restoration acts, some of which are non-obvious market-based mechanisms.

In silviculture, some of the leading considerations are based on non-ecological indicators, such as improving the productivity of plantation forests by selecting the fastest growing species, homogenizing compositions/structures of planted trees for efficient wood production, and selecting sites that have no major nutrient deficiencies and contain enough soil for adequate rooting depth (Puettmann and Tappeiner, 2014; West, 2014). Thus, in order to implement a successful coral reef restoration project, in addition to economic and market-based considerations, attention should be given to key ecological/biological properties, natural dynamics, and long-term ecological trends, including global change drivers (Rinkevich, 2006, 2008, 2014, 2015).

3. The underwater silviculture- 'gardening' the coral reef

Rehabilitation of reef ecosystems may progress by implementing either preventive (to be termed below as 'passive' measures) or active restoration measures that lead to diverse restoration

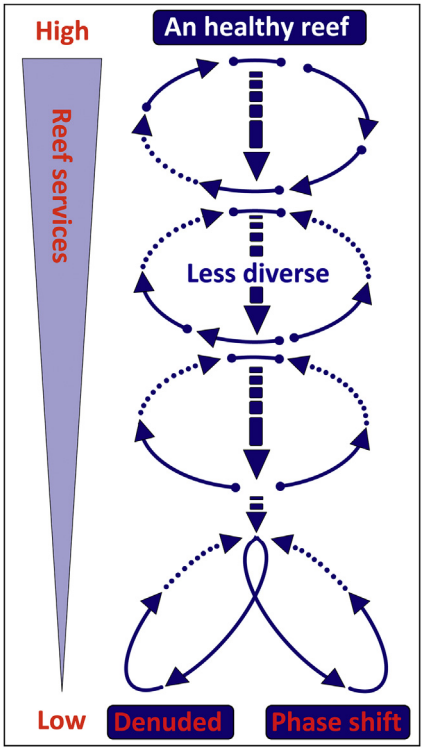

Fig. 1. Multiple 'restored reef-state' scenarios can be developed by using various active reef restoration acts with specific site considerations and assorted tradable reef services. Increasing ecosystem resilience involves the maintenance of ecosystem infrastructure and the 'healthy' functioning of reefs. For simplicity's sake, only general trends are illustrated. Anthropogenic and global change stresses lead to the emergence of poorly or partly restored reefs that are characterized by decreasing ecological complexity and minimal reef services, compared to healthy or intact reefs, a process that may take several stages (down-pointing arrows) and may lead to either a denuded reef or to a phase shift. However, employing the idea presented here, that is, developing novel tradable rights as part of the coral gardening concept for reef restoration, may enhance reef services to the level found in healthy reefs. These instruments allow for the existence of rehabilitated reefs at different complexities and reef service states (there are several steps, as depicted by arrows pointing upwards) that could develop into other conditions, culminating in the achievement of healthy reef status. Arrows pointing upwards represent the cumulative outcomes of active reef restoration (solid lines) and the ecological values added by tradable reef services (dash lines). The path from a denuded or phase shifted reef to a healthy reef is a long journey that includes several restoration acts and the long term use of assorted tradable reef services.