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Surveys

Twenty thousand sterling under the sea: Estimating the value of protecting deep-sea biodiversity

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ABSTRACT

The deep-sea includes over 90% of the world's oceans and is thought to be one of the most diverse ecosystems in the world. It supplies society with valuable ecosystem services, including the provision of food, the regeneration of nutrients and the sequestration of carbon. Technological advancements in the second half of the 20th century made large-scale exploitation of mineral, hydrocarbon and fish resources possible. These economic activities, combined with climate change impacts, constitute a considerable threat to deep-sea biodiversity. Many governments, including that of the UK, have therefore decided to implement additional protected areas in their waters of national jurisdiction. To support the decision process and to improve our understanding for the acceptance of marine conservation plans across the general public, a choice experiment survey asked Scottish households for their willingness-to-pay for additional marine protected areas in the Scottish deep-sea. This study is one of the first to use valuation methodologies to investigate public preferences for the protection of deep-sea ecosystems. The experiment focused on the elicitation of economic values for two aspects of marine biodiversity: (i) the existence value for deep-sea species and (ii) the option value of deep-sea organisms as a source for future medicinal products.

1. Introduction

1.1. Deep-sea Ecosystem Services

The deep-sea is the largest ecosystem on the planet (Thiel, 2003). It includes all ocean areas, from the shelf edge at −200 m water depth, down to the deepest trenches at −11000 m, and covers 65% of the Earth's surface (Thistle, 2003; Tyler, 2003). Despite this vast geographical extent, it was long thought that the deep-sea environment hosts little or no life (Tyler, 2003), mainly because of its extreme conditions, such as total darkness, low temperatures, high pressure, and low food availability (Thistle, 2003). However, today we know that a high diversity of life is found in the deep oceans, which might even rival the diversity of tropical rainforests (Grassle and Maciolek, 1992; van Dover, 2000). It is also an area that sustains major ecosystem services (ES), which are crucial for life on Earth as we know it. The deep-sea provides society not only with provisioning services such as food and hydrocarbons, but also with important regulating services, such as temperature regulation, regulation of atmospheric greenhouse gases, and absorption of waste and pollutants (Armstrong et al., 2010, 2012). Most importantly, it supports ocean life by cycling nutrients and providing habitat for a vast array of species.

Some authors have argued that only final ES should be taken into consideration for economic valuation, leaving supporting services out of the equation (Boyd and Banzhaf, 2007; Wallace, 2007), to avoid double counting of their value and because they are extremely difficult to value (Armstrong et al., 2012). However, in particular for the deep-sea environment, supporting services might constitute the biggest contribution to life on Earth and Armstrong et al. (2010, 2012) highlighted the importance of considering them to identify the deep-sea's main values. Less tangible cultural ES such as the scientific, existence, and inspirational values of the deep-sea ecosystem are often overlooked, as well as the value of maintaining biodiversity for generations to come. Finally, we can consider the option value of deep-sea tourism and finding medicinal products. Such ES may sound like science-fiction, but future technological improvements might well allow these options to become reality. To date, the small amount of literature on deep-sea ES is mainly of a descriptive nature and next to nothing is known about the economic values of protecting this environment.

1.2. Main Threats to Deep-sea Biodiversity

Marine ecosystem quality and the ES these ecosystems provide have declined dramatically over the last century (Barbier et al., 2011; Worm

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et al., 2006) and ecosystem degradation comes at a cost for society, as the provision of important ES is affected (Barbier et al., 2011; NRC, 2006). To be able to value these changes, it is crucial to understand the threats to the marine ecosystem and their effects on biodiversity. Scientists agree that despite its remoteness, the deep-sea is far from being unaffected by human activity and wide-spread changes are already noticeable today (Benn et al., 2010; van den Hove and Moreau, 2007; Fosså et al., 2002; Ramirez-Llodra et al., 2011). Climate change, which is resulting in increasing ocean surface temperatures and ocean acidification, is thought to be the biggest future challenge for the deep-sea ecosystem (Ramirez-Llodra et al., 2011). The most immediate threats however, are related to the fishing sector, oil and gas exploitation, cable laying, pipeline construction, underwater noise and water pollution from shipping routes, waste dumping, drill cuttings from mining activities, and pollution from terrestrial sources (Armstrong et al., 2010, 2012; Benn et al., 2010; Ramirez-Llodra et al., 2011).

Whereas the environmental impact of mining on the seabed is still unknown, deep-sea fishing has been identified as having a major impact (Benn et al., 2010). Fisheries have targeted ever deeper fish stocks since the 1950s, even though deep-sea species are particularly vulnerable to overexploitation, due to their slow growth and late maturity (Morato et al., 2006). Many deep-sea activities are likely to increase globally over the next decades (Glover and Smith, 2003; Ramirez-Llodra et al., 2011), such as mining activities for deep-sea resources like rare earth metals (e.g. gold, copper, zinc, and cobalt), and hydrocarbons (e.g. oil, gas, and gas hydrates) which will pose new potential threats to the deep-sea ecosystem (Halfar and Fujita, 2007; Kato et al., 2011; Ramirez-Llodra et al., 2011; Rona, 2003). Mineral and hydrocarbon resources are already technologically exploitable today, with extraction being mainly limited by cost considerations. As mineral and hydrocarbon prices rise, the economically viable exploitation of these remote resources is expected to increase.

1.3. Current Marine Legislation

Recognising and quantifying the economic value of biodiversity is the key to sustainable ocean management (TEEB, 2012). Ocean ecosystems are particularly vulnerable to degradation, due to the fact that they are often located across political borders, and because there is a general deficit of good governance in ocean areas (TEEB, 2012). Some international agreements to administer and control the exploitation of marine resources already exist [we refer the reader to Thiel (2003) for further detail on regulatory organisations of deep-sea areas]. The UN Convention on Biological Diversity (CBD; 1992) triggered biodiversity conservation goals globally, so that today Marine Protected Areas (MPAs) not only exist in shallower waters, but also in the deep-sea. Aspirations of some conservation groups go as far as demanding protection for at least 20–30% of each ocean habitat (Balmford et al., 2004). Currently, it is very uncertain if such goals will be met in the near future.

The international community failed to meet its CBD target to protect 10% of the oceans by 2012 (UNEP, 2010, 2012). In 2010 only 1.6% of the oceans were protected, and most of the MPAs are located in the shallower areas (UNEP, 2012). The UN has declared 2011–2020 the Decade on Biodiversity (DEFRA, 2011) and many nations are currently extending their national MPAs to apply with the CBD's Strategic Plan for Biodiversity 2011–2020 (EP, 2012). This plan highlights natural capital as society's life insurance, stresses the economic importance of biodiversity (EP, 2012), and sets the scene for environmental values to enter cost-benefit analyses (CBAs). When "hard" economic facts (i.e. monetary values) are presented to decision makers rather than qualitative types of value, they can serve as incentives for protection (Morling, 2005; Tinch et al., 2011). The inclusion of the non-use values of protection can have a positive influence on the acceptance for conservation management decisions (Tinch et al., 2011). However, non-use values are difficult to obtain in general and estimates are mostly non-existent for the deep-sea.

1.4. Main Challenges to Valuing Deep-sea Ecosystem Services

Science has a limited understanding of how biodiversity is affected by human impacts, and how changes in biodiversity bring about changes to the supply of ES. The major part of the deep-sea remains unknown and some scientists refer to it as one of the "least understood" environments on Earth (Ramirez-Llodra et al., 2010; Tyler, 2003). The available information on deep-sea ES is mostly of a descriptive nature and the majority of experts would be reluctant to put numbers on the ES changes that we have to expect in the future. However, one of the biggest challenges of attaching economic values to deep-sea ES and biodiversity is not the lack of scientific certainty about the baseline and future trends, but rather the unfamiliarity of the general public with the deep-sea environment. This is relevant given the likelihood that researchers will need to use stated preference methods to estimate values for deep-sea biodiversity. Ocean literacy across the population is thought to be limited in general (Steel et al., 2005), and awareness can be expected to be even lower for the deep-sea. The deep-sea environment remains remote to the majority of people (Ramirez-Llodra et al., 2011). Most members of the general public also poorly understand complex ecological concepts such as biodiversity (Christie et al., 2006; Ressurreição et al., 2011; Spash and Hanley, 1995; Turpie, 2003). However, people are able to learn and form their values given an appropriate approach to measurement (Christie et al., 2006), by combining new information on biodiversity attributes with their attitudes and beliefs. Another factor that makes stated preference valuation difficult for the deep-sea is the lack of charismatic species, which has been shown to be an important factor determining WTP (Christie et al., 2006). However, interest in the deep-sea is rising (Tyler, 2003), thanks to public outreach incentives of international large scale projects, such as the Census of Marine Life, and documentaries like the BBC's 'Blue Planet' (Beaumont et al., 2008).

1.5. Previous Studies Valuing Deep-sea Biodiversity and Ecosystem Services

The socio-economic valuation of marine ES lags far behind that of terrestrial ecosystems. A global valuation of ES estimated an annual flow value for the marine environment (including coastal waters) of $20.9 trillion, or 63% of the value provided by all ecosystem services globally (Costanza et al., 1997), although there are well-known problems with the interpretation of this figure. For the UK, figures on marine ES values have been estimated based on benefit transfer and mostly market-based approaches (Beaumont et al., 2006, 2008), and a related study looking into the economic value of implementing an MPA network for the UK waters estimated benefits of protection to range from £10.2–23.5 billion for a 20 year period (Hussain et al., 2010).

A study in Ireland estimated non-use values that the general public had for the protection of cold water coral (CWC; deep-sea species) habitats off the Irish coast (Glenn et al., 2010; Wattage et al., 2011). The respondents of this survey were willing to pay (WTP) for CWC protection between €0–10 per person. Follow-up questions identified different non-use motives for protecting CWCs, including existence and bequest values. Marine biodiversity valuation studies often focus on single or high profile species, such as CWC, and Ressurreição et al. (2011) argue that other ecosystem components and low profile species should be taken into account. A second case study, which included parts of the deep-sea in addition to shallower waters, focused on valuing species loss around the Azores archipelago (Ressurreição et al., 2011). A contingent valuation survey was undertaken which discussed the protection of a wide range of species, compared to the single species approach in the Irish CWC study. Choice scenarios were presented as one-off payments for avoiding reductions in species richness and resulted in WTP estimates of €405 to €605, per visitor or resident, for preventing 10–25% losses in marine species richness in the region. A study from the UK elicited respondents' values for a network of marine sites in coastal as well as off-shore areas and found WTP for halting the loss of marine