

## Quantification of environmental externalities in the utilization of ecosystem services – a long-term perspective on trade-offs in fisheries in the southern North Sea

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### Summary

Externalities or external costs, i.e. non-market effects in the utilization of ecosystem services (ES), are trailed for plaice as a target species for fisheries in the southern North Sea, for benthic habitats affected by the fisheries and for a non-target by-catch species, thornback ray, in relation to catches obtained from the plaice fisheries as ES. Alternatively to monetary valuation of ecosystem services, relative ecological risk assessment (RERA) is applied to quantify externalities in a historical period 1924 to 1938 and for 1985-2010 with the German EEZ as reference area. Two reference levels are adopted for each component, i.e. the target reference level representing conditions equivalent to maximum sustainable yield (MSY), and the limit reference level indicating a high risk of extinction. During the entire period, ecosystem state was below the target reference level for all ecosystem components representing a state of chronic negative change except for plaice in the years 2008-2010, when fisheries was approaching MSY levels. Thornback ray became locally extinct. The relationship between utilization of ES and its environmental costs, i.e. externalities, is not invariant. Spatial management is proposed as one means to alleviate externalities while still exploiting ES.

### Introduction

Pivotal in ecosystem based management (EBM) is the analysis of ecosystem state in relation to the provision of ecosystem services (ES) (Granek et al., 2010), a need also recognized by modern economic theory (Kumar, 2005). This links the provision of ecosystem services to production conditions of the ecosystem. In turn, the concept of ecosystem health based on the primary principle of preserving resilient and productive ecosystems (Rapport et al., 1998) pointing into the same direction allows to derive such limits based on production modeling. To this end, alternatively to monetary valuation of ecosystem services, relative ecological risk assessment (RERA) is applied to quantify externalities or external costs, i.e. non-market effects in the utilization of ecosystem services (ES). This approach corresponds to the strong sustainability concept in economic theory (SS). The SS concept bridges the gap between economic theory and ecosystem based management in that full substitutability in capital sources is not permitted (Daly, 1992). A minimum of either type of capital (natural, economic, socio-cultural) must be preserved to reach sustainability (Daly, 1992) corresponding to the Critical Natural Capital concept (Ekins et al., 2003).

### Materials and methods

Two reference levels are adopted for each component, i.e. the target reference level representing conditions equivalent to maximum sustainable yield (MSY), and the limit reference level indicating a high risk of extinction. EBM sustainability reference points can be easily defined within this framework, and it allows to follow temporal trends in as indicators of ecosystem state (Levin et al., 2009). Externalities are trailed in a historical period 1924 to 1938 and for 1985-2010 with the German EEZ as reference area for plaice as a target species for fisheries in the southern North Sea, for benthic habitats affected by the fisheries, for a non-target by-catch species, thornback ray, and functional diversity in relation to catches obtained from the plaice fisheries as ES.

## Results and Discussion

During the entire period, ecosystem state was below the target reference level for all ecosystem components representing a state of chronic negative change except for plaice in the years 2008-2010, when fisheries was approaching MSY levels. Due to high fishing effort in the 1930's and after 1981, selected benthic communities and thornback ray were confronted a high risk of extinction. For benthic communities, exchange with less impacted sites is assumed to have replenished the more impacted sites, whereas thornback ray became locally extinct. The relationship between utilization of ES and its environmental costs, i.e. externalities, is not invariant, caused by changes in the ecosystem's carrying capacity and technological progress. Spatial management is proposed as one means to alleviate externalities while still exploiting ES. It is suggested that the target reference level is sufficient to meet requirements for Critical Natural Capital, thus linking the RERA concept and the economic concept of strong sustainability (Fig. 1).

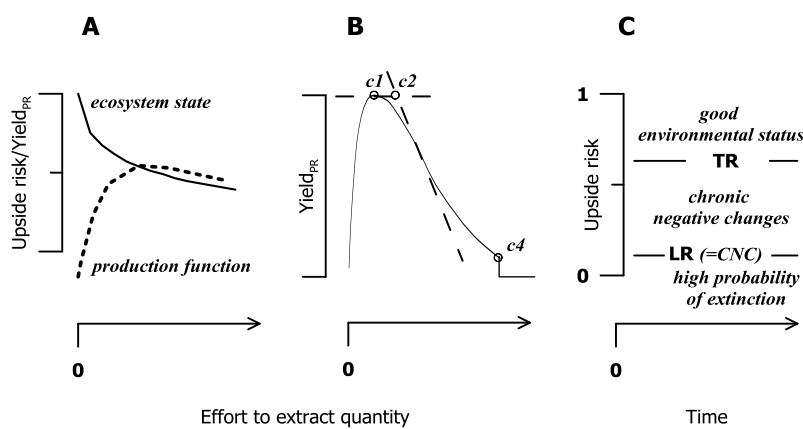


Fig. 1

The concept of reference in RERA: (A) Rationale for the RERA model reflecting a monotonously declining ecosystem state while the production function reaches some optimum. (B) Reference points in relation to production in a simplified yield-per-recruit model (YPR). C1 – Target reference point equivalent to Maximum Sustainable Yield (MSY), c2 – inflection point until which stock productivity is not severely impaired, c4 – Limit reference point equivalent to Maximum Sustainable Fishing Mortality (MSF). (C) Quality attributes for ecosystem state when upside risk is greater than the target reference point (TR), smaller than TR but greater than the limit reference point (LR) or smaller than LR. CNC = Critical Natural Capital level suggested equivalent to LR.

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