Ecological Indicators 72 (2017) 194–202

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Indicators of the ‘wild seafood’ provisioning ecosystem service based on the surplus production of commercial fish stocks

G.J. Piet[a,*], H.M.J. van Overzee[a], D.C.M. Miller[a], E. Royo Gelabert[b]

[a] Institute for Marine Resources and Ecosystem Studies (IMARES), Haringkade 1, 1976 CP, IJmuiden, The Netherlands
[b] European Environment Agency, Kongens Nytorv 6, 1050 Copenhagen K, Denmark

A R T I C L E I N F O

Article history:
Received 25 April 2016
Received in revised form 2 August 2016
Accepted 3 August 2016

Keywords:
Ecosystem services
Seafood provisioning
Sustainable exploitation
Fisheries management
Spawning stock biomass
Fishing mortality

A B S T R A C T

The ‘Wild Seafood’ Provisioning Service (WSPS), on which commercial fisheries rely, is probably one of the best studied marine ecosystem services due to its economic relevance and because extensive information sources exist for assessment purposes. Yet, the indicators often proposed are not suitable to describe the capacity of the ecosystem to deliver the WSPS. Therefore this study proposes surplus production (SP), a well-established concept in fisheries science, as the basis to calculate the capacity of marine ecosystems to provide the WSPS. SP is defined as the difference between stock production (through recruitment and body growth) and losses through natural mortality. This is, therefore, the production of the stock that could be harvested sustainably without decreasing the biomass. To assess the sustainability of the exploitation of the WSPS we also developed an indicator for this based on SP and compared it to existing fisheries management indicators. When both SP-based indicators showed a decreasing trend, contrasting with an increasing trend in the existing fisheries management indicators, the calculation of the SP-based indicators was scrutinized revealing that the weighting of the stocks into an aggregated indicator, strongly determines the indicator values, even up to the point that the trend is reversed. The aggregated indicators based on SP-weighted stocks can be considered complementary to existing fisheries management indicators as the former accurately reflect the capacity of the commercial fish to provide the WSPS and the sustainability of the exploitation of this service. In contrast the existing fisheries management indicators primarily reflect the performance of management towards achieving fisheries-specific policy goals.

1. Introduction

Ecosystem services are the final outputs or products from ecosystems that are directly consumed, used (actively or passively) or enjoyed by people (Fisher et al., 2009; Haines-Young and Potschin, 2013; Maes et al., 2013). Marine ecosystem services include provisioning services, such as wild seafood including fish and shellfish specified as “Nutrition” from “Wild animals and their outputs” in the Common International Classification of Ecosystem Services (CICES); regulation and maintenance services (such as the sea’s ability to absorb greenhouse gases); and cultural services (such as the availability of charismatic marine species to observe or to research). We get many benefits from these services such as nutrition, climate regulation and recreation.

The “ecosystem services” concept is essentially anthropocentric because, even though ecosystem characteristics, including structures, processes and functions, have the potential to deliver services (i.e. service “supply”), these only become services if there are people who directly utilise and thus benefit from them (i.e. service “demand”) (Fisher et al., 2009; Haines-Young and Potschin, 2013; Maes et al., 2013). This concept, however, can be used as a ‘common language’ to structure our thinking on the complex relationship between ecosystems and socio-technical systems, which is required for the conservation and best management of these ecosystem characteristics to support the sustained delivery of the services on which human well-being depends. In the ecosystem services ‘cascade’ model (de Groot et al., 2010; Haines-Young and Potschin, 2010; Maes et al., 2013), adopted by Liquete et al. (2013) for a review of marine and coastal ecosystem services assessments, the above-mentioned ecosystem characteristics underpin the CAPACITY of an ecosystem to provide services, where the functions that ultimately contribute to human well-being cause the FLOW of ecosystem services, and these, in turn, deliver societal

* Corresponding author at: Wageningen IMARES, P. O. Box 68, IJmuiden, 1970 AB, The Netherlands
E-mail address: gerjan.piet@wur.nl (G.J. Piet).

http://dx.doi.org/10.1016/j.ecolind.2016.08.003
1470-160X/

BENEFITS. Service benefits can then be expressed in monetary (i.e. for the fishers) or alternative values (e.g. nutritional for those eating the fish). This conceptual framework can, therefore, be used to structure the indicators or metrics required for an assessment that supports informed management decisions to enhance human well-being. The Liquete et al. (2013) review of marine and coastal ecosystem services showed that the few studies that deal with the assessment of marine ecosystem services have mainly focused on the 'Wild Seafood' Provisioning Service (WSPS), involving fisheries, probably due to its economic relevance and the existence of market prices to value it. According to this review, some of the most meaningful indicators of this service include: abundance or biomass of commercial marine living resources (i.e. CAPACITY), catches or landings (i.e. FLOW) and income from fisheries (i.e. BENEFIT). In this paper, we consider several of these indicators together with two newly developed indicators centred around surplus production to assess their performance in describing the WSPS and its exploitation by fisheries.

The abundance or biomass indicators proposed to assess the WSPS can be considered to represent the ecosystem capacity as, theoretically, all the biomass can be harvested. However, in doing so, the ability of the resource to generate more harvestable biomass through recruitment and/or growth may be compromised. As such it should be considered a "non-renewable resource with a renewable flow of services" (Barbier, 2012). Current fisheries management aims specifically to conserve this ability, which is effectively captured in one of the two indicators commonly used to report the status of commercial fish species, i.e. Spawning Stock Biomass (SSB), representing the amount of biomass of a fish stock above a certain age/size that is considered mature and thus contributing to recruitment (Myers and Barrowman, 1996). For a good capacity indicator we should distinguish between the part of the resource that can be sustainably harvested and the part required to sustain next year's recruitment. Only the former truly reflects the current fish resource's potential for WSPS delivery. We propose surplus production (SP), a well-established concept in fisheries science (Russell, 1931), as the basis to calculate such capacity indicator(s) for the WSPS.

Surplus production is defined as the difference between stock production (through recruitment and body growth) and losses through natural mortality. This is the production of the stock that could be harvested without decreasing the biomass, i.e. if removals can be replaced by stock production each year, the fishery is sustainable (Graham, 1935). Fished populations are more dynamic than unfished populations, with a higher turnover of individual fish as the older fish are replaced by younger, faster growing fish. The environment of fish is very rarely static with conditions in the aquatic environment varying substantially over time. This varying environment interacts with the complex biological processes affecting surplus production levels through variability in growth rates, recruitment, and natural mortality rates. Surplus production, therefore, appears to be the best indicator of the capacity of the fish stock to deliver the WSPS. Hence, in this study we explore two SP-based indicators to describe the supply-side of the WSPS and we assess their suitability to inform ecosystem-based fisheries management towards a sustained delivery of this service.

Fish catches or landings (as proposed by Maes et al., 2013) are indicators associated with the flow of the WSPS. This flow is determined by a highly selective fishing activity reflecting, e.g., quota allowances, which is why these indicators may not show the full potential of the ecosystem to provide the service (Hattam et al., 2015), nor whether this provision is sustainable. Moreover, fishing activities and landings do not necessarily reflect any accompanying decline in fish stocks, but rather may just reflect changes in human preferences (Hattam et al., 2015) or societal decisions aimed at, e.g., achieving conservation targets. As such, the most common fisheries indicator, i.e. landings, which is catch minus the discards, relates to the "demand" side for ecosystem services assessment (i.e. by representing how much of the flow is actually consumed, used or enjoyed by people) rather than to the "supply" side, i.e. to the ecosystem's potential for service delivery, for which we propose SP as the preferred indicator. The ratio of SP/landings, however, reflects to what extent the exploitation of the ecosystem's capacity is sustainable. This ratio can be used to comprehensively inform policy aimed at sustainable exploitation of the marine resources as well as a sustained delivery of ecosystem services (European Commission, 2011) on the performance of fisheries management. As such, we will explore in this paper if this ratio can provide anything that complements the information provided by existing fisheries management indicators.

2. Material & methods

This study introduces three potential indicators for the WSPS: surplus production (*SP*) representing the capacity of the ecosystem to deliver the service, and two metrics reflecting the sustainability of the exploitation of the food provisioning capacity (*SFP*) and management performance to achieve this sustainability (*MPS*), but which differ in how they are calculated across the whole resource as they represent different perspectives (respectively food provisioning perspective and management performance perspective). A simple way to calculate surplus production for a single stock, requiring any type of assessment model output, is to start from the basic equation that calculates the change in fish stock biomass:

$$B_{stock,y+1} - B_{stock,y} = (recruitment + body\ growth) - natural\ mortality - C_{stock,y}$$

and rearrange this into

$$SP_{stock,y} = (B_{stock,y+1} - B_{stock,y}) + C_{stock,y}.$$

Where $B_{stock,y}$ represents the biomass of a specific stock in year y, '*recruitment*', '*body growth*' and '*natural mortality*' are components of net stock production due to natural processes, i.e. *SP*, and '*catch*' ($C_{stock,y}$) represents the impact of the fishery as removals from the stock. In practice, the data often only represents the landings (*L*), which is catch minus the discards.

Total SP for a specific year *y* in any marine ecosystem/region is then the aggregate across all fish stocks in that ecosystem/region.

$$SP_y = \sum_{i=stock}^{n} SP_{stock,y}$$

And the two metrics that reflect the sustainability of the exploitation of the food provisioning capacity:

$$SFP_y = \frac{SP_y}{\sum_{i=stock}^{n} L_{stock,y}}$$

$$MPS_y = \frac{\sum_{i=stock}^{n} SP_{stock,y}/L_{stock,y}}{n}$$

which only differ in the method of aggregation across stocks, i.e. for SFP each stock is weighted by their contribution to SP, while MPS is based on an aggregation where every stock is equally important.

In addition we present three indicators which are based on existing fisheries management indicators and are often used to inform policy on what are considered the main aspects of stock status but are now calculated to reflect the status of all marine species that contribute to the WSPS, i.e. all commercial (shell)fish stocks. To that end the following aggregate indicators (i.e. across stocks) are