Marine Pollution Bulletin 133 (2018) 53–64

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

The impact of seaweed cultivation on ecosystem services - a case study from the west coast of Sweden

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ARTICLE INFO

Keywords:
Aquaculture
Seaweeds
Kelp
Saccharina latissima
Environmental impact
Ecosystem services

ABSTRACT

Seaweed cultivation attracts growing interest and sustainability assessments from various perspectives are needed. The paper presents a holistic qualitative assessment of ecosystem services affected by seaweed cultivation on the Swedish west coast. Results suggest that supporting, regulating and provisioning services are mainly positively or non-affected while some of the cultural services are likely negatively affected. The analysis opens for a discussion on the framing of seaweed cultivation – is it a way of supplying ecosystem services and/or a way of generating valuable biomass? Exploring these framings further in local contexts may be valuable for identifying trade-offs and designing appropriate policies and development strategies. Many of the found impacts are likely generalizable in their character across sites and scales of cultivation, but for some services, including most of the supporting services, the character of impacts is likely to be site-specific and not generalizable.

1. Introduction

Seaweed aquaculture has been pointed out as an alternative or complement to terrestrial biomass production (Stévant et al., 2017; Barbot et al., 2016). In contrast to land-based agriculture there is no need for fresh water and arable land for the cultivation of seaweeds and in most cases, fertilization is not needed. Cultivation of aquatic plants is a large industry globally with total production at 27 million tons in 2014 (FAO, 2016). However, in Europe the industry is still young and the main part of production is in Asian countries, dominated by China and Indonesia who together produce 91% of the world market supply (FAO, 2016). In Sweden, seaweed cultivation is currently limited to test sites of a few hectares.

Seaweed cultivation is an industry with the potential to contribute to economic activity as well as the provisioning of ecosystem services. From an industrial perspective, the biomass can potentially be used in a variety of ways, including the development of complex materials, pharmaceuticals, extraction of food or feed ingredients, and biofuels. Studies have also shown that the cultivation leads to significant uptake of dissolved nitrogen (N) and phosphorous (P) (e.g. Holdt and Edwards, 2014; Pechsiri et al., 2016), which is particularly relevant along the eutrophicated parts of the European coasts.

Aquaculture development is increasingly gaining attention and support by policy makers, as a means for meeting development targets as well as sustainability targets (EU COM, 2012; EU COM, 2014). In Sweden, the cultivation of seaweed has been identified by Swedish Agency for Marine and Water Management (2015) as a potential means to contribute to the program of measures to reach Good Environmental Status (GES) according to the Marine Strategy Framework Directive (EC, 2008).

Adequate aquaculture practices which balance economic, environmental and social performance could provide a benchmark for future development supporting political frameworks such as the MSFD and the Marine Spatial Planning Directive (EC, 2014). However, emerging industries can result in unforeseen ecological and societal consequences (Cottier-Cook et al., 2016). Given the early life of this industry in Europe, careful impact studies are needed. Potentially, the cultivation of seaweeds can have both negative and positive effects on the environment, but these effects remain to be specifically identified and assessed.

Different perceptions of economic, social and environmental consequences from various aquaculture development trajectories may lead to controversies (Baulcomb, 2013). Such controversies may prevent a sustainable future expansion of the sector (Krause et al., 2015). In order to illuminate consequences of aquaculture development and facilitate trade-offs between different interests associated with e.g. spatial

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https://doi.org/10.1016/j.marpolbul.2018.05.005
Received 10 October 2017; Received in revised form 24 April 2018; Accepted 3 May 2018

Table 1
Ecosystem services in Kattegatt/Skagerrak, status of the service; good (G), moderate (M), and poor (P) (Bryhn et al., 2015).

	Ecosystem service	Status	Motivating factors for status classification
Supporting	S1. Biogeochemical cycling	M	Oxygen cycle, nutrient status, carbon cycle (low Ph).
	S2. Primary production	M	Elevated phytoplankton concentrations, loss of eelgrass and macroalgae.
	S3. Food web dynamics	P	Fish populations, bottom fauna, habitats.
	S4. Biodiversity	M	Habitats, species abundance.
	S5. Habitat	P	Biological oxygen demand, bottom fauna, physical disturbance.
	S6. Resilience	M	Observed regime shifts, loss of habitats and biodiversity.
Regulating	R1. Climate and atmospheric regulation	M	Marine regulation of climate has good potential, but not sufficient given human greenhouse gas emissions.
	R2. Sediment retention	M	Pressures from bottom trawling and shipping, coastal zone vegetation.
	R3. Regulation of eutrophication	M	Coastal and pelagic nutrient concentration.
	R4. Biological regulation	M	Deterioration of top-down food web dynamics, increased transport of parasitic microorganisms from agricultural land to marine systems due to climate change (precipitation patterns).
	R5. Regulation of toxic substances	M	Seafloor activities release embedded toxic substances, observed concentrations in commercial fish species and sea birds.
Provisioning	P1. Food	P	Current status of commercial fish species abundance.
	P2. Raw material	P	Current status of commercial fish species abundance (e.g. for feed).
	P3. Genetic resources	G	Genetic material from within and between species biodiversity. Potential supply exceeds demand.
	P4. Chemical resources	G	Resources for e.g. pharmaceuticals and food ingredients. Potential supply exceeds demand.
	P5. Ornamental resources	G	Current use is mainly sustainable. Potential supply exceeds demand.
	P6. Energy (from biomass only)	G	Current production is mainly sustainable. Potential supply exceeds demand.
	P7. Space and waterways*	G	Space is currently abundant but increased competition expected.
Cultural	C1. Recreation	M	Eutrophication status, abundance of recreational fish species, satisfaction of recreationists (survey), bathing water quality.
	C2. Aesthetic values	M	Litter abundance, probability of oil spills.
	C3. Science & education	G	Increasing scientific interest in marine environments.
	C4. Cultural heritage	M	Loss of culturally important activities in coastal villages.
	C5. Inspiration	G	Inspiration to e.g. culture. Loose connection to water quality.
	C6. Natural heritage	M	Related to current water quality status.

*Not included in Bryhn et al. (2015) due to its abiotic character. Classification from Swedish EPA (2008).

allocations, ecosystem services assessment is a useful tool through its ability to visualize the link between human well-being and the environment (Baulcomb, 2013). While a number of studies have emphasized individual ecosystem services such as eutrophication mitigation (Holdt and Edwards, 2014; Kim et al., 2015, 2017) and carbon sequestration (Chung et al., 2011; Duarte et al., 2017), studies that take on a holistic ecosystem services assessment for seaweed cultivation are to our knowledge not existing in the scientific literature. Cabral et al. (2016) assess provisioning (Food provision and Raw material) and cultural (Cultural heritage and identity, Cognitive benefits, Recreation and Notable biodiversity) ecosystem services affected by seaweed farms along the French Atlantic coast. The study highlights the difficulties involved with assessing regulating and maintenance (supporting) services. Given the data-driven method of the study, these services were excluded from their analysis due to a lack of suitable indicators. The study further highlights that more research is needed concerning the “production” of (positive impact on) ecosystem services associated with seaweed farming.

This paper makes a contribution to the field by presenting an extensive qualitative assessment of ecosystem services being positively or negatively affected by seaweed cultivation, including regulating and supporting services along with provisioning and cultural services. This type of holistic ecosystem services assessment can feed into cost-benefit analysis and builds up knowledge as part of an array of various assessment tools, which together form a sustainability assessment (Scharin et al., 2016). The study is set up using a case with active seaweed cultivation along the Swedish west coast, in the Skagerrak basin. The biochemical characteristics as well as the human use of this coastal environment are similar to that of many temporal regions in the North Atlantic and North Pacific coasts, being suitable for seaweed aquaculture.

2. Method

Ecosystem services can be defined as the ecosystem's direct and indirect contributions to human well-being (TEEB, 2010). The assessment frameworks around the term have developed over the last decade. Our method is based on:

1) Using a specific classification scheme (e.g. MA, 2005; TEEB, 2010; CICES – EU COM, 2013); in our case, a gross list of marine ecosystem services in Kattegat and Skagerrak from Bryhn et al. (2015) is used. This list is based on supporting, regulating, provisioning and cultural services, in line with MA (2005) and TEEB (2010) but with specific services pointed out for the marine ecosystems of the Swedish coast.