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A GIS-based tool for an integrated assessment of spatial planning trade-offs with aquaculture

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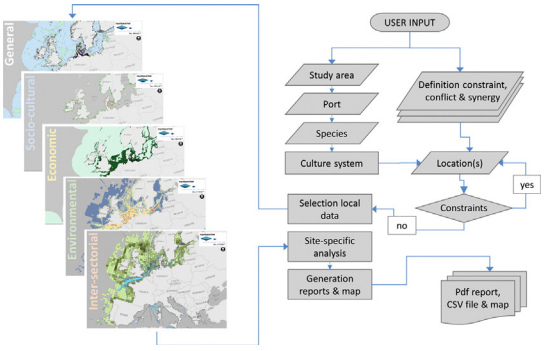
HIGHLIGHTS

- The selection of aquaculture sites in a multi-use context requires integrative tools.
- The new AquaSpace tool allows for a spatially explicit and integrated assessment.
- Assessment indicators cover economic, environmental and social effects.
- Tool outputs can facilitate marine spatial planning and trade-off discussions.
- The GIS AddIn is freely available and builds on open datasets at European scale.

GRAPHICAL ABSTRACT



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ABSTRACT

The increasing demand for protein from aquaculture will trigger a global expansion of the sector in coastal and offshore waters. While contributing to food security, potential conflicts with other traditional activities such as fisheries or tourism are inevitable, thus calling for decision-support tools to assess aquaculture planning scenarios in a multi-use context. Here we introduce the AquaSpace tool, one of the first Geographic Information System (GIS)-based planning tools empowering an integrated assessment and mapping of 30 indicators reflecting economic, environmental, inter-sectorial and socio-cultural risks and opportunities for proposed aquaculture systems in a marine environment. A bottom-up process consulting more than 350 stakeholders from 10 countries across southern and northern Europe enabled the direct consideration of stakeholder needs when developing the GIS AddIn. The AquaSpace tool is an open source product and builds in the prospective use of open source datasets at a European scale, hence aiming to improve reproducibility and collaboration in aquaculture science and research. Tool outputs comprise detailed reports and graphics allowing key stakeholders such as planners or licensing authorities to evaluate and communicate alternative planning scenarios and to take more informed decisions. With the help of the German North Sea case study we demonstrate here the tool application at multiple spatial scales with different aquaculture systems and under a range of space-related development constraints. The computation of these aquaculture planning scenarios and the assessment of their trade-offs showed that it is entirely possible to identify aquaculture sites, that correspondent to multifarious potential challenges, for instance by a low conflict potential, a low risk of disease spread, a comparable high economic profit and a low

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impact on touristic attractions. We believe that a transparent visualisation of risks and opportunities of aquaculture planning scenarios helps an effective Marine Spatial Planning (MSP) process, supports the licensing process and simplifies investments.

Software availability

Name of software: AquaSpace tool - a GIS AddIn
Developers: Antje Gimpel, Sandra Töpsch, Vanessa Stelzenmüller
Email: antje.gimpel@thuenen.de
Year first available: 2017
Operating System: Microsoft Windows 7, Windows 8/8.1 (32 or 64 bit) or Windows 10
Processor/CPU: 2.7 GHz Intel Core i5 processor or equivalent (4 cores) (hardware below/above will increase/decrease tool run times)
System RAM: 4 GB total minimum, 16 GB recommended
Windows Feature .NET Framework: .NET 4.6 Framework
ESRI ArcGIS license required: ArcGIS Desktop Basic, Standard or Advanced with Spatial Analyst Extension
Python Environment: Standard Python library 32bit of ArcGIS installation 10.3 and higher
Program size: 1.7 MB; GDB 400 MB
Availability: https://gdi.thuenen.de/geoserver/sf/www/aqspce.html
Cost: nil

1. Introduction

Worldwide the demand for protein from aquaculture is increasing, triggering an inevitable expansion of the sector in coastal and offshore waters. (Maritime) aquaculture production may contribute to food security and relieve some of the pressures on wild stocks (FAO, 2014). In Asia, Norway or Canada aquaculture has already become an important human activity in coastal waters in terms of spatial expansion and economic viability (EEA, 2017). These developments take place at a much slower rate in European member states. As a result, European aquaculture as a future management objective addressing sustainable use is currently a matter of debate (EC, 2017). Further steps towards the Europe 2020 strategy should involve efforts to create a stable environment attractive to investors (Remotti and Damvakerak, 2015). As a management tool, Marine Spatial Planning (or Maritime Spatial Planning; MSP) can allocate space for upcoming activities such as aquaculture at sites with both favourable operational characteristics as well as lower potential for conflict with other sectors (Christie et al., 2014; Guerry et al., 2012; Stelzenmüller et al., 2017). MSP aims to integrate ecological, social, and economic interests, interactions among human activities, regardless of whether cross-border or inter-sectorial nature, whether conflict or synergy (Ehler and Douvere, 2009; Foley et al., 2010; Halpern et al., 2008). Since MSP is a public process, the implementation of strategic plans integrates greater accountability and transparency of decision-making by including a wide range of stakeholders from all sectors (Ehler and Douvere, 2009; Gilliland and Laffoley, 2008; Stelzenmüller et al., 2013; Wever et al., 2015). The MSP process is characterized as dynamic and evolving, integrating multiple feedback loops and permanent revisions (Ehler and Douvere, 2009). It can therefore increase the effectiveness of investments. MSP was identified by the European Commission as the cross-cutting policy tool that contributes to "sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources" while "applying an ecosystem-based approach as referred to in Article 1 (3) of Directive 2008/56/EC with the aim of (…) achievement of good environmental status" (EC, 2014b). In Art. 51 of EU regulation no 508/2014 "the identification and mapping of the most suitable areas for developing aquaculture" is fostered. The regulation establishes the European Maritime and Fisheries Fund (EMFF) in support of MSP, promoting a balanced and inclusive territorial development of fisheries and aquaculture areas (EC, 2014a).

The development of aquaculture should follow an Ecosystem Approach to Aquaculture (EAA) which comprises six steps (FAO and World Bank, 2015). Scoping (i) includes the establishing of the relevant geographical scales or ecosystem boundaries and the relevant stakeholders and institutions within each. The Identification of issues and opportunities (ii) integrates the selection of criteria thresholds to address the issues including considerations of risks (risk assessment and risk mapping). Subsequently, the maximum production is determined during carrying capacity estimation (iii), whereas the allocation of area/user access (iv) and/or management rights (consultation with stakeholders and setting operational and management objectives) are conducted according to this agreed production. Based on the results, the final management plans are developed (v). Their implementation and compliance is monitored (vi) and evaluated regularly, leading to planning and implementation adjustments – within the scope of the initially assessed opportunities and risks.

As yet, integrating such frameworks in MSP processes constitutes a challenge for European countries. In support of EAA, spatially explicit methods and tools are needed to assess both the environmental opportunities and risks of spatial planning options within important European ecosystem types. Some practical solutions are already available to support MSP. The number of spatially explicit tools highlights the usefulness of Geographic Information System (GIS)-based tools for MSP (Pınarbaşı et al., 2017; Stelzenmüller et al., 2017; Stelzenmüller et al., 2013). Nevertheless, specific tool functions are needed to support the planning and management of sustainable aquaculture development. Each step of the EAA framework can benefit from tool functions addressing the key issues which constrain or strengthen the growth of aquaculture.

In the course of the EU project AquaSpace the current and future obstacles for the expansion of aquaculture has been elaborated in nine case studies at regional levels with a total of 305 experts and stakeholders from the fields of nature conservation, governance, industry, science and administration. The outcomes (issues mentioned) of those regional stakeholder workshops have been pooled and ranked by the number of times case study outcomes included the same issue (Gimpel et al., 2016). The results showed that the majority of constraints were related to the EAA step of opportunity and risk assessment with a focus on economic and market concerns (Fig. 1). Further it became clear that unfavourable production conditions or a negative image of both aquaculture production and aquaculture products push back potential farmers and investors. Environmental threats such as high potential of pollution e.g. through faecal contamination were issued as being of nearly equal importance. This was followed by policy and management issues mostly related to low accountability in aquaculture and other sector issues (e.g. insufficient marine spatial management) (Gimpel et al., 2016).

In detail, the study revealed a need for integrated planning tools allowing i) the explicit consideration of economic and market issues; ii) a spatially explicit assessment of cumulative risk and an analysis of conflicts and synergies between sectors; iii) a comprehensive assessment of environmental effects at different spatial scales; and iv) to be easily handled by end-users such as industry and policy-makers. Hence, a clear gap was identified regarding an integrative decision support tool, which facilitates a systematic process for calculating and

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