How coastal strategic planning reflects interrelationships between ecosystem services: a four-step method

Li, R., Woltjer, J., van den Brink, M. and Li, Y.

Ruiqian Li, Johan Woltjer, Margo van den Brink, Yongfu Li (2016) How coastal strategic planning reflects interrelationships between ecosystem services; *Marine Policy*, 70, pp. 114–127.

1. Introduction

Coastal areas are difficult to manage because they involve dynamic natural systems that are increasingly under pressure from expanding socio-economic systems (Turner, 2000). One central challenge for coastal management and planning is to develop innovative approaches for managing diverse uses of ecosystems through a range of activities (Lester et al., 2010). To meet this challenge, an ecosystem services (ESs) approach has been increasingly adopted in ecosystem-based coastal management, marine spatial planning and strategic environmental assessment (e.g., Böhnke-Henrichs et al., 2013; Partidario & Gomes, 2013). The concept of ESs helps us assess how these services benefit humanity and how human actions generally impact ecosystems and the delivered ESs (Carpenter et al., 2009; MA, 2005). The Millennium Ecosystem Assessment (2005) developed four broadly employed ES categories to help understand the above question: provisioning, regulating, cultural and supporting services.

A key difficulty in integrating these services into natural resource management and planning is their complex and dynamic interrelationships in terms of trade-offs and synergies. Trade-offs arise when the attempt to optimize a single service leads to reductions or losses of other services (Holling & Meffe, 1996). A typical example would be a situation where offshore wind farm development enhances energy production but simultaneously has negative impacts on biodiversity (Busch et al., 2011). ES synergies often arise when multiple services are enhanced simultaneously (Raudsepp-Hearne et al., 2010). For instance, marine protection areas maintain habitats while also producing important a nursery function for certain fish (Shen et al., 2011). These interrelationships usually emerge when several services respond to a driver modified by human management or due to the interplay between ESs (Bennett et al., 2009). It has been argued that more clarity on these interrelationships may reduce the risk of negative trade-offs and enhance potential win-win scenarios (Bennett et al., 2009; Kelble et al., 2013; Lester et al., 2013).

The consideration of ESs and their interrelationships in policy documents has been increasingly studied in environmental and planning literature (Hansen et al., 2014; Sitas et al., 2014; Turnpenny et al., 2014). In particular strategic plans are concerned with coordinating diverse preferences and spatial uses of ESs within certain ecological and physical constraints. Scholars have argued that strategic plans function as political documents that are important in framing human-nature relationships and addressing anthropocentric pressures and ES dynamics (Hansen et al., 2014; Wilkinson et al., 2013). Previous studies have shown that there are trade-offs and synergies mentioned in strategic plans, which are usually in relation to, for instance, competing/multiple spatial uses, nature conservation, and environmental pollution (Piwowarczyk et al., 2013; Wilkinson et al., 2013). Strategic plans can restrict a certain ES and in this way potentially eliminate conflicts (e.g. restrict tourism and leisure to protect tranquility and biodiversity; Piwowarczyk et al., 2013), or refer to indirect and multiple effects of preserving a kind of ESs. For instance, some plans have shown a favor of protecting water supply and later recognized additional services such as recreation and climate regulation (Wilkinson et al., 2013).

The literature confirms that activities, impacts, trade-offs and synergies are key elements represented in many policy documents including strategic plans (e.g. Potts et al., 2014; Turnpenny et al., 2014; Wilkinson et al., 2013). It has also been found that a clarification of the integration of ES interrelationships may improve the quality of strategic plans and decision-making processes (Piwowarczyk et al., 2013; Sitas et al., 2014). However, the multiple ES-interrelations and ES trade-offs are often considered implicitly while making decisions on planning and management (Lester et al., 2013). This is particularly true for coastal strategic planning, especially when both land and sea uses that cause off-site and long-term effects make ES interrelationships uncertain and complex (Halpern et al., 2008; Rodríguez et al., 2006). To improve the ability of coastal strategic planning to be more sustainable and adaptive, a structured method is needed to clarify the integration of ES interrelationships in strategic planning documents.

Current approaches for measuring ES trade-offs and/or synergies can be broadly grouped into four main approaches: mapping (e.g. Costanza et al., 1998; Crossman et al., 2013; Martínez-Harms & Balvanera, 2012), modeling (e.g. Chisholm, 2010; Swallow et al., 2009), social-survey analysis (e.g. Hauck et al., 2013; Potts et al., 2014), and content analysis (e.g. Piwowarczyk et al., 2013; Wilkinson et al., 2013). In addition, a large number of recent studies have used hybrid methods of mapping and modeling (e.g. InVEST and ARIES; Nelson et al., 2009; Villa et al., 2009), or mapping and social-survey analysis (e.g. SolVES; Sherrouse et al., 2011). Such approaches have also been employed in the field of coastal and marine management to ascertain the influence of diverse activities on key ESs (e.g. Brown et al., 2001; Busch et al., 2011; Martinet & Blanchard, 2009).

Among those approaches, content analysis could be an important starting point for evaluating the quality of strategic plans concerning ES thinking (Wilkinson et al., 2013), as it can reveal in a transparent manner which ES and their interrelationships have been included. Moreover, content analysis may enable further discussion on the continuity of attention to ES interrelationships within and between strategic plans. The analysis may also lead to a discussion on links between awareness as presented in plans and operational processes (Hansen et al., 2015). Previous content analysis approaches are mainly used for identifying ESs themselves in policy documents. There is little systematic and aggregative analysis of how ES interrelationships are framed in policy language, particularly in coastal planning discourse.

The objective of this paper is therefore to present a four-step method, based on content analysis, to assess ES interrelationships in coastal strategic planning documents. In this way, this paper aims to clarify ES interrelationships formulated in policy language, and it aims to provide insights into complex aspects of the coastal environment. Such clarification may enable strategic planning to be more adaptive and sustainable in coastal areas. The following section will explain the four-step method that we have formulated. Next, Jiaozhou Bay in China is used as a case to show the application of the method in practice. Then we will reflect on our method from an empirical perspective and a methodological perspective.

2. A four-step method to analyze ES interrelationships

Step 1: Selecting coastal strategic planning documents

In the literature, other authors typically start a content analysis of strategic planning documents with a demarcation of the research scope (Hansen et al., 2015; Sitas et al., 2014). So which coastal strategic plans are taken as the focus of research, for which period and why? In this context, previous studies have noted that a content analysis of coastal strategic planning documents is conditioned by the fact that diverse sorts of plans often have been developed within different government agencies (Piwowarczyk et al., 2013). Scholars have also noted that the various involved government agencies usually have different foci of interest and a restricted concern of ESs (Lester et al., 2013). In addition, previous studies suggest that in particular strategic plans that have an overarching view concerning ESs, and that therefore have a broad influence on more specific spatial plans, are helpful to analyze the discursive representation of ESs (Hansen et al., 2015). Finally, previous studies usually focus on a certain progressive period, within which ES-related thinking has appeared in policy discourse; strategic plans that have been formulated within such a period are likely to embed ESs, trade-offs and synergies (Turnpenny et al., 2014). To summarize, for this initial step of demarcating the research scope, it is important to select documents based on the following criteria: (1) documents that have been developed within different key sectors, including urban planning, economic, environmental and water sectors; (2) documents that have an overarching and influential view on the allocation of ESs (e.g. guide other sub-plans, or related policies refer to these documents often); (3) documents that make efforts to involve innovative thinking and arrangements for ES governance (e.g. promote innovative instruments such as payment for ESs).

Step 2: Identifying ESs

Step 1 serves to formulate a database of relevant coastal strategic planning documents. Before being able to analyze interrelationships among ESs, the identification of which ESs are actually mentioned in the selected plans is an essential foundation (Hauck et al., 2013). It has been argued that a poor identification of ESs often results in insufficient discussion for uncovering trade-offs and realizing synergies (Hauck et al., 2013; Piwowarczyk et al., 2013). Against this background, content analysis accompanied by text interpretation is generally seen as a useful method to identify ESs (Hansen et al., 2015; Wilkinson et al., 2013). To better understand the inclusion of ES interrelationships, the second step therefore aims at identifying coastal ESs themselves by employing content analysis accompanied by text interpretation.

According to Wilkinson et al. (2013), to enable coding consistency across different plans, it is important to design a coding system. This paper proposes a ES coding system (Table 1) based on the four standard classification system put forward in the Millennium Ecosystem Assessment (MA, 2005). Considering the particular ESs produced by coastal and marine ecosystems, the coding system has been specified and complemented with a range of concepts and examples from other research (Li et al., 2015). There are several reasons for choosing the MA classification. First, the four categories play a fundamental role because other modified classification schemes have widely employed them as a foundation (e.g. Atkins et al., 2011; Haines-Young & Potschin, 2010). Second, in order to qualitatively identify how activities and ES interrelationships may be portrayed in strategic planning, scholars generally hold the view that it is appropriate to adopt the MA typology which has been used as a basis for prompting the discussion of social preference and values towards the environment (Bryan et al., 2010). This classification would thus serve our research goals better than others, which aim at valuing ESs (Atkins et al., 2011; Haines-Young & Potschin, 2010), uncovering the processes of delivering benefits (De Groot et al., 2002; Wallace, 2007), analyzing spatial characteristics (Costanza, 2008), or distinguishing between ES excludability and rivalness (Fisher et al., 2009).

A third reason to adopt the MA classification concerns the supporting services. Current studies of valuation usually exclude supporting services or subsume them in the group of regulating services to avoid double counting of ES values (Hein et al., 2006; Turner et al., 2003). However, in our case, double counting of supporting services should not be an issue since no valuation will be made in the method. Recent research (Hauck et al., 2013; Ring et al., 2010) has suggested that it is important to consider supporting services and their institutional environment, as some supporting services (e.g. habitat protection, biodiversity and resilience maintenance) have become inherent to political discourses across the world. Fourth and finally, to gain a broad view of how coastal and marine resources are used and affected by human activities through strategic planning, some traditional abiotic services (regardless of ecological production processes) are considered to be important and inclusive. As the provisioning group under the MA classification shows flexible space for inclusion, space for navigation, industrial development and infrastructure and offshore wind have been added to this group and in this way also enrich the MA classification, following, for example, Atkins et al. (2011).

<Insert Table 1>

Subsequently, each selected coastal plan can be examined sentence by sentence in order to identify the coastal ESs listed in the coding system. If a phrase or a sentence is referred to in a way that links it to the meaning of an ES concept or that contains any example stated in the coding system (Table 2), it should be marked. For example, if a plan prescribes the encouragement of overseas fishery or the establishment of an offshore fishing base, this should lead to a code ‘fishery and seafood’ under the category of provisioning services. To easily code and aggregate terms and phrases in documents, computer-aided tools for qualitative data analysis such as NVivo software and Atlas.ti software can be used (Weitzman & Miles, 1995). In any case, it is important to note and summarize references/codes to ESs from the documents. This identification is helpful to “explore word usage or discover the range of meanings that a word can have in normal use” (Hsieh & Shannon, 2005). The occurrence counting of ESs could be conducted to understand the different extents of ES emphases. However, the objective of this step is not quantifying ESs, but contextualizing ES codes to analyze their trade-offs and synergies.

Step 3: Identifying drivers, ESs and their effects

The third step is aimed at answering the ‘how’ question, that is, identifying activities that act as drivers, affect ESs and their links. This step typically focuses on coding texts on a more aggregated level and creating themes to link and describe the underlying meanings (Graneheim & Lundman, 2014). Screening and coding should thus focus on different types of activities (i.e. key drivers) that refer to the ESs as identified in Step 2. Direct and indirect effects between a type of activity and ESs can be coded and grouped into a theme, which can then be named as one type of interrelationship.

To better identify the effects and properly manage trade-offs and synergies, various scholars have argued that it is critical to understand the cause of the relationships, that is, the cause-effect mechanisms (Bennett et al., 2009; Gari et al., 2015; Nelson et al., 2009). The aggregation of the interrelationships should rely on a clear cause-effect mechanism. In this context, the typology promoted by Bennett et al. (2009) makes the following distinction: (1) “effects of drivers on multiple ESs”; (2) “interactions among ESs”. These mechanisms cover a variable relationship which goes beyond a linear relationship between ecosystem structure (e.g. land cover) and ESs. The typology of Bennett et al. (2009) has become widely accepted in the literature, and offers a useful way to further substantiate Step 3. Specifically, the typology indicates that the direction of the effect is either from drivers to ESs or from ES to ES, that is, bidirectional or unidirectional. This may be interpreted through the certain texts. Generally, words such as “cancel,” “forbidden,” “limit,” “control,” “reduce”, or “avoid” can be considered as negative effects. Narratives that include words such as “enhance,” “stimulate,” “provide,” “explore,” “preserve,” “restore,” “create,” “improve,” “benefit”, and “guarantee” indicate typical positive effects. For instance, if a plan prescribes that measures for restoring natural properties of aquiculture ponds should be taken to guarantee sea water quality, this will lead to a negative effect of the measures on the provisioning service of seafood. Meanwhile, the reduction of seafood from aquiculture may be interpreted as a positive influence on the service of water purification.

However, when carrying out a content analysis it is first of all important to keep in mind that this involves normative judgments on whether a word is interpreted as indicating positive effects or negative effects on ESs. It is impossible and undesirable for a content analysis not to involve subjectivity based on the researcher's own knowledge and view. The key point here is that "the researcher must 'let the text talk' and not impute meaning that is not there" (Graneheim & Lundman, 2004). For instance, in the case of creating industrial areas in a spatial plan, "create" directly means a promotion of using the provisioning service of spatial resource for industrial production. "Create" here may also be perceived as negative impacts on supporting and regulating services. If the texts did not mention the impacts on other services, however, the latter negative judgement should be avoided. A second key point to keep in mind is that the importance of coding the relationships between drivers and ESs lies not in quantitative results (e.g. the number of times the relationships appear). Rather, the aggregated-level coding process focuses on specific concepts of services, words and terms regarding impacts, and sentence constructions. The aim here is to represent the latent content concerning drivers and ES interrelationships, which can be seen as the "relationship aspects" of codes in content analysis (Graneheim & Lundman, 2004). Therefore it is more appropriate to show the conceptual and aggregated relationships in a qualitative manner.

Step 4: Constructing relational diagrams

Although previous studies employed diverse quantitative and qualitative methods to analyze cause-effect mechanisms, the majority of these studies proved that it is useful to present the results of the interrelationships in various graphical ways (e.g. King et al., 2015; Martín-López et al., 2014; Nelson et al., 2009). It has been argued that visualization can offer a structured and straightforward approach to diverse actors for understanding ES interactions, communicating conflicting interests and discussing solutions (King et al., 2015; Raudsepp-Hearne et al., 2010). Therefore, the fourth step is aimed at depicting the identified interrelationships from Step 3 in a graphical way.

While the mechanisms of Bennett et al. serve as a guidance for Step 3, Step 4 aims to establish relational diagrams following the way in which Bennet et al. (2009) proposed to structure driver-ESs and ES-ES mechanisms. These relational diagrams use symbols to indicate drivers, effects and services (Bennett et al., 2009). Figure 1 shows some examples of relational diagrams, consisting of basic symbols to structure ES relationships. In each relational diagram, a topmost rectangle can be used to show the driver affecting ESs and the rectangles below are ESs; the solid arrow can indicate a positive influence, while the dotted arrow can indicate a negative effect; arrows may illustrate the directions of effects. Interrelationships can be further classified in terms of the attributes of a driver (the horizontal axis) and the degree of ES interactions (the vertical axis). The set of coordinates formulated by Bennett et al. (2009) is useful to show the attributes of drivers and interconnections. Specifically, drivers can be categorized into two groups (see Figure 1): a shared driver that directly affects multiple ESs; and an independent driver, which has direct impact on one service and indirect impacts on other services. The judgment of the degree of interactions is general, namely the more ESs involved, the more and stronger the interactions will be.

<Insert Figure 1>

To better understand trade-offs and synergies among a range of identified interrelationship themes, relational diagrams can be demonstrated in two groups. A trade-off group can consist of diagrams about managing services that may co-vary negatively (more of one means less of another; Ring et al., 2010), while a synergy group can involve co-varying positively (more of one means more of another; Ring et al., 2010) as a result of certain activities.

3. The application of the four-step method to Jiaozhou Bay

The four-step method was applied to the case of Jiaozhou Bay in China to assess its related coastal strategic plans. Jiaozhou Bay is located on the southern coast of Shandong Peninsula in East China (Figure 2). The case is well-known for the diverse ESs for regional development and the severe conflicts of natural resources caused by intensive and long-term anthropogenic pressures (Ge & Zhang, 2011; Zhao et al., 2005). There are various policy documents and scientific reports available for a better understanding of how ES interrelationships are presented in coastal strategic plans.

<Insert Figure 2>

3.1 Selecting strategic plans

The first step was undertaken by focusing on coastal strategic plans that were formulated during the period 2008 – 2013, which is known to be a progressive period in which ecological issues and initiatives have been increasingly emphasized in the Jiaozhou Bay area. Attention was also paid to government agencies that have developed influential plans regarding ESs, such as the Urban Planning Bureau, the Development and Reform Commission, and the Municipal Government. Finally, four strategic plans for Jiaozhou Bay were chosen and collected from different official websites and responsible authorities. The "Conservation and Development around Jiaozhou Bay" Strategy of Qingdao (Plan 1) in 2008 was the first of these plans to promote the concept of integrating ecological protection with industrial development for Qingdao City. It was an important urban space development strategy that enabled Qingdao to be part of The Development Plan of Shandong Peninsula Blue Economic Zone (Plan 2). This plan is the first national sustainable development strategy with a marine economy theme that highlights optimizing both seascape and landscape, producing modern marine industrial systems and enhancing marine ecological civilization. Two statutory urban strategic plans – The Twelfth Five-Year National Economic and Social Development Plans of Qingdao (Plan 3) and The Overall Urban Plan of Qingdao (2011-2020) (Plan 4) – also reflect the role of coastal and marine resources in Jiaozhou Bay in improving citizens' well-being and the urban economy.

3.2 Identifying ESs

Subsequently, following the process described in Step 2, the four strategic plans were analyzed. In total, 356 pages were screened by employing NVivo software. According to the coding system, a range of well-established coastal ESs could be identified. Explicit and implicit terms/references concerning coastal ESs could be recorded and summarized (see for more information about this step also Li et al., 2015). This second step thus provided information about different extents of ES inclusion in the four strategic planning documents (i.e. Table 2). Results show that provisioning services and cultural services were more widely discussed than regulating and supporting services. In this case, ESs that were most frequently discussed by all plans were the provision of coastal space for industrial development and the cultural service of cognitive values. This consistent ES focus may be due to an overarching influence from the high demands of coastal industries and the increasing research need for marine production and safety. By contrast, regulating services of seawater intrusion and algal blooms were only mentioned in one coastal strategic plan, which may indicate that different planning objectives and themes caused diverse ES focuses.

<Insert Table 2>

3.3 Inclusion of drivers and ESs

The third step is aimed at identifying drivers, relevant ESs and their relationships on a more aggregated level. For this purpose, various activities (i.e. drivers) were identified involving ESs that were considered to be managed. Subsequently, these codes were grouped into a theme in relation to the same activity. Each theme was named as a relational type. Consequently, Table 3 demonstrates ten typical activities with related ESs, which can be aggregated as ten types of interrelationships. These ten types of interrelationships consist of four trade-off relationships and six synergy relationships. Examples of the document quotes with respect to each type of interrelationship are presented in the final column of Table 3. The key words (e.g. “create” and “limit”) that indicate positive or negative effects are underlined. The text passages in which these key words are embedded are helpful for identifying whether the relationship involves a driver-ES form or a ES-ES form. The “category” columns in Table 3 show to which category each service involved belongs; this may facilitate a more general awareness about which categories of ESs have been actively involved in trade-offs and synergies.

<Insert Table 3>

Results of the Jiaozhou Bay case show that the provisioning services were most often regarded to be under direct management, causing changes to other services. For instance, Plan 4 (Type 4) acknowledged that controlling the use of coastal spatial resource for construction projects could affect “marine hydrodynamic conditions and self-purification capacity” (Plan 4, p.29). Cultural, regulating and supporting services more often appeared as positively co-varying services where synergies were concerned. Examples include tourism, marine culture, landscape, water purification, storm surge prevention and maintenance of biodiversity and wetland habitats (Table 3). Moreover, the results also allow for an assessment of the continuity of attention to drivers, trade-offs and synergies within and between the coastal strategic plans under study. Specifically, the four plans all referred to three drivers and their effects on ESs (i.e. controlling reclamation, restoring natural shoreline, and building wetlands park/reserve). There are different focuses among the plans with regard to the mentioning of other drivers and related ESs. For example, regarding Type 10, only

Plan 1 and Plan 3 dramatically highlighted the construction of new towns for stimulating multiple ESs.

3.4 Visualizing the ten relational types of drivers and ESs

After the identification of drivers and ESs, the final step of framing diagrams was conducted. First, each type of interrelationship listed in Table 3 was structured by using the symbols of rectangle, dotted arrow and solid arrow (see for an explanation Step 3). Then ten small diagrams were formulated and grouped into two big diagrams by separating trade-offs from synergies (Figure 3 and Figure 4). For each group, small diagrams were illustrated according to the attribute of drivers and the degree of ES interactions.

<Insert Figure 3>

<Insert Figure 4>

As a result, the graphical presentation facilitates an easy way to identify the emphasized drivers and their direct and indirect effects, particularly with regard to the regulating and supporting services. It is now possible to identify which key and potential links may have been overlooked. For instance, in Type 1, defining an island protection area could maintain the habitat function for the increase of biodiversity (supporting service), while the habitat/nursery function of the reserve also provides a spillover effect that is important for commercial fishery (provisioning service) (Grafton & Kompas, 2005; Shen et al., 2011). However, the indirect influence on fishery provision was not mentioned in any of the analyzed plans. For other types, interrelationships pertaining to some regulating services, e.g. carbon storage, algal blooms prevention, and erosion control were also generally underappreciated.

In addition, the diagrams show that the selected strategic plans put little emphasis on temporal and spatial issues that were crucial for ES interrelationships. Regarding the spatial aspect, one example is the wetlands park (Type 9), which could be influenced by pollution from the upper reaches outside administrative boundaries – its management plan was restricted to the local scale rather than a cross-border view. The frequency of activities relative to ecosystems' temporal dynamics is also critical for a better understanding of how a particular activity influences ES changes (Halpern et al., 2008). However, only the management of reclamation restriction in the bay (Type 4) indicated an awareness of the need to control long-term severe cumulative impacts. There was no other mention of such awareness in the plans.

4. Discussion

4.1 Empirical reflection

The case study results demonstrate how the four-step method presented in this paper could be useful in identifying a range of drivers and ES interrelationships implicitly considered by planners and policy-makers.

The four-step method that has been developed uncovers that different attention is being paid to the four categories of ESs when talking about trade-offs and synergies. Trade-offs are frequently linked to provisioning services, while synergies often involve other categories of services (see Section 3.3). To put this understanding in a further international context, Table 4 illustrates a range of international case studies on ES interrelationships using different approaches. These cases confirm that trade-off decisions, as perceived by decision-makers, experts, researchers and communities, show a general preference for provisioning services. One reason could be that provisioning services are utilized in regard of exclusive types of spatial use (i.e. landscape or seascape), and another reason is that they are highly tangible and always directly identified (Carpenter et al., 2006; Hauck et al., 2013; Rodríguez et al., 2006). Diverse approaches reveal that regulating and supporting services are more likely to shape synergistic links in various study areas (Table 4), because they work as functional services and profoundly influence ecosystem resilience (Bennett et al., 2009; MA, 2005). Overall, the application of the four-step method to the empirical case of Jiaozhou Bay shows that the findings (Table 3) accord with these general assumptions and reported findings.

<Insert Table 4>

Results of the application also include the identification of overlooked links, temporal and spatial issues, and the continuity of plans' attention to ESs (see Sections 3.3 and 3.4). These findings illustrate the added value of the four-step method in empirical studies compared to other methods. First, it is useful to expose which intangible links (particularly concerning regulating and supporting services) are not addressed in strategic planning discourse. It will remind policy-makers of the need to focus on intangible, vulnerable services and indirect impacts. Second, by focusing on specific drivers and the scope of effects on ESs, it is possible to find that there is little emphasis in strategic plans on temporal and spatial issues. It will remind policy-makers of the uptake of temporal and spatial perspectives, which are crucial for managing ES interrelationships (Halpern et al., 2008; Rodríguez et al., 2006). Third, content analysis is capable of revealing whether strategic plans lack continuity of attention to ESs (Wilkinson et al., 2013). The findings of the Jiaozhou Bay case confirm that the four-step method has such capacity (Section 3.2) and brings the continuity assessment forward to drivers, trade-offs and synergies (Section 3.3). Furthermore, a potential contribution of this four-step method is worth to mention here. Clarifying the interrelationships framed in plans could facilitate a comparison with implementation, finding which links have not been reformed into daily decision-making.

Overall, the outcomes reported give planners and policy-makers insights into the importance and possible ways of assessing and managing ES interrelationships. However, it is also important to recognize that such clarification is not a simple task in practice. The integration of ES interrelationships in policies is considerably influenced by complex institutional contexts (e.g. fragmented governance structures and market-oriented preferences). There are challenges that strategic planning will face: for instance, how ES interrelationships can be comprehensively interpreted, when it is necessary to broadly balance different ESs, and how governance can maintain a grip on ES trade-offs and synergies.

4.2 Methodological reflection

The four-step method presented in this paper mainly draws on content analysis and clear cause-effect mechanisms. Content analysis has helped to establish straightforward and detailed qualitative insights of a specific policy situation. Its advantage is to offer a contextual understanding of how ES thinking has been shaped and thereby enhancing decision-making on ES trade-offs and synergies through planning processes (Piwowarczyk et al., 2013; Wilkinson et al., 2013). Comparing with the other three existing groups of approaches (i.e. mapping, modeling and social-survey analysis), a whole range of ESs can be taken into account through the coding system. This expanding perspective enables more comprehensive discussions on interrelationships than other single-issue ways. Although this method used a broad and perhaps partly inexplicit ES definition and classification promoted by the MA (2005) to create the coding system, its flexibility leaves sufficient space for further detailed mechanism analysis and, more importantly, an understanding among multiple stakeholders about ES concepts and classifications. The typology promoted by Bennett et al. (2009) provides a more causal description of ES interrelationships than the modeling and mapping methods (Lautenbach et al., 2010). By adopting this typology, the method presented in this paper provides a step towards an explicit distinction among the cause of relationships, namely, an expanding set of policy interventions (i.e. drivers) and interactions among services.

The scope of the findings suggests that the four-step method and the other three groups of approaches could cross-fertilize each other. Apart from the contextual information and the broad scopes informed by the method presented, its qualitative understanding about the way of implicitly managing ES interrelationships is likely to enhance non-scientific audiences' acceptance of ES quantification approaches (Kelble et al., 2013). In turn, the content analysis concerning ES mechanisms requires for spatial, biophysical, economic and social-value data to enhance its explicitness and accountability. In particular, perspectives of stakeholders could be investigated through social methods to help with finding indirect interrelationships that have been ignored in plans. Therefore, links would be clearer between drivers and actors' benefits from ES changes. It may provide a way of translating social values back into strategies or even abstract goals for ES governance, and ultimately creates space for solutions.

The method formulated in this paper could also facilitate planning processes. For instance, when planners define the goals and scope, the method may inform a balance in social-economic and ecological goals that affect drivers and related ESs. During the stage of designing strategies, the visualized causal description could make the proposal explicit and understandable for actors, reminding them overlooked links. In the stage of revision and approval, suggestions on managing key drivers and their indirect, cumulative impacts to reduce conflicts could be put forward based on this method. Finally, the method may also be helpful to assess whether the implementation processes produced outcomes that are synchronized with the consideration of interrelationships as presented in plans.

The four-step method is only a preliminary step towards incorporating ES trade-offs and synergies into coastal strategic planning, and there are challenges facing implementation. First, different planning contexts determine which and to what extent diverse ESs can be acknowledged within a coastal area. Sometimes, the interpretation of policy documents is not straightforward, making it hard to code and quantify ESs. Second, given the guiding role played by strategic planning, only a few detailed ES interrelationships could be described. Third, a dominant activity (one with an intensive or frequent influence) co-exists with other activities that have relatively minor effects (Halpern et al., 2008). This fact adds complexity to ES interrelationships and the long-term cumulative impacts analysis. Thus, it is a real challenge to identify and manage all possible drivers and the different extents of their impacts. Moreover, quantifying ESs across landscapes or seascapes and through time, and monitoring small changes in the interrelationships are also difficult (Bennett et al., 2009), but it would further refine the approach.

5. Conclusion

This paper argued that a more explicit and integrated inclusion of trade-offs and synergies among ESs will make coastal strategic planning more adaptive and sustainable, and that a structured method to assess this inclusion is needed. A four-step method is formulated in this research that depends on content analysis with a focus of ES-interrelationship mechanisms. The application in a case study showed that the method is useful to identify which drivers and ES interrelationships may be formulated in policy language in coastal strategic plans. It can reveal critical information in agreement with other studies and add values with regard to identify overlooked interrelationships, temporal and spatial issues, and the continuity of plans' attention. The four-step method distinguishes itself among other approaches by informing contextual information, identifying a wide scope of drivers and ESs and their consequences based on a more causal mechanism. It has potentials of cross-fertilizing other approaches. These efforts may broaden strategic planning discussions, make ES integration more explicit, and inform practical planning processes in different ways. Therefore, this four-step method is a worthwhile starting point to inform better understanding of how current coastal strategic plans may frame ES interrelationships.

References

Atkins, J.P., Burdon, D., Elliott, M., & Gregory, A.J. (2011). Management of the marine environment: Integrating ecosystem services and societal benefits with the DPSIR framework in a systems approach. Marine Pollution Bulletin, 62(2), 215-226.

Bennett, E.M., Peterson, G.D., & Gordon, L.J. (2009). Understanding relationships among multiple ecosystem services. Ecology Letters, 12(12), 1394-1404.

Böhnke-Henrichs, A., Baulcomb, C., Koss, R., Hussain, S.S., & de Groot, R.S. (2013). Typology and indicators of ecosystem services for marine spatial planning and management. Journal of Environmental Management, 130 (30), 135-145.

Brown, K., Adger, W.N., Tompkins, E., Bacon, P., Shim, D., & Young, K. (2001). Trade-off analysis for marine protected area management. Ecological Economics, 37(3), 417-434.

Bryan, B.A., Raymond, C.M., Crossman, N.D., & Macdonald, D.H. (2010). Targeting the management of ecosystem services based on social values: Where, what, and how?. Landscape and Urban Planning, 97(2), 111-122.

Butler, J.R.A., Wong, G.Y., Metcalfe, D.J., Honzák, M., Pert, P.L., Rao, N., van Grieken, M.E., Lawson, T., Brucec, C., Kroon, F.J., & Brodiee, J.E. (2013). An analysis of trade-offs between multiple ecosystem services and stakeholders linked to land use and water quality management in the Great Barrier Reef, Australia. Agriculture, Ecosystems & Environment, 180(1), 176-191.

Busch, M., Gee, K., Burkhard, B., Lange, M., & Stelljes, N. (2011). Conceptualizing the link between marine ecosystem services and human well-being: the case of offshore wind farming. International Journal of Biodiversity Science, Ecosystem Services & Management, 7(3), 190-203.

Carpenter, S.R., Mooney, H.A., Agard, J., Capistrano, D., DeFries, R.S., Díaz, S., Dietz, T., Duraiappah, A.K., Oteng-Yeboah, A., Pereira, H.M., Perrings, C., Reid, W.V., Sarukhan, J., Scholes, R.J., Whyte, A., & Clark, W.C. (2009). Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. Proceedings of the National Academy of Sciences 106(5), 1305-1312.

Carpenter, S.R., Bennett, E.M., & Peterson, G.D. (2006). Scenarios for ecosystem services: an overview. Ecology and Society, 11(1), 29.

Chisholm, R.A. (2010). Trade-offs between ecosystem services: water and carbon in a biodiversity hotspot. Ecological Economics, 69 (10), 1973-1987.

Costanza, R. (2008). Ecosystem services: multiple classification systems are needed. Biological Conservation, 141(2), 350-352.

Costanza, R., d’Arge, R., de Groot, R., Farber, S., Grasso, M, Hannon, B, Limburg, K, Naeem, S, O’Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., & van den Belt, M. (1998). The value of the world’s ecosystem services and natural capital. Ecological Economics, 25(1), 3-15.

Crossman, N.D., Burkhard, B., Nedkov, S., Willemen, L., Petz, K., Palomo, I., Drakou, E.G., Martı´n-Lopez, B., McPhearson, T., Boyanova, K., Alkemade, R., Egoh, B., Dunbar, M.B., & Maes, J. (2013). A blueprint for mapping and modelling ecosystem services. Ecosystem Services, 4, 4-14.

De Groot, R.S., Wilson, M.A., & Boumans, R.M. (2002). A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics, 41(3), 393-408.

Eigenbrod, F., Anderson, B.J., Armsworth, P.R., Heinemeyer, A., Jackson, S.F., Parnell, M., Thomas, C.D., & Gaston, K.J. (2009). Ecosystem service benefits of contrasting conservation strategies in a human-dominated region. Proceedings of the Royal Society, B-Biological Sciences, 276, 2903-2911.

Fisher, B., Turner, R.K., & Morling, P. (2009). Defining and classifying ecosystem services for decision making. Ecological Economics, 68(3), 643-653.

Gari, S.R., Newton, A., & Icely, J.D. (2015). A review of the application and evolution of the DPSIR framework with an emphasis on coastal social-ecological systems. Ocean & Coastal Management, 103, 63-77.

Ge, Y., & Zhang, J.Y. (2011). Analysis of the impact on ecosystem and environment of marine reclamation-A case study in Jiaozhou Bay. Energy Procedia, 5, 105-111.

Gee, K., & Burkhard, B. (2010). Cultural ecosystem services in the context of offshore wind farming: a case study from the west coast of Schleswig-Holstein. Ecological Complexity, 7(3), 349-358.

Graneheim, U.H., & Lundman, B. (2004). Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. Nurse Education Today, 24(2), 105-112.

Haase, D., Schwarz, N., Strohbach, M., Kroll, F., & Seppelt, R. (2012). Synergies, trade-offs, and losses of ecosystem services in urban regions: An integrated multiscale framework applied to the Leipzig-Halle region, Germany. Ecology and Society, 17(3), 22.

Halpern, B.S., McLeod, K.L., Rosenberg, A.A., & Crowder, L.B. (2008). Managing for cumulative impacts in ecosystem-based management through ocean zoning. Ocean & Coastal Management, 51(3), 203-211.

Hansen, R., Frantzeskaki, N., McPhearson, T., Rall, E., Kabisch, N., Kaczorowska, A., Kain, J., Artmann, M., & Pauleit, S. (2015). The uptake of the ecosystem services concept in planning discourses of European and American cities. Ecosystem Services, 12, 228-246.

Haines-Young, R., & Potschin, M. (2010). Proposal for a Common International Classification of Ecosystem Goods and Services (CICES) for integrated environmental and economic accounting. Copenhagen: European Environment Agency. Retrieved from - http - //www.nottingham.ac.uk/cem/pdf/UNCEEA-5-7-Bk1.pdf.

Haines-Young, R., & Potschin, M. (2010). The links between biodiversity, ecosystem services and human well-being. In D. Raffaelli (Ed.), Ecosystem Ecology: a new synthesis, (pp. 110-139). CUP - Cambridge.

Hauck, J., Görg, C., Varjopuro, R., Ratamäki, O., & Jax, K. (2013). Benefits and limitations of the ecosystem services concept in environmental policy and decision making: some stakeholder perspectives. Environmental Science & Policy, 25, 13-21.

Hein, L., Van Koppen, K., De Groot, R.S., & Van Ierland, E.C. (2006). Spatial scales, stakeholders and the valuation of ecosystem services. Ecological Economics, 57(2), 209-228.

Holling, C.S., & Meffe, G.K. (1996). Command and control and the pathology of natural resource management. Conservation Biology, 10(2), 328-337.

Holt, A.R., Godbold, J.A., White, P.C., Slater, A.M., Pereira, E.G., & Solan, M. (2011). Mismatches between legislative frameworks and benefits restrict the implementation of the Ecosystem Approach in coastal environments. Marine Ecology Progress Series, 434, 213-228.

Hsieh, H.F., & Shannon, S.E. (2005). Three approaches to qualitative content analysis. Qualitative Health Research, 15(9), 1277-1288.

Kelble, C.R., Loomis, D.K., Lovelace, S., Nuttle, W.K., Ortner, P.B., Fletcher, P., Cook, G.S., Lorenz, J.J., & Boyer, J.N. (2013). The EBM-DPSER conceptual model: integrating ecosystem services into the DPSIR framework. PloS ONE, 8(8), e70766.

King, E., Cavender-Bares, J., Balvanera, P., Mwampamba, T.H., & Polasky, S. (2015). Trade-offs in ecosystem services and varying stakeholder preferences: evaluating conflicts, obstacles, and opportunities. Ecology and Society 20(3), 25.

Grafton, R.Q., & Kompas, T. (2005). Uncertainty and the active adaptive management of marine reserves. Marine Policy, 29(5), 471-479.

Lautenbach, S., Volk, M., Gruber, B., Dormann, C.F., Strauch, M., & Seppelt, R. (2010). Quantifying ecosystem service trade-offs. In International Environmental Modelling and Software Society (iEMSs) 2010 International Congress on Environmental Modelling and Software Modelling for Environment's Sake, July (pp. 5-8). Ottawa - Canada. Retrieved from - http - //www.biometrie.uni-freiburg.de/mitarbeiter/dormann/lautenbach2010iemsconference-estradeoffs.pdf

Lester, S.E., Costello, C., Halpern, B.S., Gaines, S.D., White, C., & Barth, J.A. (2013). Evaluating tradeoffs among ecosystem services to inform marine spatial planning. Marine Policy 38, 80-89.

Lester, S.E., McLeod, K.L., Tallis, H., Ruckelshaus, M., Halpern, B.S., Levin, P.S., Chavez, F.P., Pomeroy, C., McCay, B.J., Costello, C., Gaines, S.D., Mace, A.J., Barth, J.A., Fluharty, D.L., & Parrish, J.K. (2010). Science in support of ecosystem-based management for the US West Coast and beyond. Biological Conservation, 143(3), 576-587.

Li, R., et al. (2015). Ocean & Coastal Management.

Martinet, V., & Blanchard, F. (2009). Fishery externalities and biodiversity: Trade-offs between the viability of shrimp trawling and the conservation of Frigatebirds in French Guiana. Ecological Economics, 68(12), 2960-2968.

Martínez-Harms, M.J., & Balvanera, P. (2012). Methods for mapping ecosystem service supply: a review. International Journal of Biodiversity Science, Ecosystem Services & Management, 8(1-2), 17-25.

Martín-López, B., Iniesta-Arandia, I., García-Llorente, M., Palomo, I., Casado-Arzuaga, I., García Del Amo, D., Gómez-Baggethun, E., Oteros-Rozas, E., Palacios-Agundez,I., Willaarts, B., González, J.A., Santos-Martín, F., Onaindia, M., López-Santiago, C., & Montes, C. (2012). Uncovering ecosystem service bundles through social preferences. Plos ONE 7, e38970.

Martín-López, B., Gómez-Baggethun, E., García-Llorente, M., & Montes, C. (2014). Trade-offs across value-domains in ecosystem services assessment. Ecological Indicators, 37, 220-228.

Millennium Ecosystem Assessment (MA). (2005). Ecosystems and human well-being: biodiversity synthesis (a report of the MA). World Resources Institute, Washington, DC.Retrieved from - http - //www.millenniumassessment.org/documents/document.354.aspx.pdf

Nelson, E., Mondoza, G., Regetz, J., Polasky, S., Tallis, J., Cameron, D.R., Chan, K.M.A., Daily, G.C., Goldstein, J., Kareiva, P.M., Londsdorf, E., Naidoo, R., Ricketts, T.H., & Shaw, M.R. (2009). Modelling multiple ecosystems services, biodiversity conservation, commodity production, and tradeoffs at landscape scale. Frontiers in Ecology and the Environment, 7 (1), 4-11.

Partidario, M.R., & Gomes, R.C. (2013). Ecosystem services inclusive strategic environmental assessment. Environmental Impact Assessment Review, 40, 36-46.

Piwowarczyk, J., Kronenberg, J., & Dereniowska, M.A. (2013). Marine ecosystem services in urban areas: Do the strategic documents of Polish coastal municipalities reflect their importance?. Landscape and Urban Planning, 109(1), 85-93.

Potts, T., Burdon, D., Jackson, E., Atkins, J., Saunders, J., Hastings, E., & Langmead, O. (2014). Do marine protected areas deliver flows of ecosystem services to support human welfare?. Marine Policy, 44, 139-148.

Raudsepp-Hearne, C., Peterson, G.D., & Bennett, E.M. (2010). Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. Proceedings of the National Academy of Sciences, 107(11):5242-5247.

Ring, I., Hansjürgens, B., Elmqvist, T., Wittmer, H., & Sukhdev, P. (2010). Challenges in framing the economics of ecosystems and biodiversity: the TEEB initiative. Current Opinion in Environmental Sustainability, 2(1), 15-26.

Rodríguez, J.P., Beard Jr, T.D., Bennett, E.M., Cumming, G.S., Cork, S., Agard, J., Dobson, A.P., & Peterson G. D. (2006). Trade-offs across space, time, and ecosystem services. Ecology and Society, 11(1), 28.

Salzman, J., Thompson Jr, B.H., & Daily, G.C. (2001). Protecting ecosystem services: Science, economics, and law. Stanford Environmental Law Journal, 20, 309-332.

Shen, G.Y., Huang, L.F., Guo, F., & Shi. B.Z. (Eds.). (2011). Marine Ecology (the third edition). Beijing, China - Science Press, 340.

Sherrouse, B.C., Clement, J.M., & Semmens, D.J. (2011). A GIS application for assessing, mapping, and quantifying the social values of ecosystem services. Applied Geography, 31(2), 748-760.

Sitas, N., Prozesky, H. E., Esler, K. J., & Reyers, B. (2014). Exploring the gap between ecosystem service research and management in development planning. Sustainability, 6(6), 3802-3824.

Swallow, B.M., Sang, J.K., Nyabenge, M., Bundotich, D.K., Duraiappah, A.K., & Yatich, T.B. (2009). Tradeoffs, synergies and traps among ecosystem services in the Lake Victoria basin of East Africa. Environmental Science & Policy, 12(4), 504-519.

Turner, R.K. (2000). Integrating natural and socio-economic science in coastal management. Journal of Marine Systems, 25(3), 447-460.

Turner, R.K., Paavola, J., Cooper, P., Farber, S., Jessamy, V., & Georgiou, S. (2003). Valuing nature: lessons learned and future research directions. Ecological economics, 46(3), 493-510.

Turner, K.G., Odgaard, M.V., Bøcher, P.K., Dalgaard, T., & Svenning, J.C. (2014). Bundling ecosystem services in Denmark: Trade-offs and synergies in a cultural landscape. Landscape and Urban Planning, 125, 89-104.

Turnpenny, J., Russel, D., & Jordan, A. (2014). The challenge of embedding an ecosystems approach: patterns of knowledge utilisation in public policy appraisal. Environment and Planning C, 32(2), 247-262.

Van der Biest, K., D'Hondt, R., Jacobs, S., Landuyt, D., Staes, J., Goethals, P., & Meire, P. (2014). EBI: An index for delivery of ecosystem service bundles. Ecological Indicators, 37, 252-265.

Villa, F., Ceroni, M., Bagstad, K., Johnson, G., & Krivov, S. (2009). ARIES (Artificial Intelligence for Ecosystem Services): A new tool for ecosystem services assessment, planning, and valuation. In 11Th annual BIOECON conference on economic instruments to enhance the conservation and sustainable use of biodiversity, conference proceedings. Venice, Italy. Retrieved from - http - //www.ariesonline.org/docs/ARIESModelingGuide1.0.pdf

Wallace, K.J. (2007). Classification of ecosystem services: problems and solutions. Biological Conservation, 139(3), 235-246.

Weitzman, E., & Miles, M.B. (Eds.). (1995). Computer programs for qualitative data analysis: A software sourcebook. California - Sage Publications.

Wilkinson, C., Saarne, T., Peterson, G.D., & Colding, J. (2013). Strategic spatial planning and the ecosystem services concept-An historical exploration. Ecology and Society, 18(1), 37.

Zhao, S.J., Jiao, N.Z., Shen, Z.L., & Wu, Y.L. (2005). Causes and consequences of changes in nutrient structure in the Jiaozhou Bay. Journal of Integrative Plant Biology, 47(4), 396–410.

List of Tables

Table 1. Coastal ecosystem services related to coastal spatial planning (Li et al., 2015).

Category	ES & Examples
Provisioning	Fish & seafood
	Energy production (biomass fuel, offshore oil and gas, wind, tide and wave power)
	Biochemical and pharmaceutical uses
	Transport and navigation (use of waterways for shipping)
	Coastal space for industrial development and infrastructure
	Residential and industrial water supply (abstraction of water for residential and industrial purposes)
	Urban ecological intervals (dividing different developing groups/function zones)
Regulating	Prevention of floods, storms, tsunamis and typhoons (protection by biogenic structures)
	Seawater intrusion
	Algal blooms
	Erosion and siltation control (maintenance of productive sediments, mitigating the effects of sea-level rise)
	Water purification and waste treatment
	Climate regulation (balance and maintenance of the atmosphere)
Cultural	Tourism and recreation (beach tourism, sunbathing, diving, windsurfing and kite-surfing, fishing, spas and wellness centers, bird-watching)
	Cognitive values (education and research arising from the marine environment, school excursions, monitoring global environmental change and indicators of ecosystem health, long-term environmental records)
	Esthetic beauty (landscape)
	Cultural heritage and identity (value associated with the marine environment itself)
	Sea sports (competitive sailing, yacht races and other seawater competitions)
Supporting	Maintenance of biodiversity
	Maintenance of habitats
	Resilience of ecosystems (ability to cope with natural and anthropogenic change)
	Soil formation

Table 2 Coastal ecosystem services presented in coastal strategic documents for Jiaozhou Bay (Li et al., 2015).

Category	Plan 1	Plan 2	Plan 3	Plan 4	Sum	%
Four services sum					162	100
Provisioning					64	39.5
-Fishery and seafood	0	3	5	2	10	6.2
-Energy production	1	2	1	1	5	3.1
-Biochemical and pharmaceutical use	1	3	5	2	11	6.8
-Transport and navigation	2	2	3	2	9	5.6
-Coastal space for industrial development and infrastructure	4	6	6	5	21	13.0
-Space for urban ecological space	1	0	0	3	4	2.5
-Residential and industrial water supply	0	1	1	2	4	2.5
Regulating					20	12.3
-Flood, storm, tsunami & hurricane prevention	0	2	1	2	5	3.1
-Seawater intrusion	0	2	0	0	2	1.2
-Algal blooms	0	1	0	0	1	0.6
-Erosion and siltation control	0	1	1	0	2	1.2
-Water purification and waste treatment	1	2	3	2	8	4.9
-Climate regulation	1	1	0	0	2	1.2
Cultural					49	30.2
-Tourism and recreation	5	3	3	3	14	8.6
-Sea sports	0	1	2	1	4	2.5
-Cognitive values	1	7	6	6	20	12.3
-Aesthetic beauty	2	0	0	2	4	2.5
-Cultural heritage and identity	0	0	4	3	7	4.3
Supporting					29	17.9
-Maintenance of biodiversity	2	4	1	1	8	4.9
-Maintenance of habitats	3	4	5	9	21	13.0
-Ecosystem resilience	0	0	0	0	0	0.0
-Soil formation	0	0	0	0	0	0.0

Table 3. Drivers and ESs of trade-offs and synergies included in strategic planning for Jiaozhou Bay

	Driver	Service A	C*	Service B	C*	Service C	C*	Service D	C*	Service E	C*	Examples of document quotes*
Trade-off												
1	Defining an island protection zone	Economic development that changes topography and geomorphology	P	Biodiversity	S							Plan 2, p.23: “designate island protected areas, in which any economic development that may change the island’s topography and geomorphology is forbidden for saving rare wild animals and marine species” ; “defining an island’s protected area can preserve natural conditions for biodiversity”
2	Development of estuarial wetlands	Modern manufacturing industry	P	Wetlands	S							Plan 1, p.4: “when developing the estuarial wetlands of Yang river, local modern manufacturing industries should be controlled in terms of spatial allocation, giving priority to the preservation of wetlands in planning” Plan 4, p.26: “limit the scale of land use of industrial development in coastal cities and guide the establishment of ecological intervals (e.g. wetlands and rivers)”
3	Natural shoreline restoration	Intertidal/pond aquaculture	P	Coastal aesthetic sense and landscape	C	Water purification	R					Plan 1, p.9: “strengthen efforts to protect the coastline by stopping intertidal/pond aquaculture to restore its natural coastal condition” Plan 2, p.8: “restore natural shorelines and beautify artificial shorelines with a focus on Jiaozhou Bay, Shidao Bay, Weihai Bay, Zhifu Bay and Laizhou Bay in order to optimize their natural landscape” Plan 4, p.5: “increase efforts to protect coastline, actively promote the legislation of Jiaozhou Bay, stop pond aquaculture to restore natural coastal landscape and to improve the governance of pollution sources, guarantee no more water areas would be shrunk due to reclamation”

								Plan 4, p.28: “in the important coastal scenic tourist areas, intertidal aquaculture and pond aquaculture should be canceled to restore natural coastal landscape”
4	Shoreline division for reclamation control, industrial development, petrochemical zone control	Land use for industry, agriculture, port development	P	Environmental capacity within the bay, self-purification capacity	R	Landscape resource	C	Plan 3, p.26: “divide a controlling line of reclamation in Jiaozhou Bay to ensure that the proportion of the natural coastline will not decrease; thereby avoiding any change of the seabed topography and the destruction of the natural landscape, as well as the reduction of environmental capacity caused by the change of shoreline shape” Plan 4, p.3: “the Huangdao heavy petrochemical area should be strictly restricted to the planning area, emphasizing environmental protection and pollution reduction to the bay”; “during the planning period, if there is a need for industrial expansion, any reclamation is not allowed in Jiaozhou Bay” Plan 4, p.29: “controlling the coastal development and construction projects around Jiaozhou Bay will limit the erosion of the bay area and water quality, thereby protecting the marine hydrodynamic conditions and self-purification capacity” Plan 4, p.28: “industrial and port businesses should not be allowed to occupy high-quality beaches and shoreline” Plan 4, p.5: “strictly control the urban land-use scale surrounding the central wetland reserve, creating conditions for the ecological restoration of natural wetlands’ functions”
Synergy								
5	Special agriculture	Marine food	P	Leisure and	C			Plan 2, p.10: “developing high-efficiency agriculture in coastal areas within a leisure and tourism corridor to produce high-quality vegetables, fruit and

	construction	supply		tourism				crops”; “promoting certification for pollution-free agricultural products, green food and organic food and cultivating brand products through tourism to enhance agriculture” Plan 3, p.50: “actively expand the agricultural function through cooperative development of tourism, cultural science, experience participation, leisure and other characteristic industries” Plans 4, p.14: “accelerate the cultivation of modern agricultural industry system by emphasizing the research of high-quality species, as well as the establishment of aquaculture base and demonstration area of offshore marine pasture together with leisure, sightseeing and tourism agriculture”
6	Upgrading port function	Shipping	P	Port tourism	C			Plan 1, p.4: “focus on creating a tourism industry that features a large industrial port in Tuandao, introducing cruise port and tourism industry, forming a new port economy pattern, and building port economic service area; meanwhile, stimulating the development of tourism, business and leisure industries and shaping the beautiful bay mouth skyline” Plan 1, p.5: “make the west coast form an industrial tourism that is characteristic of a large-scaled industrial port, targeting at the integration and upgrade of Jiaozhou Bay tourism resources”
7	Excavating artificial river, restoring natural waterways	Protection from flood and storm surge	R	Water purification	R	The landscape of ecology island chain	C	Plan 1, p.3: “excavate the artificial river and restore the natural waterways in Hongdao area for creating a chain of ecological islands in northern Jiaozhou Bay”; “enhancing the capabilities of urban areas to prevent damage from flooding, drainage and storm surges”; “increasing the environmental capacity for better water quality”

8	Constructing regional industrial cultural clusters	Marine culture	C	Tourism	C	Technology	C					Plan 3, p.85: “promote a deep integration of marine culture, history, economy, science, technology and tourism in terms of accelerating the construction of regional industrial cultural clusters”; “vigorously develop new cultural formats, enhance the level of creation industries, and enable the added value of marine cultural industry to achieve at least 10% of the city's total GDP” Plan 3, p.36: “establish a range of comprehensive regional clusters that feature modern fisheries, coastal business tourism, port logistics, modern equipment manufacturing, island protection and sustainable utilization, and popular science education”
9	Building wetlands park or wetlands reserve	Habitat protection	S	Ecotourism	C	Biodiversity	S	Urban air and water purification	R	Urban spatial landscape	C	Plan 1, p.3: “protect the tidal flat wetlands in Moshui River, Dagu River and Yang River though the establishment of wetlands park with a function of eco-tourism” Plan 2, p.22: “implement the protection and restoration of typical habitats such as tamarix forests, seagrass beds and coastal wetland... to strengthen the protection of marine biodiversity, critical marine ecological environment, and landscape…to maintain the coastal ecological health and functions” Plan 3, p.26: “accelerate the development of urban wetlands parks to improve waterfowl habitat restoration and biodiversity conservation; by doing so, ‘a city’s green kidney’ can be created to increase its capacity of environmental regulation”; “make full use of the landscape value and cultural attributes of wetlands to enrich residents' leisure activities”
10	New town constructi	House	P	Tourism	C	Wetlands	S	Business	P	Marine scientific research,	C	Plan 1, p.5: “to achieve functional complementarity and mutual development, the new urban areas of Shaohai in Jiaozhou City should be in accordance with multi-functional requirements: aggregating the construction

on	history & culture	of wetlands ecology, shoreline leisure, high-grade residential area, tourism, history, culture and business in one urban waterfront area; using ecological corridors as a skeleton (e.g. water system, greenspace and roads); taking the large water body of the city as a core” Plan 1, p.6: “the new town of Hongdao would rely on its good ecological environment and landscape resources to develop functions of exhibition business, residential leisure, tourism and commerce, marine scientific research, aiming at becoming an important international exhibition center and an administrative and cultural center” Plan 3, p. 18: “gradually integrate the new town construction of Shaohai with the development of the new industrial district in Jiaozhou Bay”; “cooperatively speed up the construction of residential landscape, tourism, urban commercial area, ecological wetlands and other functional areas to create a modern service industry and a high-end manufacturing industry for the new town”

C*: **C**ategory: P-provisioning service, R-regulating service, S-supporting service, C-cultural service

Examples of document quotes*: the words that can indicate positive/negative impacts in terms of drivers-ES and ES-ES are underlined

Table 4 Common ES trade-offs and synergies of different types of ecosystems and methods

Source	Type of ecosystems	Study areas	Drivers	Trade-offs (vs.)	Synergies (&)	Methodology
Piwowarczyk et al., 2013 [a]	Coastal	Polish coastal municipalities	No specific	• (P-C) ports and fishery vs. beaches recreation • (S-C) biodiversity vs. leisure • (C-C) tourism vs. landscape		Content analysis
Wilkinson et al., 2013 [b]	Urban	Melbourne and Stockholm	Land use change	• (P-R) timber production vs. freshwater supply	• (P-C) agriculture and forestry production & recreational services	Content analysis
Salzman et al., 2001 [c]	Watershed	USA	Water management	• (P-S, P-R) agricultural food vs. soil erosion, flood protection and protection of species	• (R-R) watershed preservation & flood control	
Hauck et al., 2013 [d]	Agriculture, forestry, water	Finland, Germany, and Poland	No specific	• (P-S, P-R) industrial forestry vs. biodiversity, erosion, natural flood protection, purification of groundwater and natural carbon sinks	• (S-P, C-P) biodiversity and tourism & organic agriculture • (R-R, R-S) flood protection & water purification, erosion prevention, climate regulation and biodiversity	Survey, interview, focus group discussion
Holt et al., 2011 [e]	Estuary wetland	UK	No specific	• (P-C, P-R, P-S) fishing and farming vs. recreation, algae and biodiversity maintenance	• (C-C) aesthetic enjoyment & natural heritage	Workshop, content analysis
Potts et al., 2014 [f]	Marine	UK	Marine Protected Areas management		• (S-C) species & cultural wellbeing and tourism/nature watching • (S-S, S-R, S-P, S-C) habitats & supporting, regulating, provisioning	Expert workshop

					and cultural services	
Busch et al., 2011 [g]	Coastal	Schleswig-Holstein, Germany	Offshore wind farm construction	• (P-C, P-S) offshore wind vs. recreation and habitat	• (P-R, P-P, P-C) renewable energy production & climate regulation, fishery and marine culture	Questionnaire, researchers workshop
Martín-López et al., 2012 [h]	Territorial	Spain, the Iberian Peninsula	No specific	• (P-R, P-C) provisioning vs. regulating and almost all cultural services		Questionnaire, statistical analysis
Butler et al., 2013	Floodplain	Tully–Murray catchment, Australia	No specific	• (P-R) food and fibre production vs. water quality	• (R-C) water quality & floodplain recreational and commercial fisheries	Statistical analysis
Raudsepp-Hearne et al., 2010	Pre-urban agricultural	Quebec, Canada	No specific	• (P-R, P-C) crop and pork production vs. both regulating and cultural services		ArcGIS, ES proxies
Turner et al., 2014	Territorial	Denmark	No specific	• (P-C, P-R) crop production vs. sense of place, carbon storage, and wetland water purification	• (R-C) carbon storage & sense of place and nature appreciation • (P-P) crop production & livestock production	ArcGIS, ES proxies
Nelson et al., 2009	Watershed	Willamette Basin, Oregon	Land use change	• (P-R, P-S) agricultural crop products, timber harvest, and rural–residential housing vs. hydrological services, soil conservation, carbon sequestration, and biodiversity conservation	• (S-R, S-P, S-C) biodiversity conservation & other ES	InVEST
Eigenbrod et al., 2009	Watershed	Lake Victoria Basin, East Africa	No specific	• (P-R) agricultural production vs. sediment control		Biophysical models and GIS

Gee, K Burkhar, 2010	Forrest	Jonkershoek Valley, South Africa	Afforestation	• (P-R) timber production vs. water supply	• (R-P) carbon sequestration & timber production	Ecological-economic model
Haase et al., 2012	Rural-urban	Leipzig-Halle region, Germany	Soil sealing; brownfield restoration	• (P-C) food supply vs. recreation potential • (P-R) food supply vs. climate regulation • (C-R) recreation vs. carbon storage	• (S-C) bird species diversity & recreation • (P-R) food supply & carbon storage • (S-R) biodiversity potential & carbon storage	Biophysical models, mapping
Van der Biest et al., 2014	Watershed	Grote Nete Basin, Belgium	No specific	• (P-R) food production vs. climate regulation • (P-R) wood production vs. climate regulation		Model and mapping

a, b, c: ES trade-offs and synergies perceived by decision-makers and planners

f, g: ES trade-offs and synergies perceived by experts or researchers

d, e, h: ES trade-offs and synergies perceived by stakeholders (e.g. fishers, NGOs, planners, sectoral workers and local communities)

List of Figures