



Synthesis

A framework for incorporating sense of place into the management of marine systems

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ABSTRACT. Successfully managing current threats to marine resources and ecosystems is largely dependent on our ability to understand and manage human behavior. In recent times we have seen increased growth in research to understand the human dimension of marine resource use, and the associated implications for management. However, despite progress to date, marine research and management have until recently largely neglected the critically important role of “sense of place,” and its role in influencing the success and efficacy of management interventions. To help address this gap we review the existing literature from various disciplines, e.g., environmental psychology, and sectors, both marine and nonmarine sectors, to understand the ways in which sense of place has been conceptualized and measured. Doing so we draw on three key aspects of sense of place, person, place, and process, to establish a framework to help construct a more organized and consistent approach for considering and representing sense of place in marine environmental studies. Based on this we present indicators to guide how sense of place is monitored and evaluated in relation to marine resource management, and identify practical ways in which this framework can be incorporated into existing decision-support tools. This manuscript is a first step toward increasing the extent to which sense of place is incorporated into modeling, monitoring, and management decisions in the marine realm.

Key Words: *human dimensions; indicators; management; marine environment; place attachment; values*

INTRODUCTION

Marine resources provide critical goods and services that underpin societal well-being (Guerry et al. 2015). However, in common with all natural resources, their long-term sustainability is under threat from a range of complex, unpredictable, and often synergistic pressures associated with climate change (Hoegh-Guldberg and Bruno 2010, Doney et al. 2012, Pecl et al. 2017) and human population growth and development (IPCC 2014). Given the complex social-ecological context in which marine resources are embedded it has become increasingly apparent that the success of marine resource management is largely dependent on understanding and successfully managing human behavior (Fulton et al. 2011). For example, the inclusion of human dimensions of resource use, e.g., cultural beliefs, community values and norms, in formal laws, regulations, and incentives is known to increase acceptance of these by diverse community groups, adding to the likelihood that these groups will foster proenvironmental behaviors (Jolls et al. 1998). Similarly, understanding human-resource interactions is essential for understanding why certain resource uses occur and persist, and how these are likely to change in the future (Brandenburg and Carroll 1995). This is critical for allowing decision makers to anticipate future changes in resource use, and to proactively develop appropriate governance responses (Boyd et al. 2015). Accordingly, incorporating human dimensions into decision-making processes for natural resource management is critical for the long-term sustainability of marine resources (Fulton et al. 2011).

In recognition of the need to better account for human dimensions in the management of marine resources, there has been a shift away from traditional hierarchical models of governance toward more holistic and participatory approaches that acknowledge and integrate the interests of all stakeholders into decision-making processes (Lange et al. 2013). We have also observed increased research effort to understand, among other things, drivers of human behaviors and indicators to measure behavioral change (Abrahamse and Steg 2013), measurements of natural capital (Smith et al. 2017), as well as ecosystem services and their impacts on human well-being. Despite this progress, models widely used in marine applications to test and evaluate alternative management strategies have neglected the social and human psychological dimension (Fulton et al. 2011), including “sense of place” (SoP). Because these models are used for management decision making, the potentially critically important role of SoP, and the ways in which it can influence the success of management interventions, remain largely unknown (Kaltenborn 1998, Cantrill and Senecah 2001).

What is sense of place?

Following Tuan’s significant work on SoP (Tuan 1974, Tuan 1976), the concept has been discussed and developed in many disciplines, including psychology, sociology, human geography, and economics (Lewicka 2011). This has resulted in wide and varied interpretations of SoP that have originated and been adapted according to practical application and understanding in various contexts. For clarity, we consider SoP under its broadest definition, referring to the emotional bond that people have with

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a specific place. Fundamentally a positive SoP equates with a positive emotional bond with a place (Bell et al. 2018) and contributes to well-being (Stedman 2002). In linking well-being and SoP, we take guidance from the concept of salutogenesis (Pitt 2018). This term and associated literature originates in medical sociology (Antonovsky 1979) and underscores the link between sense of place, the quality of the environment (Mittelman et al. 2017), and health and well-being outcomes (Frumkin 2003).

The link between SoP and human behavior is underscored by the theory of planned behavior (Fishbein and Ajzen 1975, Ajzen 1991). Attitudes and intentions are shaped by the emotional bond people form with a place, and this influences how they conduct themselves, i.e., their environmental behavior, and the decisions they make (Vaske and Kobrin 2001, Halpenny 2010, Newman et al. 2017). Examples from the literature indicate that a stronger SoP will lead to proenvironment behaviors that support conservation and management efforts (Williams and Patterson 1996, Tonge et al. 2014, Sawitri et al. 2015). In contrast, a degraded natural (or built) environment can reduce people's SoP, which in turn can negatively influence their behavior, leading to increased environmental degradation (Brehm et al. 2006). Furthermore, not only does SoP impact people's behavior in relation to common property resources, it has also been shown to influence their behavior in relation to privately owned property and resources (Jorgensen and Stedman 2001, Stedman 2003). However, it is important to highlight that SoP is not always positively related to improved sustainability outcomes. For instance, strong ties between identity and place and some cultural practices can affect resilience (Lyon 2014), and lead to maladaptation and poorer environmental outcomes (Câmpeanu and Fazey 2014, Fazey et al. 2016). Nevertheless, it is clear that by no longer ignoring, but instead taking account of, and better using SoP in decision making related to marine resource use, should improve the effectiveness of those decisions and potentially improve sustainable use of natural resources.

Although conceptually the importance of SoP in relation to marine resource management has been identified (Halpern et al. 2012, Gurney et al. 2017), academic scholarship regarding its practical application in relation to marine resource management has been limited to date. This is partly owing to a lack of SoP indicators that could be measured and monitored over appropriate spatial and temporal scales to inform governance responses. To address this, we develop a framework that identifies the key indicators of SoP that can allow decision makers to measure and monitor SoP in relation to marine systems. We also identify how this framework and associated indicators can be integrated into existing decision-support tools, e.g., social-ecological models, to inform the management of marine resources (see Appendix 1 for a detailed example).

A BRIEF OVERVIEW OF SENSE OF PLACE

The concept of SoP is not new, with theoretical origins stemming from at least Tuan's fundamental work (Tuan 1974, Tuan 1976). SoP comprises both a person's or group's attachment to a place and the meaning of a place, but greater analytical emphasis has been given to place attachment (Masterson et al. 2017). In essence, place attachment is a positive emotion that people have about a place (defined by their place dependence and identity). Another important concept is "place meaning," being the adjectives that

describe the kind of place it is and the images it conveys (Stedman 2003). SoP is a more general feeling about a place (Hashemnezhad et al. 2013) and comprises both place attachment and place meaning.

SoP as a concept was explored in the 1980s through the work of Hay (1988) and Williams and Roggenbuck (1989), who identified the importance of the concept for natural resource management and subsequently proposed a psychometric approach to measure it. Since this time, SoP has been applied to a range of disciplines (reviewed by Lewicka 2011) and various methods to measure SoP have been developed, most typically to elucidate how closely people identify with a specific place and how much they depend on that place for their well-being, such as their income or achieving life goals (Tonge et al. 2014). Studies have also demonstrated that a person's SoP is not constant, but changes over time, for instance, with experience or learning, and disruption or environmental change (Carter et al. 2007). Insights have also been gained into how SoP might be utilized in decision-making processes to improve resource outcomes (but see Brown and Raymond 2007, Acedo et al. 2017, Masterson et al. 2017). For example, SoP for rural farmers has been shown to increase as their experience in farming grows (Raymond et al. 2010). Although research into SoP has certainly intensified, exploration into its usefulness at a practical level remains limited.

Part of the difficulty associated with measuring SoP in a way that is useful and meaningful for environmental management relates to ambiguity in its exact definition and meaning (Shamai 1991). This arises because not only is SoP apparent in its biophysical attributes, it also emerges as a result of people's interactions with interwoven and complex social, political, and psychological processes (Williams and Vaske 2003, Tonge et al. 2013). An important dimension of SoP that has implications particularly for marine management, is that a person's SoP does not solely rely upon being physically located within a place, or being able to physically access that place. Rather, a person's emotional bond to place also plays a large role. That is, a place can be meaningful and important to a person both in their mind and/or by being physically present (Agnew 1987, Gurney et al. 2017). Hence, a person's SoP can exist beyond the bounds of a specific physical place, but may resonate within everyday life through memories or photographs, or objects in the home collected from that place (Booth 2008). Complex connections make SoP hard to measure. For instance, the existence of the Great Barrier Reef will contribute to people's SoP even if they may never visit it (Marshall et al. 2018). Conversely, being forcibly displaced from an area that one has always known, for example, as a consequence of sea level rise, can be very traumatic for groups of (indigenous) people with a strong SoP (Corlew 2012).

In this paper, we use the tripartite approach developed by Scannell and Gifford (2010a) and applied by Lewicka (2011) to build our framework of SoP for marine systems. The tripartite approach conveys attachment to a place as stemming from a combination of aspects related to person, place, and process (Scannell and Gifford 2010b, Zia et al. 2014). A SoP associated with experiences that are related to person, place, and process can be visual, psychological, or spiritual, or a combination of these (Tuan 1976, Mohammad et al. 2013), resulting in an emotional bond that people have with a place (as per the previously mentioned broad

definition we adhere to in this research). The various bonding routes are described below.

According to (Lewicka 2011), the person aspect of SoP has attracted more research attention than place and process. Numerous studies across disciplines have shown that strong predictors of SoP are attributes of the person whose SoP is being measured (Jorgensen and Stedman 2006). For instance, length of residence, an easily observable personal attribute, is one of the strongest predictors of SoP. Potentially related to residence length are the experience and familiarity a person has with a place, which also relate to greater SoP (Carter et al. 2007). Similarly, historical connection with a place, including family and religious ancestry and personal investments, e.g., ownership, influence SoP (Brehm et al. 2006). A recent Australian study (Brown et al. 2015) demonstrated that people from coastal areas tend to be attached to smaller defined areas, i.e., one specific beach, than noncoastal residents, who are more likely to be attached to a larger geographical space, i.e., the ocean, likely due to deeper connection to these coastal areas influenced by the factors described above.

Similarly, the place attributes of a landscape can influence a person's SoP. Place attributes can be estimated or measured relatively easily, although difficulties do arise, given that the potential number of physical features that may affect SoP is infinite (Lewicka 2011). For example, landscapes can be characterized by features such as vegetation, color, texture, and slope (Carter et al. 2007) amongst others, and these may all impact upon SoP. In addition, there are many intangible physical features that facilitate attachment (Kaplan 1984), for example, the turning of the seasons, an enjoyable weather event, or the movement of light across a body of water. Place aspects are multiple, and their inclusion should be based on local circumstance and common sense to ensure they are useful predictors of SoP (Lewicka 2011).

In contrast, whereas measures of person and place may be readily identifiable (observable), the process aspect relates to how SoP exists, and relies on environmental psychology to explain human responses to a landscape (Jacobs 2011, Lewicka 2011). The process component includes the behavior that a person manifests as a consequence of their emotional response to a place and their unique cognitive processes that incorporates their knowledge and memories of a place. The concept is possibly best described as a mental representation where "a place" becomes a "place of mine" via emotional and cognitive bonds. In other words, the place-related self becomes a subsystem of the self (Knez 2014). The process component of SoP reflects a sense of self-continuity, which is the ability to perceive and experience that we are the same person over time (autobiographical memory), extending temporally backward into the past and forward into the future (Hershfield 2011). Autobiographical memory will influence a person's behavior (Lewicka 2011), but it is a dimension of a person that is not easily expressed in terms of a simple explanatory variable.

Similar explanatory difficulties apply to the (psychological) processes that inform how environmental aesthetics affect SoP and behavior (Kaplan and Kaplan 1989). Personal, collective, and cultural memories and background will influence how people relate to places, and these relationships are expected to change over time and with experience (Booth 2008). Because a significant part of SoP is embodied within the process of both living and

remembering a place, the concept is complex and dynamic and can be hard to define, further complicated by the fact that SoP can arise from entirely individualistic, as well as shared social experiences.

THE APPLICATION OF SENSE OF PLACE TO MARINE SYSTEMS

For the most part, empirical investigations of SoP have ascribed meaning to terrestrial places, whereas marine systems have received less attention (although see recent paper by Gurney et al. 2017). There is a body of work on coastal landscapes and communities containing social perspectives on place attachment, from marine resource dependencies (Marshall et al. 2012), and resilience (Marshall and Marshall 2007, Clarke et al. 2018) to, for instance, climate change (Metcalf et al. 2015). There is also research around Australian indigenous people's relationship with "sea country" (McNiven 2004). Even though this social coastal perspective exists, there is less literature related to how people may feel about, their attachment to, or their SoP, in relation to marine places (but see for instance Jacobsen 2010).

Consequently, there is a relatively low theoretical and empirical understanding of the role of SoP in relation to management of the marine environment. Some attempt has, however, been made to identify differences and complementarity in attributes of SoP in terrestrial and marine settings (Poe et al. 2016). For instance, having a water feature or water body in the environment will increase SoP in terrestrial settings (Wynveen et al. 2010, Tonge et al. 2013, Gagné and Rasmussen 2016).

The small amount of empirical research to date on SoP in a marine context has mainly focused on recreation and tourism use of marine spaces, and specifically, fringing coral reefs. For example, in relation to the Great Barrier Reef, Wynveen et al. (2010) ascribed 10 place-related meanings with a balance of place attributes (the marine setting) and person and process attributes contributing to SoP. Place-based attributes included, for instance, aesthetic beauty, lack of built infrastructure/pristine environment, abundance and diversity of coral and other wildlife (Wynveen et al. 2010). Attributes related to person and process included desirable recreation activities, safety and accessibility, and experiences with family and friends (Wynveen et al. 2010; see Table 1 for more extensive list). Similarly, research in the Ningaloo Marine Park and World Heritage Area in Western Australia, also found that tourism-related SoP was influenced by the physical environment (Tonge et al. 2013). In this case, a seemingly paradoxical physical attribute that positively influenced SoP was isolation. People seek isolation in their choice of place and destination, but this isolation then encourages them to seek interaction and close proximity to other people in the camping areas, in essence reversing the isolation. Person and process attributes that influenced SoP in the Ningaloo region included recreational activities, social situations, and social ties (Tonge et al. 2013). In the industrial harbor of Gladstone in Queensland, SoP was one of several social and economic indicators in a report card that provides ongoing snapshots of progress toward specific ecosystem health goals in that harbor (Pascoe et al. 2016).

Aside from these few case studies, the exploration of SoP in relation to marine contexts has remained anecdotal and nonprescriptive, or relates to understanding community relationships to fishing (Khakzad and Griffith 2016). For

Table 1. Categories (A to E) of 35 marine attributes (indicators) that contribute to place, person and process aspects of sense of place (SoP). This list is not exhaustive and attributes may have been missed in our attempt to summarise.

Attributes (indicators)	Place	Person	Process	Examples of measurement of indicators or how the indicators should be measured.
A Marine flora & fauna (7)				
1 Abundance	✓			Areas with high abundance of marine life may be interpreted as healthy and well managed and can have attractive aesthetical properties.
2 Diversity	✓			Similar to abundance, areas with many different flora and faunal species may be perceived as diverse and visually attractive.
3 Native species [†]	✓			Native species persistence in areas can mean that invasive species and pests have not had excessive impact, and/or point to unique ecosystem qualities. These areas may be perceived as having high natural and cultural values.
4 Charismatic species [‡]	✓		✓	Charismatic species, e.g., those that have a compelling attractiveness like whales, turtles, dugongs, etc., will draw emotional responses, and exposure to and knowledge of these species is likely to foster attachment to their habitat locations.
5 Iconic species ^{†‡}	✓ ^s		✓	Similarly to charismatic species, iconic species can invoke emotional responses and have intrinsic value in their own right. Iconic species are different from charismatic species in that they are important to cultural identity. This can include species associated with national identity such as crocodiles.
6 Endangered species [‡]	✓			Species that are vulnerable or endangered may have a greater perceived value by virtue of their rarity and this may foster attachment to their habitat locations.
7 Invasive species [†]	✓			Highly altered areas; changes due to weeds and other pests might reduce the value of a marine environment and attachment to place.
B Marine ecosystem (8)				
1 Remoteness [‡]	✓			Remote locations, e.g., measured in terms of distance from urban areas or from people, are potentially of great SoP value because effort has to be made to visit the place, and it may be perceived as rare. The effort made may increase the value and attachment to the place. However, remoteness may also mean that people never get there to experience it and fail to develop an attachment.
2 Uniqueness of natural resource [†]	✓			Similar to vulnerable species, unique ecosystems, i.e., the Great Barrier Reef, may be attributed more value and people may feel a greater need to protect them, and have greater attachment to retaining them.
3 Lasting special places [†]	✓	✓	✓	Places can be special because of their unique ecosystem of flora and fauna, but also because of other features of natural beauty. Places that are established and experienced over time will become associated with myths and stories. People will have greater attachment to places that are special.
4 Recognized/protected coastal heritage [†]	✓			Coastal heritage areas (e.g. old piers and fishing spots) will be special places for people because these places can be rare, native as well as beautiful, and likely to foster SoP.
5 Naturalness of surroundings	✓		✓	Naturalness (untouched and unspoiled) can be a perception rather than being related to any real natural values. If a place looks natural it may be associated with high aesthetic values creating an attachment to the place. Sounds and smells are known to elicit emotional responses, trigger memories, etc., and could also play a role in fostering SoP.
6 Habitat damage	✓			Damaged habitat may be visually less appealing and hold lower intrinsic value. This may affect attachment to that place.
7 Presence of rubbish	✓			If a place is polluted or littered with rubbish its aesthetic value will be affected, as well as the perceived health of the area, and people may be less attached to it.
8 Good water quality	✓			Places with good water quality, low pollution, and low turbidity will appear healthier and therefore generate higher levels of attachment.
C Marine connections[‡] (6)				
1 Spiritual connection		✓	✓	People can have spiritual connections with marine species that have a special role in their lives and their culture, and these species can represent intrinsic value that generates SoP.
2 Spirit animals [‡]		✓	✓	Spirit animals hold special value to indigenous people and create attachment to places and habitats where these spirit animals reside.
3 Cultural identity		✓	✓	A person can feel a connection to the sea if it is part of their cultural identity. For instance, indigenous people of the Torres Strait have a special connection to the sea that is part of their Torres Strait Islanders identity. Cultural identity is expected to generate high attachment to place.
4 Recognized traditional (respect) area [†]		✓		Some marine areas have special values related to respect for the environment. Recognized areas, subject to traditional respect, are of great value to indigenous people and can generate high attachment to these places.
5 Ancestral knowledge base [†]			✓	Historical association with place and knowledge creates an attachment to place.
6 Traditional use rights [†]			✓	Longer associations and extended use cements an attachment to place.
D Marine experiences and uses (10)				
1 History of family and social use			✓	Family history of commercial or recreational fishing, or school educational trips and experiences will create a greater attachment and SoP.
2 Recreational opportunities [†]		✓		Some marine areas are used for recreational fishing or diving activities because they have been made possible, i.e., dive zones, green zones that allow recreational but not commercial fishing. Greater use and interactions with an area creates SoP.

(con'd)

3	Educational values	✓		Educational experiences in a location will expose people to knowledge that they may not have been aware of, thus increasing attachment to these places.
4	Congestion	✓		Concentrated use of an area, for instance, many recreational fishers in the same area, will reduce people's attachment to a place, and may also lead to conflict among user groups, which may further reduce SoP.
5	Exclusion	✓	✓	Exclusion can result from regulation that prohibits access, or remoteness that means a place cannot be readily accessed, for either logistical or financial reasons. (Perceived) exclusion from an area, reduces the opportunity to interact with it and may reduce the chance of fostering SoP.
6	Coastal infrastructure	✓		The presence of infrastructure means people can access a place, be exposed to it, and develop a relationship with it. However, for some people having access can mean they are less likely to visit it, because this high availability reduces its rarity value and the likelihood of becoming attached.
7	Income earning potential	✓		Places with high potential for creating income and opportunity may increase people's desire to exploit these areas and people can become attached to them for their economic potential.
8	Economic resource dependence [†]	✓		Dependence on a place by virtue of it creating income will make people more attached to a place.
9	Engagement in governance [‡]	✓		Engaging in the management of a place can expose people to the values of a place and elements of its uniqueness. This exposure and familiarity, as well as ability to influence governance of the place, can increase attachment to it.
10	Memory of unpleasant events	✓		Unpleasant experiences in a place can create a negative association to this place and engender a lower attachment to the place. For example, occurrence of sea sickness or near-death experiences, i.e., sailing into a storm.
E	Objects, stories, and memorabilia (4)			
1	Stories about marine environment		✓	Exposure to books and movies, i.e., Jaws, Jonah being swallowed by a whale, Noah's ark, popular 's marine TV programs, as well as tales, i.e., hearing the sea in a seashell, can create a sense of wonderment and attachment to a place.
2	Marine species as pets		✓	People connect with nature through pets. For example, keeping marine fish as pets gives people a sense of connection to the marine environment.
3	Marine objects in the home		✓	Connecting to nature through biophilia. Wilson (1984) proposes that we have an innate tendency to connect with nature, i.e., explanation of why we have pot plants, pets, images of nature, and natural objects, e.g., sea shells, in our homes.
4	Marine artwork, photography, and film		✓	People can hold and also develop attachment to places of beauty through their experiences of photographs, e.g., wilderness calendars, and art signifying marine areas. Attachment can also be enhanced through film and documentaries.

[†]Obtained from literature (Ocean Health Index, Wynveen et al. 2010 and Tonge et al. 2013) but rephrased for clarity.

[‡]For instance, some iconic species listed in the Australian Atlas of living organisms (<https://lists.ala.org.au/iconic-species?fq=kvp%20group:Mammals>) are not endangered and separate listing is recommended.

[§](<http://www.ecosystemserviceseq.com.au/step-5-services/iconic-species>) The definition for iconic species is: "species revered as emblematic or charismatic (e.g. whales, dugongs, koalas etc) ... or that have played an important part in the history or economy of people ... or that in another way capture the imagination of the public."

^{||}Not all indicator groups are relevant in all places.

^{*}Some iconic species are important to cultural identity through their involvement in traditional activities. We refer to those as totem animals.

example, Jentoft (2000) suggested that small fishing communities experienced deep-rooted place attachments, but did not explore the underlying drivers for this attachment. Similarly, a review of fisheries- and marine-related social-ecological assessment projects by Breslow et al. (2016) showed that SoP was one of 38 social indicators of wellbeing. However, the studies reviewed by Breslow et al. (2016) interpreted factors that explain SoP quite differently, with little consistency among studies. For instance, some studies used variables that related directly to the marine environment including "access to traditional marine and coastal use rights" and "invasive species" to contribute to strength of SoP. Others used variables of a more indirect nature, for example, the "number of people involved in place-based activity," and "the level of engagement of place-based community, households, and families" to contribute to the strength of SoP.

It is evident that empirical studies of attributes of the marine environment that contribute to SoP are limited. Nevertheless, empirically untested attributes are currently used to evaluate SoP in various marine research contexts. A notable use of SoP in a marine context is in the Ocean Health Index (OHI), which measures the health-state of the world's oceans by means of an

index score calculated using existing global data (Halpern et al. 2012). The OHI assesses the ocean's role in the cultural, spiritual, and aesthetic lives of people through measurement of SoP, which is inferred from two proxies. Sense of place in the OHI is quantified by estimating the following:

1. lasting special places that are "... geographic locations that are valuable to people for aesthetic, spiritual, cultural, recreational, or existence reasons" (<http://www.oceanhealthindex.org/methodology/goals/sense-of-place/lasting-special-places>)
2. iconic species that are "... animals or plants which are important to cultural identity as shown by their involvement in traditional activities such as local ethnic or religious practices and/or which are locally or more broadly recognized for their existence and aesthetic values" (<http://www.oceanhealthindex.org/methodology/components/iconic-species-list>).

The OHI has the potential to influence international marine policy and, although many indicators used in this index are indeed robust, the SoP indicator could potentially be improved by making a stronger link to the extensive (though mostly terrestrial-

based) SoP literature and by building upon the limited number of empirical marine-based studies currently available. Clearly there are significant challenges in measuring SoP, but as described above, some progress has been made in providing snapshot measures at points in time.

From a management perspective, it would be useful to be able to quantify how SoP changes over time, both to understand how changes in natural and human-development of environments mediate changes in SoP and how this in turn creates two-way dynamic feedbacks between the human and natural systems. Understanding drivers of SoP, and dynamic feedbacks in social-ecological systems would improve the ability to make forward predictions under alternative, plausible scenarios, e.g., alternative development scenarios, as well as increase the potential for using SoP as a performance statistic to quantify the performance of alternative management scenarios.

A FRAMEWORK FOR INCORPORATING SENSE OF PLACE INTO THE MANAGEMENT OF MARINE SYSTEMS

Exploring the ocean's role in people's SoP is not easy, particularly when compared to the more straightforward measurement of biological or ecosystem indicators, i.e., fish size, biodiversity, or habitat type. Traditional valuation techniques, as, for instance, used by economists, cannot easily measure perceptual and emotional qualities that make marine locations feel special and distinct from anywhere else. Nevertheless, other social survey techniques can give insight, as evidenced by the extensive empirical terrestrial literature (Lewicka 2011). The empirical evidence that is available in Australia is centered on recreation and tourism in protected coral reef areas (e.g., Gurney et al. 2017), where place-based aspects of SoP might be more apparent. The limited number of applicable valuation techniques, and the exclusive focus on special places, means there is little empirical insight into the influence of various attributes of the broader marine environment on SoP.

As we showed in the previous section, the rationale for choice of attributes is sometimes obscure in studies where marine-related attributes have been used to derive a measure of SoP. This is no doubt partly due to limited observational data (Halpern et al. 2012) and the lack of theoretical insight. Nevertheless, the (mostly) terrestrial literature suggests that SoP influences people's environmental behavior. This behavioral response is likely to be equally relevant in the marine environment. It would therefore seem prudent to attempt to better understand the different attributes of the marine environment that influence SoP.

As a first step, we develop a list of 35 marine related attributes (or indicators). We present the environment and the human domains separately, but acknowledge that they comprise a social-ecological system and are intricately linked (Masterson et al. 2017). From a social-ecological systems perspective, the various attributes are assumed to comprise an interconnected social and biophysical reality (Masterson et al. 2017). The 35 indicators for the marine environment and human domain can be loosely organized into five categories. These categories were developed inductively based on the reviewed literature and relate to the marine environment (A and B) and the person interacting with this environment (C, D, and E) forming a total of five indicator categories reflecting the dimensions of SoP.

1. marine flora and fauna,
2. marine ecosystems,
3. marine connections,
4. marine experiences and uses, and
5. objects, stories, and memorabilia.

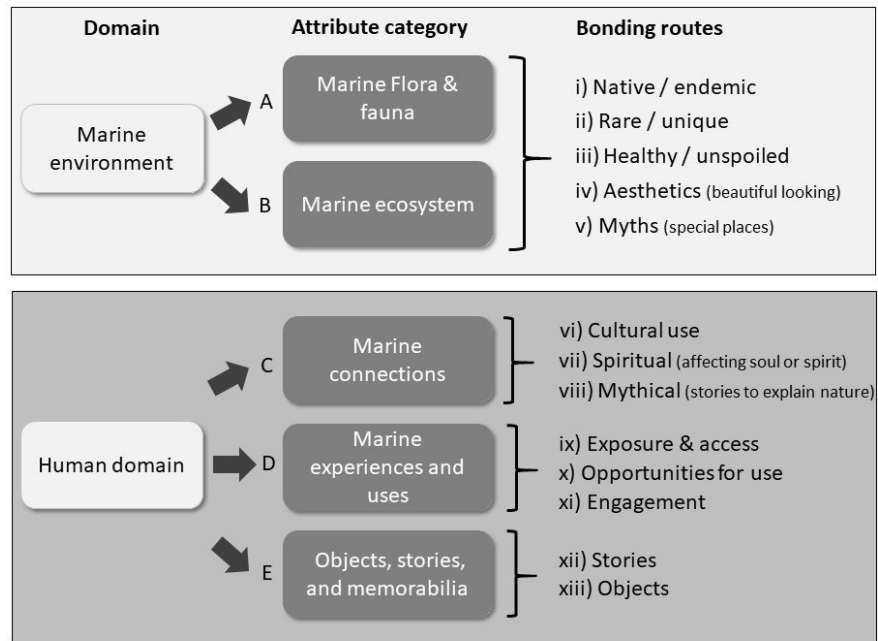
The 35 attributes (see Table 1) were identified differently for the marine environment and the human domain. The attributes that relate to the marine environment (categories A and B) drew largely on the combined experience of the authors. They were chosen on the basis of indicators^[1] commonly used in ecosystem based management (EBM; Rochet and Rice 2005, Shin et al. 2012, Plagányi et al. 2014) and for the purpose of management strategy evaluation (MSE) of fisheries and marine systems (Punt et al. 2001, 2016, Dichmont et al. 2014, Fulton et al. 2014, Pascoe et al. 2017), explained in more detail in the Future Directions section below^[2]. The attributes for the human domain (categories C, D, and E) were more substantially based on the above reviewed literature, but also drew on the combined experience of the authors in MSE and EBM (Sainsbury et al. 2000, Punt et al. 2001, Plagányi et al. 2013). Each of the attributes were checked against the bonding routes that theoretically and practically link them to SoP.

We provide a rationale for the inclusion of various SoP attributes under each category and use published evidence where available. For each of the attributes, we identify if there is an associated place, person, and process aspect (Table 1). Where a process aspect is associated with the marine environment (i.e., charismatic and iconic species contribution to SoP is related to a place, but also process in Table 1), it means that the values are location-specific but also a consequence of the emotional response that is person-specific and time-dependent. As described earlier, process-related attributes are sensitive to a person's different emotional responses to the environment they are in (and their attachment to it) because people are shaped by their personal history and experiences. For instance, a resident in a coastal community might be particularly attached to their local marine environment because of their interactions with charismatic species when they were a child. These memories might make the marine environment a special place for them and their family and affect their SoP.

The list of indicators (Table 1) is not intended to be exhaustive. Moreover, the list needs to be used with the understanding that SoP does not develop through simple cumulative addition of attributes because this would not adequately reflect the nuance of SoP processes. It provides a framework to help construct a more organized and consistent approach to data gathering. Moreover, this ensures that the marine environment is considered and better represented in SoP studies, and incorporated into models used to drive management of the marine environment. This list provides a first attempt to generate discussion and future research relating to SoP in the marine context that will inform future refinements and improvement to this framework. However, as further empirical evidence relating to SoP becomes available, this list should be refined.

Some interesting observations can be made on the attributes in each of the subcategories in Table 1. Most of the attributes in the first two categories (marine flora, fauna, and marine ecosystems)

Fig. 1. Conceptual links between domain, five attribute categories, and different processes that are (mostly) positively linked to well-being and expected to mediate greater SoP in the marine environment.



are place-based, with 4 of the 15 attributes also having a process component. The 6 marine connections attributes relate mainly to person and process, while the 10 commercial and noncommercial marine uses are mainly related to place and person. The 4 attributes for marine perceptions and symbolism are person and process-based.

We list several bonding routes (i to xiii in Fig. 1) in line with our broad definition of SoP (the emotional bond that people have with a specific place). The bonding routes in the human domain are based on the reviewed literature, and are empirically conceptualized by Poe et al. (2016), who suggest that a person's SoP is derived from four processes (not to be confused with the process component of SoP): use of the marine environment; connections to the marine environment; emotional and sensory experiences; and associated human interactions. We also support our choice of bonding routes by additional literature not reviewed above, including the influence of the following: aesthetics (Yi-Fu 1974), cultural use (Poe et al. 2016, Thompson 2016); the telling of stories (Ryden 1993, Marks et al. 2016); being engaged and through exposure (Brinckerhoff 1994), and having mythical and spiritual connections (Steele 1981, Low 1992). For the bonding routes for the marine environment, links are made via native/endemic areas (Forristal et al. 2014); natural areas (Lin and Lockwood 2014); unspoiled environments (Cox et al. 2006, Keske et al. 2017); system health (Horwitz et al. 2001); and waterscapes (Pitt 2018).

The link between bonding routes, attributes, and SoP can be best illustrated through an example. SoP is expected to be greater for marine areas with a high abundance of marine life and a diverse

array of species (attributes A1 and A2 in Table 1, respectively). A marine area with rich and abundant marine life is likely to render it aesthetically pleasing (bonding route iv in Fig. 1) and the marine environment is more likely to appear healthy and unspoiled (bonding route iii in Fig. 1; Cox et al. 2006, Keske et al. 2017).

FUTURE DIRECTIONS

The sustainable management of our oceans relies on the ability to influence and guide human use of the marine environment (Costanza et al. 1998). As outlined in the preceding sections, SoP is likely to influence environmental behaviors and thus outcomes. Most extractive uses of the marine environment, such as fishing, and nonextractive uses, including recreation and tourism, are managed by government authorities, who have different management tools and control methods at their disposition (Cochrane 2002). These same authorities will need to monitor the outcomes of their management actions, and ensure that it is sustainable, both spatially and temporally.

Gaining a measure of SoP can be helpful in several ways. Specifically, our proposed SoP framework can be incorporated into sustainable marine management as a means of capturing the often neglected social and human psychological dimension. Understanding and characterizing SoP could expand the toolbox of management approaches that can be used as levers to achieve desired outcomes. Importantly, SoP can also be integrated into existing approaches for evaluating management strategies and impacts before they are implemented, so-called management strategy evaluation (MSE). MSE is widely used in marine applications to evaluate how effective alternative management

strategies are likely to be before they are implemented, and what the potential trade-offs are in terms of achieving prespecified objectives (Punt et al. 2016). MSE is a modeling-based approach that aims to evaluate and compare the robustness of possible management strategies (Sainsbury et al. 2000, Punt et al. 2001). MSE essentially evaluates the consequences of several management strategies to determine the trade-offs in meeting operational objectives (Punt et al. 2016). Some common biological and economic operational objectives for fisheries include maintaining biodiversity, profitable fishing fleets, protecting iconic species, safe employment, and maintaining cultural traditions. For each objective, several indicators give insight into whether objectives may be met (Rice and Rochet 2005), i.e., indicators such as species diversity, mean trophic levels, and average fish size (Kaplan and Leonard 2012, Coll et al. 2016) provide insight into the biodiversity objective.

To date, the indicators (related to each of the operational objectives) that are used to summarize MSE model outputs have been largely restricted to the natural sciences and economics (Dichmont et al. 2008, van Putten et al. 2012, Österblom et al. 2013, Plagányi et al. 2013, Melbourne-Thomas et al. 2017, Nielsen et al. 2017). Even when natural components of the models are well resolved, the relational aspects that underpin their human components often only incorporate economic behavioral drivers, i.e., profit maximization, whereas social, i.e., networks, and psychological behavioral drivers, i.e., social norms, are frequently underrepresented. Indicators that add extra complexity about social aspects of the human system, such as equity, health, and safety, are missing (Fulton et al. 2011). Moreover, indicators that apprise of how people may relate to the marine environment, such as SoP, are exceedingly rare (Lewicka 2011), but could certainly be included as part of MSE frameworks. This includes SoP related to remoter, perhaps unvisited marine environments, because some of the factors impacting these environments can also be the result of human behaviors and activities that originate at a distance, e.g., the consumption and disposal of plastics, and greenhouse gas emissions. We anticipate that the next step, in terms of use of SoP as part of decision-making frameworks, would be to dynamically capture changes in SoP in response to changes in other system components, as well as two-way feedbacks between human and natural systems, to further enhance the predictive power and breadth of decision making tools.

Here, we provide an important first step for incorporating SoP into marine resource management approaches, such as MSE. As we have described above, SoP affects the emotional bond that people have with a place, influencing their attitudes and intentions (Ajzen 1991), and thus their behavior in a terrestrial context, and SoP's influence on behavior with respect to marine resources is likely to proceed likewise. It is recognized that the marine environment plays a role in our SoP (Tonge et al. 2014), but little is known about the empirical reality of this. A number of ocean and marine studies and indices have used SoP as an objective outcome of a healthy marine environment (Halpern et al. 2012). However, the attributes used to measure SoP are not based on observational studies and neither to date have they been robustly tested. The framework of potential marine attributes that might contribute to SoP that we have proposed serves as a starting point for improving use of the concept in marine studies. In particular, in terms of evaluating and testing the robustness of possible management strategies and the

likelihood of meeting operational objectives (Sainsbury et al. 2000, Punt et al. 2001), we also anticipate that the indicators will identify how various management strategies might affect SoP and will provide important information that can guide its research development.

CONCLUSIONS

In this study, we have used the tripartite organizing structure by Scannell and Gifford (2010a) and discussed in Lewicka (2011) to develop a SoP framework with 5 categories encompassing 35 marine environment attributes (Table 1), and the processes by which they may affect SoP. By addressing the complex and interrelated dimensions of the person, place, and process that constitute SoP, we offer a holistic approach to understanding and measuring an important human-dimensions concept. This also ensures that our suggestions can be practically applied in existing management to achieve EBM, using approaches such as MSE.

This paper is intended to be a significant first step in understanding, measuring, and incorporating marine SoP, to ultimately improve management of our oceans. Because SoP is an important determinant in how people behave in relation to marine places and environments, incorporating this social dimension into marine management appears essential for sustainable resource use. It should no longer be overlooked, but can in many cases enhance how we manage marine systems. Research on SoP in the marine realm will need to be further developed through trial and application, and we make no claims that such a complex concept will be easy to define and operationalize. We also acknowledge that our framework leaves unanswered questions as to how changes in the marine environment might affect SoP and how SoP dynamics might change behavior in a system feedback. We highlight these as important areas for future modeling research.

[1] The term “indicators” is commonly used in modeling applications, but in the context of this research we use it interchangeably with attributes.

[2] The authors of this current paper initially became interested in better understanding the utility of sense of place in a marine context because they were modeling a local multiple-use marine system to evaluate different management approaches for the marine system and also to better represent traditional owners' interaction with the oceans (van Putten et al. 2013) and reflecting this in management (Plagányi et al. 2013). The marine environmental attributes and categories are partly based on the authors combined experience in modeling these social-ecological marine systems.

Responses to this article can be read online at:

<http://www.ecologyandsociety.org/issues/responses.php/10504>

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Appendix 1. Example of simple marine social-ecological model that incorporates a sense of place.

This appendix provides a simplified example of the implementation of the concept of ‘sense of place’ using a hypothetical marine-based socio-ecological system (SES) with feedback in the system.

For simplicity, we describe the environment by three temporally-varying environmental variables describing land, water and fish resource quality. Together, these variables are used to define a sense of place *index* (SoPI) for two resource user groups. The model incorporates feedback between the environmental variables and the resource users via the SoPI, and is able to predict long-term (decadal) changes in i) the number of residents of a small coastal community, ii) tourist visitation numbers, iii) environmental quality, and iv) the SoPI for both resource user groups. We use our model to describe various changes to urbanization and the natural environment, and show how ignoring sense of place can change our long-term predictions regarding the state of the natural environment and the socio-demography of the resident human population. Thus, our model suggests that SoP should be accounted for when predicting the long-term impact of potential development scenarios.

Box 1: An example of a small coastal community in Tasmania, Australia that illustrates the model elements.



Orford is a scenically situated town of around 600 residents (Census 2011) located approximately 80 kilometres northeast of the urban centre of Hobart, Tasmania, Australia. Orford has extensive views towards Maria Island, as well as the Prosser River and Prosser Bay (Figure A1.B1). It has a number of picturesque east-facing beaches and is surrounded to the west and south by hilly and vegetated forests.

Orford has a permanent population of an older demographic (mainly retirees), but also caters for the younger working age groups (as evidenced by the presence of a local primary school). The predominantly residential settlement relies on neighbouring centres to provide higher order health and educational services. Aside from the permanent residents, there is a large influx of ‘shack owners’ in the summer months. Participation in recreational fishing is high on the east coast of Tasmania (27%). Recreational fishing is a very important pastime for both the ‘shack owners’ and the permanent residents of Orford. Orford is popular with holidaymakers and tourists in the holiday season, some of whom will participate in recreational charter fishing.

The coastal location and the recreational activity potential are an integral part of living in this region. The coastal aesthetics of the region are further enhanced by Maria Island, which lies off the coast of Orford and is a UNESCO World Heritage Site (Environmental Resources Management 2007) (Figure A1.B1). Maria Island has important natural and indigenous values and significance in terms of the European presence and use of the island (Tasmanian Parks and Wildlife Service 2013). A marine reserve (Maria Island Marine Reserve) was established in 1991 along a 7 km length of coastline that includes a no-take zone and fishing zone. There is currently no permanent population on Maria Island, but around 18,000 tourists visited the Island in 2014 using a tourist ferry leaving from the Orford area (Tasmanian Parks and Wildlife Service 2013). Maria Island receives mostly day or multiple day visitors who undertake recreational activities, including swimming and diving. Recreational vessel traffic to the south of Maria Island can access secluded bays with safe mooring sites for yachts during the summer months. Diving activities also take place around the island mostly by self-organised divers (dive club members) who are likely to visit using their own boat.

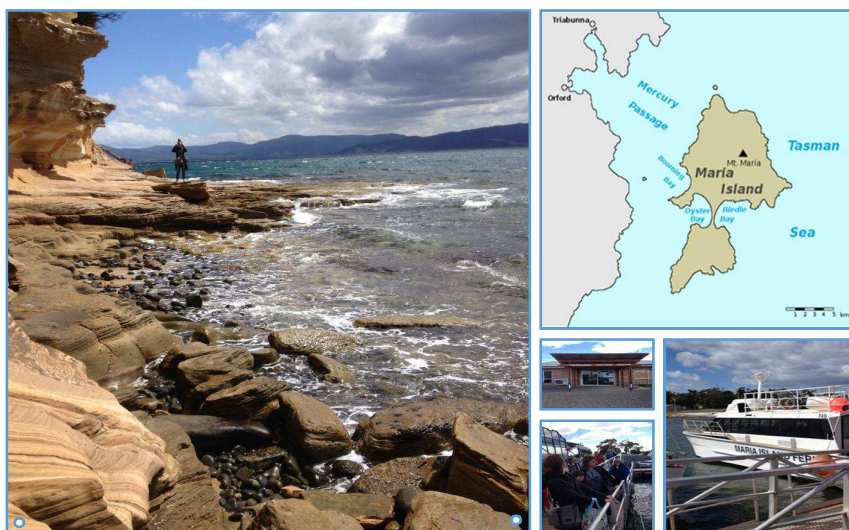


Figure A1.B1: Map of the study area and image from the passenger ferry and Maria Island.

Employment in Orford is mainly in retail, services and hospitality, but residents are also employed in construction and industry (aquaculture and fish processing). There are a few commercial fishers resident in the area (targeting rock lobster, abalone and several other species). Immigration to the area is influenced by employment availability. Employment opportunities are created by existing industries and businesses, and new local developments. Several developments have been planned, or have at some stage proposed, for the coastal community (Parliament of Tasmania 2015). Currently a Spring Bay Mill Project, a golf course, and a Marina development have been proposed. In addition, a new aquaculture development has just been established. Some of these developments will impact the marine environment via changes to the terrestrial environment (i.e. the nutrient input via the golf course). The golf course development will also likely have a positive impact on tourism. Other initiatives, such as the fish farm will likely impact water quality. The latter will affect marine resource users' sense of place illustrated by the fact that there has been much public protests in relation to establishment of the aquaculture farm (see for instance <http://www.abc.net.au/news/2018-04-12/tassal-okehampton-bay-expansion-victory-over-opponents/9644784>). This may lead some recreational fishers to leave the area if access becomes more difficult or fish abundance declines. The visual impact of the fish farms may also lead to those who don't extract marine resources to move away. Thus, if these two-way feedbacks between the natural and human systems are not accounted for, the consequences of alternative development scenarios will not be accurately predicted.

Conceptual framework

The state of the SES is defined by a set of environmental variables and groups of resource users. Our model predicts how the state of the SES changes deterministically over time, both in terms in how the users perceive and exploit the natural environment. Here, we consider two resident groups (X): observers (O) and users (U); however, the model can be readily extended to more groups. The number of resource users in both of these groups is driven by births and deaths (λ), immigration (I_x), and emigration (M_x) (see Figure A1.1 and Table A1.1 for definition of symbols and variables, and Table A1.2 for equations and model specification). The resource user's SoPI (node labelled sense of place index (S_x) Figure A1.1) responds reactively to changes in environmental variables (which in turn change as a consequence of investment in local developments – see also Box 1 for descriptive example).

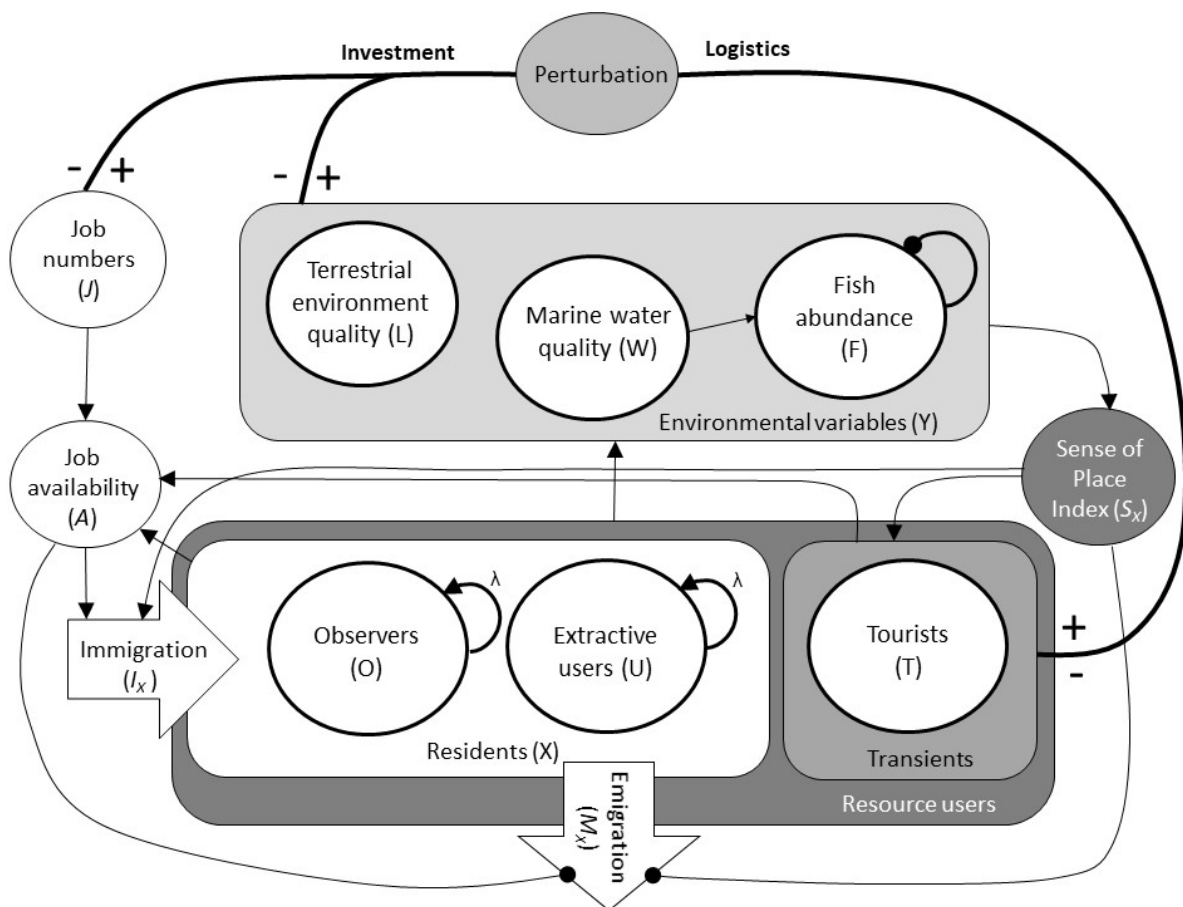


Figure A1.1: Conceptual model of a simplified socio-ecological system. Positive relationships are indicated by line ending with an arrow, and negative influences are indicated by line ending with a dot. The relationship between job numbers and job availability, which positively influence immigration and negatively influence emigration of residents is indicated with solid lines. The relationship between the quality of the environmental variables, the sense of place index (SoPI), is also indicated. A reactive response to more pristine or better quality environmental variables may lead to higher levels of the SoPI, which positively influences immigration of residents and transient numbers and negatively influences emigration. The interactions between the environmental variables are shown by the arrows in the environmental variables box. The relationship between job availability and residents are also indicated.

The environmental variables ($Y = L, W, F$) may be any aspect of the environment that influences affinity, including natural variables, but also resources that are managed and utilised. The environmental variables may be influenced by resource user numbers and these variables may also influence each other, as is typical of ecosystem models (i.e. W positively affects F). Fish abundance is self-limiting, indicated by the self-effect (see figure A1.1). Variation among individuals in how they respond to the environmental variables is captured by assuming that they can be divided into sub-groups ($X = O$ or U), schematically represented by the different circles in Figure A1.1. Note all individuals within a particular *sub-group* can be assumed to respond to the environmental variables in the same way.

The dynamics of the environmental parameters and the resident population are influenced by feedback on each other via the SoPI (S_x), which is a summary of the environmental variables. Each resident group is associated with a SoPI. The feedback occurs because SoPI determines immigration (positive relationship – where a greater SoPI will lead to more immigration) and emigration rates (negative relationship) of each user group.

In this example, resource users are categorised as either residents or tourists (T). Residents and tourists differ with respect to the way they enter and leave the system. Resident movements are explicitly modelled via immigration and emigration rates, which are influenced by the SoPI. For instance, a healthy and clean local marine environment and the availability of facilities that enable access to the marine environment, will encourage immigration and reduce emigration from an area. The number of tourists in the system is determined directly from the SoPI. For example, clean and attractive locations attract more visitors. Thus, tourist numbers respond faster than resident numbers with respect to environmental change.

Resident numbers can increase through births and are also linked to local employment (J), which is reflected in their movement rates being dependent on local job availability (A). The presence of transients may also generate local jobs for residents, which positively influences resident numbers.

Table A1.1: Variables used to model a socio-ecological system of a small coastal community.

Variable	Definition
U	extractive users (who extract resources from the marine environment)
O	observers (who do not extract resources from the marine environment)
X	number in the resident-group ($X = O$ or U)
L	terrestrial environment quality
W	marine water quality
F	fish abundance
Y	environmental condition ($Y = L, W$ or F)
d	number of dependents supported by each full-time worker
T	transient tourist group
β	parameter describing tourist responses to the environment
λ	population growth rate (births-deaths)
I	annual immigration
M	annual emigration
T_0	upper limit to the additional number of jobs created by tourism (and thus also indicating the upper limit to the number of tourists) if the environment were ‘pristine’
J	jobs in the community (in the absence of tourists)
S	sense of place index score (SoPI)
w and l	positive constants
A	actual number of jobs available to residents
a	relative number of jobs available to residents

α_X	parameters that characterise resident group X
η and $\phi = 1 - \eta_S(1 - S_X)$ η_S relates immigration to the SoPI (note: $0 \leq \eta_S \leq 1$).	a non-negative constant representing the minimum number of group X that immigrate to the community each year when the SoPI for the group is at its maximum of one
γ and $\phi = 1 - \gamma_S S_X$ γ_S relates emigration to the SoPI (note: $0 \leq \gamma_S \leq 1$);	a non-negative constant representing the maximum fraction of group X that emigrate from the community each year when the SoPI for the group is at its minimum value of zero. Emigration increases as the SoPI, S_X , decreases.

Table A1.2: Model specification for the socio-ecological system of a small coastal community.

Model equation	
$N_{U,t}$	Number of extractive users (U) at time t
$N_{O,t}$	Number of observers (O) at time t
$N_t = N_{U,t} + N_{O,t}$	Total resident population size at year t
$Y (= L, W, F)$	Environmental variables
$E_{Y,t}$	Value of the environmental variable in year t
$L_t = \exp(-lN_t)$,	Land quality expressed as a negative relation with resident population size and tourist numbers
$W_t = \exp(-wN_t)$	Water quality expressed as a negative relation with resident population size and tourist numbers
$E_{F,t+1} = \left[1 + r \left(1 - \frac{E_{F,t}}{E_{W,t}} \right) \right] E_{F,t} \exp[-q(N_{U,t} + cN_{T,t})]$	Environmental value equation where r is the net fish growth rate, q is fish catchability and c is the fishing pressure derived from tourists relative to resource-users (which we assume here is constant for reasons of simplicity). Note that water quality sets the carrying capacity of the fish stock
$N_{T,t} = T_0 \prod_{Y=L,W,F} f(Y_t, \beta_{Y,0}, \beta_{Y,1})$,	Tourist number equation for year t as positively influenced by L , W , and F at the start of the modelled year
$f(X, \beta_0, \beta_1) = \frac{\exp(-\beta_1[X - \beta_0])}{1 + \exp(-\beta_1[X - \beta_0])}$.	Logistic relationship between additional tourism-related job creation and additional tourist visits
$A_t = J_t + N_{T,t} - N_t$ and $a_t = (J_t + N_{T,t} - N_t)/(J_t + N_{T,t})$,	Actual (A_t) and relative (a_t) number of jobs available to residents in year t respectively
$N_{X,t+1} = (1 + \lambda)[1 - M_X(S_{X,t}, a_t)]N_{X,t} + I_X(S_{X,t}, A_t)$	Equation describing changes in population numbers of resident-group X
$S_{X,t} = \prod_{X \in L,W,F} f(X_t, \alpha_{X,0}, \alpha_{X,1})$,	Sense of place score (SoPI) for resident group X in year t . Resident movement rates depend on job availability and $S_{X,t}$, and it may depend on any of the environmental variables which are expected to have a positive effect on the SoPI for all resource-user groups.
$I_X(S_X, A) = \max\left\{ \phi \eta_1, \phi \left(\eta_1 [1 - \phi] + \frac{A}{2} \right) \right\}$,	Immigration of resident group X . If the SoPI is high, then movement into the community when jobs are available is likely to be faster, thus shifting the immigration curve upwards. In contrast, a high SoPI might lower emigration out of the community. Immigration decreases as the SoPI, S_X , decreases. The $A/2$ term indicates that both resident groups are equally represented in the wider community. For simplicity we have assumed that the η -parameters are the same for both resident groups, but this can be relaxed.
$M_X(S_X, a) = \max\{\phi \gamma_1, \phi(\gamma_1 [1 - \phi] - a)\}$,	Emigration equation

Marine socio-ecological model specification

We illustrate the approach in the context of a small coastal fishing community with two types of residents and a transient tourist group. For convenience when describing immigration and emigration (see below) we set the units of population size for both residents and transients in terms of full-time resident jobs. Thus, $N_{U,t} = 100$ means the community contains 100 full-time extractive users in year t . Also, for convenience we set the baseline values of the environmental variables (e.g., unfished fish stocks, natural water conditions) to be unity. The extractive users (U) are fishers and extract fish from the marine environment. The baseline model parameter values are shown in Table A1.3. In the absence of empirical data to inform parameter choices, illustrative values (with justification) were selected, and considered to qualitatively at least capture realistic system dynamics.

Table A1.3: Model parameters, baseline values, and rationale for the assumptions.

Model parameters	Symbol	Baseline value	Rationale
intrinsic population growth rate	λ	-0.02	The growth rate in many small regional coastal communities in Australia is negative due to their demographic characteristics (with a disproportionate number of people in the older age groups)
effect of population size on terrestrial quality	l	0.0003	Higher population numbers will exert greater pressure on the quality of the terrestrial environment. For instance, through littering and vegetation clearance. This effect is assumed to be greater in the terrestrial context than for the marine environment.
effect of population size on water quality	w	0.0006	Greater population size will also exert greater pressure on water quality. For instance, through nutrient runoff, erosion, or pollution.
net annual fish growth rate	r	0.3	The intrinsic rate of population increase, based roughly on an average value for many fished marine species.
fish catchability per unit population size	q	0.0005	Catchability coefficient relates biomass abundance to the capture or fishing mortality. It will be a value between 0-1 (0 being no catch and 1 being the entire stock), and typically will be very small.
tourist effect on fishing rates relative to resident	cT	0.25	Tourists mostly go fishing using charter operators, whereas recreational fishers are locals who mostly will use their own boat (and do many day trips over a given year). Tourists are therefore expected to have lower fishing rates than local residents
Job number (J) conversion parameter	Symbol	Baseline value	Rationale
number of tourists associated with every tourist job	mult. T	25	It is estimated that 1 full time equivalent (FTE) (spread over many different services and businesses) will be added from an additional 25 tourists visiting the community per year. For example say a small town receives around 16,000 tourists per annum. If an additional 4,000 were to visit it would create 160 jobs (not all in tourism, but also e.g. in retail services and construction).

number of new residents associated with every new job	mult. X	3	On average a new job (FTE) will bring an employee and their family to the community. The average family size is 2.6 but a rounded average of 3 is assumed.
Simulation parameters	Symbol	Baseline value	Rationale
initial density of fish	E_{init}	0.50	Sets fishery at ‘reasonable level’ of exploitation which is a commonly-used default corresponding to the level that yields the maximum sustainable yield
initial number of jobs supported by the community	J_{init}	800	The assumption is that there are 800 resident jobs plus 116 tourism jobs (at T_0), adding up to 916 which is slightly higher than the number of residents (885) meaning the model will start off with active job-driven immigration
initial number of observers	Q_{init}	450	There are slightly more residents who are observers (and do not actively fish) than resource users
initial number of extractive users	U_{init}	435	There are slightly fewer residents who actively extract fish resources from the marine environment (through fishing thus affecting fish abundance) than residents who are observers
tourist carrying capacity	T_0	200	It is assumed that the number of tourists the community can support is around a quarter of the number of people who live in the community (in this case 23%)

Perturbations to the marine SES model

Without any development or perturbation, the system will eventually settle to an equilibrium state. However, the model can be used to explore how the community responds to perturbations. Two types of perturbations were implemented: an investment (e.g. building of tourist accommodation or fish processing facility that will lead to job growth) and logistics (e.g. a social media campaign that enhances tourist visitation) (Table A1.4).

Table A1.4: Details of the direct influences (response connections) for four scenarios, the base case and three perturbation types.

Scenario abbreviation	Description	Perturbation type	Long term Effect on land quality	Long term Effect on water quality	Change in tourist capacity	Change in jobs for residents
Base	Base case	Base case	-	-	-	-
Fish	Introduction of fish processing plant	Investment	-	negative	-	positive
Urban	Upgrading of urban infrastructure	Investment	positive	-	-	positive
Tourism	Tourism development	Investment	positive	-	positive	positive
Social	Social media & advertising campaign	Logistics	-	-	positive	-

The distinction between the perturbation types is made on the basis of the pathway and sequence by which they influence the SES: investment first influences job numbers, but can also affect the environmental variables; logistics first influences resource user numbers (it can

attract both tourist visitation and residency). The two types of perturbations can be positive or negative as shown by the lines ending in + or – Figure A1.1). For example, an investment perturbation could lead to negative job numbers if a school were to be closed. Similarly, a negative social media campaign could lead to downward pressure on visitation numbers.

An investment perturbation is defined by the time frame over which it occurs and the number of permanent jobs (δJ) it creates. Such perturbations will result in attracting new residents to the area through immigration. Investment perturbations could also have a direct effect on land quality, water quality, or fish abundance.

Model results

We first present the hypothetical relationship between environmental variables, resource users, and the SoPI, because this relationship is key to the model and is a novel aspect. The curves in panels A, B, and C of Figure A1.2 show that tourists are more concerned about land quality compared to water quality and fish abundance *ceteris paribus*. These relationships can be established empirically, for instance, using different surveys and survey designs of resource user groups in a particular geographic location. A relatively strong positive response to improved land quality by tourists can be deduced from the steepness of the curve for tourists in panel A compared to panels B and C. Observers and extractive users are similar in their concern for water quality (the curves for these two resource users lie close together) but differ with respect to land quality and fish abundance *ceteris paribus*. Panel C in Figure A1.2 shows that a low level of fish abundance has the greatest effect on the SoPI for extractive users (the short-dashed curve lies below other curves at low levels of fish abundance). In contrast, panel A shows that low levels of land quality do not have such a great effect on extractive users compared to the other two resource user groups *ceteris paribus*.

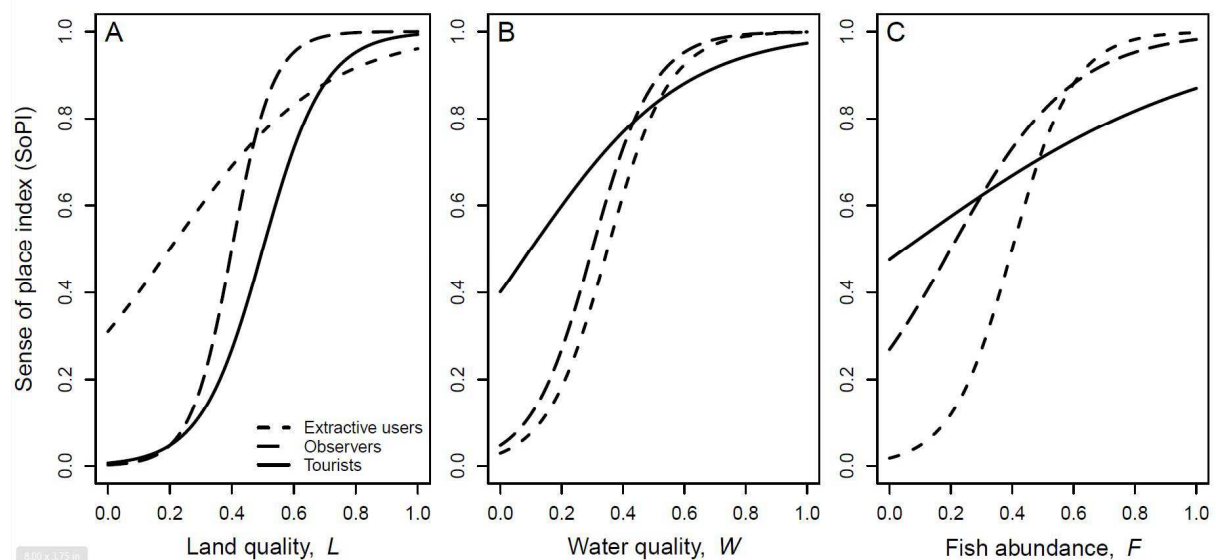


Figure A1.2: Relation between (A) land quality, (B) water quality, and (C) fish abundance and the sense of place index. Curves are plotted for residents who are either extractive users (short-dashed line) or observers (long-dashed line), and tourists (solid line). Unless indicated, the remaining parameters are set to $L = W = F = 1$ and $T = 0$.

Assuming the SoPI relations shown in Figure A1.2, we considered four different perturbation scenarios (Table A1.4). In each case we perturbed the system in year 10 and tracked changes in SoPI for each group over the following 20 years. In order to assess the effect of a SoPI on consumer-resource feedbacks we performed simulations when SoPI was fixed throughout the simulation and also when it changed in response to changing environmental conditions.

In the case of the Fish scenario, when the SoPI was dynamic the three resource user groups all experienced rapid declines in their SoPI due to the introduction of the fish processing plant in year 10 (Figure A1.3, black lines). SoPI values slowly improved as environmental conditions improved but levels never returned to pre-perturbation levels. SoPI improved because relative fish abundance gradually improved (Fig. A1.4), which was due to lower catches after many resource users had left the system due to the perturbation. Importantly, when SoPI was ignored catch numbers did not decline much after the perturbation, as resource user numbers were more stable, which led to further reductions in relative fish abundance (Figure A1.4).

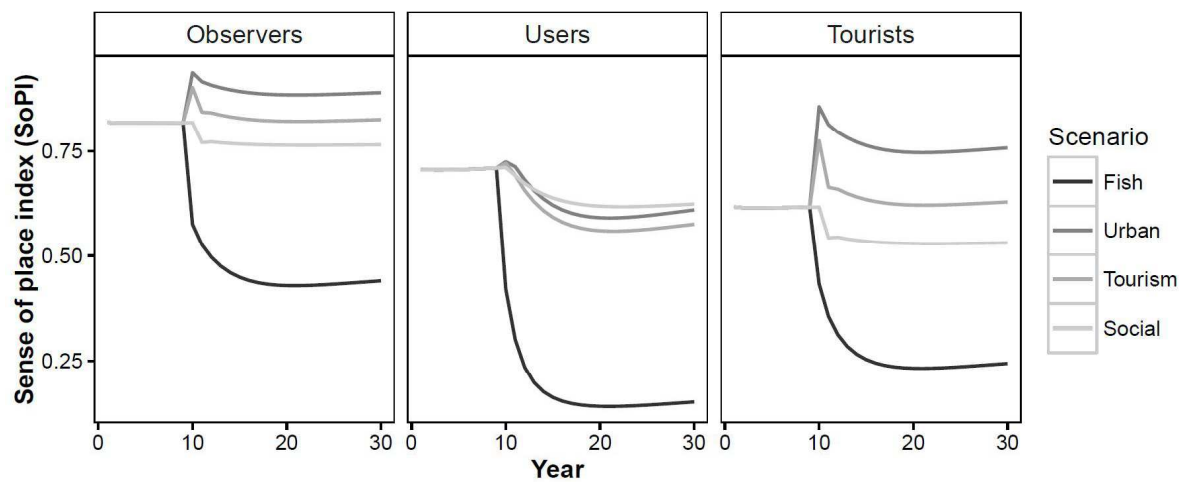


Figure A1.3: Modelled sense of place index for observers, users and tourists of a hypothetical marine socio-ecological system with feedback between land quality (L), marine quality (W), and fish abundance (F), for four perturbation scenarios.

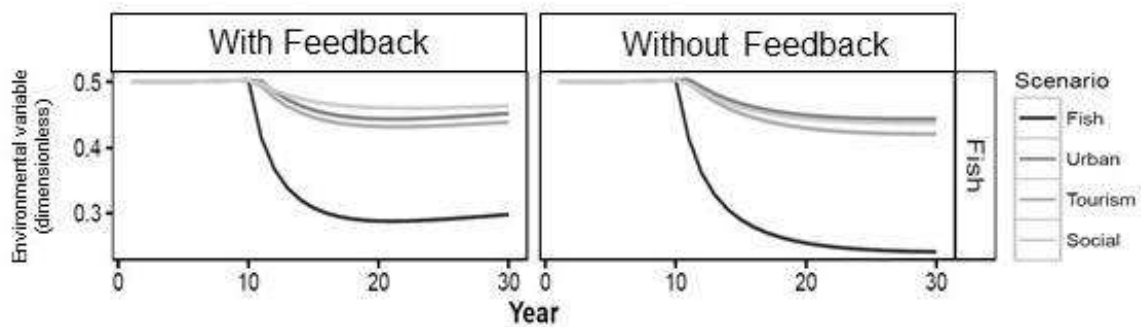


Figure A1.4: Predicted changes in relative fish abundance (F) for a hypothetical marine socio-ecological system with and without feedback between SoPI and the environmental variables land quality (L), marine quality (W), and fish abundance (F), for four perturbation scenarios.

SoPI dynamics for the three other perturbation scenarios are presented in Figure A1.3. In each of these examples the change in the SoPI associated with each group differently substantially (Figure A1.3), which affected both the absolute and relative numbers of individuals present in

the community in each of the three groups (O, U, and T) over time. A common outcome was that relative fish numbers declined as a result of each perturbation (Figure A1.4), and fish numbers failed to recover in the long-term when the SoPI was static (Figure A1.4, right panel). Again, lack of recovery in the absence of a dynamic SoPI was caused by continued high levels of fish exploitation. These simulations demonstrate the importance of considering a dynamic sense of place variable when predicting long-term community outcomes.

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