Socialscape Ecology: Integrating social factors into spatially-explicit marine conservation planning

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Abstract:

Conservation planning is the process of locating, configuring, implementing and maintaining areas that are managed to promote the persistence of biodiversity. In this review, we analyze the ways in which social processes have been integrated into Marxan, a spatially explicit reserve design planning tool. Drawing on 89 peer-reviewed articles published 2005-2020, we analyze the ways in which human activity, values, and processes are spatialized in the environment; something we call socialscape ecology. To quantify this, we used nine categories including three count categories (social costs, targets, and parameters) and six rank categories (reliance on proxies versus direct observation, integration of temporal change, inclusion of sea tenure, analysis across scale, provisioning analysis, and stakeholder participation). We show that remarkably little change occurred over time across eight of the nine categories. One exception to this was an increase in number of studies that integrated temporal variation in their analysis. Ultimately, we argue that greater attention to and integration of social processes and variables into Marxan will improve marine managers' understanding of not only the ecological but also the social, cultural and political processes that influence the social and ecological success of marine conservation efforts.

1. Introduction

Systematic conservation planning (SCP) is a process that helps decision-makers strategize and implement spatial conservation schemes that both adequately protect biodiversity and are cost-effective (Margules & Pressey, 2000). Although SCP has existed for over 35 years, past work has shown that these processes have not adequately included analysis and integration of a variety of social processes and variables (Natalie C. Ban, Adams, Pressey, & Hicks, 2011; Koehn, Reineman, & Kittinger, 2013; Noble, Harasti, Pittock, & Doran, 2019; Polasky, 2008; St. Martin & Hall-Arber, 2008; Whitehead et al., 2014). The evaluation of this inadequacy is predicated on the assertion that robust analysis and consideration of social factors in conservation planning will improve ecological and social outcomes (Natalie C. Ban, Hansen, Jones, & Vincent, 2009; Noble et al., 2019; Pınarbaşı, Galparsoro, & Borja, 2019; Wallace, Wagner, & Smith, 2016). Integrated analysis across social and ecological systems is rooted in the field of landscape ecology, which emerged post World War II in Europe to consider the interdependence of patterns and processes between biota, climate, soil, and human at the broadest levels of nested, spatially heterogeneous environments (Farina, 2008; Naveh &

Lieberman, 2013; Turner, 1989; Urban, 1987). Although landscape ecology focuses on elements of human use and processes in a landscape, these social elements are most often framed in terms of disturbance of ecological processes and are generally undertheorized (Endter-Wada, Blahna, Krannich, & Brunson, 1998; Field, Voss, Kuczynski, Hammer, & Radeloff, 2003; Turner, 1989).

In this paper, we use “socialscape ecology”¹ to refer to a method of analyzing the complex and interdependent social systems (e.g., economic, cultural, political) underlying human-nature interactions. An early contributor to the field of landscape ecology, Monica Turner, codified landscape level processes according to three characteristics: structure, function and change (1989:173). Here we emulate this framework in relation to socialscapes where “structure” refers to the spatial configuration of human interests and processes, such as the total number of people living on the coast of a region or the shape and size of an important cultural site. “Function” refers to the relationships between these different social structures; for example, a spatial analysis of how market access influences fishing intensity, how resource governance strategies impact resource-use rule transgressions, or the way in which spiritual beliefs affect claims over marine areas.² “Change” refers to the variation of these social structures and exchanges over time; for example looking at how climate change influences fisher catch rates over time, or rates of coastal development.

We draw on socialscape ecology to understand how social processes are integrated into systematic marine conservation planning, using the design and implementation of marine protected areas (MPAs) as a case study. With the world’s oceans experiencing increasing anthropogenic pressures, governmental and non-governmental conservation organizations around the globe have embraced MPAs as a solution to conserve marine biodiversity, manage marine fisheries, and provide a variety of other ecosystem services (Boonzaier & Pauly, 2016; Jantke et al., 2018; Venter et al., 2014). In the past two decades there has been an exponential increase in the total marine area under protection (UNEP-WCMC and IUCN, 2020).

Several Decision Support Tools (DST) have been created to streamline the spatial allocation of MPAs, with a focus specifically on reserves, or no-take zones. Marxan was designed to aid systematic reserve design by allowing conservation planners to set targets for biogeographic and ecological features weighted against layers representing costs to local populations or industry (Ball, Possingham, & Watts, 2009). Nearly a decade later, Marxan with Zones was created, which allows regions within the same proposed conservation area to be categorized using different zones such as no-take, or fishing limited by gear type (Watts et al., 2009). Subsistence fishing may be categorized as a cost in one zone and a target in a different zone. Marxan is one of the most popular and widely used DSTs in marine spatial planning (Marxan, 2020). With the expanding knowledge and use of this software, increasing numbers of social variables have been considered alongside ecological variables in the reserve design process (Natalie C. Ban et al., 2009; C. J. Klein et al., 2008b; Stephanson & Mascia, 2014). Including accurate data on the location and intensity of human use activities in marine environments is cited as a critical factor in creating cost-effective and socially acceptable MPAs (Natalie Corinna Ban & Klein, 2009; Lundquist, Granek, & Bustamante, 2005; Polasky, 2008; Smith, Eastwood, Ota, & Rogers, 2009). Attention paid to socioeconomic and political realities

¹ The word “socialscape” has been used by other authors to elucidate the relationship between sexual desire and urban living (Collins, 2004), and to describe the “social interaction aspects” of a festival environment as perceived by a festivalgoer (Gration & Raciti, 2014).

² A similar concept called “social determinants” including “market conditions, technical factors, scale of production, and the policy environment” has been applied to corn yield; (Kaufmann & Snell, 1997)

can produce significantly different conservation assessments as compared to prioritizing biological targets (O'Connor, Marvier, & Kareiva, 2003). These factors determine the long-term success of an MPA as well as whether people whose livelihoods and cultural identity are tied to a marine environment are harmed in the process of conservation. However, there is a lack of systematic treatment in the Marxan literature of the scales and complexity of human activities, values, and processes in a land or seascape.

We investigated nine social variables based on key arguments in existing marine conservation literature concerning what social factors influence the ecological and social effectiveness of a protected area. The three count variables are: the total number of social cost variables, negative social costs or target variables, and social parameters. Social costs in Marxan reflect the negative impact reserve placement would have on resource harvest value, cultural value, spiritual value or other elements of human interests and needs (Ball et al., 2009). Marxan is designed to minimize costs. Generally, costs are combined into a single index, or run independently under separate planning scenarios. Social targets, similar to biodiversity or habitat-specific targets, are the amount of each social feature (e.g., traditional fishing grounds) that the software is instructed to select. Because the importance of including nuanced social costs data in conservation planning efforts is widely recognized in the SCP literature (Álvarez-Romero et al., 2018; Natalie C. Ban et al., 2009; Natalie C Ban et al., 2013; Cheok, Pressey, Weeks, Andréfouët, & Moloney, 2016), we additionally included six ranked categories concerning key social processes influencing conservation outcomes. These variables include: data source, temporal change, sea tenure, scale, provision, and participation. Additionally, we analyze whether a country's development status, using the UN Human Development Index (HDI), influences the complexity or nuance with which researchers integrate social variables in Marxan.

There are many ways these categories intersect and overlap; thus, their separation is more heuristic than deterministic. This article provides an initial framework to understand the way in which conservation scientists and practitioners have categorized and incorporated social factors into Marxan. Planning for the needs and rights of humans in seascapes alongside the threats to biodiversity caused by human use is a critical part of conservation planning that will ultimately help attenuate inevitable human-caused threats and improve protected area outcomes (Chan et al., 2007; Naughton-Treves, Holland, & Brandon, 2005; Richardson, Kaiser, Edwards-Jones, & Possingham, 2006).

2. Social variables

2.1 Data source

The first ranked category focuses on the source of data used in each study. It emphasizes the importance of collecting robust, ground-truthed and nuanced social data (Hamel, Pressey, Evans, & Andréfouët, 2018; Metcalfe et al., 2017). Data for fishing, the most common social factor integrated into Marxan, ranged from a simple function of distance to shore to spatialized catch data de-aggregated by gear, vessel, and sector (e.g., commercial, subsistence, recreational, etc.) (Adams, Mills, Jupiter, & Pressey, 2011; Cheok et al., 2016; Grantham et al., 2013). The use of surrogate or proxy measures is helpful when the availability of desired data is scarce, or limitations exist on time and funding (Weeks, Russ, Bucol, & Alcalá, 2010). However, the use of proxies has been associated with costly siting mistakes and is problematic when these proxies replace input from local stakeholders on appropriate MPA boundaries (Álvarez-Romero et al.,

2018; Ruiz-Frau et al., 2015; Weeks et al., 2010). Fine-scale direct observation and social data collection such as obtaining VMS or fisher logbooks, conducting stakeholder surveys or participatory mapping, and integrating local ecological knowledge (LEK) reflects the dynamic lived realities and social tensions embedded in the conservation planning processes, and are necessary for accurate and socially-nuanced Marxan analyses (Smith et al., 2009; Thornton & Scheer, 2012).

2.2. Temporal change

The second ranked category focuses on how studies measure and integrate temporal changes in socio-ecological processes, which is essential for the long-term efficacy of MPAs. (Cowen, 2006; Runge, Tulloch, Possingham, Tulloch, & Fuller, 2016). Models predicting future resource conflicts and fishing-effort redistribution have been used to anticipate future costs and challenges to management, although these types of considerations in the use of DSTs are still rare (Brown et al., 2015; Maina et al., 2015). Conservation scholars have identified inclusion of climate change predictive modelling as an essential yet often overlooked opportunity in marine reserve design (Álvarez-Romero et al., 2018; Carr et al., 2019).

2.3 Sea tenure

The third ranked category emphasizes the extent to which studies integrated local rights to marine resources and spaces, broadly understood as sea tenure. Preserving local people's access to and control over traditional fishing grounds, sacred sites, and other culturally important areas is important both in terms of the ethics of conservation and in the reduction of conflict between local resource users and management authorities (Almudi & Kalikoski, 2010; Natalie C. Ban & Frid, 2018; Foale & Manele, 2004). The loss of community-held rights to access can divest small-scale fishers of their livelihood, and the achievement of biological targets is often impossible when local populations are hostile to conservation efforts that upset traditional access arrangements. Conversely, communities are more likely to participate in and drive conservation efforts when they seek to build on previously established tenure systems (Natalie C. Ban & Frid, 2018; Sharma & Rajagopalan, 2013).

2.4 Scale

The fourth ranked category includes an analysis of how researchers integrated upstream drivers of socio-ecological change, including attentiveness to multi-scalar social processes (O'Connor et al., 2003). Ultimate drivers are considered the underlying causes of resource use. While the physical expressions of these ultimate drivers (e.g. fertilizer runoff, overfishing, oil spills, etc.) are often easier to quantify, conservationists run the risk of ignoring the root causes of biodiversity loss which operate on regional, national, and international scales (Lambin et al., 2001). Without considering ultimate drivers, reserves may further jeopardize biological diversity by inadvertently displacing threats to nearby, unrestricted areas (Ewers & Rodrigues, 2008). Ultimately, a multi-scalar iterative approach will help reduce incongruity within the planning process and will help match reserve design to goals articulated across these scales (Natalie C. Ban et al., 2009; O'Connor et al., 2003).

2.5 Provision

The fifth ranked category focuses on whose values and interests are most explicitly served, or “provisioned” for, in the reserve prioritization process. Provisioning refers to reserve

design aimed to enhance ecosystem services for users at a highly localized scale (e.g., enhancing a locally-important fishery). Additionally, it includes consideration of how local stakeholder needs and values influence reserve design (e.g., protecting traditional fishing grounds or an important cultural sites). The focus on protecting local access to resources and directly provisioning local resource users is found to be critical to both the social acceptance and long-term ecological success of an MPA (Natalie C. Ban & Frid, 2018; Diver, Vaughan, Baker-Médard, & Lukacs, 2019; Jumin et al., 2018; C. J. Klein et al., 2008a).

2.6 Participation

The sixth ranked category focuses on who participated in shaping the goals and parameters of Marxan. Reviews of DST use emphasize that Marxan was designed to, “support, not make, decisions on the location of conservation areas,” and that any best-solution set must then be assessed for acceptability and efficacy by stakeholders (Natalie Corinna Ban & Klein, 2009; Green et al., 2009; Smith et al., 2009). Even the most socially nuanced data undergoes a degree of flattening in order to fit the constraints of Marxan that can obscure the dynamic nature of socioecological relationships. Stakeholder participation in decision-making surrounding MPA siting has taken the form of exhibitions at local festivals, presentations at community meetings, and individual consultations (Natalie C. Ban et al., 2009; Jumin et al., 2018). Presentation of findings in a timely, coherent, and culturally sensitive manner is essential both in terms of research ethics as well as ultimate efficacy of the conservation intervention (Smith et al., 2009).

Category	Social Nuance Rank		
	1	2	3
Data source	Relied only on proxy data, such as distance from closest population center as a surrogate for fishing pressure	Used some social data that was ground-truthed or collected by researchers at a local or regional level.	Data sources were specific to the sites in question and recently collected. Common data sources in this category were surveys of local stakeholders, landings logbooks, VMS records, boat-based surveys, etc.
Temporal change	Some consideration of social or socio-environmental change (e.g. climate change) through proxy factors such as sea surface temperature.	Included some data from a significant period of time (e.g., more than a decade) to show temporal trends of resource use or other social processes.	Included data from a significant period of time and explicitly referenced projected patterns of future resource use, resource conflicts, or other social factors influenced by environmental and/or social processes over time.
Sea tenure	Included some element of fisher or community resource use and access patterns.	Recognition of local marine tenure systems and preliminary inclusion of these areas into the reserve siting framework	Clear recognition of local marine tenure and integration of these claims into the reserve planning process. Recognition that rights can exist at the individual, collective or broader community level.
Scale	Primarily focused on proximate drivers of marine resource use. Guided by stakeholder interest/values at primarily one scale.	Consideration of proximate and some ultimate drivers of marine resource use. Some input from stakeholders and experts at multiple scales from different backgrounds/fields.	Included input from stakeholders at multiple scales (local, regional, and national) and experts from multiple fields. Consideration of both proximate as well as ultimate drivers of marine resource use (e.g. inclusion of global or regional human impact aggregates alongside other regionally or locally specific social data collection).
Provision/Access	Included at least one way of spatializing human activities and interest in reserve design other than strict avoidance.	Included explicit ecosystem service provision goals, focused on an element of sustainable use, or considered the benefits in addition to costs of placing a reserve adjacent to high-use areas	Explicitly focused on ecosystem service provision, enabling sustainable use, and the benefits in addition to costs of placing a reserve adjacent to a high use area. Potentially included the protection of traditional or indigenous fishing grounds, historical or cultural sites, and/or other sites of high human value or interest.
Participation	Minimal participation from stakeholders concerning reserve siting or the overall goals of the spatial prioritization process.	Some engagement of stakeholders concerning different iterations of reserve network design.	Deep engagement with stakeholders at every step of process from helping shape the goals/priorities of the reserve or network, to helping determine what social data should be collected and analyzed, to weighing in different solutions produced by Marxan.
Count			
Social cost	Total number of social costs listed by authors. Costs in this category are selected against in each run of Marxan. Examples include areas of high fishing effort, ports, sewage pollution, urban centers.		
Social target	Total number of negative social costs or social targets listed by authors. Often, although not exclusively associated with the use of layers in Marxan with Zones. Examples include small scale fishing effort, recreation areas, areas adjacent to tourist facilities.		
Social parameters	Total number of “shadow” social factors. Examples include “locking out” planning units associated with industrial and commercial interests, or “locking in” units tied to stakeholder preference.		

Table 1. Categories of social factors integrated into Marxan including six rank categories and three count categories.

3. Methods

3.1 Database

This review relied on a detailed search ending on August 19, 2020 of key words using several databases including Google Scholar and ProQuest Summon Search. All selected items had to contain the word “Marxan” in the title or text of the document. We further narrowed this group to documents that contained any of the following exact phrases “marine reserve,” “marine protected area,” and/or “marine conservation,” and lastly narrowed our search further by only including studies with any of following exact phrases: “case study,” “social,” “socio-economic,” or “human.” These terms were searched for in English-language studies, resulting in a collection of documents from 2005 to summer of 2020. A total of 778 studies were retrieved using these search words. These studies were further culled by reviewing abstracts and methods sections to exclude purely theoretical models and thought pieces on spatial planning that were not grounded in data from a particular place, case studies that did not include any socio-economic cost layers, or comparisons of previous studies that offered no new nuances to existing data. We account for boundary length modifier (BLM) as a social parameter when the authors specifically state it to be a proxy for a social concern such as management feasibility. However, we did not include studies that only included area as a cost without a stated social reasoning. This resulted in a total of 89 studies. We read each article and book chapter to determine their use of socioeconomic factors in Marxan or Spexan⁵ analysis. Layers of data, usually extracted from the Methods section of papers, were recorded in Excel (see Supplemental Material).

To aid in spatial comparisons, all scales were converted to km², although the original scale or scale range was noted. Climate change was included as a social factor even though it contrasts with other factors included in the dataset that tend to be more proximate social variables, such as fishing or tourism. Climate change, while caused by anthropogenic activities, cannot be quantified from direct use of coastal resources. It was mainly used in modeling the effects of thermal bleaching in coral reaches, although ocean-wide effects were also measured.

We included book chapters and journal articles but chose not to include grey literature (organization reports, memos, etc.). While some reports from conservation organizations emerge on search engines such as Google Scholar, many do not and would be arbitrarily left out of analysis. Tracking down a comprehensive sample of reports by marine conservation practitioners would entail a different, and much more network-based, approach to obtaining articles.

3.2 Categorization & Analysis

In order to categorize the way in which marine spatial planners consider social factors in Marxan we came up with nine variables to capture social factors in the studies (Table 1). Each study received a summed total calculated from reported variables in each count category (costs, targets and parameters) and scored from 0-3 for each rank category.

Social cost and target counts were recorded in both a “flattened” count, which quantified costs based on authors’ stated social categories, and a “generous” count, which quantified the total number of factors captured by a given cost layer. For example, a handful of studies used a human impact cost layer (Halpern et al., 2015; Halpern et al., 2008). These studies used the human impact score as a single layer (e.g., flattened count of 1), but a large number and variety of social factors went into generating the layer (e.g., “generous” count of 41). Social parameters additionally quantified “shadow” social factors embedded in the technical application of Marxan such as exclusion of planning units containing artificial habitats (piles, marina and rock wall) associated with industrial and commercial purposes (e.g. Banks et al.(2005)), or “locking in” or “locking out” certain areas due to stakeholder preference (e.g. Ban et al. (2009)). Consideration

of social parameters highlights the biases and assumptions that researchers may rely on when using Marxan.

3.3 Human Development Index

Human development index rankings were determined for the country associated with each case study region. Rankings were taken from the United Nations Human Development Reports, based on the year in which each study was published (UNDP, 2020). For studies that included multiple countries or used marine regions that included multiple EEZs, each country was considered separately in the ranking process. Islands of overseas territories were accounted for in the “small island developing states” ranking.

4. Results

There were 28 meta-categories of social variables included by researchers in our database (see Appendix S1), the most common three variables being commercial fishing, subsistence fishing, and tourism. The cumulative sum of cost variables used within our dataset increased over time, with a notable increase after 2010 in the number of cost variables used per study. However, this increase flattened after 2017 (Figure 1a). A similar trend occurs with the cumulative sum of negative social cost/target variables used per study over time (Figure 1b). However, the total number of negative social costs/social target variables is small, approximately 1/10th the sum, of regular social costs. The total social parameter variables used also didn't significantly change over time (S4).

Qualitative assessments of six ranked social variables indicate no significant increase over time except for studies integrating temporal change (Figure 2b). A cluster of studies in 2015 and 2016 scored higher than the average ranks per year in the rest of the dataset across four variables: scale, temporal change, data source, and provision (Figure 2). The social variable that the greatest number of studies ranked above a zero in was social data source, followed by temporal change and scale (Figure 3). The fewest studies ranked above a zero in the marine tenure, provision, and participation variables.

The correlation plot between rank variables illustrates that there were some trade-offs among the six variables. The strongest of these occurred with the temporal variation variable, where studies that ranked high in terms of integrating temporal variation in their studies tended to rank lower in marine tenure and provisioning (Figure 4). The strongest correlation occurred between participation in planning and consideration of marine tenure (Figure 4).

There was no significant trend across the HDI score of the countries used as case studies and the cumulative sum of either the number of social cost variables or the number of social targets/negative cost variables employed (Figure 5). One slight trend worth noting is that countries with the highest HDI score (>0.9) tended to have a somewhat higher number of social targets/negative social cost variables, and a lower number of social cost variables (Figure 5).

Figure 1. Cumulative sum of (a) total cost variable counts and (b) total target variable counts across all papers over time. The dark black curves (with corresponding grey standard error bands) represent LOESS smoothing functions with default smoothing parameters.

Figure 2. Six social category rank totals per paper over time. Each study ranked on a scale from 0-3 concerning how well they integrated a) scale: considering not just proximate but also ultimate drivers of marine resource use, b) temporal change: analyzing socio-ecological trends over time and integrating future projections, c) sea tenure: integrating local marine resource rights regimes, d) social data: relying on ground-truthed site-specific data, e) participation of resource users: iterative engagement with local resource users at multiple steps of the planning and implementation process, and f) provisioning goals: explicit focus on designing marine reserves to provision local resource users in multiple ways. The dark black curves (with corresponding grey standard error bands) represent LOESS smoothing functions with default smoothing parameters.

Figure 3. Alluvial plot representing total number of studies with ranks of 0-3 across six social categories.

Figure 4. Correlation plot between rank variables illustrating the relative trade-offs among the six rank variable across all studies.

Figure 5. Cumulative sum of (a) total cost variable counts and (b) total target variable counts in relation to the HDI of all nations represented in the dataset. If multiple nations were represented in a paper, the cost and target sums calculated for the paper were applied to each nation. The dark black curves (with corresponding grey standard error bands) represent LOESS smoothing functions with default smoothing parameters.

5. Discussion

A growing number of studies demonstrate the importance of integrating social factors into conservation (Álvarez-Romero et al., 2018; Jumin et al., 2018; Pınarbaşı et al., 2019; Polasky, 2008). Yet despite immense advances in systematic conservation planning research and technology this review shows that collectively researchers are not making parallel improvements in the nuance with which they integrate social factors and processes into marine reserve design.

Our work here builds on the review conducted by Alvarez Romero et al. (2018), which analyzed researchers' use of socioeconomic variables along with other factors in SCP over time. We deepen their analysis by looking at a broader array of social variables and processes that relate to how human activities and values are integrated into SCP and focus more specifically on Marxan's use within the SCP literature.

In relation to the defining characteristics of socialscape ecology, studies included in this review tended to focus their efforts on integrating social “structure” data, and less so elements of “function” and “change” in a seascape. Socialscape structure data are often easiest to obtain, facilitated by technology such as remote sensing that allows researchers to count, measure and define human spatial features in a seascape (Weeks et al., 2010). Function and change data are not only often harder to obtain, but more difficult to spatialize. Function characteristics tend to consider more ultimate drivers of resource use and are relational by definition, thus require at least two social variables to examine. Similarly, variables related to change rely on longitudinal data to spatialize future trends, which requires data over a significant span of time. The relative difficulty of integrating function and change socialscapes characteristics is evidenced in part by the trade-off observed between researchers' integration of temporal variation (typically climate change) in their analysis and other rank categories such as marine tenure or provisioning local resource users.

The ecological success of an MPA is often tied to the degree to which the local community supports and enforces the protected area (Natalie C Ban et al., 2009). Therefore, the highest scoring articles not only considered numerous social factors across multiple scales, but also directly engaged local stakeholders in participatory mapping, either through focus group workshops or one-on-one interviews, and solicited input from stakeholders at multiple points in the planning process.

For example, Ban et al. (2009) outlined a comparative analysis of community-based versus science-based approaches to marine conservation in the traditional territories of the Gitga'at First Nation and the Huu-ay-aht First Nation. The values and interests of local resource users, obtained from interviews and community-wide meetings, guided the goals and priorities embedded in the Marxan analysis, as opposed to being reduced to a single cost layer. Ban et al. (2009) also explicitly integrated sea tenure, demonstrating a deeper understanding of resource use rights and sovereignty that goes beyond site use frequency. In a study from Fiji, Wendt et al. (2016) also demonstrated high levels of social nuance by drawing on spatialized social factors including cultural use, subsistence fishing, feasibility of enforcement and disputed areas. These data were obtained through participatory mapping and community-wide workshops. By spatializing the current and future needs of local residents, these articles stand out for their multi-faceted approach to marine spatial planning.

Thirteen of the 89 studies relied on human impact indices to integrate multiple social variables into their studies. The most widely used index was created by Halpern et al. (2008), and updated (2015). Some studies used the entirety of Halpern's human impact layer to represent social costs in Marxan (Carissa J. Klein et al., 2013) while others used single layers of the index such as shipping lanes (Lagabriele, Lombard, Harris, & Livingstone, 2018) or artisanal fishing (Beger et al., 2015). While human impact indices provide a relatively easy way for researchers to integrate temporal and macro-level social processes, it was rare for them to be included alongside nuanced source or participation data, demonstrating that they pose a risk for reliance on global quantitative trends over ground-truthed patterns of human preference and involvement.

Articles that scored high across all categories tended to consider a holistic range of social costs that influence marine systems, as opposed to just extractive activity such as fishing. These articles also tended to use higher resolution, directly observed data. Although most high scoring articles included numerous social variables, this was not always the case. For example, Habtermariam & Fang (2016) included three variables: non-consumptive tourism, cultural sites, and subsistence fishing. However, the detail and content of these data layers demonstrated the authors were thinking holistically about the needs and desires of the people who lived in the area of interest. To approximate non-consumptive tourism, the presence/absence of swimming and snorkeling areas was included in analysis. Cultural uses were provisioned for through the inclusion of archeological and religious sites, and subsistence fishing was spatialized through participatory mapping with resource users which engaged with stakeholders at multiple points throughout the siting process. Similarly, Wendt et al. (2016) included only four social variables in analysis, but these variables incorporated the preferences of residents in relation to protected areas. Workshops separated stakeholders in sub-categories, such as subsistence fishers, commercial fishers, environmental groups, community leaders, and women, before using participatory mapping to identify priority areas for conservation.

Articles that scored higher also tended to include selecting both *for* and *against* particular social features in a seascape. While some of the social factors integrated as a target or negative

cost served local uses categorized broadly as “community interest” or “cultural sites” (Natalie C Ban et al., 2013; Green et al., 2009), others explicitly served non-local uses considered less threatening to biodiversity conservation such as “research facilities” (Klein et al. 2008), “tourism infrastructure” (Klein et al. 2008, Ban et al. 2013, Giakoumi et al. 2011), and “dive sites” (Natalie C Ban et al., 2013; Green et al., 2009).

Additionally, articles that scored higher tended to involve stakeholders at multiple scales and consider some of the underlying drivers of resource use. For example, a siting process lead by (Lagabriele et al., 2018) in South Africa was notable for its inclusion of a wide range of stakeholders that considered conservation and marine use priorities across multiple scales, including interviews of conservation scientists, urban planners, and representatives from the commercial fishing and recreational sectors. Their process of stakeholder involvement lasted nearly a decade before Marxan was even introduced into the siting process. By employing analysis that attempts to identify both proximate and ultimate drivers of marine resource use, an element of social justice can enter conservation planning by shifting some of the responsibility for habitat degradation and over-extraction from local users to causal factors at national and international levels. More research is needed that directly attends to how scale affects the elements of socialscape ecology that are integrated into protected area design and how this might influence reserve effectiveness.

By identifying social parameters present in studies, we sought to quantify the “shadow social factors” embedded in how researchers use Marxan. Examples include “locking out” planning units containing artificial habitats (piles, marina and rock walls) (Banks et al., 2005), or “locking in” planning units due to stakeholder preference (Natalie C. Ban et al., 2009) and reduced management costs adjacent due to proximity to other MPAs (Haupt, Lombard, Goodman, & Harris, 2017). While the social parameter count did not vary significantly over time (S4), it’s unclear if this trend is correct or is due to inadequate sampling. The social parameters variable helps underscore the black-box nature of technically complex software like Marxan and emphasize the ways in which these often “hidden” parameters shape Marxan output. Only social parameters that were explicitly mentioned in papers were recorded in our database. It is likely that other researchers modified parameters in Marxan that involved social processes and did not mention it. For example, management concerns such as monitoring costs and enforcement feasibility influence how researchers configure boundary-length modifiers (BLMs) (Stewart & Possingham, 2005). However, few researchers were explicit about their rationale for the BLM parameters they set.

It is important to note that many of the studies we include in this review do not claim to be creating MPAs for immediate implementation. Many state that their case study is for demonstrations or theoretical purposes only (Cheok et al., 2016). However, all studies analyze real data from case studies around the world. Additionally, they make important claims about the relevance of their findings to applied conservation. Ultimately, developing and nuancing analysis of the marine socialscape will strengthen the overall application of Marxan globally.

6. Conclusion

Given that humans are a critical part of ecosystems globally, conservation objectives will be more efficiently and effectively achieved through the integration of a socialscape analysis. The process of investigating and integrating elements of the socialscape in conservation planning will help guard against uncertainty and create more socially acceptable and longer lasting

conservation strategies. One major difficulty, similar to the uncertainty in biological models, is that many social factors can change, are multi-faceted, and are interdependent. Layering various components of the socialscape into conservation planning adds additional uncertainty to the process, but remains an imperfect best option to a lack of integrating these factors.

Beyond parameters set in Marxan, there are broad concerns over the black-box nature of this decision-support tool. While proponents of Marxan argue that it is simply a tool to help conservation planners make informed decisions, others suggest that software like Marxan has the potential to exacerbate existing social inequalities given differences in scientific, computational and technological literacy (Pınarbaşı et al., 2019; St. Martin & Hall-Arber, 2008). For example, Kirlin et al. (2013) explain that the use of Marxan to design a marine protected area network for the California Central Coast (Carissa Joy Klein, Steinback, Scholz, & Possingham, 2008) was legally rejected through the Marine Life Protection Act because it was “not sufficiently transparent to policy makers or stakeholders.” This legal issue emphasizes the risks involved in relying too heavily on Marxan and other highly technical DSTs without high levels of transparency and stakeholder involvement in setting the parameters of Marxan and informing what types of information are included in an analysis. The six rank categories outlined in this paper can help future researchers structure their consideration of these broader social values and political processes.

This article uses Marxan as a case study to provide an initial framework for understanding how conservation scientists have categorized and incorporated social factors into SCP. Improving our analysis and integration of socialscape ecology will allow for planning that incorporates the needs and right of humans in seascapes alongside the threats to biodiversity caused by human use. This will ultimately make conservation efforts more ethical and effective.

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