Ecosystem Services 37 (2019) 100910

Contents lists available at ScienceDirect

Ecosystem Services

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

Multiple values and knowledge integration in indigenous coastal and marine social-ecological systems research: A systematic review

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ARTICLE INFO

Keywords:
Indigenous and local knowledge (ILK)
Indigenous people
Ecosystem services
DPSIR
Knowledge integrations

ABSTRACT

This systematic review explores patterns in the peer-reviewed literature related to the integration of multiple values in coastal/marine SES in indigenous settings. We extract metadata from 109 papers across five domains: 1) general study characteristics, 2) transdisciplinarity, 3) methodology, 4) SES elements (and their relationships), and 5) values. We use latent class analysis, descriptive statistics, and different visualization tools to elicit, synthesise and highlight the identified research patterns. Our results suggest that the peer-reviewed literature can be categorised across two main research approaches, *contextual research* and *causal research*. The former mainly uses qualitative techniques to study the drivers and pressures in such coastal/marine SES, providing a rather comprehensive understanding of these issues. The latter tends to engage better relevant stakeholders as a means of explaining relationships/impacts within such SES. Furthermore, causal research studies employ a more robust methodological portfolio. We argue that cross-fertilization between these distinct research approaches can contribute towards a more effective integration of different knowledge systems and values in indigenous coastal/marine contexts. In particular, *contextual research* can point "where we need to go", while *causal research* can employ novel tools to assess in depth the multiple values related to the ecosystem services provided by indigenous coastal/marine SES.

1. Introduction

Marine and coastal areas are some of the world's most complex Social-Ecological Systems (SES). Several coastal and marine ecosystems are biodiversity hotspots with unique flora and fauna (CBD, 2016; García and Vasconcelos, 2017; Moore et al., 2017; Thurstan et al., 2018). They provide habitats that are essential for species reproduction and the supply of multiple ecosystem services[1] that meet material, cultural, and spiritual needs (Himes-Cornell et al., 2018; Moore et al., 2017; Oleson et al., 2015). These systems are vital for a large portion of the global population, contributing in diverse ways to their livelihoods and well-being (CBD, 2016; Henson et al., 2017; Hughes et al., 2017).

For centuries, indigenous communities around the world have relied on marine and coastal ecosystems as the cornerstone for their social, economic and cultural activities (Augustine and Dearden, 2014; Cochran et al., 2013; Eckert et al., 2018; Gauvreau et al., 2017). These ecosystems are indispensable to indigenous communities as they often represent multiple values (e.g. bequest, intrinsic, instrumental) that are fundamental for their worldviews, beliefs, and cultural norms. This diverse set of values influences how ecosystem services are perceived/valued and depend on different factors such as culture, scale (i.e. individual, collective), and time (i.e. values can change over time) (Díaz et al., 2016; Pascual et al., 2017). These values are often expressed through totemic entities and sacred places embedded in marine species

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[1] Ecosystem services are the benefits that people obtain directly and indirectly from ecosystems and are broadly grouped across four categories namely a) provisioning services, b) regulating services, c) cultural services and d) supporting services (MA, 2005). Coastal and marine SES provide many different provisioning services, mainly from aquatic organisms and genetic material, for food, fuel, medicine and other direct uses (MA, 2005). Important regulating and supporting services include, among many others, habitat provision, flood protection, erosion control, and water purification (Barbier et al., 2011). Coastal and marine SES also provide many non-material benefits related to spiritual enrichment, recreation, education and aesthetic experience, among others (Rodrigues et al., 2017).

https://doi.org/10.1016/j.ecoser.2019.100910
Received 20 September 2018; Received in revised form 11 February 2019; Accepted 9 March 2019
2212-0416/

and seascapes, which provides a spiritual connection between indigenous communities and their surroundings (McNiven, 2004; Movono et al., 2018; O'Neill et al., 2012; Patankar et al., 2016).

However, anthropogenic activities and natural processes have contributed to the escalating degradation of key coastal and marine habitats such as mangroves, coral reefs, fisheries, coastal tundra, and fjords (Eckert et al., 2018; Evseev et al., 2018; Henson et al., 2017; Hughes et al., 2017). Moreover, some coastal zones where indigenous communities are located are among the most threatened from climate change (Gauvreau et al., 2017; Hiwasaki et al., 2014; McNamara and Prasad, 2014). Conflicts driven from the expansion of commercial fisheries, a lack of government recognition, and heavy marine traffic have compromised the management, access, and usage rights of indigenous communities on marine resources (Fuentes et al., 2015; Himes-Cornell et al., 2018; Miraglia, 2002; Moore et al., 2017; TEBT-EBBA, 2008). Such processes affect (often disproportionally) indigenous communities who view such ecosystems as their main livelihood source and social support system (Augustine and Dearden, 2014; Cochran et al., 2013; Gauvreau et al., 2017; Oleson et al., 2015; Vierros et al., 2010).

Indigenous communities have developed and used over generations traditional knowledge systems to manage, use, and conserve marine resources (Díaz et al., 2016; Gauvreau et al., 2017; Johnson et al., 2016; Oxfam, 2016; Rutherford et al., 2015; Vitale, 2017). Scholars have suggested that including the perspectives of indigenous communities is critical (and essentially their right) for the sustainable management of marine/coastal resources (Begossi, 2014; OHCHR, 2013; Raymond-Yakoubian et al., 2017; United Nations, 2007) and the effective collaboration among stakeholders (Gadamus and Raymond-Yakoubian, 2015; Setti et al., 2016; Sobrevila, 2008). Stakeholders from government, academia, civil society, and the private sector have identified that the integration of this local knowledge is a top priority for facilitating an effective science-policy interface for the sustainable use and management of biodiversity and ecosystem services (Gonzalo and Maffi, 2000; Saito, 2017; Thompson et al., 2017). This entails, among others, finding new ways of integrating the multiple values, valuation approaches and knowledge systems that capture the breadth of the benefits derived from ecosystems that are important to indigenous communities (Beck et al., 2014; Himes-Cornell et al., 2018; Pascual et al., 2017).

However, there has been limited progress in the development of effective ways to combine Indigenous and Local Knowledge[2] (ILK) and modern scientific knowledge for various reasons. First, there is an unequal footing between well-established methodologies from modern science and ILK (which is often unfamiliar to non-indigenous scholars), which has prevented the use of these traditional knowledge systems in current scholarship and practice (Chilisa, 2017; Ludwig, 2016; TEBT-EBBA, 2008). Second, the frequent use of economic valuation for coastal/marine ecosystem services often skews the discussion in favour of a single (monetary) value, which is different to the multi-value perspective of indigenous people. This single value perspective can set different expectations of what constitutes sustainable resource management and make collaborative work challenging (Beltrán, 2000; Carter, 2010; Gratani et al., 2011; O'Neill et al., 2012; Vierros et al., 2010). Third, there is a general lack of collaboration between scientists and ILK holders, which has marginalized the latter from the production of new research and relevant policies (Chilisa, 2017; Hiwasaki et al., 2014; Obermeister, 2017). Fourth, ILK has often been mobilized based on its utility to pre-conceived notions, and mainly to capture the information needed to advance modern science (Ludwig, 2016), rather than integrate ILK meaningfully to create new ways of eliciting knowledge.

Multiple technical, structural and perception barriers have alienated the active participation of indigenous communities and have contributed to the lack of proper integration between knowledge systems. Technical barriers include (a) communication limitations (e.g. remote communities that speak only their indigenous language), (b) low levels of literacy and formal education among the indigenous groups, (c) poor accessibility due to remoteness and lack of infrastructure; and (d) a technological divide due to the lack of familiarity with modern scientific methodologies and tools (Hiwasaki et al., 2014; Oleson et al., 2015; Setti et al., 2016; Smith et al., 2017; Vierros et al., 2010).

Structural barriers emanate from bureaucratic government systems and often impede the effective participation of indigenous communities in the formulation of management plans. Governments tend to follow top-down approaches that offer certain operational and logistics advantages. Even though top-down approaches allow for a more efficient use of resources, they ultimately fail to integrate ILK and marginalize the perspective and needs of indigenous communities (Gaymer et al., 2014; Marlor, 2010; Vierros, 2017).

Perception barriers relate to the doubts about the credibility of ILK sources. Most ILK practices are rooted in traditions and are mostly transmitted orally between generations, with generally few formally documented cases (McNamara and Prasad, 2014; Movono et al., 2018). Modern scientific methods often perceive these sources of knowledge more as anecdotal accounts rather than reliable information (Gadamus and Raymond-Yakoubian, 2015; Obermeister, 2017). Modern scientific methods "expect" that knowledge must be replicable, pass a series of rigorous tests, and a peer-review process, all of which already frame the integration of knowledge through a very specific lens. As a consequence, modern scientific methods are often superimposed over ILK, as a need to justify the credibility of ILK (Hiwasaki et al., 2014; Marlor, 2010).

Apart from its academic importance, knowledge integration is increasingly considered essential for creating an effective science-policy interface to solve critical environmental problems. Recently the first work programme of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) re-affirmed the importance of knowledge integration (Díaz et al., 2015; Perrings et al., 2011). In this aspect, the IPBES builds on the Millennium Ecosystem Assessment (MA) and TEEB (The Economics of Ecosystems and Biodiversity) and identifies ILK as an important element (alongside modern scientific knowledge) for finding options to manage SES in a sustainable manner (Beck et al., 2014; Díaz et al., 2015; Löfmarck and Lidskog, 2017; Tengö et al., 2017). Key to this has been the effort to illustrate the multitude of values that peoples ascribe to SES and ecosystem services, including intrinsic, instrumental, relational values (TEEB, 2010; Pascual et al., 2017). There have been strong calls to promote pluralistic valuation as a means to break away from normative approaches that fail to capture the full range of benefits that indigenous people perceive from nature (Pascual et al., 2017).

However, we need to note that apart from the often-discussed dichotomy between ILK and modern scientific approaches, there is also a large variation among the scientific techniques deployed to elicit values in indigenous marine/coastal SES. Currently a large array of very different qualitative, quantitative, and mixed-method techniques are used for this purpose (see Section 3.2 and 3.4). As it will be discussed later in this paper, these techniques have different capabilities, explanatory power, strengths and limitations. In fact there is an ongoing debate about the boundaries between quantitative and qualitative research techniques and some of the preconceived notions of utilising mixed-methods (Morgan, 2018; Sandelowski, 2014). Several scholars have pointed that rather than focusing on their dichotomies, we need to focus on the purpose that each method serves and the synergies they can achieve (Morgan, 2018; Sandelowski, 2014). Furthermore,

[2] Indigenous and local knowledge (ILK) can be defined as a "*cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment.*" (Pascual et al., 2017: 14).

preconceived notions that different methodological approaches may reveal different truths and that using mixed-method approaches automatically translates into a robust methodological study have been challenged (Greene and Caracelli, 1997; Sandelowski, 2014). More importantly, however, such research needs to be designed having the indigenous community context in mind (Pascual et al., 2017; Spoon, 2014).

It is within this context that this systematic review attempts to understand how different values have been articulated, captured, and integrated in indigenous coastal and marine SES. We identify how this has been approached within the peer-reviewed literature, and what have been the challenges, barriers, and strategies that researchers and practitioners have encountered. We extract, analyse, and visualize metadata from 109 published studies (*Section 2*) to identify (a) general research characteristics (*Section 3.1*), (b) main research approaches (*Section 3.2*), (c) transdisciplinarity (*Section 3.3*), (d) methodologies (*Section 3.4*), (e) relationships between the main SES elements (*Section 3.5*), and (f) elicited values (*Section 3.6*). We synthesise this information to identify the strengths and limitations of current approaches at the interface of values and coastal/marine ecosystem services in indigenous settings (*Sections 4.1 and 4.2*). We outline some proposals for the effective cross-fertilisation between approaches (*Section 4.3*) and the limitations of the current systematic review (*Section 4.4*).

2. Methods

2.1. Review structure

This study follows a systematic literature review protocol to provide a proper snapshot of the current academic landscape on how indigenous perspectives are considered in studies in coastal and marine SES. In particular we followed a four step process described below:

- *Step 1:* Systematic literature selection (*Section 2.2*).
- *Step 2*: Systematic extraction and analysis of metadata from the selected literature (*Section 2.3*).
- *Step 3*: Identify patterns in the metadata (*Section 2.4*).
- *Step 4*: Compare and contrast the strengths and weaknesses of the literature collected (*Section 4*).

All authors of this systematic review contributed to the design of the overall protocol and its specific steps. To ensure the consistent implementation of the protocol, only the corresponding author executed Steps 1–2. Once the meta-data were elicited in a consistent manner, all co-authors undertook jointly Steps 3–4. Whenever unexpected literature cases not predicted within the protocol were encountered during Step 1–2, all authors were consulted to review and update the procedures as needed.

2.2. Literature selection

We identified the relevant literature following three rounds of document filtering (see below), with each of these rounds entailing a more extensive review of the literature. During the first round we identified potentially-relevant documents using appropriate keywords (see below). During the second round we read the abstract of each study and then removed the non-relevant studies from the analysis. For the final round, all documents that we deemed relevant we downloaded the full document and read the entire manuscript to ensure that it meets the inclusion criteria (see below).

We used three categories of search words to identify the reviewed studies (Okhovati et al., 2017; Zupic and Čater, 2015). First, search words had to reflect coastal and/or marine systems such as those outlined in the technical report of the Convention on Biological Diversity (CBD) (AIDEnvironment, 2004). Second, search words had to reflect indigenous people, which is the interest target group of this review. Third, search words had to reflect some type of value system, including ILK, beliefs, customs, and worldviews. All search words are included in Fig. S1, Supplementary Electronic Material.

The literature search queries were performed for the research title, abstract, and keywords. The searched terms needed to be present in any one of those fields to be considered for the second round of literature selection. We relied on two advanced search functions to ensure a comprehensive coverage of each term, while reducing the number of non-relevant results (Falagas et al., 2008; Okhovati et al., 2017). The first function involved the use of wildcards to avoid discarding relevant results. This function allowed for the definition of stem words and covered all derivative words that contained the same stem (i.e. searching for "coast*" matched with coastal and coastline). The second function allowed for the definition of compound search words, where two keywords must be adjacent to each other within a user-defined distance. This function helped refine the search to relevant material by providing a context to the keyword (Zupic and Čater, 2015). For example, searching for "indigenous + people" will avoid non-relevant results such as "indigenous plant species", while still matching with "indigenous and ancestral people". For this last function we set a distance of up to 7 words to avoid discarding possible relevant studies.

In order to maximize the journal coverage we conducted the literature search in Scopus and Web of Science, the two most extensive databases for peer-reviewed materials and a frequent source for bibliometrics analyses (Mongeon and Paul-Hus, 2016). The same search words and advanced search functions were used in both search engines without setting any further restrictions (e.g. year, field, publication type). The search in Scopus produced 356 documents and in Web of Science 308 documents. A total of 495 unique documents remained after combining the identified documents and removing the duplicate documents. After analysing the abstract and keywords of each of these documents, a total of 145 documents appeared to match our selection criteria. We then read the full text of each of these 145 documents and ended up with 109 documents that met our study criteria and deemed relevant for the metadata extraction (*see Table S1, Supplementary Electronic Material for full list*).

2.3. Metadata extraction and analysis

Overall five types of metadata content were extracted from each study. These metadata were analysed, and the main trends were visualized as a means of identifying possible knowledge gaps, challenges, and barriers for the integration of multiple knowledge system.

The first type of metadata includes general study characteristics such as the study site and the academic impact of the study. For the former we used Google maps to obtain the approximate longitude and latitude coordinates based on actual reported study sites. For the latter we collected the number of citations received until June 2018 and the journal's two years citations per document based on Scimago 2017 Journal Ranking. From the location metadata two heatmaps were created using QGIS version 3.2. These heatmaps illustrate where these studies are more densely concentrated compared to national population and land rights recognition (*see Section 3.1*). The first heatmap overlays research density with a layer containing the percentage of land that each country has officially recognized as indigenous land (Dubertret and Alden Wily, 2015). The second heatmap overlays research density with a layer containing an estimate of indigenous population with different degrees of governmental recognition (Jacquelin-Andersen, 2018; UNDESA, 2017). Countries were color-coded based on indigenous population and classified under five brackets. Due to the high concentrations of indigenous populations in a few countries, we set the upper and lower limits of the brackets as non-constant intervals in order to achieve an equal number of countries per bracket. Finally, the relative academic impact of these studies is discussed and visualized through a bubble chart comparing journal impact factors and number of citations (*see Section 3.2*).

The second type of metadata captures aspects of transdisciplinarity in each study. Journal disciplinary fields as reported by Scopus were used as a proxy for the academic field of each study. We extracted information about the authors' collaboration with different institutions (e.g. academia, civil society, government agencies) across countries, as well as the different types of stakeholders involved during the development of the research reported in each study (e.g. local communities, private sector, ILK holders). There is an increasing trend of different research fields merging together to address sustainability science issues (Kajikawa et al., 2014). We used unique open source visualization tools to visualize the relevant metadata and illustrate the diversity of fields involved in these studies (Mauri et al., 2017). This visualization shows the evolution of the academic fields involved in research related to indigenous people in marine and coastal systems (*see Section 3.3*). Chord diagrams helped us convey two layers of information related to the current state of collaboration between the institutions in which the authors were affiliated. First the arcs capture the relative participation of certain types of institutions compared to each other. Second, the size of the links between the arcs explains the collaboration frequency between these institutions. Links that originate and end within the same arc explain the collaboration between same institution types across different countries (*see Section 3.3*). We also developed spider web diagrams that convey trends about the integration of different types of stakeholders. The spokes within the diagram represent the year of publication while the diagram axis expresses the percentage of studies that integrated a given stakeholder (*see Section 3.3*). Finally, we extracted the degree of stakeholder integration ranging from high levels of public participation (i.e. studies were there was a productive discussion between stakeholders or adopted a co-design approach) to low levels (i.e. studies where stakeholders only received information and were consulted only to extract information) (*see Table S2, Supplementary Electronic Material*) (Mostert, 2003).

The third type of metadata is related to the methodologies used within each study. We extracted the different data capturing tools (e.g. interviews, questionnaires, workshops), analysis methods (e.g. narrative analysis, remote sensing, descriptive statistics), and theoretical frameworks (e.g. sustainable livelihood approach, value base paradigm, decolonial approach). We extracted the methodologies that were expressed explicitly or could be inferred within the methodology and results sections of each study. Open source dendrograms (Mauri et al., 2017) were used to visualize the landscape of the research methodologies used (*see Section 3.4*).

The fourth type of metadata relates to the main issues that indigenous people face in marine and coastal SES when different value systems are being integrated reflecting the viewpoints of the different stakeholders involved. We use the Drivers, Pressures, States, Impacts, and Responses framework (DPSIR) to systematize this information as this approach (a) offers a thorough understanding of an entire SES, (b) captures causal relationships between its different elements (i.e. drivers, pressure, state, impact, response), and (c) has been extensively used in marine and coastal ecosystem (Gari et al., 2015; Kristensen, 2004; Lewison et al., 2016). Apart from extracting the different DPSIR elements from each study, we also capture the type of impact (either negative or positive for the SES) and the effect of the DPSIR element for the SES. We elicit the magnitude of these effects based on our critical reading of each study and use a five-level Likert scale (1 = Significant degradation, 2 = Moderate degradations, 3 = Remains the same, 4 = Moderate improvement, 5 = Significant improvement). For studies where the trend was inconclusive or uncertain, we did not assign a score but flagged it as "uncertain".

We summarize the DPSIR outcomes using an alluvial diagram (Mauri et al., 2017) where (a) each DPSIR element shows the relative influence of each variable over the SES; (b) the links between DPSIR elements show the cause-effect relationship; and (c) the width of the links represents the frequency of these connections across the different studies (*see Section 3.5*). Additionally, we summarize the main variables within each DPSIR element in a table as a means of showing the trend and the consensus level. This consensus reflects the level of agreement between the different studies, where a value of 1 represents a full consensus while a value of 0 represents a complete disagreement (Tastle and Wierman, 2007) (*see Section 3.5*). Finally, bar charts for each DPSIR element depict the ratio between positive and negative impacts of each variable to the SES.

The fifth type of metadata focuses on the values elicited in each study. In particular for each study we identify which ecosystem services are studied, and then we extract both the type of values represented for the subjects of the study (i.e. bequest, instrumental, relational, intrinsic, existence, option) (Díaz et al., 2016; Pascual et al., 2017; TEEB, 2010) and the valuation method used (e.g. ethnoecological, economic valuation, non-market oriented valuation) (Díaz et al., 2016). The trend of these perceived benefits from ecosystems was also analysed through a five-level scale (1 = Significant degradation, 2 = Moderate degradation, 3 = Remains the same, 4 = Moderate improvement, 5 = Significant improvement). Where needed we recorded the cases of uncertainty. An alluvial diagram was used to depict the flow between types of perceived values, ecosystem services, and valuation methods (*see Section 3.6*). Finally, to summarise the results a table containing trends, consensus, and uncertainty levels was created (*see Section 3.6*).

2.4. Latent class analysis

To classify these studies we used Latent Class Analysis (LCA), a statistical tool that allows the analysis of multivariate categorical data. LCA allows the identification of latent classes among studies, or in other words, it allows the clustering of studies based on similar research patterns. LCA uses observed variables defined by the user as a means of finding this cluster through unobserved or "latent" classes (Haughton et al., 2009; Henry et al., 2015).

We extracted 12 different observable variables that characterize each study including research design (e.g. case study, action research, experimental), type of research question (i.e. exploratory or descriptive), methodological approach (i.e. qualitative, quantitative, mixed) (*see Table S3, Supplementary Electronic Material for full list*). The analysis was conducted using open access poLCA R package (Linzer and Lewis, 2013, 2011). The LCA models were re-estimated ten times until the maximum likelihood solution was found and the analysis was run for up to five classes. Following the parsimony criteria we use the model with the lowest Bayesian information criterion (BIC) to determine the appropriate number of classes to select (Linzer and Lewis, 2013, 2011). A sensitivity, specificity, and accuracy analysis were conducted to determine the suitability of the selected model (Dziak et al., 2018). These tests allowed for an assessment of the proportion of studies that were accurately predicted compared to the estimates from the LCA model. Ultimately, we used the research classes identified through the LCA to organize the results of the metadata analysis (*see Section 3.2*). The ability to group similar types of research studies and go through an exhaustive analysis for each of these clusters helped us to clearly compare strengths and weaknesses in the current academic landscape.

3. Results

3.1. General characteristics

Most of the reviewed studies (68%) were conducted in developed countries (e.g. Australia, Canada, United States, New Zealand) while the remaining were distributed in 18 developing countries or regions (*see Table S4, Supplementary Electronic Material, in "Location"*).

Figs. 1 and 2 reveal two main concentrations of studies. The first is in Canada's west coast, British Columbia among First Nation people. These studies mainly cover issues related to indigenous rights, and management and access to marine resources with high cultural value such as abalone *(Haliotis kamtschatkana)*, sea otters *(Enhydra lutris)*, and

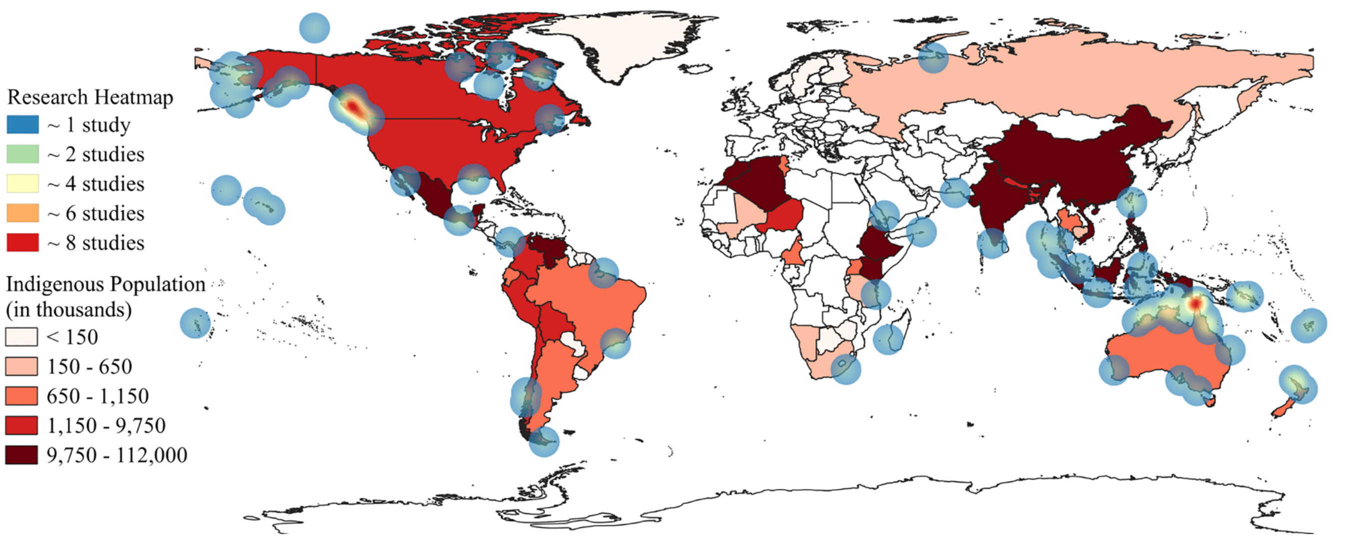

Fig. 1. Heatmap of the sites of the reviewed studies and population of indigenous people by country *Note:* The upper and lower limits of population brackets are set up to distribute an equal numbers of countries within each level. For more detail on the percentage of indigenous population relative to the national population refer to Table S5 in the Supplementary Electronic Material.

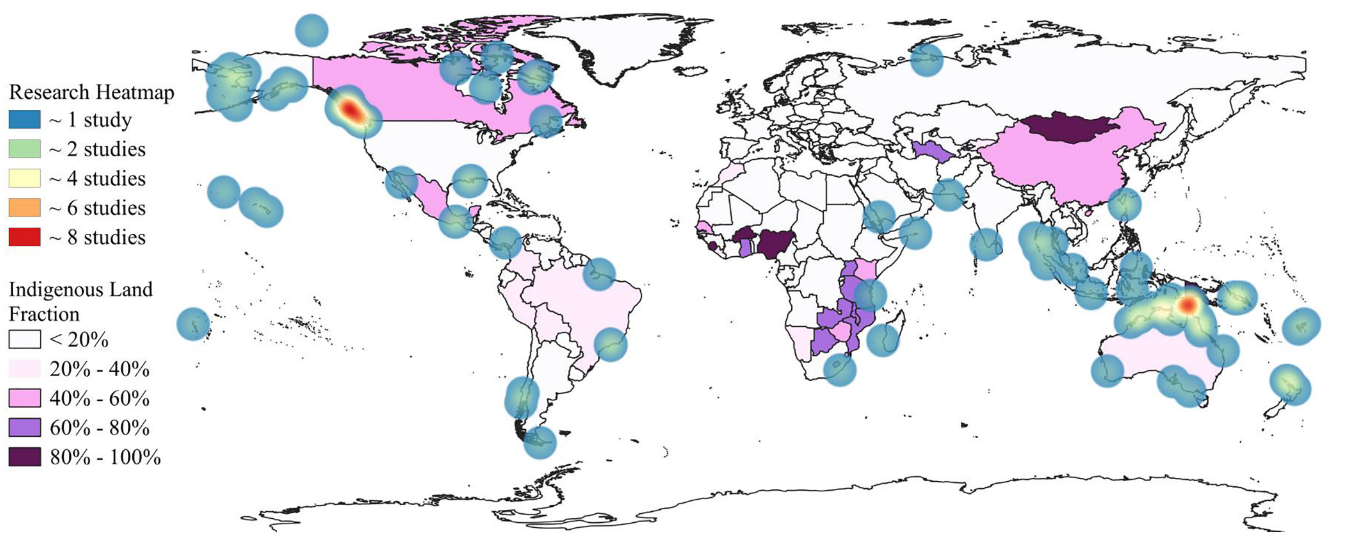

Fig. 2. Heatmap of the sites of the reviewed studies and recognized indigenous land ownership by country *Note:* Indigenous land fraction represents the recognized indigenous land area compared to the national land mass.

clams *(Protothaca staminea, Saxidomus gigantea, Venerupis philippinarum)* (Augustine and Dearden, 2014; Levine et al., 2017; Marlor, 2010; Menzies, 2010; Sloan, 2004). The second cluster is in the Torres Strait, North of Australia focusing on Torres Strait Islanders and Australian aboriginals. These studies mainly cover issues concerning commercial fisheries and marine resources with high economic value such as rock lobster *(Panulirus ornatus)* (Hutton et al., 2016; Lalancette, 2017; van Putten et al., 2013), and the protection of culturally significant species such as dolphins *(Orcaella heinsohni, Sousa* sp.*, Tursiops* sp.*)*, dugongs *(Dugong dugon)*, and sea turtles *(Chelonia mydas, Natator depressus)* (Butler et al., 2012; Fuentes et al., 2015; Grech et al., 2014; Nursey-Bray et al., 2010).

Interestingly, Fig. 1 suggests that there are few studies in coastal countries with large indigenous populations[3] such as China, India, Indonesia, Venezuela, Mexico, Philippines, Vietnam, and Kenya. Fig. 2 suggests that the two main clusters of studies are conducted in countries with higher indigenous land right recognition such as Canada, Papua New Guinea and, to some extent, Australia. Some countries such as India, Venezuela, United States, and Chile with large population of indigenous people have low land recognition and little research conducted in indigenous marine/costal SES.

3.2. Latent classes: contextual and causal research approaches

The LCA identifies two latent classes that fit the best solution that carry the lowest BIC. Class 1 contains 55% of the studies and Class 2 the remainder 45% (*see Table S6, Supplementary Electronic Material*). The sensitivity analysis suggests that the two latent classes are a good model, with an overall accuracy of 99% (*see Table S7, Supplementary Electronic Material*). While not all variables within the LCA showed a distinctive pattern between the two classes (*see Fig. S2, Supplementary Electronic Material*), some interesting results emerge. Class 1 is characterized by studies that contextualize indigenous issues, focusing mostly on descriptive research questions and qualitative research.

[3] Despite the general lack of detailed information about the spatial distribution of indigenous people settlements globally (whether inland or in coastal areas), there are some available general population estimates (Dubertret and Alden Wily, 2015).

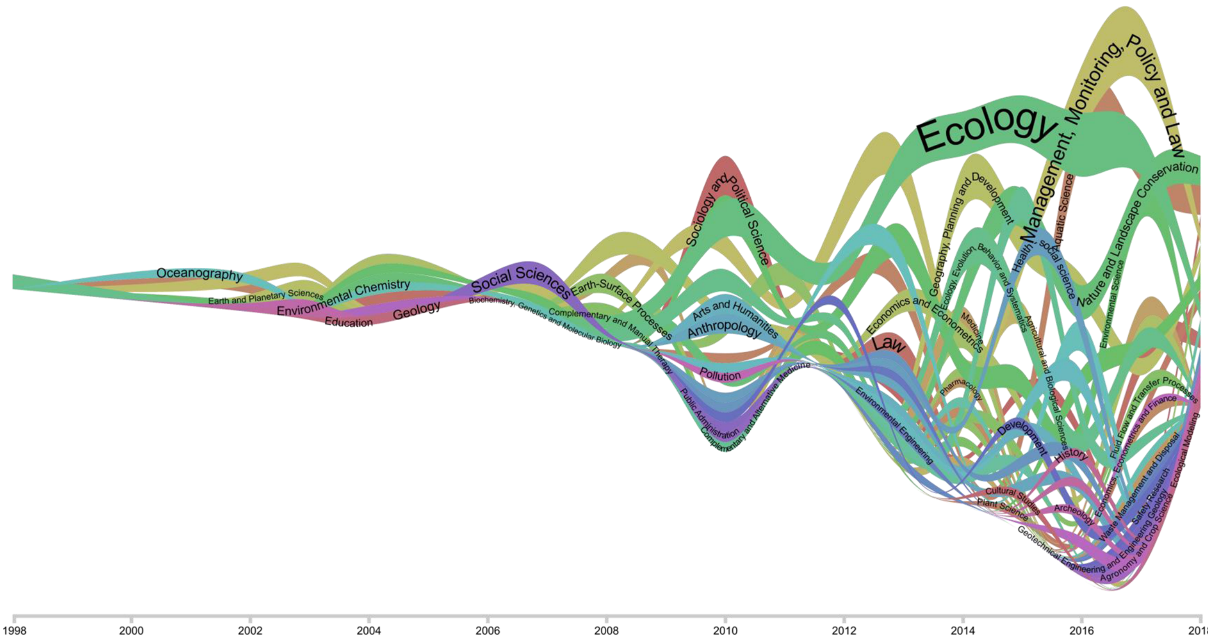

Fig. 3. Evolution of the main academic fields represented in the reviewed studies *Note:* For a full list refer to Table S8 in Supplementary Electronic Material.

These studies frequently aim to raise awareness about the relationship between indigenous people and coastal/marine ecosystems. These include, among others, studies that seek to recapture traditional understanding of coastal/marine systems, and methods and values of ecosystem services preserved through customary practices, oral history, and archeological evidence, with the aim of addressing present challenges such as urban development, marine resource management, and indigenous rights (McMillan and Prosper, 2016; Roberts et al., 2016; Saleh, 2004; Suluk and Blakney, 2009).

On the other hand, Class 2 studies seek to explain the causal flow between system pressures, their impact on the SES, and people's responses. It contains studies that address exploratory research questions using quantitative, qualitative, and mixed-method research approaches. Some of the main research themes include mapping and assessing fisheries supply chains and how they affect the SES on issues such as coastal pollution and marine resource management (Butler et al., 2013; Hutton et al., 2016). Many of these studies found ways to integrate ILK and modern scientific techniques such as remote sensing to assess potential conflicts between different stakeholders (Espinoza-Tenorio et al., 2013; Moore et al., 2017), identify suitable protected areas (Ban et al., 2009, 2008), and determine the value of adaptation measures against climate change (Hoverman and Ayre, 2012; Laidler et al., 2011).

Considering their unique set of characteristics, for the remainder of this paper we will refer to studies within latent Class 1 as *"contextual research"* and studies within latent Class 2 as *"causal research"*. The overall academic influence of these studies seems to be growing, as not only the number of relevant studies increases in the last few years, but they are also being published in higher impact journals (*see Fig. S3, Supplementary Electronic Material*). Even though *contextual research* studies are more prevalent, they tend to be published in lower impact journals and have few articles that are highly cited. On the other hand, *causal research* tends to be published in higher impact journals and have, on average, higher citation rates.

3.3. Transdisciplinarity

There is an increasing trend towards a broader representation and collaboration between academic disciplines and fields in studies related to coastal/marine SES in indigenous settings (Fig. 3). Initially studies came from just a few fields within the environmental, agricultural, and biological sciences such as oceanography, environmental sciences, and management and policy studies. Currently studies come from a plethora of different academic disciplines and fields through academic fields such as computer sciences, economics, biochemistry, arts and humanities, and pharmacology, among others (*see Table S8, Supplementary Electronic Material*).

Fig. 4 outlines the types of institutions engaged in this type of research and presents in detail the authors' cross-collaboration within (and between) institutions. In a sense Fig. 4 provides a snapshot of the stakeholders directly involved in the conceptualisation, design, and execution of the reviewed studies. Distinct patterns emerge when comparing between research classes. Most *contextual research* studies are predominately produced within academia compared to other types of institutions. Most of the collaborations tend to be between academic institutions from different countries (Fig. 4), and only in a few studies are indigenous community members integrated actively in the research team (McMillan and Prosper, 2016; Roberts et al., 2016; Suluk and Blakney, 2009). In contrast, authors from *causal research* studies tend to be more open to collaborations with multiple non-academic institutions such as research institutes and indigenous group agencies (e.g. traditional institutions in charge of local marine resource management) (Butler et al., 2013; Fuentes et al., 2015; Gratani et al., 2011). However, interestingly, there seems to be less collaboration with actual indigenous community members within *causal research* studies, compared to *contextual research* studies.

The level of stakeholders' integration also varies between research classes. Despite a lack of *causal research* studies in the early 2000s (we found only 1 study from 1998), they tend to integrate more stakeholders (and at a higher proportion of studies) compared to *contextual research* (Fig. 5). Furthermore, even though indigenous communities are the most frequently integrated stakeholders in both classes, there seems to be a different level of contribution to the actual research. *Causal research* studies tend to integrate more meaningfully the input of indigenous people than *contextual research*. Higher integration of indigenous communities through co-design approaches is observed in the *causal research* class (10% of all studies) rather than the *contextual research* class (5% of all studies). This also applies for general public participation through co-design, discussions and consultations (*see Table S4, Supplementary Electronic Material, in "Indigenous People Integration"*).

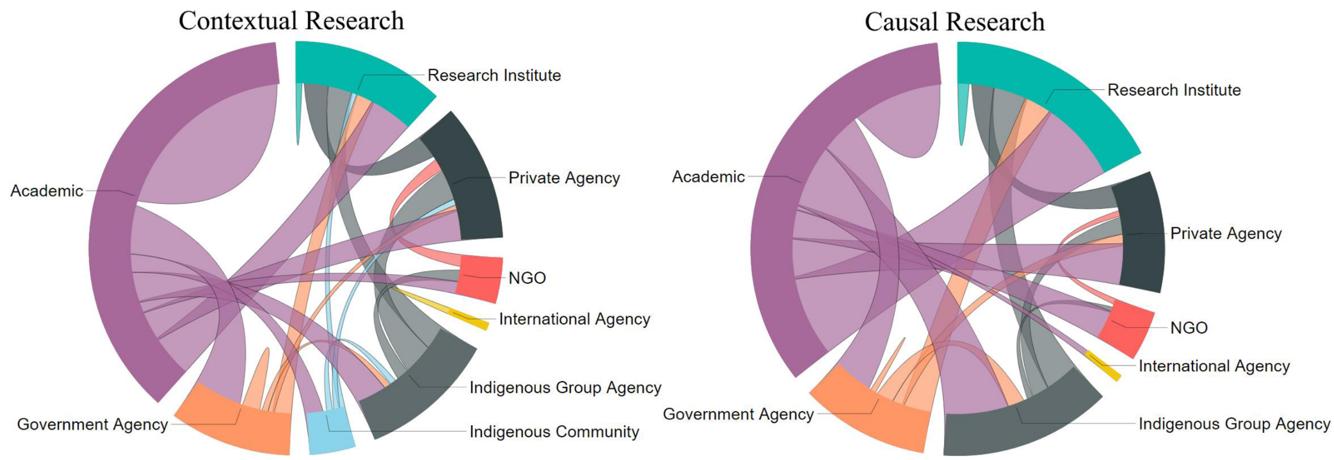

Fig. 4. Collaboration between the reviewed studies authors' institutions for each research class *Note:* The "arcs" represent the frequency of authors' institutions that participated in the study. The "links" between the arcs shows the collaboration between authors' intuitions for each study. Links that start and end within the same arc represent collaboration between the same type of institution from different countries.

3.4. Methodologies

A closer look of the data collection tools, analytical methods, and theoretical frameworks used in each study also identified distinct patterns between research classes. Fig. 6 clearly shows the differences and similarities between the types of tools, methods, and frameworks used within each research class. Overall, while it seems that both research classes implement the same type of data collection tools, a closer examination revealed that *causal research* studies tend to use multiple types of data collection tools in their studies (*see Table S9, Supplementary Electronic Material, in "Data Collection Tool"*). Furthermore, *causal research* studies tend to use more frequently multiple tools to collect primary data (e.g. questionnaires complemented with focus group discussions) (73% of studies) than *contextual research* studies (43% of studies) (*see Table S4, Supplementary Electronic Material, in "Multi Tools"*).

The biggest differences between the research classes relates to the analytical methods used. In total we identified 38 different types of analytical methods used in *causal research* studies, which is more than double the 18 methods identified in *contextual research* studies (Fig. 6). Furthermore, we found different methodological preferences between research classes. Narrative analysis is by far the most frequent analytical method in *contextual research* (77% of studies), while in *causal research* descriptive statistics is the most frequent analytical method (71% of studies) (*see Table S9, Supplementary Electronic Material, in "Analytical Methods"*).

On the contrary there are subtler differences in the use of theoretical frameworks between research classes. Interestingly, the main differences between classes lie in the objective of the adopted theoretical frameworks rather than the number of frameworks used or the frequency of their adoption. Overall *contextual research* studies tend to adopt theoretical frameworks based on anthropological and ethnographical approaches (e.g. two-eyed seeing, values-based approach, decolonial approach) that aim to understand the different aspects of coastal/marine SES in indigenous settings (Augustine and Dearden, 2014; Kronmüller et al., 2017; McMillan and Prosper, 2016). On the other hand, *causal research* studies tend to adopt theoretical frameworks that seek to explain relationships for an observed phenomenon that affects these coastal/marine SES (e.g. pressure-state-response framework, DPSIR, choice behavior approach) (Espinoza-Tenorio et al., 2013; Gunn et al., 2010; Oleson et al., 2015) (*see Table S9, Supplementary Electronic Material, in "Theoretical Frameworks"*).

3.5. Conceptual mapping of the main SES elements and their relationships

We identify key DPSIR elements and the relationship for each study, aggregate the results for all studies, and produce a conceptual map of the linkages between the DPSIR elements. From this point onwards, when we use the word "map/mapping" in the context of SES and DPSIR elements, we refer to this conceptual mapping of the system.

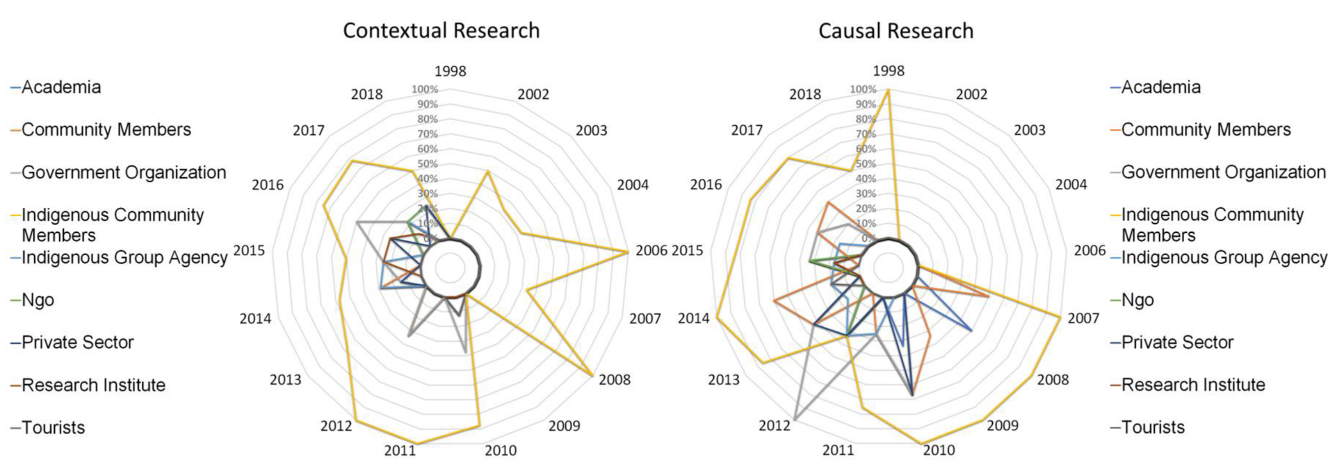

Fig. 5. Stakeholder integration in the reviewed studies for each research class *Note:* Main axis represent the percentage of studies that includes a given stakeholder for the specific year.

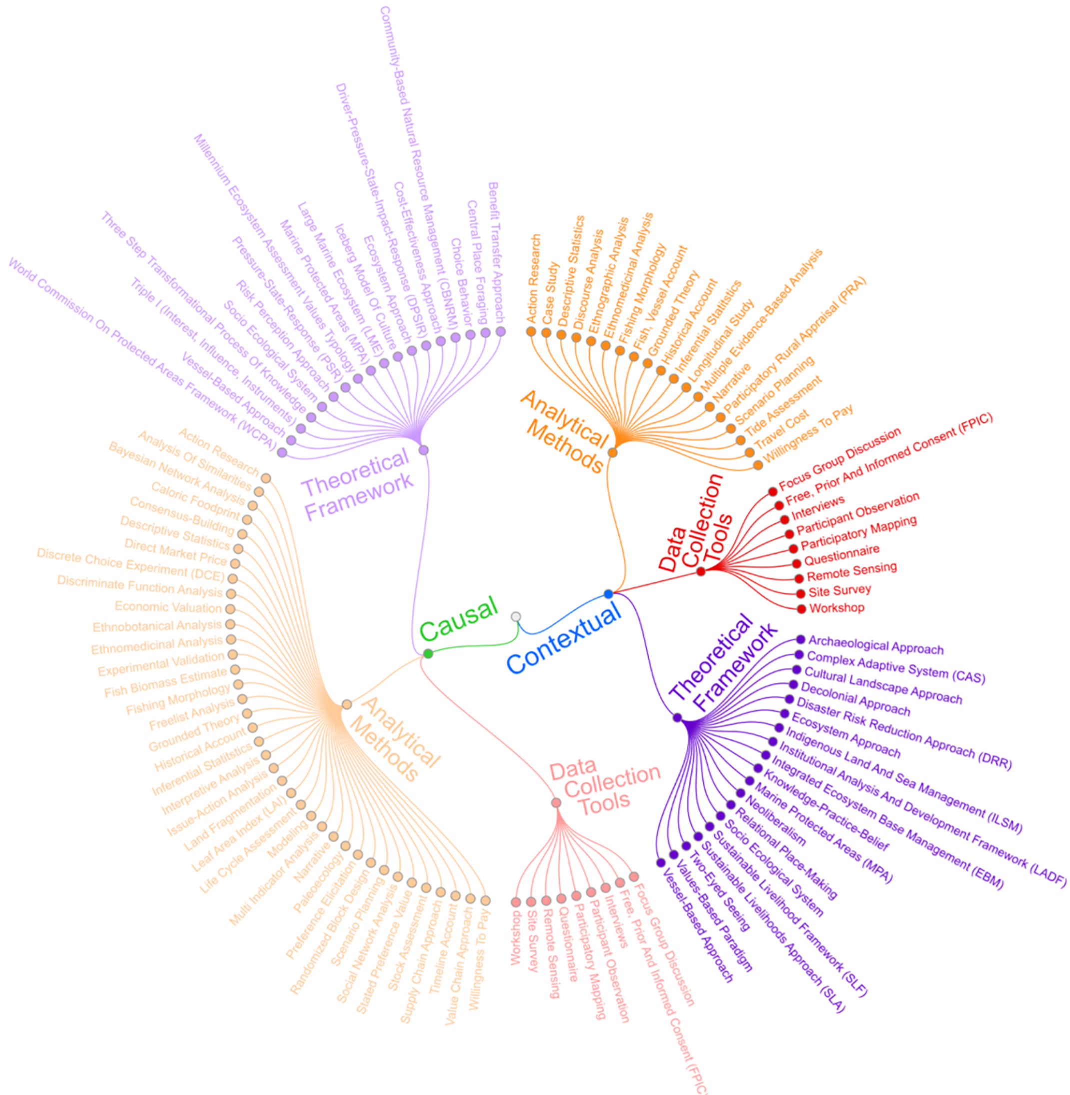

Fig. 6. Data collection tools, analytical methods, and theoretical frameworks by research class *Note:* For a full list refer to Table S9 in the Supplementary Electronic Material.

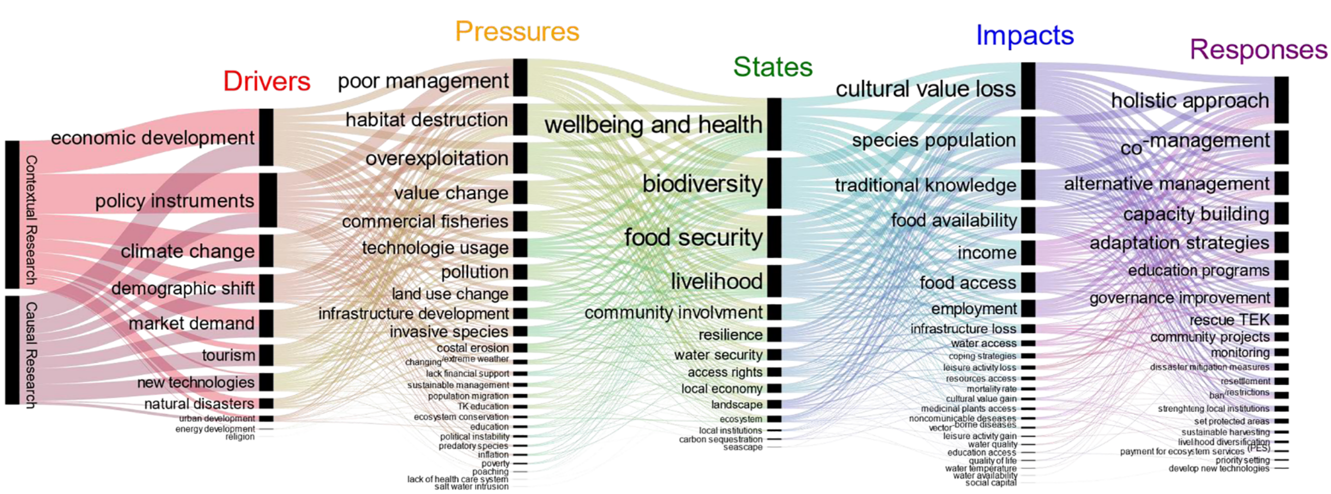

Fig. 7. Relationship between DPSIR elements within marine/coastal SES in indigenous settings for both research classes *Note:* The width of each line represents the frequency of this element as identified in the reviewed studies. Elements are aggregated from contextual and causal research studies. For a full list refer to Figs. S4–S8 in the Supplementary Electronic Material.

Fig. 7 depicts the relationship between the different DPSIR elements as extracted from the reviewed studies and illustrates the complexity of coastal/marine SES in indigenous settings. While some caution should be paid when combining the results of all studies, very revealing causal relationship emerge between DPSIR elements. In particular underlying economic drivers combined with policy instruments (that often have a lagging effect), tend to give rise to pressures related to poor resource management and habitat destruction pressures (Allamel, 2016; Marlor, 2010) (*see* Fig. 7*, Drivers and Pressures columns*). These pressures can have a substantial effect in coastal/marine SES, affecting negatively biodiversity (Lyver et al., 2015; Stephenson et al., 2014), ecosystem services (Preece et al., 2016; Zander and Garnett, 2011), and the wellbeing of indigenous communities (Brooks and Bartley, 2016; Espinoza-Tenorio et al., 2013) (*see* Fig. 7*, States column*). This often manifests through the loss of cultural values (McMillan and Prosper, 2016; Preece et al., 2016) and culturally significant marine species (Jackson et al., 2015; Liu, 2017), among others (*see* Fig. 7*, Impacts column*). The most common responses include the call for adopting integrated approaches to respond to the economic, social and cultural needs of indigenous communities considering their distinct values, ILK, and worldviews (Brooks and Bartley, 2016; Espinoza-Tenorio et al., 2013; Setti et al., 2016) (*see* Fig. 7*, Responses columns*).

To identify patterns between research classes we compare below the three most frequent variables for each DPSIR element between studies. Overall, *causal research* studies tend to identify more often Drivers and Responses that have a favourable effect to the SES, such as the capacity of policy instruments and new technologies to improve the SES (Carothers, 2013; Joyce and Satterfield, 2010) (*see Fig. S4, Supplementary Electronic Material*). The most notable difference however is observed in the trend of the DPSIR responses. *Causal research* studies often identify that integrated responses can protect marine areas and endangered species (Ban et al., 2009; Gunn et al., 2010), while *contextual research* studies show that the effectiveness of integrated approaches declines when policy instruments are designed to meet market demands (Raymond-Yakoubian et al., 2017; Turner et al., 2013) (Fig. 8).

However, the type of Impact (either positive or negative), follows a similar pattern between research classes (*see Figs. S9–S13, Supplementary Electronic Material*). For example, the results show that most responses in both research classes are perceived having a positive feedback to the marine SES (*see Fig. S13, Supplementary Electronic Material*).

3.6. Values and valuation techniques

Fig. 9 shows the values elicited in the reviewed studies, the ecosystem services they are attached to, and the valuation methods. Instrumental values are the most commonly elicited values, representing 50% of the values captured in the reviewed studies. Instrumental values are mostly attached to provisioning services such as food and raw materials (Huntington et al., 2013; Roberts et al., 2016). Relational values account for 30% of the captured value and are mostly related to cultural services linked to spiritual needs (Kikiloi et al., 2017; McMillan and Prosper, 2016). Bequest values represent 13% of all values captured and are mostly attached to supporting ecosystem services related to the maintenance of genetic diversity (Lyver et al., 2015; Oleson et al., 2015). Intrinsic, existence and option values are captured in much fewer studies (Fig. 9).

The most common valuation methods are cultural/social approaches used in 84% of the cases, mostly using ethnoecological tools. Economic and biophysical methods are also employed (e.g. direct market valuation, non-market valuation, choice experiment) but only in 16% of the cases. When comparing research classes, *contextual research* studies overwhelmingly tend to capture more than one value representing 85% of studies compared to 67% of *causal research* studies (*see Table S4, Supplementary Electronic Material, in "Multi Value"*).

Fig. 10 shows that most studies have identified that coastal/marine ecosystem services in indigenous settings are either declining or have

		Total			Contextual Research			Causal Research		
		Trend	Consensus	Uncertain	Trend	Consensus	Uncertain	Trend	Consensus	Uncertain
Drivers										
Economic Development	(n=47/23/24)	↘ 2.2	0.8	40%	↘ 2.1	0.8	26%	↘ 2.4	0.7	54%
Policy Instruments	(n=37/24/13)	↘ 2.4	0.7	24%	↘ 2.4	0.7	13%	→ 2.6	0.7	46%
Climate Change	(n=31/18/13)	↘ 1.9	0.9	26%	↘ 1.8	0.9	28%	↘ 1.9	0.9	23%
Pressures										
Habitat Destruction	(n=38/20/18)	↘ 1.7	0.8	8%	↘ 1.6	0.8	3%	↘ 1.9	0.8	5%
Poor Management	(n=36/26/10)	↘ 2.1	0.8	6%	↘ 2.1	0.7	3%	↘ 2.0	0.8	3%
Overexploitation	(n=35/16/19)	↘ 1.8	0.9	9%	↘ 1.7	0.8	3%	↘ 1.8	0.9	6%
States										
Biodiversity	(n=55/25/30)	↘ 2.1	0.8	15%	↘ 1.9	0.8	5%	↘ 2.2	0.8	9%
Wellbeing And Health	(n=53/32/21)	↘ 2.2	0.8	15%	↘ 2.2	0.8	8%	↘ 2.1	0.8	8%
Livelihood	(n=33/17/16)	→ 2.6	0.6	24%	↘ 2.4	0.7	9%	→ 2.8	0.5	15%
Impacts										
Species Population	(n=53/23/30)	↘ 2.1	0.8	15%	↘ 1.8	0.8	6%	↘ 2.3	0.7	9%
Cultural Value Loss	(n=50/30/20)	↘ 1.9	0.9	6%	↘ 1.8	0.9	4%	↘ 2.0	1.0	2%
Traditional Knowledge	(n=32/20/12)	↘ 2.2	0.7	9%	↘ 2.3	0.7	6%	↘ 2.1	0.8	3%
Responses										
Holistic Approach	(n=39/22/17)	→ 2.9	0.5	67%	↘ 2.3	0.6	38%	↗ 3.7	0.8	28%
Alternative Management	(n=24/15/9)	↗ 3.9	0.5	71%	↗ 3.6	0.4	42%	↑ 4.5	0.8	29%
Co-Management	(n=23/17/6)	↘ 2.2	0.4	78%	↘ 1.5	0.8	65%	→ 2.7	0.2	13%

↓ = significant degradation	< 0.2	< 20%
↘ = moderate degradation	0.2 - 0.4	20% - 40%
→ = remain the same	0.4 - 0.6	40% - 60%
↗ = moderate improvement	0.6 - 0.8	60% - 80%
↑ = significant improvement	≥ 0.8	≥ 80%

Fig. 8. Top three variables for each DPSIR element by research class *Note:* Parentheses represent the number of papers that studied each variable (total/contextual/causal). Trends are based on an average of the results elicited from each individual study. Consensus (of the trend) is based on the level of agreement between studies. Uncertainty is based on the percentage of studies that identifies the variable without clear trend. For a full list of variables refer to Figs. S4–S8, in the Supplementary Electronic Material.

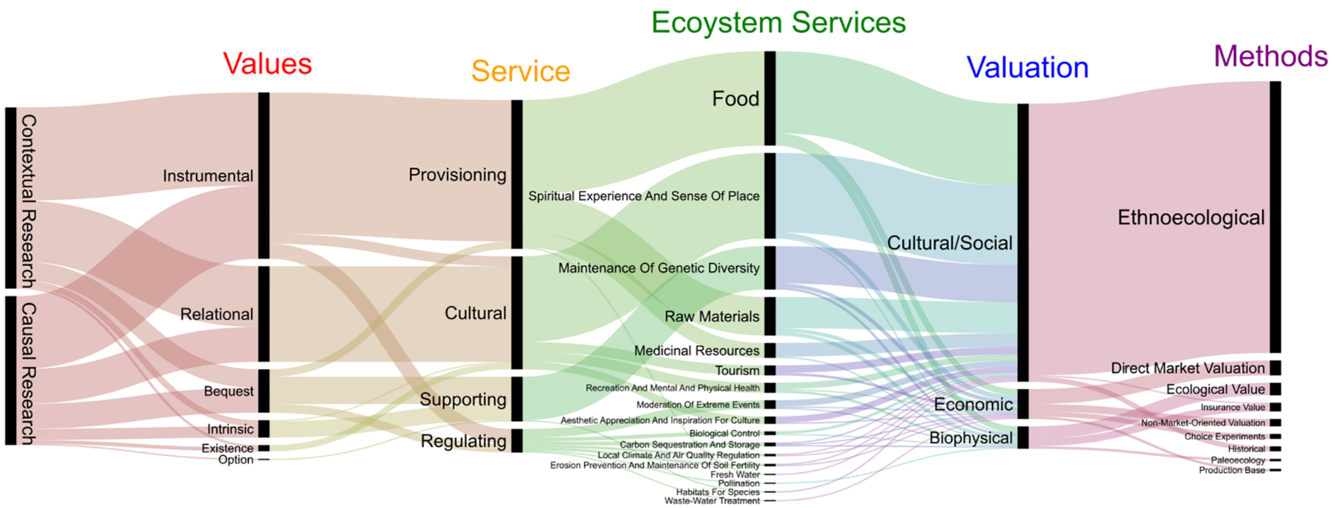

Fig. 9. Values and valuation methods for coastal/marine ecosystem service for both research classes *Note:* The width of each line represents the frequency of each element as identified in the reviewed studies. Five flow stages (from right to left) shows 1) the type of values explored in each research class, 2) the category of ecosystem services provided by each type of value, 3) the specific type of ecosystem services 4) the valuation type used to study the ecosystem services, and 5) the method used for the valuation. For a full list of ecosystem services refer to Fig. 10.

an uncertain future. Studies from both research classes suggest declines on the instrumental value of food-related provisioning services due to overexploitation (Cullen et al., 2007; Eckert et al., 2018), habitat destruction (Lauer and Aswani, 2010; Oleson et al., 2015), and poor marine resource management (Gauvreau et al., 2017; Robards and Lovecraft, 2010). Similarly loss of relational values has been linked to the loss of cultural ecosystem services triggered by the decline of culturally significant species (Menzies, 2010; Sloan, 2004) and the degradation of landscape/seascape elements (Kronmüller et al., 2017; Vaughan and Ardoin, 2014). On the other hand the effects to regulating services with bequest values remains mostly uncertain (Preece et al., 2016; Zander and Garnett, 2011).

4. Discussion

4.1. Strengths and weaknesses of contextual research approaches

Contextual research studies have so far been more successful in integrating multiple values and diverse knowledge systems for the study of coastal/marine SES in indigenous settings. The ethnoecological approaches that are predominant in these studies facilitate the collaboration of academics with indigenous and local communities, allowing the identification of a wide(r) range of values. The qualitative focus of *contextual research* studies allows for a relative comprehensive understanding of phenomena in such coastal/marine SES, by identifying key relevant elements within the SES, their linkages, and their impacts. In a sense we identify three strengths of *contextual research* approaches to study coastal/marine SES in indigenous settings: (a) direct collaboration with ILK holders, (b) multi-value orientation, (c) comprehensive conceptual mapping of coastal/marine SES.

Direct collaboration with ILK holders: Contextual research studies tend to include more often extensive direct collaboration between academics and community members (as co-authors and active partners) (*see Section 3.3*). This direct collaboration enriches the perspective of academic studies and allows for a more holistic understanding of pertinent issues in coastal/marine SES. It does not only provide a first-hand account from actors involved in the issues being explored, but also ensures that the points of view of indigenous people are not set aside or overshadowed/dominated by modern science perspectives and western values. This type of direct collaboration becomes essential when addressing politically-charged issues such as indigenous rights, and conflicts between indigenous people and governments over marine resources (McMillan and Prosper, 2016).

Multi-value orientation: Contextual research studies also tend to adopt more often a multi-value approach. In particular we identified a multi-value perspective in 85% of *contextual research* studies, compared to 67% of *causal research* studies (*see Section 3.6*). The values and benefits that indigenous people receive from coastal/marine SES are often attached to specific marine products that have instrumental value (i.e. provisioning services related to food) and relational value that connect them with their environment (e.g. series of cultural services related to spiritual/religious functions and traditional lifestyle, among others) (Augustine and Dearden, 2014; Berkes et al., 2007; Menzies, 2010; Sloan, 2004; Turner, 2003). Moreover, these perceived values by indigenous communities are not only attached to marine species, but also include landscape and seascapes elements such as springs, wetlands, rocks, and forests that elevate these areas as sacred sites of high cultural significance. Such landscape and seascape elements can have very different values to indigenous communities including instrumental value (e.g. provide directly food or income from tourism); bequest value (e.g. assets for future generations), intrinsic value (e.g. supporting services for the maintenance of genetic diversity), and relational values (e.g. provide cultural services that satisfy spiritual and recreational needs) (Harto, 2017; McNiven, 2004; Petheram et al., 2015; Walter and Hamilton, 2014).

Comprehensive conceptual mapping of coastal/marine SES: Due to their multiple value perspective, *contextual research* studies are usually better suited to identify and explain effectively complex interactions within coastal/marine SES compared to *causal research* studies (*see Sections 3.5, 3.6*). For example *contextual research* studies have considered drivers of SES change such as religion (Tang and Tang, 2010) and pressures that impact traditional institutions (Begossi, 2014; King, 2004; Suluk and Blakney, 2009; Tang and Tang, 2010). The erosion of traditional education systems that increase the risk of losing ILK, attachment to the landscape/seascape, traditional values, and culture (Austin et al., 2017; Matsumoto et al., 2014; Saleh, 2004). *Contextual research* studies have also explored possible mitigation options to unsustainable commercial fisheries based on ILK practices (Lepofsky and Caldwell, 2013; Menzies, 2010; Thurstan et al., 2018).

However, due to the generally descriptive approach of *contextual research* studies as a result of their overreliance on narrative analysis methods (*see Section 3.4*), they often neglect other important aspects related to the integration of ILK practices and indigenous values. On the one hand *contextual research* approaches rely on direct collaboration

Value	Services type	Services	Total Trend	Total Consensus	Total Uncertain	Contextual Research Trend	Contextual Research Consensus	Contextual Research Uncertain	Causal Research Trend	Causal Research Consensus	Causal Research Uncertain
Bequest	Provisioning	Raw Materials (n=6/3/3)	1.5	0.8	33%	1.0	1.0	33%	2.0	1.0	33%
Bequest	Regulating	Carbon Sequestration And Storage (n=3/1/2)	2.0	1.0	67%			100%	2.0	1.0	50%
Bequest	Regulating	Erosion Prevention And Maintenance Of Soil Fertility (n=1/0/1)			100%			0%			100%
Bequest	Regulating	Local Climate And Air Quality Regulation (n=2/1/1)			100%			100%			100%
Bequest	Regulating	Moderation Of Extreme Events (n=1/1/0)	3.0	1.0	0%	3.0	1.0	0%			0%
Bequest	Supporting	Maintenance Of Genetic Diversity (n=22/9/13)	2.3	0.7	23%	2.1	0.7	22%	2.4	0.7	23%
Existence	Cultural	Aesthetic Appreciation And Inspiration For Culture, Art And Design (n=5/2/3)	2.3	0.6	20%	2.5	0.3	0%	2.0	1.0	33%
Instrumental	Cultural	Tourism (n=8/4/4)	3.0	0.6	25%	3.3	0.6	25%	2.7	0.6	25%
Instrumental	Provisioning	Food (n=76/43/33)	2.1	0.8	33%	2.1	0.7	26%	2.3	0.8	42%
Instrumental	Provisioning	Fresh Water (n=1/1/0)	1.0	1.0	0%	1.0	1.0	0%			0%
Instrumental	Provisioning	Medicinal Resources (n=12/7/5)	2.3	0.5	25%	2.2	0.3	29%	2.5	0.7	20%
Instrumental	Provisioning	Raw Materials (n=25/16/9)	2.4	0.7	36%	2.3	0.8	25%	2.8	0.7	56%
Instrumental	Regulating	Biological Control (n=3/1/2)	4.0	1.0	33%	4.0	1.0	0%	4.0	1.0	50%
Instrumental	Regulating	Erosion Prevention And Maintenance Of Soil Fertility (n=1/1/0)	1.0	1.0	0%	1.0	1.0	0%			0%
Instrumental	Regulating	Moderation Of Extreme Events (n=6/1/5)	3.0	0.6	33%	4.0	1.0	0%	2.7	0.6	40%
Instrumental	Regulating	Pollination (n=1/1/0)			100%			100%			0%
Instrumental	Regulating	Waste-Water Treatment (n=1/0/1)			100%			0%			100%
Intrinsic	Cultural	Aesthetic Appreciation And Inspiration For Culture, Art And Design (n=1/0/1)	4.0	1.0	0%			0%	4.0	1.0	0%
Intrinsic	Supporting	Maintenance Of Genetic Diversity (n=13/5/8)	2.7	0.6	54%	3.0	0.6	60%	2.5	0.6	50%
Option	Supporting	Habitats For Species (n=1/0/1)	2.0	1.0	0%			0%	2.0	1.0	0%
Relational	Cultural	Recreation And Mental And Physical Health (n=8/4/4)	2.2	0.7	25%	1.7	0.8	25%	2.7	0.6	25%
Relational	Cultural	Spiritual Experience And Sense Of Place (n=69/45/24)	2.3	0.7	35%	2.2	0.6	33%	2.4	0.7	38%

Trend	Consensus	Uncertain
= significant degradation	< 0.2	< 20%
= moderate degradation	0.2 - 0.4	20% - 40%
= remain the same	0.4 - 0.6	40% - 60%
= moderate improvement	0.6 - 0.8	60% - 80%
= significant improvement	≥ 0.8	≥ 80%

Fig. 10. Types of values related to each ecosystem service by research class *Note:* Parentheses represent the number of papers that studied each ecosystem services (total/contextual/causal). Trends are based on an average of the results elicited from each individual study. Consensus (of the trend) is based on the level of agreement between studies. Uncertainty is based on the percentage of studies that identifies each variable without clear trend.

with ILK holders to capture indigenous perspectives comprehensively (see above), but on the other hand they might miss the perspectives of other important stakeholders. Furthermore, while qualitative methods are fit for identifying multiple pressures within coastal/marine SES, these techniques by themselves are not enough to prioritize the effects of different pressures within the SES. Considering the above, *contextual research* approaches have essentially three weaknesses: *1) issue-orientation, 2) stakeholder imbalance, and 3) relevance ambiguity*.

Issue-orientation: Generally speaking, the ethnographic frameworks used in *contextual research* studies can help develop a comprehensive narrative by describing the issues that indigenous people located in coastal/marine SES face. However, such studies often conclude after describing the issue, without exploring viable solutions and implementation methods (Dunlap, 2018; Suluk and Blakney, 2009). In this regard these studies are issue-oriented, rather than solution-oriented. While neither research class shows high levels of indigenous knowledge integration at the co-design level, there are some differences between research classes. C*ontextual research* studies exhibit a lower degree of knowledge integration compared to *causal research* studies (5% and 10% of studies respectively), implying that the role of indigenous communities is often limited to being information providers (*see Table S4, Supplementary Electronical Material, in "Indigenous People Integration"*). This reinforces the notion that since these *contextual research* studies mainly aim to describe phenomena within coastal/marine SES, co-design components become less crucial. Thus although *contextual research* provides comprehensive analyses by capturing conflicts from indigenous communities' perspectives, values, ILK, worldviews, belief, and traditional livelihood systems, they are often devoid of any clear solution pathway (Clifton and Majors, 2012; Dunlap, 2018).

Stakeholder imbalance: A high proportion of *contextual research* studies involve indigenous community members through multiple research tools (*see Section 3.3*) (Austin et al., 2017; Carter, 2010; O'Neill et al., 2012). However, the inclusion of other relevant stakeholders is considerably lower compared to *causal research* studies (Ashaletha and Immanuel, 2008; McDonald et al., 2008). Although specific research objectives and perspectives of *contextual research* approaches might justify this trend, some studies implement participatory research tools such as workshops with participant selection within a homogenous group without including other key actors (Petheram et al., 2015; Raymond-Yakoubian et al., 2017). While this enables researchers to focus on targeted groups, it might introduce biases in the study outcome, as the perspective of one stakeholder group is overrepresented. For example several *contextual research* studies have sought to explore indigenous marine resource management or the protection of endangered species in coastal/marine SES considering only the perspective of local communities (Gauvreau et al., 2017; Lepofsky and Caldwell, 2013; Liu, 2017; Matsumoto et al., 2014). While this helps to bring indigenous perspective and ILK to the forefront, the lack of integration of the voices of other key stakeholders (e.g. private sector actors from commercial fisheries or tourism, government agencies) the line between advocacy and research becomes blurred.

Relevance ambiguity: A key strength of *contextual research* is the ability to provide a comprehensive conceptual mapping of coastal/marine SES. However, this does not necessarily translate into a better understanding of the coastal/marine SES (Dunlap, 2018; Kikiloi et al., 2017; King, 2004). Identifying an extensive list of drivers and pressures within a SES can expand our perspective but can also introduce confusion. Providing a lengthy list of drivers and pressures without a proper explanation of their linkages, priorities or effects to the SES might divert the study focus to less relevant factors. Often *contextual research* studies that tackle five or more pressures to coastal/marine SES (e.g. climate change, overexploitation, coastal erosion, pollution, commercial fishing) often end up being inconclusive of what is most relevant (Allamel, 2016; Jackson et al., 2015; O'Neill et al., 2012; Turner et al., 2013). This broad net of causal factors that *contextual research* is capable of casting can introduce noise into the research, reducing its ability to provide specific outcomes.

4.2. Strengths and weaknesses of causal research approaches

A key feature of *causal research* studies is their use of an extensive array of quantitative and qualitative research methodologies (*see Section 3.4*) (Grech et al., 2014; Hoverman and Ayre, 2012; Laidler et al., 2011). In contrast to *contextual research* approaches that rely mainly on a few qualitative methods, *causal research* approaches often incorporate a plethora of quantitative methods. Furthermore, there is higher degree of integration between modern scientific techniques and ILK (*see Section 3.3*). Indigenous people are often more than merely information providers, as they often co-design research elements and shape significantly the research outcomes. Moreover, when collaborative methods are employed, *causal research* studies frequently rely on stakeholders from multiple sectors, rather than focusing only on indigenous communities. Overall *causal research* approaches have three main research strengths: *1) rich methodological portfolio, 2) knowledge system integration, and 3) stakeholder balance*.

Rich methodological portfolio: Causal research approaches have gradually adopted a series of innovative techniques from the social sciences. This in turn provides new and interesting options to researchers and practitioners to facilitate the integration of modern science and ILK systems. For example, discrete choice experiments are used to capture the willingness to pay among indigenous communities and capture bequest values that have been difficult to quantify in the past (Oleson et al., 2015). Bayesian network analysis is used to create scenarios that estimate how government policies affect coastal/marine SES in indigenous settings (van Putten et al., 2013). Different direct market valuation techniques are used to capture use and non-use values of ecosystem services, and to measure the social, ecological, and biological values of marine/coastal ecosystems (Evseev et al., 2018; Hutton et al., 2016).

Knowledge system integration: The contribution of indigenous people to modern scientific techniques has gradually allowed *causal research* studies move from studies about ILK, to studies with ILK (Tengö et al., 2017). One example is the integration of ILK with remote sensing to identify the location of use and non-use ecosystems services, thus highlighting possible source of conflicts during the implementation of new coastal/marine resource management programs (Ban et al., 2009, 2008; Moore et al., 2017). These integrated techniques also enable the management of marine protected areas with lifelong experiences of indigenous communities that can provide historical baseline, knowledge on biodiversity, species distributions, and breeding areas (Bethel et al., 2011; Eckert et al., 2018; Espinoza-Tenorio et al., 2013). Such approaches can enhance the integration of knowledge systems, which is now identified as a key priority area for ecosystem services research (Pascual et al., 2017).

Stakeholder balance: Causal research studies tend to integrate more frequently multiple stakeholders such as indigenous communities, NGOs, government agencies, private sector, and academia (*see* Fig. 5). This often translates into more productive collaboration that reduces frictions and increases the trust between the different actors (Hiwasaki et al., 2015; Hoverman and Ayre, 2012). Such tighter collaborations can also promote resource and knowledge sharing and produce culturally relevant solutions. For example multi-stakeholder workshops combined with community mapping techniques have produced relevant coping strategies in coastal/marine SES for climate-related hazards such as droughts and sea ice melting (Hiwasaki et al., 2015; Hoverman and Ayre, 2012; Laidler et al., 2011).

However, the general focus of *causal research* studies on assessing a phenomenon can have some trade-offs related to the research scope. As discussed on the previous section *contextual research* studies tend to rely on methodologies that cast a wide net to comprehensively identify the different elements within a system (*see Section 4.1*). On the other hand, *causal research* studies usually attempt to explore thoroughly few key drivers and impacts in the studied coastal/marine SES. Essentially, this approach of quality over quantity leads to some compromises. The focus on few variables often means overlooking the multiple values that indigenous people attach to ecosystem services in coastal/marine SES. Furthermore, the attempt to introduce economic valuation methods for non-material benefits often involves the use of proxy variables that do not necessarily capture properly the perceived values of indigenous people. Essentially *causal research* approaches have three main weaknesses as *1) solution-oriented, 2) limited values captured, 3) compromised proxies*.

Solution-oriented: There is a clear demand to produce robust and quantifiable evidence for practitioners and policymakers to facilitate the sustainable management of coastal and marine SES (Díaz et al., 2018; Grech et al., 2014; Tengö et al., 2017). However, often, there are trade-offs when attempting to satisfy such demands in indigenous coastal and marine settings. Tools that have a limited capability to capture the intricacies of the issues at hand (e.g. simple maps, indices, economic assessments) often omit the full context within which those results should be interpreted. For example, *causal research* studies have used remote sensing and participatory mapping to assess endangered species abundance and distribution to set up species protection programs (Ferguson et al., 1998; Grech et al., 2014), but have also tended to overlook the drivers and pressures behind those changes. Ethnobotanic approaches based on detailed inventories and use assessment of medicinal plant among indigenous communities can help assess the instrumental value attached to these plants, but also omit non-material benefits such as cultural or bequest values (Noman et al., 2013; Peter et al., 2014).

Limited values captured: Following from the above there is often an articulated preference to use well-established economic valuation methods that are easily understood and accepted by practitioners and policymakers (Díaz et al., 2016; TEEB, 2010). Such studies often attempt to merge different epistemological approaches hoping to capture all values that indigenous people receive from ecosystem services relying on methods that are only capable of quantifying few values. This often results in valuations that over-represent values from modern scientific approaches (mostly instrumental values), further undermining other values that indigenous communities ascribe to coastal/marine SES. For example, studies with complex SES that includes bequest and relational values often focus only on instrumental values to quantify/elicit ecosystem services (Cullen et al., 2007; Hutton et al., 2016; Preece et al., 2016).

Compromised proxies: There are often compromises in the selection of variables as inputs for models within *causal research* studies. *Causal research* studies often attempt to capture a wide range of social and cultural values using generic variables such as employment as a proxy indicator to social values of marine systems, or commodities as representative of cultural significant resources to assess cultural values of ecosystem services (Evseev et al., 2018; Hutton et al., 2016). These compromises happen due to various reasons such as data and knowledge gaps (Ban et al., 2009; TEEB, 2010). While these proxies might indeed represent a part of the social and cultural benefits derived from coastal/marine SES, by no means they represent the full spectrum of benefits they perceived from ecosystem services. In fact, one might argue that these compromises perpetuate the marginalization of the full range of values making more acceptable to focus on instrumental values rather than measuring "elusive" non-material values.

4.3. Future orientations for transdisciplinary research

Both research classes can play a constructive role in overcoming knowledge integration barriers in indigenous coastal and marine SES. While slow, some advances have been made towards bridging the unequal footing between modern science and ILK in such SES (Michel and Gayton, 2002; TEBTEBBA, 2008; Vierros et al., 2010). For example, *contextual research* studies have developed frameworks that assess both cultural and biophysical impacts, balancing in the process modern science and ILK goals (Raymond-Yakoubian et al., 2017; Scherrer and Doohan, 2011). Furthermore, the use of context-sensitive methods such as discourse analysis has helped in identifying the sources of technical gaps in *contextual research* studies (Nursey-Bray et al., 2010). Meanwhile, *causal research* studies have developed frameworks and protocols that deal with structural barriers related to the lack of guidance on how ILK should be integrated with scientific knowledge (Carter, 2008). *Causal research* studies have also addressed perception barriers, by showing, for example, the similar results of scientific and community-based approaches when developing marine protected areas (Ban et al., 2009).

At the same time there are many cases of effective knowledge integration designs (Beltrán, 2000; Ference Weicker and Company Ltd., 2009; Jonas et al., 2012; Stevens et al., 2016). For instance, some contextual research studies have used collaborative tools such as workshop that have allowed best practices to be shared, boosted trust between stakeholders, and produced robust programme designs to address both biodiversity conservation and indigenous community needs (Matsumoto et al., 2014; Walter and Hamilton, 2014). Co-management approaches during programmes design not only helps in increasing marine biodiversity, but also empowers indigenous communities and reduces ILK loss/erosion (Indian and Northen Canada Affairs, 2003; Memon et al., 2003; National Oceans Office, 2002; Stephenson et al., 2014). Furthermore, causal research studies have exceled at combining ILK with modern tools such as remote sensing to create well-rounded management plans that integrate the perspectives of indigenous communities (Ban et al., 2009; Lauer and Aswani, 2010).

Considering the above we argue that both research classes have their merits and can play a constructive role in integrating different knowledge systems and multi-value perspectives to achieve the sustainable management of marine and coastal resources in indigenous settings. In a way, through their distinctive research characteristics, strengths and weaknesses, *contextual research* and *causal research* approaches complement each other.

On the one hand, *contextual research* studies can provide the theoretical foundations and map the coastal/marine SES identifying multiple elements of these systems. These studies essentially can help to lay the research agenda about how to approach issues related to coastal/marine SES in indigenous settings. On the other hand, *causal research* studies can explore the effect of these drivers and pressure within SES and produce outcomes that facilitate the assessment of key issues. *Causal research* studies can thus play a crucial role for the effective design and implementation of policies, plans, and programmes by government agencies and traditional local authorities alike. While not many studies presently attempt to simultaneously map and assess comprehensively issues in indigenous coastal/marine SES, it would be impractical to make a call for all future research to do so. Possibly with the exception of large-scale projects that have the support of multiple stakeholders, research outcomes would likely be subpar if such ambitious goals are set in individual studies constrained by budget and expertise.

However, with some adjustments it might be possible to increase the synergies between *contextual research* and *causal research* approaches. The cross-fertilization between these approaches could accelerate the integration of ILK and multiple values, and produce research that is both relevant and exhaustive.

On the one hand, *contextual research* approaches should capitalize on their ability to provide a comprehensive view of complex coastal/marine SES. This includes the multiple perceived values and the different elements that interact within such SES. In a way, this means that *contextual research* approaches have the potential to act as a pathfinder and create a roadmap where future studies should focus. Therefore, their role should go beyond that of merely presenting the system "as is", but attempt to consciously integrate different methodologies to highlight what is relevant in such SES. In other words, they should seek to address the *relevance ambiguity* weakness discussed above (*Section 4.1*).

On the other hand, *causal research* approaches need to acknowledge that economic valuation has, so far, only captured values based on dominant western value perceptions. In this sense, the direct implementation of such studies conducted in non-indigenous settings is not necessarily relevant (or even appropriate) in indigenous settings. A "copy and repeat" process might fail to address the aspirations and values of indigenous people, as well as incorporate their unique worldviews and beliefs. There should be conscious efforts to push the present boundaries of direct economic valuation to develop novel methods to elicit such values in indigenous coastal/marine SES.

In our opinion adopting a transdisciplinary mindset (*see Section 3.3*) can facilitate the effective cross-fertilization between research types. Still we also believe that more can be done at a "grassroot" research level, where active multi-partner engagement is not always possible. First, scholars should identify whether and how the specific study should/could contribute to this cross-fertilization. Subsequently they should seek to understand the role that the specific research can play in this contextual-causal research relationship. Following this introspective self-assessment, research protocols and outputs should:

a) deliver instructions of where follow-up research should focus, provide a clear vision of SES interactions, and delineate the mechanisms that comes into play (for contextual research studies);
b) move beyond using previous studies as merely providing background context and take advantage of the initial groundwork produced by *contextual research* to implement novel research tools that will advance existing knowledge by incrementally building upon other studies (for causal research studies).

Finally, even though contextual research relies more heavily on qualitative tools and causal research on quantitative tools, each approach does not rely solely on such tools. Thus, when cross-fertilising we need to keep in mind some of the underlying debates about how the types of data, methods, purposes, and paradigms boundaries between quantitative and qualitative methods have become blurred. This, however, should not diminish the merit of mix-and-matching the arsenal of tools from both methodological approaches (Borland, 2001; Morgan, 2018); but rather emphasise how seemingly the strengths of diverse methods can be integrated (Morgan, 2018; Sandelowski, 2014). In any case, as outlined in *Section 1*, it is important to carefully consider the specific indigenous community contexts when designing such research (Pascual et al., 2017; Spoon, 2014).

4.4. Caveats and limitations

Despite its robust findings, this systematic review has some limitations including the (a) selection of keywords, (b) non-inclusion of grey literature, (c) inability to classify a priori studies in research classes solely based on their research characteristics.

Regarding (a), even though this systematic review considered a wide range of keywords, it was not possible to include all possible keywords related to indigenous contexts around the world. For example, in some indigenous settings very specific keywords become relevant (e.g. mobs in Australia) (Pannell, 2005; Pickerill, 2009). Conversely, in other contexts very generic terms become relevant (e.g. small-scale fishers in Sub-Saharan Africa) (Jacquet et al., 2010; Mills et al., 2011). In the former case, adding all specialised terms is not practically feasible, meaning that selective additions might result in the over-representation of specific indigenous contexts, thus biasing the results by disproportionally considering literature from specific indigenous settings. Furthermore, adding generic terms increases the difficulty of understanding whether the study actually reflects indigenous areas. For example, not all small-scale fishery communities in Sub-Saharan Africa are indigenous, and this is not always clarified in the methodological section of the specific studies. In this systematic review, we went through an iterative process of refining all search terms based on prevailing and commonly accepted terminology. We believe that the selected keywords are robust enough to elicit the main literature patterns. However, we acknowledge that due to keyword selection some studies might have been omitted. This sensitivity to keyword selection is a recurring criticism of systematic reviews (Berrang-Ford et al., 2015; MacLure, 2005), and needs to be taken into consideration when using the results of this study.

Regarding (b), we constrained the analysis to peer-reviewed studies, omitting grey literature. This was a conscious decision to allow for the reproducibility of the results, as the search engines used for this systematic review (i.e., Scopus, Web of Science) do not contain grey literature. In order to add grey literature in this analysis we would have had to resort to subjective additions that would have compromised the reproducibility, which is an essential requirement of systematic reviews. However, we cite relevant grey literature in the Introduction and Discussion to improve both the framing of the paper, as well put its key findings into perspective.

Regarding (c) our protocol can only determine the class in which a specific study belongs only after the methodologies, tools, and objectives have been reviewed and classified. In other worlds it is not possible to predict whether a specific study adopts a causal or a contextual research approach. Therefore, it falls on the critical capacity of the respective researchers to both characterize their research and implement the cross-fertilisation recommendations (*Section 4.3*).

5. Conclusions

There are significant challenges in managing coastal and marine SES (and the ecosystem services they provide) in indigenous settings and integrating related values and knowledge systems. Our systematic literature review identifies the trends and gaps in the current peer-review literature at the interface of values and ecosystem services in coastal and marine social-ecological systems (SES) in indigenous settings. In particular, we identify two distinctive research classes, which we refer to as *contextual* and *causal research*, each with its unique strengths and weaknesses.

Rather than categorising such research within the confines of qualitative, quantitative and mixed methods, it is much more useful to acknowledge their distinct contribution and approaches in the current research landscape. We believe that this distinction has a greater potential to provide a clearer and more streamlined pathway towards knowledge and value integration, without necessarily compromising research rigor.

Overall, we found that *contextual research* studies represent a higher proportion of the current studies. These studies are mainly concerned with presenting the context of changes in indigenous costal/marine SES. *Causal research* studies, on the other hand, tend to assess the impacts of these changes in SES, and what causes them. The integration of perspectives from multiple stakeholders is more frequent in *causal research* studies. Furthermore causal research studies have a richer methodological portfolio, with twice as many different techniques identified compared to *contextual research* studies. On the other hand, *contextual research* studies are more adept in developing comprehensive conceptual maps of coastal/marine SES and eliciting the multiple values attached to their ecosystem services.

Considering their different strengths and weaknesses, we believe that cross-fertilization and collaboration between these distinct research approaches will be indispensable in advancing the integration of the different knowledge systems and multiple values encountered in indigenous coastal/marine SES. *Contextual research* studies can act as pathfinders of important research foci in these contexts, and *causal research* studies can push the methodological boundaries to study more deeply these research priorities. We feel that there is great merit in further exploring the development of a framework(s) that can facilitate the cross-fertilization between these research classes at the grassroot research level.

Acknowledgements

Rodolfo Dam Lam is supported through a fellowship offered by the Graduate Program in Sustainability Science – Global Leadership Initiative (GPSS-GLI), at the University of Tokyo.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2019.100910.

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