



PRIFYSGOL
BANGOR
UNIVERSITY

Spatial and temporal scales of coral reef fish ecological research and management: a systematic map protocol

Lawrence, Alice; Heenan, Adel; Levine, Arielle ; Haddaway, Neal ; Powell, Farrah ; Wedding, Lisa; Roche, Ronan; Lawrence, Peter; Szostek, Claire; Ford, Helen; Southworth, Lucy; Sannassy Pilly, Jyodee; Richardson, Laura; Williams, Gareth J.

Environmental Evidence

DOI:

[10.1186/s13750-021-00217-z](https://doi.org/10.1186/s13750-021-00217-z)

Published: 25/01/2021

Publisher's PDF, also known as Version of record

[Cyswllt i'r cyhoeddiad / Link to publication](#)

Dyfyniad o'r fersiwn a gyhoeddwyd / Citation for published version (APA):

Lawrence, A., Heenan, A., Levine, A., Haddaway, N., Powell, F., Wedding, L., Roche, R., Lawrence, P., Szostek, C., Ford, H., Southworth, L., Sannassy Pilly, J., Richardson, L., & Williams, G. J. (2021). Spatial and temporal scales of coral reef fish ecological research and management: a systematic map protocol. *Environmental Evidence*, 10, [3].
<https://doi.org/10.1186/s13750-021-00217-z>

Hawliau Cyffredinol / General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

Take down policy


If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

SYSTEMATIC MAP PROTOCOL

Open Access



Spatial and temporal scales of coral reef fish ecological research and management: a systematic map protocol

Alice Lawrence^{1*} , Adel Heenan¹, Arielle Levine², Neal R. Haddaway^{3,4,5,6}, Farrah Powell², Lisa Wedding⁷, Ronan Roche¹, Peter Lawrence¹, Claire Szostek¹, Helen Ford¹, Lucy Southworth¹, Sivajyodee Sannassy Pilly¹, Laura E. Richardson¹ and Gareth J. Williams¹

Abstract

Background: Coral reefs are rapidly changing in response to local and global stressors. Research to better understand and inform the management of these stressors is burgeoning. However, in situ studies of coral reef ecology are constrained by complex logistics and limited resources. Many reef studies are also hampered by the scale-dependent nature of ecological patterns, and inferences made on causal relationships within coral reef systems are limited by the scales of observation. This is because most socio-ecological studies are conducted at scales relevant to the phenomenon of interest. However, management often occurs across a significantly broader, often geopolitical, range of scales. While there is a critical need for incisive coral reef management actions at relevant spatial and temporal scales, it remains unclear to what extent the scales of empirical study overlap with the scales at which management inferences and recommendations are made. This systematic map protocol will evaluate this potential scale mismatch with the goal of raising awareness about the significance of effectively addressing and reporting the scales at which researchers collect data and make assumptions.

Methods: We will use the Collaboration for Environmental Evidence (CEE) systematic mapping guidelines to identify relevant studies using a framework-based synthesis to summarise the spatial and temporal scales of coral reef fish ecology research and the scales at which management inferences or recommendations are made. Using tested pre-defined terms, we will search for relevant published academic and grey literature, including bibliographic databases, web-based search engines, and organisational websites. Inclusion criteria for the evidence map are empirical studies that focus on coral reef fish ecological organisation and processes, those informing management interventions and policy decisions, and management documents that cite coral reef research for management decision-making. Study results will be displayed graphically using data matrices and heat maps. This is the first attempt to systematically assess and compare the scales of socio-ecological research conducted on coral reef systems with their management.

Keywords: Evidence map, Seascape ecology, Socio-ecological system, Spatio-temporal scale, Scale mismatch, Marine protected area, Coral reef fisheries, Reef fish ecology

Background

There is increasing consensus that conventional approaches to natural resource management are inadequate to maintain ecological functions and sustain ecosystem services in the face of current and future global environmental change [1–3]. The complexity of social

*Correspondence: alice.lawrence@bangor.ac.uk

¹ School of Ocean Sciences, Bangor University, Anglesey LL59 5AB, UK
Full list of author information is available at the end of the article



© The Author(s) 2021. This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

and ecological interactions across spatial and temporal scales is considered one of the biggest challenges to effective management, and often mismatches occur between the scales of ecosystem observation, management decision-making, and the regulation of human impacts [4, 5]. Given the variety of logistical and technological constraints that accompany data collection, our scales of observation often do not match the multiple scales at which drivers determine ecosystem dynamics [6–8]. Subsequently, inferences for management derived from this empirical data are often made beyond the scale of study [4, 7, 9–11]. Although Socio-Ecological Systems (SES) management frameworks have improved the integration of social, natural, and governance systems [12–15], a multi-scale approach is crucial to better understand the interactions and feedbacks between them [16–19]. Coral reefs provide a useful lens to apply such an approach as a tightly coupled socio-ecological system [20], where ecological and social processes form a complex web of interactions across a range of spatial and temporal scales [21–23].

Mounting anthropogenic stressors have had adverse effects on the biodiversity and functioning of coral reef ecosystems [24–26] and their delivery of ecosystem services such as food security, culture, tourism, recreation, and coastal protection [27]. Chief among these stressors are mass coral bleaching events associated with warming ocean temperatures that result in broad-scale coral mortality [28–31], and restructuring of coral reef fish assemblages [32, 33]. In some locations, these impacts are so severe they lead to ecosystem regime shifts away from hard calcifying corals to dominance by non-reef-building organisms [34, 35]. In response to these threats, there has been a shift towards implementing broader-scale management tools such as networks of Marine Protected Areas (MPA) for integrated conservation and fisheries management [36–38]. Although most broad-scale threats are beyond the direct influence of local managers, management decisions are based on the best available scientific evidence, and interventions must often be implemented within existing broader governance structures [39–41]. Additional challenges for managers arise from discrepancies in this evidence base, in particular related to the effectiveness of MPAs [1, 42, 43] and Herbivore Management Areas (HMAs) as tools to increase coral reef resiliency and prevent shifts [44–48]. Some of these inconsistencies may be due to the underlying complexities associated with coral reef ecosystem dynamics across scales and the failure to acknowledge observational scale limitations when making management recommendations.

Herbivore grazing and behavioural studies show clear links between fishes and algal populations at small

(1–10 m²) spatial scales [49, 50]. However, the impact of herbivorous fishes on benthic community states and reef resilience to climate change across larger scales remains debated [42]. Despite this, some countries have proceeded in implementing HMAs as part of a resilience-based management strategy that controls the fishing of herbivores [48, 51, 52]. To improve the interpretation of ecological observations for management decisions such as HMAs, it is imperative that studies acknowledge and address scaling issues by considering the geography and local bounds on the system.

The importance of scale is evident in both the ecological and social research domain. For example, coral reef benthic community composition, fish assemblage trophic structure and herbivore feeding behaviour and therefore functional impact varies across broad environmental gradients (e.g. temperature, irradiance, and within reef system wave exposure) [53–56]. Similarly, governance structures and anthropogenic pressures (e.g. fishing, land-based pollution) vary across contexts and scales, influencing the state of coral reef ecosystems [57, 58]. They also influence the scale at which data collection is needed to evaluate these pressures and the appropriate management levers and governance levels for intervention [1, 59–61]. As our understanding grows on how local context-dependent variability in social-ecological systems interacts with larger scale processes, the need for scale-dependent nuance in management recommendations will become more pressing.

Emergent technologies that can be used to monitor the marine environment at larger scales and at a higher resolution [62, 63], will undoubtedly facilitate a better understanding of multi- and cross-scale variability in these ecosystems [64, 65]. Integrating big data from new technologies with multi-scale social drivers and fine-scale ecological processes does have its associated challenges and significant practical hurdles [62, 63]. Nonetheless, recent attempts to integrate new technological tools with traditional research methods have shown promising results [66, 67], and should enable more effective and efficient monitoring if scaling issues are addressed as a critical requirement [6]. No matter how much multi-scale data we may have access to in the future, in order to cross-calibrate, integrate and scale-up existing studies into this new big-data paradigm, there remains a key need to assess and take stock of the scale of the existing evidence base on coral reef socio-ecological research.

This paper presents a novel protocol to systematically map the scales of ecological and social data collection, and the scales at which researchers interpret data to make management inferences and recommendations. By doing so, we will highlight any mismatches in scale between the two with the goals of: (1) highlighting the

shortfall and implication of addressing and reporting the scales at which researchers collect data and make assumptions, (2) ensuring existing ecological and social observations are discussed and used as an evidence base within the bounds of their spatial and temporal domains, (3) highlighting priority scales for future ecological and social evidence that managers and policy makers need to make more informed decisions to combat current threats to coral reefs. The systematic evidence map will be created by extracting and collating metadata from relevant studies, with a basic analysis of trends and patterns from which a full systematic review can be conducted at a later date.

Stakeholder engagement

The topic of this study was formulated by Project Team members, representing a broad range of research interests and expertise from the disciplines of ecology, geography and social science, some of whom are in regular contact with natural resource managers and decision makers. Given the scope of the project, it was not deemed necessary to consult with separate stakeholder groups during the development of the project objectives and methods.

Objective of the review

The primary research question of this systematic map is ‘What are the spatial and temporal scales of coral reef fish ecological and social research and are these consistent with the scales at which researchers make management inferences and recommendations?’.

The systematic map will be built using the following predefined elements:

Population: shallow and mesophotic tropical coral reef ecosystems (0–150 m depth).

Phenomenon of interest: spatial and temporal scales investigated and discussed within coral reef research studies.

Context: ecological, social, and socio-ecological research and management literature.

The focus of the systematic map is on all tropical coral reef-associated fish species, from shallow and

mesophotic coral reef ecosystems. The systematic mapping process will involve assessing studies of these ecosystems that focus either primarily on ecological, social, or those that integrate ecological and social research. The evidence base will be categorised using a data coding framework (Additional file 1) designed to explore the following secondary questions:

- Has there been a change in the spatial scales at which coral reef fish ecological and social research has been conducted over the last 10 years?
- Is there a mismatch between the scales at which ecological data and social data are collected?
- Is there a mismatch between the scale of ecological and social data collection and the scales at which management inferences and recommendations are made?
- Is there a mismatch between the scale of the ecological and social indicators used to assess management effectiveness and the scale of the policy or management intervention?
- Of the studies identified, are there spatial patterns in scale mismatches and do they vary by region or by the scale at which the studies are conducted (i.e. at island or regional scale).

To clarify the key terms to be used in this study, Table 1 lists the definitions of the terms used in this protocol document as relevant to the study objectives.

Methods

The systematic map protocol has been developed in accordance with the Collaboration for Environmental Evidence Guidelines and Standards for Evidence Synthesis [68] and the ‘RepOrting standards for Systematic Evidence Syntheses’ (ROSES) for systematic map protocols [69] (see Additional file 2). The PREDICTER tool ([www.http://predicter.org/](http://predicter.org/)) will be used to predict the number of days for each step of the process [70] to help to inform project scheduling and the Project Team members of project time commitments.

Table 1 Definitions of key terminology to be used in this study

Term	Definition
Management effectiveness	The degree to which a policy or intervention meets its stated goal and/or meets the broader goal of improving ecological or social conditions
Management intervention	Direct actions (top-down or bottom-up), activities and/or policies designed to improve ecological and/or social conditions relating to coral reef ecosystems
Management inference	An assumption about the effectiveness of management interventions, or a recommendation for interventions, based on study findings

Searching for studies

Search string

This search strategy details the steps that we will take to ensure that a comprehensive and unbiased search is conducted of the most relevant available knowledge. We will search multiple databases using keywords to search their title, abstract and keyword lists. Advanced search options will be utilised using phrases and Boolean operators and all options used will be recorded. The Project Team members compiled an extensive set of search terms relevant to different elements of the primary question and a scoping exercise was conducted using Web of Science Core Collections to modify the search terms (see Additional file 3). The asterisk was used as a wildcard to allow for singular or plural words to be identified in the same search. A list of alternative terms was established with the aid of a thesaurus and screening of relevant citations. We will use the following search string:

(coral NOT temperate) AND (fish OR detritivor* OR herbivor* OR browse* OR graze* OR scrape* OR excavat* OR planktivor* OR omnivor* OR corallivor* OR invertivor* OR piscivor* OR carnivor*) AND (ecosyst* OR *ecolog* OR spatial OR temporal OR assemblage* OR composition OR population* OR communit* OR structure OR function* OR process* OR social OR socio* OR econom* OR human OR pressure OR manage* OR anthropo* OR conservation OR sustainab* OR livelihood OR well-being OR service OR "food security" OR seascape* OR watershed OR protect* OR subsist* OR fisher* OR govern* OR change OR recover* OR network OR reserve OR marine OR interven*).*

The searches will be limited to studies published from 2010 onwards in order to focus our study on the last decade of coral reef socio-ecological research. This particular time period has seen a noticeable increase in research that integrates social and ecological datasets to better understand socio-ecological systems [20] and studies that seek to understand the linkages between disturbances, ecological functioning, and ecosystem services [71].

Searching the literature

Searches for relevant published academic and grey literature will be conducted within (i) bibliographic databases, (ii) web-based search engines, and (iii) grey literature, including online publication databases and organisational websites and repositories. The literature will be searched in the English language with predefined search terms (see Additional file 4).

i) Bibliographic databases The following academic databases will be searched to cover a range of time-periods, subjects, and geographical scope. Searches will be performed across 6 databases, as listed in Table 2, using the predefined search string (see Additional file 4):

Search engines

The academic search engine Google Scholar will be used to search for relevant literature not identified by the bibliographic database search results. Search terms will be simplified by modifying the original search string (see Additional file 4: Table S2) and limiting the search to studies published from 2010 onwards. The citations for the first 200 results will be extracted as citations and

Table 2 List of bibliographic databases to be searched, including specific indexes, platform, date ranges and subscription location information

	Database	Indexes	Platform or Provider	Date ranges available	Subscription location
1	Web of Science	Core Collections Sci-ELO (Scientific Electronic Library Online) BIOSIS	Clarivate Analytics	1970 to present 2002 to present	Bangor University, UK
2	Scopus	n/a	Elsevier	1788 to present	Stockholm Environment Institute, Sweden
3	ProQuest SciTech	Earth, Atmospheric & Aquatic Science Database (this database includes Aquatic Sciences and Fisheries Abstracts (ASFA) and Oceanic Abstracts)	Proquest	1946 to present	Bangor University, UK
4	Springer Link	Springer Nature Experiments	Springer Nature	1980 to present	Bangor University, UK
5	Green File	n/a	EBSCO	1926 to present	Bangor University, UK
6	Directory of Open Access Journals (DOAJ)	n/a	Directory of Open Access Journals	Unknown	Bangor University, UK

added to the bibliographic databases records before removal of duplicates [72]. Documents will be downloaded using the free software ‘Publish or Perish’ (<http://www.harzing.com/resources/publish-or-perish>), and the free software Zotero (<http://www.zotero.org>) will be used to download 20 full studies at a time [73].

ii) Searches for grey literature The search for relevant grey literature will include practitioner-generated research such as unpublished monitoring reports from government agencies, consultancies, thesis repositories, and organizational websites and databases. Specifically, the following websites and sources will be accessed:

- Open Grey European Government literature database <http://www.opengrey.eu>
- Social-science Research Network (SSRN) www.ssrn.com/en/
- ETHOS dissertation repository <http://ethos.bl.uk/Home.do>
- EBSCO Open Dissertations <https://www.ebsco.com/products/research-databases/ebsco-open-dissertations>

Searches will also be conducted across 29 relevant organisational websites, using simple search terms adapted from the search strategy. The websites were chosen to represent a diversity of information across all ocean basins. For each website, the first 100 results will be screened in situ, and information from each search will be recorded and described in the final systematic map publication. Information will include website name, date accessed, search string, number of relevant studies identified at full text. Relevant full texts will be recorded for inclusion in the systematic map database. The following organisational websites will be searched for relevant literature:

1. Atlantic and Gulf Rapid Reef Assessment (AGRRA) Data Explorer—<http://www.agrra.org/data-explorer/>
2. Australian Institute of Marine Science (AIMS)—<https://www.aims.gov.au/publications.html>
3. Commonwealth Scientific and Industrial Research Organisation (CSIRO)—<https://www.csiro.au/en/Publications>
4. Convention on Biological Diversity (CBD)—<https://www.cbd.int/information/library.shtml>
5. Great Barrier Reef Marine Park (GBRMP)—<https://www.informit.org/index-product-details/REEF>
6. International Council for the Exploration of the Sea (ICES)—<https://www.ices.dk/Science/publications/library/Pages/default.aspx>
7. International Coral Reef Initiative (ICRI)—<https://www.icriforum.org/publications-resources>
8. International Coral Reef Symposium (ICRS) conference proceedings—<http://coralreefs.org/publications>
9. International Union for Conservation of Nature (IUCN)—http://www.iucn.org/knowledge/publications_doc/publications/
10. MarXiv Papers—repository for ocean and marine climate science—<https://osf.io/preprints/marxiv>
11. National Center for Ecological Analysis & Synthesis (NCEAS)—<https://www.nceas.ucsb.edu/>
12. National Park Service (NPS)—<https://www.library.nps.gov/>
13. NOAA Science Centres—Pacific Islands (PIFSC) and Southeast (SEFSC)—<https://www.fisheries.noaa.gov/resources/all-science>
14. NOAA Coral Reef Information System (CORIS)—<https://www.coris.noaa.gov/>
15. North Pacific Marine Science Organisation (PICES)—<https://meetings.pices.int/publications>
16. Open Communication for The Ocean (OCTO) Open Channels—<https://www.openchannels.org/literature>
17. Pacific Island Protected Area Portal (PIPAP)—<https://pipap.sprep.org/content/publications>
18. Reef Base—http://www.reefbase.org/global_database/
19. Reef Resiliency Network (RRN)—<https://reefresilience.org/>
20. Social Transformations Knowledge Repository (ICES)—<http://ices.dk/community/groups/Pages/WGRMES-knowledge-repository%201.aspx>
21. South Pacific Regional Environment Program (SPREP) virtual library—<http://library.sprep.org/Pein/home/home.aspx>
22. The Nature Conservancy (TNC)—<https://www.conservationgateway.org/>
23. United States Environmental Protection Agency (USEPA)—<https://www.epa.gov/nscep>
24. United States Fish & Wildlife Service (USFWS)—<https://nctc.fws.gov/resources/knowledge-resources/>
25. United Nations Environment Programme (UNEP)—<https://www.unenvironment.org/publications>
26. UNEP—World Conservation Monitoring Centre (WCMC)—<https://www.unep-wcmc.org/resources-and-data>
27. United Nations Environmental, Scientific and Cultural Organization (UNESCO) Digital Library - <https://unesdoc.unesco.org/library>

28. World Resources Institute (WRI)—<https://www.wri.org/resources>
29. World Wildlife Fund (WWF)—<https://www.worldwildlife.org/pages/wwf-peer-reviewed-publications>
30. WorldFish Center—<https://www.worldfishcenter.org/publications-resources>

Estimating the comprehensiveness of the search

One main database, the Web of Science Core Collection, was used to test the search string and scoping search results are shown in Additional file 3. Various iterations of the search string were tested against a 'benchmark' list of 20 key studies (see Additional file 3: Table S3). The authors selected the list to represent a range of ecological and social studies on coral reef ecosystems, covering a range of authors, journals, research projects, and geographies relevant to the scope of the question. The search was finalised once all the studies in the benchmark list were found. During the final scoping exercise, 6801 studies were returned using the search string's final iteration, which matched all 20 benchmark studies. During each database search, alert services will be established to capture future updates by identifying and including relevant new studies published during the project. Amendments to the search string and search strategy during the review process will be reported in the final systematic map publication.

The term 'coral' is not always used in the title or abstract of social studies related to small-scale coral reef fisheries and marine conservation's human dimensions. Subsequently, a separate list of social benchmark studies was developed to account for this important body of work. A 'benchmark' list of 10 key social study studies were selected to represent this body of work, covering a range of authors, journals, and research topics relevant to the scope of the question (see Additional file 3: Table S4). These studies will be used with non-search related methods to identify relevant studies to be included in this study. This will be conducted by using citation chasing, along with checking relevant bibliographies. We also aim to put out calls to the coral reef science community for relevant studies.

Assembling a library of search results

Studies from all bibliographic database search results will be combined with those from Google Scholar searches into the Zotero reference management software. This software was chosen because the single-click capture function used to download pdf versions of studies is compatible with more databases and websites than other similar software.

The CADIMA online review management tool (www.cadima.info) will be used to create a project workspace which will assist the Project Team in organising and managing the sources of evidence and the screening process. The tool is permanently hosted and maintained by Julius Kühn-Institut (JKI) and allows for upload of relevant titles and abstracts for candidate studies identified through the search strategy. CADIMA helps to structure and document the literature search by associating a search string with a search engine, whilst the individual search results can be uploaded to CADIMA as RIS files [74]. The first key steps involve checking if all abstracts are entered for each retrieved reference and removing duplicates from the generated merged reference list.

Study screening and eligibility criteria

Screening process

The full list of studies will be screened for relevance using the eligibility criteria (listed below) by initially reviewing each study title and abstract text at the same time. Studies that meet the inclusion criteria will then be reviewed at the full text stage. Additionally, any studies with uncertainty about the relevance based on the title and abstract will be included and reviewed at the full text stage.

To ensure consistency between reviewers at each stage of the screening, the CADIMA software provides an automated calculation of a kappa-statistic to test inter-reviewer agreement when applying the defined criteria [75]. The observed agreement is placed in relation to the one being expected by chance using a value between 0 and 1 (where 0 = a weak agreement and 1 = a perfect agreement). When a reviewer is uncertain about including a study, it will be marked for a second opinion and will be screened by a second reviewer. Where more than one reviewer independently assesses studies and inconsistencies between reviewers occur, they will be automatically identified by CADIMA and the respective reviewers asked to solve those conflicts. If necessary, the Project Team will meet to discuss inconsistencies to help improve the understanding of the inclusion criteria.

The estimated proportion of studies that will be randomly screened and checked for consistency by two reviewers will be 10% at each of the title, abstract, and full text stages. Reviewers who have authored studies to be considered within the review will be prevented from unduly influencing inclusion decisions by delegating tasks related to these studies to other Project Team members.

Eligibility criteria

The following inclusion criteria will be used to screen the relevance of studies to determine whether they will be assessed at the meta-data extraction stage:

Population: studies that include tropical and subtropical shallow (between 0–30 m depth), and mesophotic (between 30–150 m depth) coral reef ecosystems.

Subject: studies focusing on tropical coral reef fish ecology and management.

Phenomenon of interest: spatial and temporal scales investigated and discussed within research studies.

Context: ecological, social, and socio-ecological research and management literature.

Eligible types of study design: primary research studies conducted by the authors that meet the following criteria will be included:

- Studies that have observed or measured coral reef-associated fish, live (surveyed in situ using ecological methods), or dead (including catch landings, market surveys and archaeological fossil-remains).
- Purely social studies that do not encounter fish, but include surveys with fishers or community leaders about their fishing behaviour, changes in fish catch or consumption over time.
- Any quantitative or mixed method (quantitative and qualitative) study, including empirically tested data-driven theoretical models.

The following studies will be excluded:

- Purely qualitative research, theoretical, laboratory-based, or modelling studies.
- Literature reviews which do not describe methods used for search, data collection, and synthesis.
- Editorials and commentaries, meta-analyses, systematic reviews, systematic maps, evidence gap maps.
- Literature published before 2010.
- Literature whose full texts exist in a language other than English.

A full list of studies excluded at full text stage will be provided in the final systematic map publication as an additional file including reasons for exclusion. Studies that cannot be located or accessed will also be reported.

Study validity assessment

Due to the likely number of studies and wide breadth of study designs, critical appraisal and assessment of the quality of studies will not be undertaken.

Data coding strategy

During the meta-data extraction process the free software SysRev (<http://sysrev.com/>) will be used to provide a platform for collaborative extraction of data from the selected studies. Metadata will be extracted from each relevant study that satisfies the inclusion criteria using a standardised coding and data-extraction form (see Additional file 1). The authors reviewed and refined the form by conducting a pilot meta-data extraction study with the 20 benchmark studies.

Using relevant studies, we will assess the research's spatial and temporal scale and the management recommendations and inferences. Scale usually refers to the spatial (space) and temporal (time) dimensions of a pattern or process [76]. In landscape ecology, a measured variable's spatial or temporal scale refers to the 'resolution' and 'extent' [77]. 'Resolution' refers to the precision used in measurement, where 'grain' is the finest spatial resolution, or the size or duration of a single observation [76, 78]. The 'extent' of the study area fixes the outer boundary of the measured variable [77]. For example, benthic imagery collected in situ by divers has high resolution (cm), but limited extent (10 m²), whereas satellite-derived temperature data (e.g. Pathfinder) has low resolution (4–5 km), but large extent (global).

In order to assess how well modern ecological research is achieving an all-inclusive and predictive understanding of ecosystems, Estes et al. [6] quantified the spatial and temporal domains of empirical ecological observations that were published between 2004 and 2014. To do this they defined two additional dimensions for measuring temporal scale; the 'interval' (time elapsed between successive temporal replicates) and 'duration' (time elapsed between first and last temporal replicates). The study evaluated how the actual scales of observation i.e. how much the measurement covers space and time, differ from the scales the observations attempted to represent. To do this they assessed the 'actual extent', the summed area of spatial replicates, and the 'actual duration' the summed observational time of temporal replicates. Accordingly, we will estimate the following dimensions of coral fish reef ecological, social and socio-ecological research using the terminology listed in Table 3.

In this instance, we define 'replicate' as the lowest level of independent observations collected from which mean and variance is calculated, or the scale at which the authors describe as "independent replicates" within their statistical framework. Although 'sampling dispersion' is the spatial equivalent of 'observational interval' used for describing temporal scales, the Project Team decided not to incorporate it into this study given the complexities that coral reef ecosystems present when estimating areas of surveyable reef. These include

Table 3 Definitions of spatial scale and temporal scale terminology to be used in this study (adapted from Estes et al. [6])

SPATIAL scale terminology	Definition	TEMPORAL scale terminology	Definition
Sampling resolution	Area of an individual spatial replicate. The finest scale at which a complete measurement of every unit of the quantity of interest is recorded	Sampling duration	How long it took to make one observation of the phenomenon in question, at a given point in space
		Observational interval	The time that elapsed between repeated observations of the same point in space or individual organism
Actual extent	The summed area of all spatial replicates (calculated by multiplying the sampling resolution by the number of spatial replicates)	Actual duration	Summed observational time of all temporal replicates (calculated by multiplying the sampling duration by the number of repeat observations)
Total extent	The total area enclosed within a perimeter defined by the outermost spatial replicates	Total duration	The total period of time over which the phenomenon of interest was observed (between the first and last temporal replicate)

spatially complex distributions of heterogeneous habitat types, in addition to the complexities associated with depth and 3D habitat structure.

When assessing social studies, the term ‘level’ is used for describing social system organization which has no explicit spatial or temporal dimensions [79]. For the purpose of this study, the Project Team developed a list of categories representing a progression of increasing levels of social organisation that have been used by other studies and roughly relate to particular spatial scales [10, 80, 81]. The Project Team tested the suitability of the categories and amended as necessary using 4 of the benchmark studies listed in Additional file 3: Table S3 [82–85]. The final list of levels in order of increasing social organisation are: Individual; Household; Village; Community; User groups; Watershed; Sub-regional (island, district etc.); State governmental department (or similar); National governmental department; Regional (e.g. Caribbean, South Pacific etc.); and International body. The chosen level of social organization is relevant to our assessment of potential matches or mismatches and whether they are more common at certain levels. During the meta-data extraction phase there will be an opportunity to select multiple options if relevant to the particular study.

The following main categories of data will be extracted (see Additional File 1 for more detail):

- General information on the study, including year initiated, duration, location, and type of data collected (ecological, social, socio-ecological), and if there are socio-ecological linkages included in the discussion.
- Ecological study details, including depth, habitat type, survey techniques [63], and methods [86], response variables measured, habitat associations

investigated, ecosystem processes [87], and biological characteristics [71] assessed in the study.

- Social study details, including type of data sources used, type of data collected, methods used in study [88], and social system characteristics being assessed (including demographic factors, economics (e.g., markets and trade), technological factors, knowledge, attitudes and values, and institutions and governance systems [20].
- The spatial and temporal scales of the study, drivers and management interventions (spatial resolution including total extent and actual extent, and temporal interval including total duration and actual duration).
- Socio-ecological system components, including:
 - o Linkages between social factors and ecosystem conditions [20].
 - o Assessed and recommended management interventions addressed in study.
 - o Management effectiveness indicators (social and ecological) used in study [89].

Before the final meta-data extraction is initiated, consistency checking will be conducted by all Project Team members. This will include at least 20 studies randomly assigned to multiple Project Team members. Any inconsistencies will be discussed, and the meta-data extraction coding list will be amended as required. If further inconsistencies arise during the review process, the Project Team members will meet to resolve the issues. As discussed in the screening criteria section, reviewers who have authored studies to be considered within the review will be prevented from unduly influencing inclusion decisions, by delegating tasks related to these studies to other Project Team members. If

studies are missing information or details need clarifying during the review process, the corresponding authors will be contacted by email.

Study mapping and presentation

The CADIMA tool will be used to document the review process and provides the following information and data formats:

- A flow diagram summarising the study selection process;
- Reference lists for each database (xlsx) and the final reference list after duplicate removal (xlsx and RIS);
- The outcomes of the consistency check and study selection across the different stages (title, abstract, and full text) including the reasons for exclusion (xlsx);
- The filled meta-data extraction sheet (xlsx).

The project will follow a framework-based synthesis method to summarise the descriptive characteristics of the included studies according to the population, study designs, and outcomes, and will conduct additional analyses such as looking at number of studies published per year [90, 91]. The meta-data extraction sheet will be formatted to produce summary data, figures, and tables to enable summarisation of key characteristics and trends. A data matrix will be developed to provide a graphical illustration of the distribution and frequencies of key data analysis results. Heat maps will be created to identify knowledge gaps of unrepresented or underrepresented subtopics that warrant further primary research. Knowledge clusters (well-represented subtopics that are amenable to full synthesis via systematic review) will also be identified and reported. The graphics will build upon work conducted by Estes et al. [6] on similar questions in ecology focused journals between 2004 and 2014.

The data and code will be uploaded to an online open access data repository such as GitHub. The CADIMA tool will be used to make synthesis results available to third parties by displaying the documents on the web site and enable external users to download them.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13750-021-00217-z>.

Additional file 1. Meta-data coding framework. Proposed meta-data coding framework detailing information to be extracted or coded from relevant studies in the final systematic map database.

Additional file 2. ROSES for Systematic Map Protocols (Version 1.0). Reporting standards for Systematic Evidence Syntheses in environmental research.

Additional file 3. Scoping search strategy. Summarises the main steps taken to identify search terms and construct the complex search string through scoping.

Additional file 4. Search Strategy. Lists the search strings and search terms to be used in selected bibliographic databases, organizational websites and online search engines.

Acknowledgements

Authors wish to thank Dr Ivor Williams for his time in reviewing the protocol document. Expert advice during initial project development was received from Dr Beth Hall at Bangor University and Dr Christian Kohl from the CADIMA development team.

Authors' contributions

Project design and planning—AKL, GJW, AH, AL, RCR, PL, NRH, LW. Review and testing data coding—AKL, GJW, AH, AL, FP, PL, CS, RCR, HF, SP, LS. Writing the paper—AKL, GJW, AH, AL, FP, NRH, LR, LW, HF. All authors read and approved the final manuscript.

Funding

This work was supported by a NOAA Coral Reef Conservation Program grant (NA17NOS4820036), through full-time employment at the American Samoa Department of Marine and Wildlife Resources (AKL).

Availability of data and materials

Not applicable.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no financial or non-financial competing interests related to this systematic map project.

Author details

¹ School of Ocean Sciences, Bangor University, Anglesey LL59 5AB, UK.

² Department of Geography, San Diego State University, 5500 Campanile Dr, San Diego, CA 92182-4493, USA. ³ Stockholm Environment Institute, Linégatan 87D, Stockholm, Sweden. ⁴ African Centre for Evidence, University of Johannesburg, Johannesburg, South Africa. ⁵ The SEI Centre of the Collaboration for Environmental Evidence, Stockholm, Sweden. ⁶ Mercator Research Institute On Global Commons and Climate Change, Berlin, Germany. ⁷ School of Geography and the Environment, University of Oxford, Oxford, UK.

Received: 5 May 2020 Accepted: 11 January 2021

Published online: 25 January 2021

References

1. Bellwood DR, Pratchett MS, Morrison TH, Gurney GG, Hughes TP, Alvarez-Romero JG, et al. Coral reef conservation in the Anthropocene: Confronting spatial mismatches and prioritizing functions. *Biol Conserv*. 2019;236:604–15.
2. Cumming GS, Olsson P, Chapin FS, Holling CS. Resilience, experimentation, and scale mismatches in social-ecological landscapes. *Landsc Ecol*. 2013;28(6):1139–50.
3. Hughes TP, Kerry JT, Baird AH, Connolly SR, Dietzel A, Eakin CM, et al. Global warming transforms coral reef assemblages. *Nature*. 2018;556(7702):492–6.
4. Cumming GS, Cumming DH, Redman CL. Scale mismatches in social-ecological systems: causes, consequences, and solutions. *Ecol Soc*. 2006;11(1):14.
5. Epstein G, Pittman J, Alexander SM, Berdej S, Dyck T, Kreitmair U, et al. Institutional fit and the sustainability of social-ecological systems. *Curr Opin Environ Sustain*. 2015;14:34–40.

6. Estes L, Elsen PR, Treuer T, Ahmed L, Caylor K, Chang J, et al. The spatial and temporal domains of modern ecology. *Nat Ecol Evol*. 2018;2(5):819–26.
7. Levin S. The problem of pattern and scale in ecology. *Ecology*. 1992;73(6):1943–67.
8. MacNeil MA, Graham NAJ, Polunin NVC, Kulbicki M, Galzin R, Harmelin-Vivien M, et al. Hierarchical drivers of reef-fish metacommunity structure. *Ecology*. 2009;90(1):252–64.
9. Chave J. The problem of pattern and scale in ecology: what have we learned in 20 years? *Ecol Lett*. 2013;16(SUPPL. 1):4–16.
10. Gibson CC, Ostrom E, Ahn TK. The concept of scale and the human dimensions of global change: a survey. *Ecol Econ*. 2000;32(2):217–39.
11. Schneider DC. The rise of the concept of scale in ecology. *Bioscience*. 2010;51(7):545–53.
12. Berkes F. From community-based resource management to complex systems. *Ecol Soc*. 2006;11(1):45.
13. Fischer J, Gardner TA, Bennett EM, Balvanera P, Biggs R, Carpenter S, Daw T, Folke C, Hill R, Hughes TP. Advancing sustainability through mainstreaming a social-ecological systems perspective. *Curr Opin Environ Sustain*. 2015;14:144–9.
14. Guerrero AM, McAllister R, Corcoran J, Wilson KA. Scale mismatches, conservation planning, and the value of social-network analyses. *Conserv Biol*. 2013;27:35–44.
15. Ostrom E. A general framework for analyzing sustainability of social-ecological systems. *Science*. 2009;325:419–22.
16. Cumming GS, Allen CR, Ban NC, Biggs D, Biggs HC, Cumming DHM, et al. Understanding protected area resilience: a multi-scale, social-ecological approach. *Ecol Appl*. 2015;25(2):299–319.
17. Gurney GG, Darling ES, Jupiter SD, Mangubhai S, McClanahan TR, Lestari P, et al. Implementing a social-ecological systems framework for conservation monitoring: lessons from a multi-country coral reef program. *Biol Conserv*. 2019;240(November):108298.
18. Liu J, Dietz T, Carpenter SR, Folke C, Alberti M, Redman CL, Schneider SH, Ostrom E, Pell AN, Lubchenco J, Taylor WW, Ouyang Z, Deadman P, Kratz T, Provencher W. Coupled human and natural systems. *Ambio*. 2007;36(8):639–49.
19. Norström AV, Nyström M, Jouffray JB, Folke C, Graham NAJ, Moberg F, et al. Guiding coral reef futures in the Anthropocene. *Front Ecol Environ*. 2016;14(9):490–8.
20. Kittinger JN, Finkbeiner EM, Glazier EW, Crowder LB. Human dimensions of coral reef social-ecological systems. *Ecol Soc*. 2012;17(4):17.
21. Jouffray JB, Wedding LM, Norström AV, Donovan MK, Williams GJ, Crowder LB, et al. Parsing human and biophysical drivers of coral reef regimes. *Proc R Soc B Biol Sci*. 1896;2019(286):1–10.
22. McGill BJ, Dornelas M, Gotelli NJ, Magurran AE. Fifteen forms of biodiversity trend in the anthropocene. *Trends Ecol Evol*. 2015;30(2):104–13.
23. Williams GJ, Graham NAJ, Jouffray J-B, Norström AV, Nyström M, Gove JM, et al. Coral reef ecology in the Anthropocene. *Funct Ecol*. 2019;33:1014–22. <https://doi.org/10.1111/1365-2435.13290>.
24. Fabricius KE. Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Mar Pollut Bull*. 2005;50(2):125–46.
25. Lam VYY, Chaloupka M, Thompson A, Doropoulos C, Mumby PJ. Acute drivers influence recent inshore Great Barrier Reef dynamics. *Proc R Soc B Biol Sci*. 2018;285:20182063.
26. Williams GJ, Graham NAJ. Rethinking coral reef functional futures. *Funct Ecol*. 2019;33:942–7.
27. Woodhead AJ, Hicks CC, Norström AV, Williams GJ, Graham NAJ. Coral reef ecosystem services in the Anthropocene. *Funct Ecol*. 2019;33(6):1023–34.
28. Couch CS, Burns JHR, Liu G, Steward K, Gutlay TN, Kenyon J, et al. Mass coral bleaching due to unprecedented marine heatwave in Papahānaumokuākea Marine National Monument (Northwestern Hawaiian Islands). *PLoS ONE*. 2017;12(9):1–27.
29. Head CEI, Bayley DTI, Rowlands G, Roche RC, Tickler DM, Rogers AD, et al. Coral bleaching impacts from back-to-back 2015–2016 thermal anomalies in the remote central Indian Ocean. *Coral Reefs*. 2019;38(4):605–18.
30. Hughes TP, Kerry JT, Álvarez-Noriega M, Álvarez-Romero JG, Anderson KD, Baird AH, et al. Global warming and recurrent mass bleaching of corals. *Nature*. 2017;543(7645):373–7.
31. Hughes TP, Anderson KD, Connolly SR, Heron SF, Kerry JT, Lough JM, et al. Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. *Science*. 2018;359(6371):80–3.
32. Pratchett MS, Hoey AS, Wilson SK, Messmer V, Graham NAJ. Changes in biodiversity and functioning of reef fish assemblages following coral bleaching and coral loss. *Diversity*. 2011;3(3):424–52.
33. Wilson SK, Graham NAJ, Pratchett MS, Jones GP, Polunin NVC. Multiple disturbances and the global degradation of coral reefs: are reef fishes at risk or resilient? *Glob Chang Biol*. 2006;12(11):2220–34.
34. Norström AV, Nyström M, Lokrantz J, Folke C. Alternative states on coral reefs: beyond coral—macroalgal phase shifts. *Mar Ecol Prog Ser*. 2009;376:295–306.
35. Graham NAJ, Jennings S, MacNeil MA, Mouillot D, Wilson SK. Predicting climate-driven regime shifts versus rebound potential in coral reefs. *Nature*. 2015;518(7537):94–7.
36. Fidelman P, Evans L, Fabinyi M, Foale S, Cinner J, Rosen F. Governing large-scale marine commons: contextual challenges in the coral triangle. *Mar Policy*. 2012;36(1):42–53.
37. Link JS, Ihde TF, Harvey CJ, Gaichas SK, Field JC, Brodziak JKT, et al. Dealing with uncertainty in ecosystem models: the paradox of use for living marine resource management. *Prog Oceanogr*. 2012;102:102–14.
38. Pittman SJ, Kneib RT, Simenstad CA. Practicing coastal seascape ecology. *Mar Ecol Prog Ser*. 2011;427:187–90.
39. Evans L. Reconciling multiple societal objectives in cross-scale marine governance: Solomon Islands' engagement in the Coral Triangle Initiative. *Soc Nat Resour*. 2018;31:121.
40. Gruby RL, Basurto X. Multi-level governance for large marine commons: Politics and polycentricity in Palau's protected area network. *Environ Sci Policy*. 2014;36:48–60.
41. Sievanen L, Gruby RL, Campbell LM. Fixing marine governance in Fiji? The new scalar narrative of ecosystem-based management. *Glob Environ Chang*. 2013;23(1):206–16.
42. Bruno JF, Côté IM, Toth LT. Climate change, coral loss, and the curious case of the parrotfish paradigm: why don't marine protected areas improve reef resilience? *Ann Rev Mar Sci*. 2019;11:307–34.
43. Fraser KA, Adams VM, Pressey RL, Pandolfi JM. Impact evaluation and conservation outcomes in marine protected areas: a case study of the Great Barrier Reef Marine Park. *Biol Conserv*. 2019;238(June):108185.
44. Bozec Y-M, O'Farrell S, Bruggemann JH, Luckhurst BE, Mumby PJ. Trade-offs between fisheries harvest and the resilience of coral reefs. *Proc Natl Acad Sci*. 2016;113(16):201601529.
45. Graham NAJ, Bellwood DR, Cinner JE, Hughes TP, Norström AV, Nyström M. Managing resilience to reverse phase shifts in coral reefs. *Front Ecol Environ*. 2013;11(10):541–8.
46. McClanahan TR, Donner SD, Maynard JA, MacNeil MA, Graham NAJ, Maina J, et al. Prioritizing key resilience indicators to support coral reef management in a changing climate. *PLoS ONE*. 2012;7(8):42884.
47. Mumby PJ, Wolff NH, Bozec YM, Chollett I, Halloran P. Operationalizing the resilience of coral reefs in an era of climate change. *Conserv Lett*. 2014;7(3):176–87.
48. Williams ID, Kindinger TL, Couch CS, Walsh WJ, Minton D, Oliver TA, et al. Can herbivore management increase the persistence of Indo-Pacific coral reefs? *Front Marine Sci*. 2019;6:1–15.
49. Holbrook SJ, Schmitt RJ, Adam TC, Brooks AJ. Coral reef resilience, tipping points and the strength of herbivory. *Sci Rep*. 2016;6(November):1–11.
50. Hughes TP, Bellwood DR, Folke CS, McCook LJ, Pandolfi JM. No-take areas, herbivory and coral reef resilience. *Trends Ecol Evol*. 2007;22(1):1–3.
51. Chung AE, Wedding LM, Green AL, Friedlander AM, Goldberg G, Meadows A, et al. Building Coral reef resilience through spatial herbivore management. *Front Mar Sci*. 2019;6(March):1–12.
52. Cox CE, Jones CD, Wares JP, Castillo KD, Mcfield MD, Bruno JF. Genetic testing reveals some mislabelling but general compliance with a ban on herbivorous fish harvesting in Belize. *Conserv Lett*. 2013;6(2):132–40.
53. Heenan A, Williams GJ, Williams ID. Natural variation in coral reef trophic structure across environmental gradients. *Front Ecol Environ*. 2020;18(2):69–75. <https://doi.org/10.1002/fee.2144>.
54. Zgliczynski BJ, Williams GJ, Hamilton SL, Corder EG, Fox MD, Eynaud Y, et al. Foraging consistency of coral reef fishes across environmental gradients in the central Pacific. *Oecologia*. 2019;191(2):433–45.
55. Bejarano S, Jouffray JB, Chollett I, Allen R, Roff G, Marshall A, et al. The shape of success in a turbulent world: wave exposure filtering of coral reef herbivory. *Funct Ecol*. 2017;31(6):1312–24.

56. Fulton CJ, Bellwood DR. Wave exposure, swimming performance, and the structure of tropical and temperate reef fish assemblages. *Mar Biol*. 2004;144(3):429–37.
57. Cinner JE, Maire E, Huchery C, Aaron MacNeil M, Graham NAJ, Mora C, et al. Gravity of human impacts mediates coral reef conservation gains. *Proc Natl Acad Sci USA*. 2018;115(27):E6116–25.
58. Williams ID, Baum JK, Heenan A, Hanson KM, Nadon MO, Brainard RE. Human, oceanographic and habitat drivers of central and western pacific coral reef fish assemblages. *PLoS ONE*. 2015;10(4):1–1.
59. Levine A, Richmond L. Using common-pool resource design principles to assess the viability of community-based fisheries co-management systems in American Samoa and Hawai'i. *Mar Policy*. 2015;62:9–17.
60. Friedlander AM, Donovan MK, Stamoulis KA, Williams ID, Brown EK, Conklin EJ, et al. Human-induced gradients of reef fish declines in the Hawaiian Archipelago viewed through the lens of traditional management boundaries. *Aquat Conserv Mar Freshw Ecosyst*. 2018;28(1):146–57.
61. Anthony KRN, Marshall PA, Abdulla A, Beeden R, Bergh C, Black R, et al. Operationalizing resilience for adaptive coral reef management under global environmental change. *Glob Chang Biol*. 2015;21(1):48–61.
62. D'Urban Jackson T, Williams GJ, Walker-Springett G, Davies AJ. Three-dimensional digital mapping of ecosystems: a new era in spatial ecology. *Proc R Soc B Biol Sci*. 2020;2020(287):1–10.
63. Dornelas M, Madin EMP, Bunce M, DiBattista JD, Johnson M, Madin JS, et al. Towards a macroscope: leveraging technology to transform the breadth, scale and resolution of macroecological data. *Glob Ecol Biogeogr*. 2019;28(12):1937–48.
64. Soranno PA, Schimel DS. Macrosystems ecology: big data, big ecology. *Front Ecol Environ*. 2014;12(1):3.
65. Wedding LM, Lecky J, Gove JM, Walecka HR, Donovan MK, Williams GJ, et al. Advancing the integration of spatial data to map human and natural drivers on coral reefs. *PLoS ONE*. 2018;13(3):1–29.
66. Asner GP, Vaughn NR, Balzotti C, Brodrick PG. High-resolution reef bathymetry and coral habitat complexity from airborne imaging spectroscopy. *Remote Sens*. 2020;12:310.
67. Wedding LM, Jorgensen S, Lepczyk CA, Friedlander AM. Remote sensing of three-dimensional coral reef structure enhances predictive modeling of fish assemblages. *Remote Sens Ecol Conserv*. 2019;5(2):150–9.
68. Collaboration for Environmental Evidence (CEE). Guidelines and standards for evidence synthesis in environmental management. Version 5.0 (AS Pullin, GK Frampton, B Livoreil & G Petrokofsky, Eds). 2018. <http://www.environmentalevidence.org/information-for-authors>. Accessed April 2019.
69. Haddaway NR, Macura B, Whaley P, Pullin AS. ROSES Reporting standards for Systematic Evidence Syntheses: Pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps. *Environ Evid*. 2018;7:7. <https://doi.org/10.1186/s13750-018-0121-7>.
70. Haddaway NR, Westgate MJ. Predicting the time needed for environmental systematic reviews and systematic maps. *Conserv Biol*. 2019;33(2):434–43.
71. Villéger S, Brosse S, Mouchet M, Mouillot D, Vanni MJ. Functional ecology of fish: current approaches and future challenges. *Aquat Sci*. 2017;79:783–801. <https://doi.org/10.1007/s00027-017-0546-z>.
72. Haddaway NR, Collins AM, Coughlin D, Kirk S. The role of google scholar in evidence reviews and its applicability to grey literature searching. *PLoS ONE*. 2015;10(9):1–17.
73. Haddaway NR, Collins AM, Coughlin D, Kirk S. A rapid method to increase transparency and efficiency in web-based searches. *Environ Evid*. 2017;6(1):1–14.
74. Kohl C, McIntosh EJ, Unger S, Haddaway NR, Kecke S, Schiemann J, et al. Online tools supporting the conduct and reporting of systematic reviews and systematic maps: a case study on CADIMA and review of existing tools. *Environ Evid*. 2018;7(1):1–17.
75. Cohen J. A coefficient of agreement for nominal scales. *Edu Psychol Meas*. 1960;20(1):37–46.
76. Turner MG, Gardner RH, O'Neill RV. Landscape ecology in theory and practice: pattern and process. New York: Springer; 2001.
77. Pittman SJ, Wiens JA, Wu J, Urban DL. Landscape ecologists' perspectives on seascape ecology. *Seascape Ecol*. 2017:487–91.
78. Scholes RJ, Reyers B, Biggs R, Spierenburg MJ, Duriappah A. Multi-scale and cross-scale assessments of social-ecological systems and their ecosystem services. *Curr Opin Environ Sustain*. 2013;5(1):16–25.
79. Allen TFH, Hoekstra TW. The confusion between scale-defined levels and conventional levels of organization in ecology. *J Veg Sci*. 1990;1(1):5–12.
80. Lubell M. Governing institutional complexity: the ecology of games framework. *Policy Stud J*. 2013;41(3):537–59.
81. Weible CM, Sabatier PA. Comparing policy networks: marine protected areas in California. *Policy Stud J*. 2005;33(2):181–201.
82. Brown C, Jupiter S, Lin H, Albert S, Klein C, Maina J, et al. Habitat change mediates the response of coral reef fish populations to terrestrial run-off. *Mar Ecol Prog Ser*. 2017;576:55–68.
83. Guillemot N, Chabanet P, Kulbicki M, Vigliola L, Léopold M, Jollit I, et al. Effects of fishing on fish assemblages in a coral reef ecosystem: from functional response to potential indicators. *Ecol Indic*. 2014;43:227–35.
84. Pavlowich T, Kapuscinski AR, Webster DG. Navigating social-ecological trade-offs in small-scale fisheries management: an agent-based population model of stoplight parrotfish (*Sparisoma viride*) for a Caribbean coral reef fishery. *Ecol Soc*. 2019;24(3):1. <https://doi.org/10.5751/ES-10799-240301>.
85. Rassweiler A, Lauer M, Lester SE, Holbrook SJ, Schmitt RJ, Madi Moussa R, et al. Perceptions and responses of Pacific Island fishers to changing coral reefs. *Ambio*. 2019;49:130–43. <https://doi.org/10.1007/s13280-019-01154-5>.
86. Caldwell ZR, Zgliczynski BJ, Williams GJ, Sandin SA. Reef fish survey techniques: Assessing the potential for standardizing methodologies. *PLoS ONE*. 2016;11(4):1–14.
87. Brandl SJ, Rasher DB, Côté IM, Casey JM, Darling ES, Lefcheck JS, et al. Coral reef ecosystem functioning: eight core processes and the role of biodiversity. *Front Ecol Environ*. 2019;49:130–43. <https://doi.org/10.1002/fee.2088>.
88. Bennett NJ, Roth R, Klain SC, Chan K, Christie P, Clark DA, et al. Conservation social science: understanding and integrating human dimensions to improve conservation. *Biol Conserv*. 2017;205:93–108.
89. Gill DA, Mascia MB, Ahmadi GN, Glew L, Lester SE, Barnes M, et al. Capacity shortfalls hinder the performance of marine protected areas globally. *Nature*. 2017;543(7647):665–9.
90. Dixon-Woods M. Using framework-based synthesis for conducting reviews of qualitative studies. *BMC Med*. 2011;9(1):39.
91. McKinnon MC, Cheng SH, Dupre S, Edmond J, Garside R, Glew L, Holland MB, Levine E, Masuda YJ, Miller DC, Oliveira I. What are the effects of nature conservation on human well-being? A systematic map of empirical evidence from developing countries. *Environ Evid*. 2016;5(1):8.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.