ICES Journal of Marine Science, 2025, Vol. 82, Issue 12, fsaf208
https://doi.org/10.1093/icesjms/fsaf208
Received: 15 January 2025; **revised:** 7 October 2025; **accepted:** 10 October 2025
Food for Thought

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Sharpening resilience concepts to catalyze advances in marine social-ecological systems research

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Abstract

Marine social-ecological systems (SES) are increasingly affected by anthropogenic stressors such as climate change, fisheries, pollution, and habitat degradation. The responses of these complex adaptive systems, and the interactions between their ecological and social components, are still not fully understood. Resilience, vulnerability, adaptive capacity, and tipping points capture essential aspects of SES dynamics, but their heterogeneous use within the marine research community hampers progress toward integrative understanding and effective sustainable governance. Drawing from a session at MSEAS 2024, subsequent participatory activities, and a focused literature review, we examine how resilience-related concepts in marine SES are defined and assessed. We propose recommendations to guide resilience-related studies in marine SES: (1) begin with clear definitions of resilience-related concepts and underlying theory; (2) define the system, its components and boundaries, as well as the temporal and spatial scales of analysis; (3) contextualize the used methods or indicators within the wider SES research landscape; and (4) adopt a more holistic SES view by accounting for effects on system components beyond the primary focus of the study. The use of a shared set of guiding principles in marine SES research would strengthen conceptual coherence, facilitate cross-system comparisons, and support interdisciplinary integration in marine science.

Why do we need to assess the resilience of social-ecological systems?

Sustainable governance of natural resources requires the integration of social and ecological systems (SES), as many issues cannot be solved by looking separately at natural and social processes (Resilience Alliance 2010, Fischer et al. 2015, Guerrero et al. 2018). This may be especially complex for marine SES, which encompass densely populated coastal areas, often highly dynamic and data-sparse living resources, heterogeneous user groups, and complex legal frameworks—for example, concerning the use of marine space (Boussarie et al. 2023). To effectively address and adapt to the growing effects of climate change and other anthropogenic impacts on marine systems, a better understanding of the complex interactions among climate, ecosystems, and human systems is essential for identifying systemic trade-offs and feedbacks—both positive and negative—that may constrain adaptation or lead to unintended consequences of interventions (Perry et al. 2010, Bograd et al. 2019, Salgueiro-Otero and Ojea 2020).

The ecological, social, economic, and political components of marine SES can adapt to changes at different spatial and temporal scales, and with complex feedback between subsystems (Ojea et al. 2020), which may buffer naturally occurring changes at the system level (Brooks et al. 2005, Perry et

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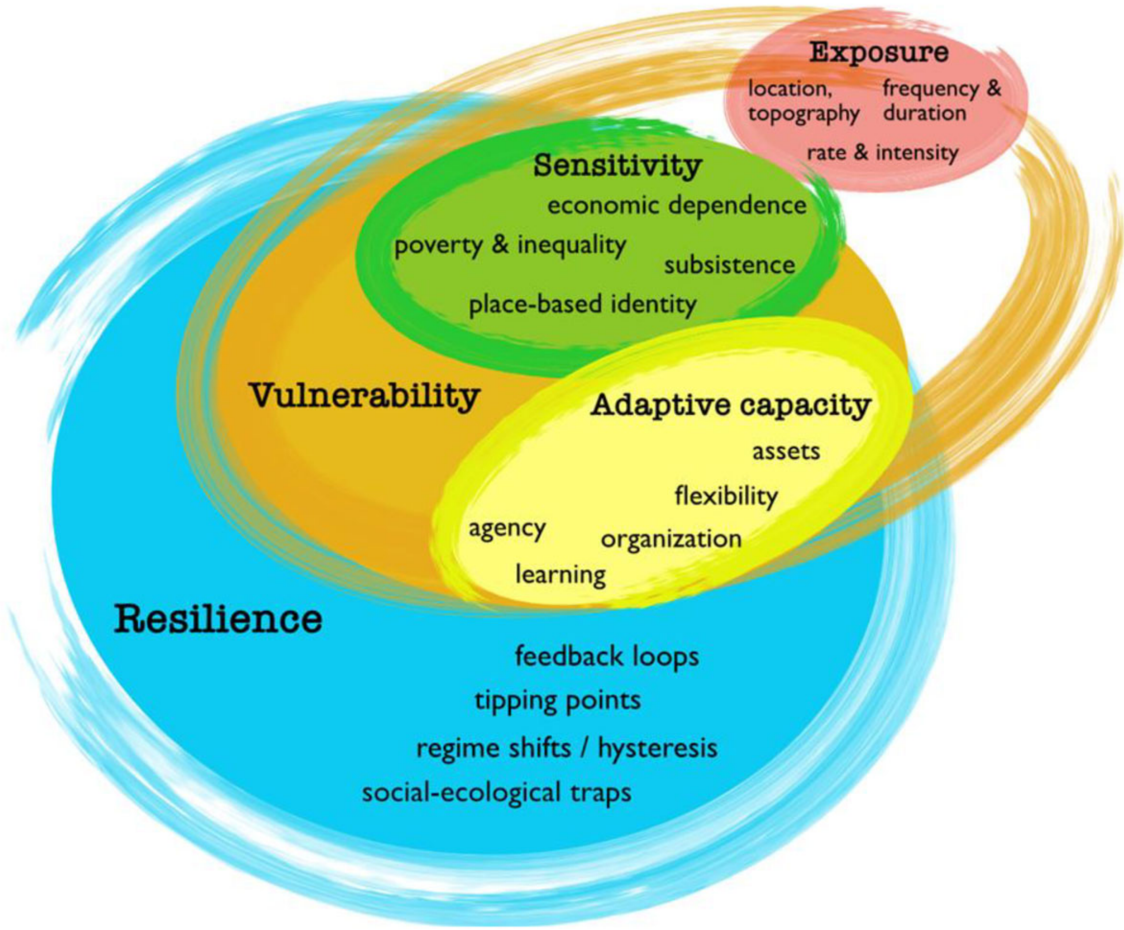

Figure 1. Key concepts related to resilience, depicting their hierarchy and overlaps, with examples for properties of sub-systems or system elements that contribute to each concept (see main text). Partially filled circle for "vulnerability" indicates that earlier definitions included "exposure" (Adger 2006).

al. 2011, Whitney et al. 2017). For instance, mobile marine species adjust their spatial distribution by migrating to different areas in response to changes in ocean temperatures (Pinsky et al. 2013, Burrows et al. 2019, Rogers et al. 2019, Gordó-Vilaseca et al. 2024). Fishers may respond to reduced availability of customary target species by modifying their gear or shifting fishing areas (Woods et al. 2022), or adapt to abrupt environmental changes (e.g. El Niño events) through individual mobility or by shifting to alternative livelihoods (e.g. Badjeck et al. 2010, Kluger et al. 2019, 2020, Bakit et al. 2023). Mobility of coastal populations in itself can function as an adaptation to environmental changes such as coastal floodings and climate change related effects (Murphy 2015). In many regions, the expansion of marine anthropogenic activities—such as shipping, mining, fossil and renewable energy plants, and nature conservation—poses another pressure on fisheries (Halpern et al. 2019, Paolo et al. 2024). Ideally, fishers can adapt to the loss of fishing grounds by relocating their activities to adjacent areas and capitalize on spillover effects, benefiting from increased fish populations along the boundaries of the fishing closure (Goñi et al. 2008, van der Lee et al. 2013).

However, the anticipated and already observed impacts of global change—such as rising temperatures, increased frequency and intensity of storms, floods, extreme events, disease outbreaks, shifts in population dynamics, and climate-induced migration—may exceed the coping capacity of ecological and social systems, especially when the rate of change outpaces the ability of ecosystems or their users to adapt (Bahri et al. 2021, Eurich et al. 2023, Stelzenmüller et al. 2024, Litzow et al. 2024). The recent COVID-19 pandemic impacts on small-scale fisheries exemplifies how socio-economic-political pressures can overwhelm resource users' adaptive capacities, as mobility restrictions alter the distribution of economic benefits, and/or closure of markets shut down entire fisheries and aquaculture value chains (e.g. Campbell et al. 2021, Manlosa et al. 2021, Kluger et al. 2023, Partelow et al. 2023). Yet, any crisis may also provide an opportunity to unlock transformation pathways toward other system states. For example, while mobility restrictions, lockdowns, trade stoppages, and market closures during COVID-19 interrupted traditional ways of commercializing seafood products, many seafood systems adapted in innovative ways, creating and developing direct seafood sale opportunities such as online markets, direct sales, focus on local markets (see Basset et. al. 2021 et al. 2021, Nyiawung et. al. 2024).

Originally proposed by Holling (1973), the concept of "resilience" is often discussed and applied as an integrated measure for the capacity of a system (an ecosystem, a SES) to respond to and buffer external pressures (Holling 1973, Carpenter et al. 2001, Walker et al. 2002). Several key concepts often associated with resilience include "vulnerability," "adaptive capacity," and "tipping points" (or "regime shifts") (Fig. 1). These concepts cover some overlapping aspects of system characteristics and behavior, particularly when describing

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marine SES functioning and responses to changes (Refulio-Coronado et al. 2021). Briefly, vulnerability has been defined as the "propensity or predisposition to be adversely affected" (IPCC 2022), while adaptive capacity describes the "ability of systems, [...] to adjust to potential damage, to take advantage of opportunities or to respond to consequences" [Millennium Ecosystem Assessment (MA) 2005 in IPCC 2022]. Once a stressor pushes a system too far, it may cross an irreversible threshold, called "tipping point" or "regime shift," with examples of this being climate change and fishing pressure leading to collapsing fish stocks (Sguotti et al. 2022, Blöcker et al. 2023).

Resilience in marine SES research has been conceptualized in diverse ways (González-Quintero and Avila-Foucat 2019), especially regarding societal dimensions (Cinner and Barnes 2019, Refulio-Coronado et al. 2021, Sguotti et al. 2024). This conceptual fragmentation represents a challenge to advancing a cohesive understanding of marine SES resilience (cf. Siders 2019). An improved understanding of resilience in marine SES may, for instance, be employed to develop and apply adaptive governance or co-management approaches that support adaptation in fisheries and marine spatial planning (MSP) to climate change, thus enhancing information flows among actors (Thiault et al. 2021, Bahri et al. 2021).

Here, we investigate the use and application of "resilience" and related concepts in marine SES, starting from case studies presented at the Marine Socio-Ecological Systems Symposium 2024 (MSEAS 2024), held in Yokohama, Japan (3rd to 7th June 2024; cf. Appendix 1). The case studies were presented within the session: "Vulnerability of marine SES to climate change and anthropogenic pressures: Adaptation as a pathway to resilience." A subsequent group discussion and participatory exercise engaged session participants in systematizing resilience-related concepts, guided by a set of predefined questions (presented later in the text). This paper integrates results from discussions during and after the conference session, making these accessible to non-participants (cf. Appendix 2), while we performed a literature review to assess how resilience and related concepts are defined in the field. Based on these findings—and recognizing the diversity of views and definitions of resilience and related concepts among participants, often without clearly articulating how resilience was studied—we propose a set of recommendations to clarify how resilience is conceptualized and assessed in marine SES research. Our recommendations aim to strengthen the theoretical foundation for future integrative and collaborative work focused on the sustainability of marine SES.

Harvesting a plurality of perspectives on resilience

The session included 13 talks covering a wide geographical range of marine SES, including Australia, China, Mexico, the Caribbean islands, Hawaii, the United Kingdom, Germany, France, and Spain (Appendix 1). A common theme in most presentations was enhancing the resilience of marine SES across its multiple dimensions and actors, while recognizing the challenges posed by the inherent complexity of SES. Nine researchers contributed case studies and participated in post-conference activities. Of these, five identified themselves as either ecologists or social-ecological scientists, and four as economists. Six case studies focused on fisheries: Newfoundland cod and hindsight risk of stock collapse (Blanz et al. 2024), sea warming effects on NW Mediterranean fisheries [Espasandín et al. in Appendix 2 (appx)], offshore wind projects and coastal fisheries on the French Atlantic coast (Buchholzer et al. 2022), kelp forests and urchin fisheries on Baja California (Tavera-Ortiz et al. appx), German North Sea flatfish fishery (Quiroga and Blanz appx.), and NW Mediterranean bottom-trawl fisheries (López et al. appx.). One study investigated the impacts of terrestrial anthropogenic activities on coral reefs and planktonic communities off the SE coast of Japan (Suarez-Caballero et al. appx.), while another focused on environmental and anthropogenic pressures on four US large marine ecosystems (Tam et al. 2017). Additionally, one study investigated residential recreational values in Hawaii coupled with ecological modeling (Mackenzie et al. appx).

The impact of isolated or combined climate change-related stressors (e.g. marine heatwaves, ocean acidification), along with various anthropogenic pressures (e.g. fisheries and nutrient enrichment) was investigated to determine their role in causing shifts in basic ecosystem functioning and ecosystem service provisioning. The methods applied included MSP, calculating compensating variation- an economic measurement that describes the amount of compensation a recreator needs to reach their original level of utility after the ecological change conditions, probability matrices, qualitative comparative analysis, surveys and semi-structured interviews, mean temperature of the catch, before-after control-impact, value chain analysis, literature review, quantitative risk analysis, machine learning, ecosystem models, and analytical models (Appendix 2).

At the end of the conference session, presenters and audience members were invited to participate in a group discussion around resilience, vulnerability, tipping points, and adaptive capacity of marine SES. Sixteen participants were divided into three groups of about six people. Two groups focused on "resilience" and one on "tipping points." All groups discussed and formulated answers to the following questions: (1) "How do you define resilience/tipping points in SES?," (2) "Do you consider the existing methodologies to assess SES resilience/tipping points effective," and (3) "If not, how can we improve them?." Answers are transcribed in Appendix 3.

Discussions with responsive participants were continued in a post-conference online meeting on 24th July 2024, combined with a subsequent written exercise for the participants to describe the main characteristics of their case studies. To facilitate this process, definitions for *resilience*, *vulnerability*, *adaptive capacity*, and *tipping points* were provided (see below). The participants specified whether the concepts were applied directly (identified/quantified by this study) or indirectly (concept applied to the studied marine SES, but not explicitly researched) in their case study (Fig. 2). Participants were also asked to share their disciplinary background, the main SES components addressed in their case studies, and any relevant management measures involved (Appendix 4).

To corroborate the perception that session participants and literature examples often refer to the notion of resilience without providing a precise, case-relevant definition or analytical framing, we complemented the previously described methodological approach with a structured, purposive literature review. This review focused on the concepts of "resilience," "adaptive capacity," "tipping points," and "vulnerability," and was conducted in the Web of Science database for the period 2001–2025, retrieving a total of 129 papers (103 original papers and 26 review papers) (see Appendix 5 for details).

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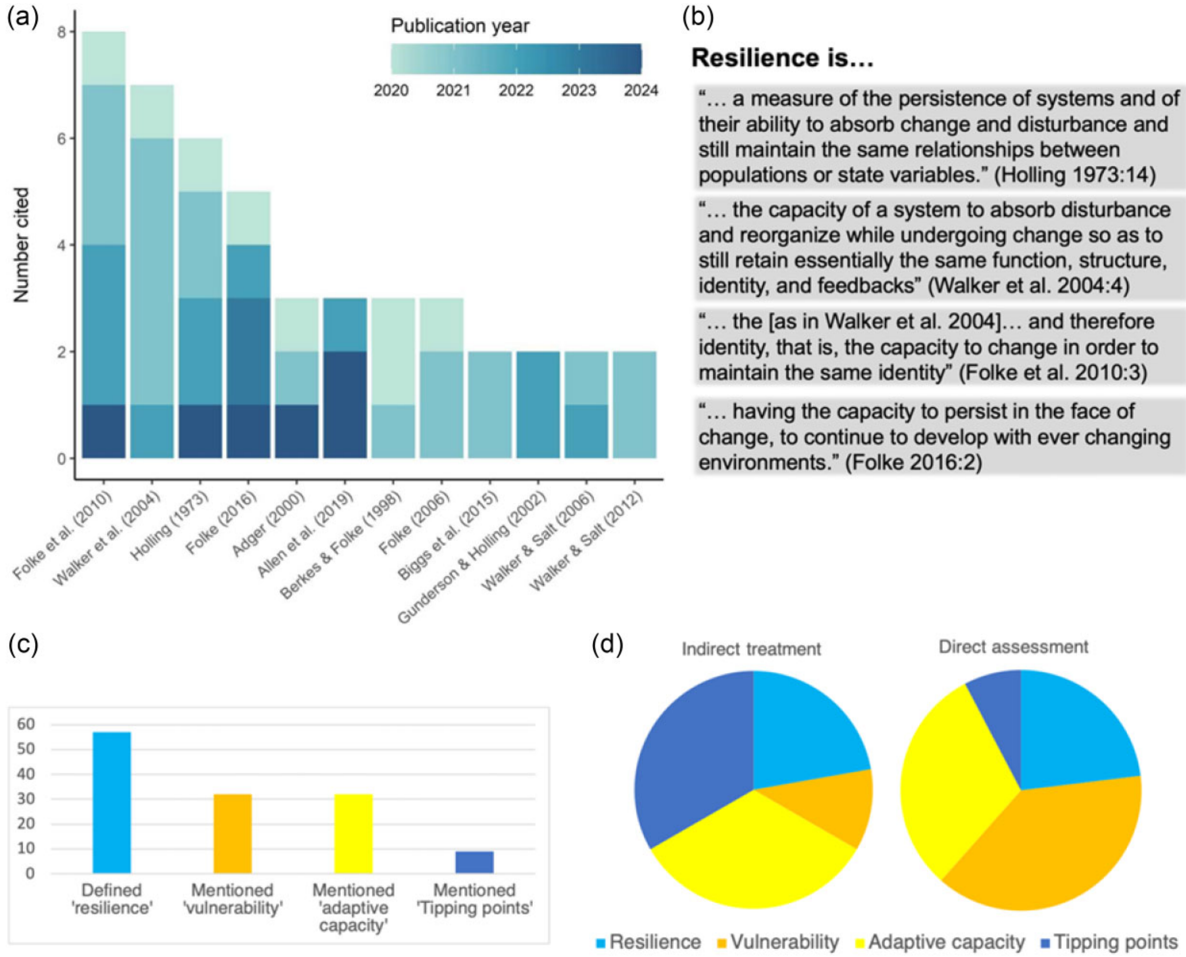

Figure 2. (a) Most commonly used resilience definitions by author and publication year as derived from the bibliographic search (see Appendix 5 for details), with colors indicating the year of citation. (b) The four most frequently cited resilience definitions as shown in Plot A, ordered chronologically. (c) Numbers of papers in the literature review (of $N = 103$) containing an explicit definition of "resilience," and also mentioning the terms "vulnerability," "adaptive capacity," and "tipping points." (d) Proportion of the case study authors ($N = 9$) providing indirect or direct (explicit) assessment of the former concepts.

Adaptive capacity

Adaptive capacity is the ability of system components (e.g. an individual organism, species or population, an actor or a group of actors, an economic sector) to adjust to changing internal demands and/or external drivers. It may be understood as the system component's capacity to alter its behavior and maintain its function (Carpenter and Brock 2008). For ecological components, this comprises the ability for physiological, behavioral and population-level adaptation, e.g. by migration, adjustment of habitat use, and genetic adaptation (Koenigstein et al. 2016). For human communities, adaptive capacity comprises primarily socio-economic aspects such as the availability of assets, flexibility, organization, learning and agency (Cinner and Barnes et al. 2019). Most case studies reported some form of adaptation within the system, occurring either at lower system levels (e.g. individual actors adjusting their behavior) or at higher hierarchical levels (e.g. management and regulatory decisions; see Appendix 4)

Explicit adaptive capacities were identified in four cases, all of them being fisheries SES. In three cases, fishers adapted by changing target species (cf. case study by Espasandín et al.; appx), lowering effort (case study by Quiroga and Blanz; appx.), and translocating species for improved yields (case study by Tavera-Ortiz et al.; appx). Another case study identified the potential ecological adaptation of species that may redistribute due to climate change (López et al.; appx). Community-level adaptations, such as re-distribution of the workforce or catch shares, or migration of user groups to other localities, were not a primary focus of adaptation strategies among the case studies.

Management measures aiming at mitigating negative effects of stressors were present or suggested in six case studies, out of which four targeted management by conserving an ecological element, i.e. lowering quotas and closing a fishery for stock recovery (Blanz et al. 2024), changing the placement of or expanding no–take zones for more efficient conservation (López et al.; appx.), establish more MPAs to protect coral reefs (Mackenzie et al.; appx.), and regulating coastal development to reduce nutrient run-off (Suarez-Caballero et al.; appx.). In two cases, the actors were the center of the management measure. Buchholzer et al. (2022) studied a specific fishing ground where offshore wind farms will be implemented, and the impact on different coastal fish-

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eries. In Tavera–Ortiz et al. (appx.), fishers practiced self-management by relocating sea urchins to improve yields, while maintaining a balance between sea urchins and kelp. And while adaptive capacity appears an integral part of resilience (cf. Fig. 1), not all studies applying resilience necessarily address the related sub-concepts. This is supported by the findings of our purposive literature review, which showed that the term "adaptive capacity" co-occurred in conjunction with "resilience" in only 32% of the analysed research papers ($n = 32$ of 103) and was defined in only 46% of the analysed review articles ($n = 12$ of 26) (Fig. 2c and Fig. S1 in Appendix 5).

Vulnerability

Vulnerability can be understood as the susceptibility or predisposition of a system to be negatively affected (UNDRR 2016) and is commonly conceptualized as a function of exposure, sensitivity, and adaptive capacity in the face of disturbances (Adger 2006, Gallopín 2006). More recently, the "exposure" aspect has been removed from the IPCC definition of vulnerability, leading to an increased focus on societal aspects (Sharma and Ravindranath 2019). The "sensitivity" dimension of vulnerability refers to social characteristics that are pre-existing and independent of the disturbance. These include, for example, a community's economic dependence on natural systems, reliance on local ecosystems for subsistence or food security, and cultural identities closely tied to specific places or resources. Other societal conditions, such as poverty and inequality, can further heighten this dependence and increase overall sensitivity (Fig. 1). Vulnerability, as a concept, is only meaningful in the presence of a stressor that poses a threat to elements of a social-ecological system (SES). It helps identify which components are particularly susceptible to that stressor, either spatially (e.g. economically important areas or key fishing grounds) or by system element (e.g. fishing fleets).

From this collection, five case studies measured vulnerabilities of SES elements to different stressors of which three were fisheries examples, i.e. the vulnerability of fisheries to environmental and economic variables (Quiroga and Blanz; appx.), decreasing cold-affinity species (Espasandín et al.; appx.), and implementations of offshore wind farms (Buchholzer et al. 2022). A fourth case study quantified the vulnerability of planktonic food webs and coral reefs to anthropogenic stressors (Suarez-Caballero et al.; appx.), and the fifth study calculated the welfare of inhabitants to changes in coastal ecosystems in Hawaii (Mackenzie et al.; appx.). Regarding the applied methods, three case studies used methods not strictly tied to the concept of vulnerability but effectively identified vulnerable SES elements. These included ecosystem modeling (Mackenzie et al.; Suarez-Caballero et al.; appx.) and analyses of mean temperature of catches and revenues (Espasandín et al.; appx.). The other two case studies defined exposure, sensitivity, and adaptive capacity for different fishing fleet segments and calculated vulnerability indices (Buchholzer et al. 2022) or assessed vulnerability to multiple drivers with a newly developed framework (Quiroga et al.; appx.).

Results of the literature showed that the dispersed picture in the application of terms related to resilience is also apparent for the term "vulnerability," which only co-occurred with "resilience" in 32% of the analysed original research papers ($n = 32$ of 103) and just 12% of the review papers ($n = 3$ of 26) provided a definition of the term.

Tipping points

Tipping points are critical thresholds where changes push a system from one state (or regime) to another (often irreversibly), where the system transitions to a new equilibrium that may have different functions and structures (Milkoreit et al. 2018, Hald-Mortensen 2024). When a system is driven past a critical threshold, it can attain an alternative stable state, and returning to the original state may be difficult or impossible (Cinner and Barnes 2019). The process of reaching tipping points in SES has been described as a change in a system characteristic that exceeds the system threshold and causes a transition to another state by positive feedback and, possibly, lack of a governance response to the initial change (Hossain and Szabo 2017, Refulio-Coronado et al. 2021). In fisheries oceanography and coral reef ecology, the concept of "regime shifts"—which refers to changes in environmental conditions that favor the dominance of one species over another—has been more widely applied (Dudgeon et al. 2010, Bell et al. 2021, Sguotti et al. 2022, Blöcker et al. 2023).

One case study explicitly focused on tipping points and identified when ecosystems or individual ecosystem components would tip into an undesirable stable state, using machine learning algorithms and data on environmental and anthropogenic stressors (Tam et al. 2017). Three case studies reported the possibility of tipping points to occur or having already occurred, e.g. eutrophication in a coastal ecosystem, the transition of kelp forests to urchin barrens, and the stock collapse of the Newfoundland cod (see Appendix 4).

Based on the group discussion after the conference session (see Appendix 3 for transcribed responses), existing methods to assess SES tipping points were perceived as overly complex and noisy. Participants emphasized the importance of using indicators and focusing on key trends and system properties to simplify complex dynamics, as well as the need to clarify the timescales over which methods yield meaningful results. They also noted that methods for detecting tipping points or early warning signals are often data-intensive and commonly applied in disciplines other than those in which they were originally developed. Thus, they could benefit from more comprehensive data and interdisciplinary science. In addition, inter- or multidisciplinary research would naturally increase the likelihood to identify cascading events through positive feedbacks in different SES subsystems.

The absence of any mention of "resilience" in our four case studies dealing with tipping points may indicate limited overlap of this research sub-field with resilience-focused research. Furthermore, in some cases, the term "tipping points" may be used to underline the urgency of a topic, instead of linking to a description of system behavior. This observation is supported by our purposive literature review, in which "resilience" and "tipping points" co-occurred in only 9% of the analysed original research papers (9 out of 103) and only 27% of the reviews (7 out of 26) included a definition of "tipping points" (Fig. 2c and Fig. S1 in Appendix 5).

Resilience

Resilience combines aspects of the three concepts treated above. Resilience is understood as an internal property of a system, describing its capacity to maintain relevant sys-

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tem characteristics or the provision of system services in the face of an external disturbance or shock, which may include biophysical, social, economic, institutional, and political factors (Refulio-Coronado et al. 2021 and references therein).

A primary outcome of the session discussions on resilience was that understandings of the concept vary among researchers and across disciplines. The concept of "vulnerability was much more often addressed explicitly than the concept 'tipping points'" (Fig. 2d). Blanz et al. (2024) quantified resilience as the probability of a fish stock collapse. The case study by Lowe Mackenzie et al. (cf. Appendix) calculated impacts to economic welfare under scenarios of coral reef decline for residents of Hawaii by estimating compensating variation—a measure of the monetary compensation required to maintain residents' utility levels under changing ecological conditions. Tam et al. (2017) used species richness and diversity to describe ecosystem resilience. The vagueness in definitions of the concept of resilience are likely explaining the relatively low number of case studies (3 of 9) explicitly researching resilience. Marine SES are complex systems and their research by definition explicitly requires a multi- or interdisciplinary perspective. Yet, every complex SES is different, and so our case studies vary in scientific disciplines and SES subsystems being examined. Thus, it is not surprising to find a plurality of concepts and definitions for the same boundary object: resilience.

This vagueness in defining resilience was corroborated by the answers given by participants to survey questions (Appendix 3). Participants described existing methods for assessing marine SES resilience as challenging to apply, noting that these methods are often vague, overly specific, or too theoretical, as they rely heavily on model outputs or statistical analyses. Participants also pointed out that the methods used to assess resilience are too focused on economy and do not include strong indicators of culture (e.g. traditional practices). Instead, methods should account for the importance of scale (individual, population, community, ecosystem) and consider shifting baselines. According to participants, these methods could be improved by accounting for coupled modeling, communicating the limits of statements and results, include qualitative approaches, consider all dimensions of resilience (human, physical, biological), recognize biodiversity indicators, and identify better targets/goals.

Consistent with participants' perceptions, Woods et al. (2022) found that most studies on fisheries adaptation focus on ecological resilience and climate change adaptation, while social resilience is often overlooked. Despite the lack of a clear consensus on the definition of resilience within a single discipline—such as ecology—recent research has proposed more uniform approaches to its quantification (e.g. Sguotti et al. 2024).

Both in the presentations and the participatory activity led by session contributors, resilience was not only vaguely defined but often implicitly referenced rather than explicitly articulated. This finding aligns with our own literature review, which revealed a relevant proportion of studies referring to "resilience" without clearly defining it. Only 56% of the original studies (n = 57 of 103) included an explicit definition (Fig. 2c). Even among review papers—where one might expect greater conceptual clarity—35% (n = 9 of 26) did not define the term (Fig. S1 in Appendix 5). In Fig. 2, we show (a) the most commonly used resilience definitions by author and publication year, based on our bibliographic search, and (b) the four most frequently cited resilience definitions.

To address the conceptual vagueness surrounding resilience and enhance understanding of current and future changes in marine SES, we argue that researchers across disciplines should explicitly state the definition of resilience they apply, as well as the specific SES components considered (e.g. ecological, social, economic, or multiple). The same applies to resilience related concepts such as vulnerability, adaptive capacity, tipping points, as well as other "unifying concepts" in ecology and SES research (e.g. ecosystem stability; van Meerbeek et al. 2021).

Toward a common understanding of resilience for marine SES research

Specific recommendations can be given even for studies focusing on partial aspects of resilience. Studies on adaptive capacity would benefit from attempting to consider the multiple dimensions of adaptive capacity in human communities, as opposed to considering only a limited set of responses by a specific user group, e.g. a spatial shift in a fishing fleet (cf. Fig. 1, Carpenter and Brock 2008, Cinner and Barnes 2019). Studies of vulnerability should clarify if they refer to a framework including aspects of "exposure," or to later definitions only considering aspects of sensitivity and adaptive capacity. Assessments of tipping points or regime shifts should explicitly incorporate interactions with human subsystems—going beyond the ecological components of SES—to include societal dimensions of adaptation. This would support a more integrated understanding of system dynamics. Even studies focusing on a subset of system elements can contribute to advancing integrated SES research by explicitly considering potential interlinkages in system responses and identifying connections to resilience. Moving toward a systems-integrated description of resilience may enable us to move beyond one-dimensional, disciplinary assessments of impacts, which do not incorporate knowledge about interactions among subsystems and feedback loops. This is exemplified by a fisheries case study, in which reduced fleet capacity and/or range of target species of a fishing fleet after a decrease in fish biomass can be understood as a reduction in adaptive capacity from a socio-economic perspective (e.g. Stelzenmüller et al. 2024, Beckensteiner et al. 2024). However, from an ecological perspective, those changes can increase adaptive capacity in the long term, as pressure on the ecosystem and the risk of overfishing are reduced. Integrated measures of resilience across SES subsystems would thus consider both social and natural aspects. This underlines the importance of being aware of and mentioning SES elements not directly assessed in the study, which can be supported for example by incorporating input from local stakeholders or an extended literature analysis. A methodological pluralism that enables an adequate understanding of complex systems (Norgaard 1989) should go along with an awareness of terminology and categories of resilience when describing system impacts and changes.

To enhance our understanding of the functioning of marine SES and support better-informed decisions regarding their management and governance, we provide the following recommendations (Fig. 3) for studies focusing on marine SES re-

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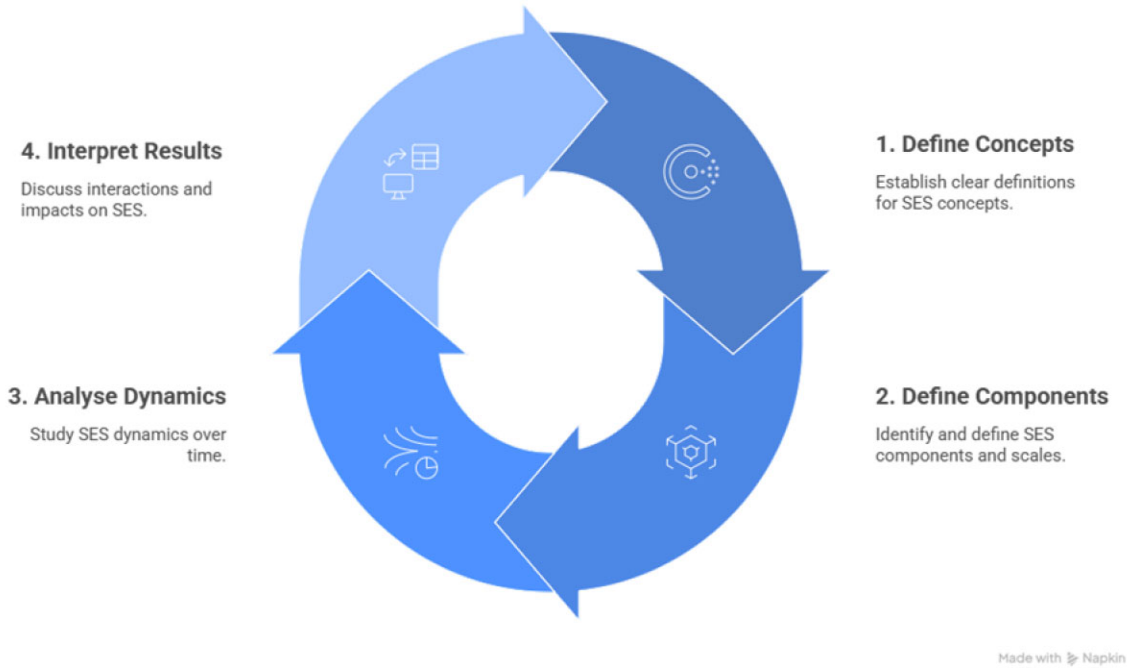

Figure 3. Proposed workflow and recommendations for conducting studies on marine social-ecological system (SES) resilience and related concepts (Figure generated with https://app.napkin.ai/, 22 September 2025).

silience and related concepts (viz. vulnerability, adaptive capacity, tipping points):

(1) Present clear (working) definitions of the respectively applied concepts.
(2) Define analysed SES components and the temporal and spatial scales of analysis.
(3) Analyse SES dynamics over time and try to identify potential positive and negative feedback loops in system behavior. Where feasible, apply numerical methods and indicators to assess the responses of the SES under study.
(4) Interpret results within a holistic SES framework, including a discussion of potential interactions and impacts on system components beyond the primary focus of the study.

We argue that following a more unified set of aspects and evaluation criteria in applying resilience and other related concepts in marine SES would allow to: (i) gain a better general understanding of how different drivers impact SES functioning; (ii) compare impacts of different drivers in a SES at different temporal and spatial scales; (iii) systematically compare how different marine SES and their individual actors respond to similar external drivers; (iv) improve multidisciplinary collaboration in the study of marine SES by providing boundary concepts for different fields. Based on a common understanding of concepts, it is then possible to develop comparable measures and methods across disciplines.

Advancing the explicit treatment of SES resilience and related concepts in the interdisciplinary marine science community necessarily leads to interesting and stimulating discussions, new encounters, and crucial insights for ongoing scientific debates. The group activity during the MSEAS 2024 conference described herein provided an excellent opportunity and a good example of how the parallelity of a conference session can be turned into a consolidating, fruitful endeavor, bringing together researchers from different disciplines and regions of the world. Even more importantly, this advances the integrated understanding of marine SES resilience in the scientific community, and enables us to move toward a more sustainable use of marine and coastal systems by facilitating a discursive common ground. We strongly believe these fruitful, mutually enriching learning exchanges should be given space, at scientific conferences and beyond.

Acknowledgments

We thank all participants of MSEAS 2024 Session 10 for their valuable input and the anonymous reviewers for their constructive comments.

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Supplementary material

Supplementary data is available at *ICES Journal of Marine Science* online.

Conflict of interest: None declared.

Funding

I.M. was supported by the Portuguese Foundation for Science and Technology through FCT-IP Program Stimulus of Scientific Employment (https://doi.org/10.54499/2021.03721.CEECIND/CP1665/CT0005), CIIMAR's strategic funding UIDB/04423/2020 and UIDP/04423/2020, and the project SHIFT-MARES (CEXC/5710/2024) funded by PLANAPP(Portugal). J.L. was funded by the project SEAwise (Horizon 2020; 101000318). S.K. was funded through the NOAA Climate Program Office, Climate and Fisheries Adaptation Program, and through the Research for Sustainability (FONA) program of the German Federal Ministry of Education and Research (BMBF). M.L. was supported by a PhD-fellowship (FPU program) and the project BITER (PID2020-114732RB-C31) of the Spanish Ministry of Science, Innovation and Universities. E.Q. and B.B. were supported by The German Federal Ministry of Education and Science as part of the SeaUseTip Project [grant no. 01LC1825C, 2018]. L.E. acknowledges the contribution to the European Union's Horizon 2020 research and innovation programmes under grant agreement no. 869300 (FutureMARES project) and No 101059877 (GES4SEAS), as well as the support from the Catalan government through the iMARES research group of quality from the Institute of Marine Sciences (ICM-CSIC) and the "Severo Ochoa Centre of Excellence" accreditation to ICM-CSIC (#CEX2019-000928-S). L.E. and M.L. attendance to the MSEAS conference was also financially supported by ICES and PICES organizations. J.S.-C. was supported by JST SPRING (grant no. JPMJSP2106) and CONAHCYT (CVU 1108919). T.T.-O. was supported by the Marine Stewardship Council's Ocean Stewardship Fund for Student Research Grant funding and Consejo Nacional de Humanidades, Ciencias y Tecnologías (CVU 775707).

Data availability

The data underlying the findings of this study are available from the published literature and in its online supplementary material.

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