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Governance mapping: A framework for assessing the adaptive capacity of marine resource governance to environmental change

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ABSTRACT

Marine social-ecological systems are influenced by the way humans interact with their environment, and external forces, which change and re-shape the environment. In many regions, exploitation of marine resources and climate change are two of the primary drivers shifting the abundance and distribution of marine living resources, with negative effects on marine-dependent communities. Governance systems determine 'who' makes decisions, 'what' are their powers and responsibilities, and 'how' they are exercised. Understanding the connections between the actors comprising governance systems and influences between governance and the environment is therefore critical to support successful transitions to novel forms of governance required to deal with environmental changes. The paper provides an analytical framework with a practical example from Vanuatu, for mapping and assessment of the governance system providing for management of coral reef fish resources. The framework enables a rapid analysis of governance systems to identify factors that can encourage, or hinder, the adaptation of communities to changes in abundance or availability of marine resources.

1. Introduction

Climate change is already influencing the abundance and distribution of marine living resources in many parts of the world [1–6]. This has profound consequences on the functioning of ecosystems and, consequently, affects well-being of marine-dependent communities deriving both direct (e.g. consumption and sale of fish) and indirect (e.g. tourism) benefits from the resources [4,7,8]. These changes tend to have negative effects but may also provide opportunities and positive outcomes in certain circumstances and geographical locations [9]. Negative effects include conflicts between traditional, recreational and commercial fishers over reduced availability of marine resources [10], while positive changes may include new harvesting opportunities [11]. However, a gain for one community, industry or region may be a loss for another. For example, the shift to the north and west of mackerel in the North Atlantic in the early 2000s, possibly associated with climate change, resulted in a decrease in abundance of the species in Norwegian waters and an increase in the waters of the Faroe Islands and Iceland. The increased abundance in their waters led the Faroe Islands and Iceland to make unilateral decisions to increase their quotas substantially, leading to conflicts with Norway and the EU, which also fish for mackerel in this region [12].

Autonomous and planned adaptation efforts by fishers, industry, and management authorities to the changes in the resource system can

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be inhibited by barriers related to governance [13]. This is particularly relevant in building adaptive capacity of fisheries in the context of climate change [14]. Indeed, many problems observed in the biophysical environment can be attributed to the functioning or malfunctioning of governance systems – actors (individuals and organisations) and systems of rules (institutions) structuring their interactions. Perverse market incentives, lack of enforcement measures, poor monitoring and licencing systems, absent or inappropriate user rights control, loss of traditional management knowledge and authority are among the causal determinants of human actions that degrade the marine environment and increase the vulnerability of marine-dependent communities [15–17]. Dealing with ecosystem changes and overall resource sustainability arguably requires adaptive governance which can anticipate environmental changes, develop and strengthen social networks, build leadership and trust, support the acquisition of knowledge to promote innovative responses to increase benefits, support adaptation, and minimise associated negative impacts to communities [4,18–21].

There is a high degree of common understanding of the general structure and processes required for effective governance of human use of marine resources, for example through fishing. The details and the effectiveness of these structures and processes vary substantially across different scales of activity, value of the activity and available governance or management capacity [e.g. [22]] but the fundamentals remain the same. In essence, effective marine governance requires understanding the social, economic and ecological features and dynamics of the system. It also entails being clear about the objectives, and setting rules and regulations to achieve those objectives, ensuring as far as possible that those rules and regulations are adhered to. Another important aspect is to monitor changes in key indicators of social, economic and ecological status and well-being, and revising the rules and regulations, and sometimes objectives, as necessary to respond to change [23–25].

The current prevailing practice in fisheries, as an important example of marine resource use, is that the ecological, or biological, objectives for a particular case are typically set in the form of reference points, either targets to be aimed for, such as a preferred biomass or abundance at which sustainable yield remains high, or limit reference points, below which yields become low and sustainability may be threatened. A wide range of management tools can then be applied to ensure that use of a resource adheres to those reference points [e.g. [26]]. When applied effectively, these tools have frequently been found to achieve the desired results under relatively stable conditions but they were not designed to build resilience and, while still necessary, are not necessarily sufficient under substantial environmental change, including climate change. For marine resource use governance systems to cope with climate change, they need to be able to respond both to known or expected changes and also unexpected surprises [26].

Understanding the intricate connections between the actors comprising governance systems and between the governance system and the environment is therefore critical to support successful transitions to novel forms of governance required to deal with environmental changes. However, developing an understanding of the structure and functioning of marine governance systems is challenging [27]. Such understanding must cross scales to develop a sound appreciation of social and environmental dynamics, and to identify key institutions and actors that influence adaptation at these different scales. It also requires gaining insights into the behavioural attributes that influence individual and organisational decisions in order to better anticipate their effects on the resource system and to determine the best course of action.

There is a growing body of the literature that identifies a range of governance attributes that are positively linked to successful adaptation of resource-dependent societies to environmental change [e.g. [21,28–30]]. A range of frameworks and analytical approaches have been developed to assist with the identification and analysis of various individual, community and management attributes, as well as political and economic aspects that influence adaptive capacity of marine communities [see [31]]. They include vulnerability assessments [27,32], and analyses of implementation of ecosystem approaches to fishery management (EBFM) [16,25,33,34]. Researchers have also identified specific management attributes that contribute to sustainable harvest outcomes [e.g. [23]]. However, studies that aim to analyse the complexities of governance and the relationships between governance and ecological systems across different social, economic and political contexts are rare. Proposed frameworks and sets of adaptation principles and criteria tend to offer general insights into various governance attributes deemed relevant for climate change adaptation. At the same time, they do not uncover complexities of individual governance systems to demonstrate how they incorporate proposed attributes or could be reformed to improve adaptive capacity. In particular, substantial knowledge gaps remain with respect to methodological approaches to analysing complex governance systems in diverse marine-dependent communities [but see [35]].

This article presents an analytical framework and practical guidelines designed to gain detailed insight into relevant aspects of the operation and structure of marine governance systems to examine their capacity to adapt to changes in marine resources. It builds on Ostrom's Institutional Analysis and Development (IAD) framework [36,37], which is a generic framework that disaggregates (or 'unpacks') components of complex social-ecological systems (SES) into common sets of elements. The framework has been widely applied to structure analysis of various common-pool resource management systems, including fisheries [e.g. [38,39]] and is constantly refined following tests in different situations [40]. We unpack components of the IAD framework by structuring several sub-systems of marine resource governance to develop detailed understanding of how these components interact and affect the state of the resource system. Governance mapping [29,41] is employed as a method to capture and visualise the dynamics of the system. The framework provides foundation for the assessment of marine governance systems to identify specific gaps and opportunities and the ability of actors to address environmental problems, including climate change.

The next section of the paper describes the conceptual foundations of the study after which governance mapping is described. The framework for assessing the vulnerability of marine governance systems is demonstrated using a case study from Vanuatu in the Western Pacific.

2. Conceptual background

2.1. Governance, institutions and actors

The concept of 'governance' describes 'who' makes decisions, 'what' their powers and responsibilities are, and 'how' they exercise this power and influence [42:116]. Governance generally consists of two interacting components: the institutional framework and the organisational system [43:28]. While institutions define how actors work, actors respond to institutions and may in turn shape and modify them [44].

In essence, institutions structure human interactions with the purpose of creating greater behavioural regularity and increased predictability of interactions and outcomes [44,45]. Institutions can include 'formal' (written) rules that are articulated in laws, regulations, agreements, policies, plans and other regulatory instruments, and 'informal' rules [39] which are embedded in established practices, customs, shared discourses, informal agreements and understandings, roles and routines (i.e. social norms) [46,47]. Both formal and informal rules tend to operate in parallel and are considered effective (i.e. rules 'in use') when they define and transform behaviour [48:54].

Individual actors are the smallest 'acting unit' [47] of the governance system undertaking different roles. They can, for instance, be customary leaders, resource managers, fishers and/or consumers. Their behaviour in these different roles is influenced by the formal and

informal rules as well as their individual attributes such as their information processing capacity, worldview, preference or motivation, and capabilities [45,47,49–51]. Individuals are also affected by emotions and unconscious motivations which influence the way they interpret information and make decisions [50,52–56]. As such, psychological and social processes interact and create an exchange system in which power relations, personal motivations, conflict, cooperation and coordination shape decision-making [51,57].

Individuals can operate as an organised body of people (organisational actors), who have a particular purpose [43:28] and are guided by a set of rules that structure their interactions to achieve organisational goals [45]. A community, government agency, fisheries body, or a commercial business are all examples of organisational actors. In marine SES organisational actors may perform different functions such as fishing compliance monitoring, post-harvest production, or servicing of the sector [58]. The behaviour of these organised groups of actors is determined by individual processes as well as the organisational goals and processes, interpersonal information processing capacities, and available human, technical and financial resources [49]. The ability of organisational actors to learn and create, or modify, norms, policies, and objectives will affect their ability to adapt [43].

In resource management governance systems can take many forms. Each comes with particular advantages and disadvantages, but with respect to fisheries management they can be grouped in the following five types [according to [39, 57]]:

a) Bureaucracy-based: The government owns the resource property rights on behalf of the public. The focus is on developing regulation to sustainable stock levels while also meeting social and economic objectives (input controls). Developing management plans can be quite a fraught process when trade-offs between objectives and stakeholder groups apply and conflicts arise. Policy adjustment can be costly and time-consuming and the ability to adapt to, for instance, stock fluctuations, technological advances, or changing socio-economic and political conditions can be reduced.
b) Market-based: Property rights are transferred from government to resource users, for instance, using individual transferable quotas (ITQ) in combination with the total allowable catch (TAC; an output control). The role of the regulatory authorities is to determine the TAC and to distribute this among rights holders, in some cases allowing temporary or permanent transfers of the rights. Compared to a bureaucracy-based arrangement, a market-based arrangement is, in principle, more adaptive because decisions on TAC are determined on a yearly or seasonal basis. Adjustments to the TAC are mostly driven by environmental factors. However, quotas may be also influenced by social, economic or even political considerations. Generally economics factors prevail and less emphasis is placed on social objectives, such as maintaining social equity and small-scale fishing communities [59].
c) Community-based: Property rights are held by a community of people or a sub-group within a community. While different types of regulation can structure the system, the behaviour is influenced by social norms which can also sanction non-compliance. Different goals and values can be embedded in community-based arrangements, which may contrast with commercial harvest initiatives. These include resource user control, the preservation of community culture and transmission of traditional knowledge, internal accountability, and preservation of small fishers and communities. Adaptation may be aided or hindered in community-based management depending on the flexibility and inherent strength of the social or cultural system within which it is embedded [60].
d) Co-management: The management responsibility is shared between government and user groups [61]. Co-management arrangement can be combined with market-based incentives (i.e. where ITQ rights-holders agree on the TAC for the next period). Co-management forms have been developed as they can create a sense of ownership and responsibility and improves decision-making and uptake of local knowledge. For example, local knowledge can improve the quality and timeliness of information used to manage these systems. They can also result in better choices of alignment of local conditions and the institutional arrangement, which in theory can reduce transaction costs. Co-management arrangements are unique in that they can combine policy instruments to fit local conditions.
e) Network governance: An autonomous governance system with legally independent actors who create "products or services based on implicit and open-ended contracts to adapt to environmental contingencies and to coordinate and safeguard changes" [57]. This type of governance supports learning through network connections and appears to be more adaptive. For this reason it is becoming more frequent in common-pool resource management such as fisheries [62,63] and in resource conservation [64]. In practice, hybrid forms of governance are often applied with elements of a–e [e.g. [65,66]]. For example, formal inclusion of fishers in management decision-making sometimes requires bureaucratic regulation of the fishery as an industry [67].

Policy objectives can be achieved in different types of governance systems [28]. However, understanding how they operate and perform in particular contexts is important to identify challenges and opportunities to improve resource use, management and adaptation [39].

2.2. Social-ecological systems and the institutional analysis and development framework

The Social-ecological systems concept [68:18,69] places emphasis on the interdependencies between people and ecosystems, and complexity of ecological, social and social-ecological interactions. Ostrom [69:419] identifies four universal and interacting building blocks of regularised social interactions at any governance level: resource systems (e.g. fishery, grazing areas); resource units (e.g. fish, feed); governance systems, and users. The components affect each other and associated social, economic and political settings and related ecosystems [see [70], also in Appendix A].

The IAD framework [36,37] conceives SES through the lens of nested 'action arenas', which are the social spaces where actors interact [70:11]. They consist of actors – individuals and organisations – who make choices in various action situations and produce particular modes of interactions and outcomes. Action arenas are affected by three sets of exogenous variables: (a) biophysical and material conditions, (b) the attributes of the community, and (c) the rules or set of instructions that lead to an action situation [47:17]. We apply the concept of action arena to further unpack the structure of marine SES.

2.3. Functional structure of marine SES

Governance systems can affect the functioning of marine SES in many different ways. For example, the rules can prescribe the boundaries of the resource system, specify what and how many resource units can be harvested, and in which locations and during which time periods. The rules can define who has the right to harvest and which technologies are allowed. They can also specify resource and compliance monitoring and sanctioning processes, and information gathering and exchange processes. Actors can be authorised to change some of the established rules or adopt new rules [40]. In practice, there are multiple types of actor interactions and outcomes which cumulatively affect human-resource interactions and outcomes. This raise the issue of how to approach governance characterisation and assessment in a structured way.

In essence, actors make choices and interact in interconnected subsystems in various action situations and produce a broad range of outcomes [40,71]. As McGinnis [71] demonstrates, any resource governance system can perform at least nine generic functions:

Table 1
Governance sub-systems performing key governance functions in marine social-ecological systems.

Sub-systems	Description
Resource planning and regulation (rule-making)	Governs actors' involvement in regulation of resource allocation, extraction and distribution
Resource allocation and extraction	Governs actor – resource interactions, including resource use, ownership, allocated amounts, extraction technologies, permitted harvesting areas, seasons and types of resource units.
Consumption, production and distribution	Governs consumption, processing, distribution and sales of marine resources
Compliance monitoring, sanctioning and conflict resolution	Governs control of harvesting activities, compliance and conflict resolution
Resource monitoring and information exchange	Governs monitoring of the state of marine resources and processes of knowledge/information generation and exchange

Fig. 1. Key linkages of governance sub-systems in marine social-ecological systems.

consumption, financing, production, provision, monitoring and sanctioning, rule-making, coordination and dispute resolution. Drawing on this study, the IAD framework [69] and review of interactions that tend to be regulated in fishery statutes, we propose to distinguish between five functional governance sub-systems in marine SES (Table 1). They produce different sets of outcomes – regulatory framework (*Resource planning and regulation*), extraction levels (*Resource allocation and extraction*), resource demand (*Consumption, production and distribution*), compliance (*Compliance monitoring, sanctioning and conflict resolution*), and knowledge about the state of the resource (*Resource monitoring and information exchange*) – cumulatively affecting human-resource interactions in the SES (Fig. 1).

In what follows, the application of the governance mapping analytical framework will be demonstrated to unpack a marine SES, map its elements and assess their potential to contribute to, or hinder, adaptation to changes in the resource.

3. Methods

3.1. Governance mapping

Governance mapping is a process of cognitive or conceptual mapping; a methodology used to help articulate ideas in a manner that unpacks meaning to the degree that others can understand [29,72]. Governance maps depict the actors–both individuals and organisations–in their social positions and their existing or potential interactions in 'action arenas' mediated by institutions [41,72,73]. Maps can depict actor networks within one or across several governance systems.

The approach proposed in this paper consists of four steps to collect data and construct maps to describe and assess marine governance systems (See Appendix A for more detailed instructions).

3.1.1. Define the policy issue

Governance mapping is purpose driven and aimed at addressing

specific policy issues and problems [29]. The first step is to define the policy issue of concern and select focal unit(s) of analysis [40]. This includes the definition of system boundaries, such as geographical area (e.g. coastal zone, reef), type of resource (e.g. targeted fish species, ecosystem), and the nature of human-environment interactions (e.g. resource extraction, pollution, conservation) (Table A1; Appendix A). Confining the analysis to specific policy issues and focal units (e.g. particular coastal communities) is necessary as many large-scale policy problems, such as climate change adaptation, can be otherwise overwhelmingly complex and involve large numbers of actors operating at different administrative levels and scales.

3.1.2. Describe the SES

Identifying and describing socioeconomic and biophysical characteristics of the SES are essential to understand the challenges that affect the resource and identify which institutions and actors are or can be effective in addressing them. Ostrom's elaboration of the components of SES [69,74] provides a useful approach to identify the range of variables affecting the operation and sustainability of SES (Table A2; Appendix A; see also [75,76]).

Marine SES are not isolated units. Various pressures such as water pollution, agricultural runoff and coastal development can influence the abundance and distribution of marine resources [77]. Examining how these sectors interact and influence one another enables the identification of external opportunities and threats affecting the SES and people's capacity to adapt to current or future changes in the resource (Table A3; Appendix A).

3.1.3. Identify actors and interactions

A governance map cannot be produced until the causal links between exogenous variables, actors, interactions and outcomes are established. The process of gathering institution-actor data consists of two interactive steps. The first involves identifying and describing actors in positions (e.g. resource users, knowledge providers, enforcement authorities) (Table A4; Appendix A). The second involves determining patterns of interactions and the rules that authorise or influence the interactions within a sub-system (Tables A5 and A6; Appendix A). The main output of this step is data tables that support the development of governance maps (Section 3.1.4) and governance assessment (Section 3.2).

In climate change adaptation research, this step involves obtaining data on actor's attributes that influence their ability to adapt to changes in the resource system selected for the analysis. Actors in marine SES are constantly adapting in response to resource variability (e.g. ecosystem and management changes) [78]. For example, important attributes of resource users are their motivation to undertake actions required to (sustainably) exploit the resource (e.g. decrease catch, switch to consumption of other resources, change equipment, cooperate with other users), their capacities (e.g. skills, availability of resources to switch to extraction of other species, access to other sources of income), and ability to learn and obtain information about the state of the resource [78,79]. Authority, trust, leadership, flexibility to make decisions, capacity to obtain information and enforce rules are important attributes of management authorities [[79] and references within].

3.1.4. Create governance maps

Visual maps are created to represent the governance system in graphic form. In mapping governance systems, it is important to define the levels of complexity, depth and detail to be included in each subsystem or component and be clear about the intended audience, aims and outcomes of the map. For example, in some cases a map of the relationship between governance sub-systems will be sufficient to depict the issues related to governance. In other cases, it will be necessary to detail the actors in each sub-system according to rules governing the interactions between them, and to represent the outcomes from these interactions.

The mapping process starts with a list of actors and interactions (See Table A7, Appendix A as example) and involves the choice of map elements and symbols, and decision on how to represent relationships in the map, e.g. colours, shapes, lines. This is a very important step and should not be neglected as the adequate choice of map elements is essential for system understanding and effective communication. In the example described in Section 4 we chose to represent the 'Resource planning and regulation' sub-system in black and white as a relationship map. A white circle and a thick black outline represent 'government' and 'community' authorities; one letter inside the circle was used to represent their names. Actors are represented as flat coloured circles with white text within, in the form of two uppercase letters that identify actor names. White circles with thin black line represent actions or authority, connecting 'government' and 'community' to actors. Full lines represent an interaction that is known and understood and that must happen for the action to flow. Dashed lines represent interactions that are optional or not well understood.

The relationship map does not show, however, how specifically each actor navigates the system and what roles or positions they have in other sub-systems (e.g. consumer, knowledge provider etc.). Hence, there might be a need to create a "story cycle" diagram for each of the actors to show, mostly in a sequential logic, how they behave in the system - their actions and interactions with other actors – to accomplish their aims. The Actor Story Cycle is based on the actor-interaction table (Table A7; Appendix A) where interactions of each actor are detailed. The Story Cycles are accompanied by information about the actor and their roles and motivations. For the Story Cycles a white circle with a thick coloured outline and two letters to represent their names were used. The sub-systems are colour coded, meaning that every actor that belongs to a particular sub-system is represented with the same colour. Actors are represented as flat coloured circles with white text within, in the form of two uppercase letters that identify actor names. Full and dashed lines were the same as in the relationship map.

3.2. Framework for assessing vulnerability of marine governance systems

The assessment step evaluates how the SES governance performs against criteria characterising effective adaptation. It requires decisions regarding the following assessment design elements: (1) assessors; (2) points of reference, (3) assessment criteria and (4) assessment methods, discussed in detail below.

3.2.1. Select assessors

Assessment of governance can be undertaken using a range of techniques from interactive participatory approaches to more rapid expert appraisal. Selecting assessors thus depends on the nature of assessment, which can range from a first-pass rapid assessment to a full in-depth assessment. A rapid assessment can use the literature and expertise of the assessors to provide a preliminary, or 'first-pass' assessment of one or more sub-system of interest. It can be undertaken without detailed data to develop a preliminary understanding about the governance issues [80]. In this assessment there is a risk of bias and incoherence due to limited information sources and focus of expertise [81,82]. Experts' bias can be reduced through open discussions between assessors about how they scored [82]. In order to cover different aspects of governance performance, it is also recommended to employ an interdisciplinary team of people (e.g. economics, political science, law, marine ecology, fisheries) who have knowledge of the design and operation of the SES in question. For the first-pass assessment of the case study (Section 4), we have involved a small group of experts (scoring process and assessors' expertise are provided in Appendix C).

An in-depth assessment requires involvement of a broader group of assessors to describe and assess the five proposed sub-systems. Assessment can be conducted via surveys targeting a representative sample and categorising data for detailed analysis of responses (e.g. managers, resource users, male/female, age groups, etc.). A 'Delphi

type' expert assessment method [83] can also be applied to the broad stakeholder group.

3.2.2. Define points of reference

Assessment design involves the selection of normative points of reference to which observed results can be compared and classified [84,85]. Governance maps generally depict actors, interactions and outcomes as they exist at a selected point in time. While the baseline reference point tends to be the current state of the resource system, different adaptation objectives can be selected for different timeframes to assess the ability of governance system to cope with future changes. For example, one can look at the adaptation objective of maintaining marine livelihoods where current extraction levels of a certain species are high (baseline). These can be changed and contrasted with alternative arrangements and biophysical drivers. For example, through the use of scenarios in simulation models that can incorporate both the biophysical projections and potential responses, such as restrictions in extraction levels enforced through improved customary or government authority [86,87:300–30].

3.2.3. Select assessment criteria

Criteria are normative statements specifying what performance aspects are evaluated [85]. Assessors are required to identify and determine the relevance of various governance attributes from both institutional and organisational components of the governance system in relation to the problem under analysis and evaluate how they can potentially assist with or hinder the ability of the SES to cope with and adapt to environmental changes.

The diversity of actors and interactions in marine SES implies dealing with a broad range of governance attributes and evaluative criteria. Different disciplines of environmental and social sciences have provided a variety of insights into issues affecting adaptive capacity of these SES [e.g. [69,74,79,88]]. Appendix B provides a non-exhaustive list of attributes and assessment criteria that play a role in environmental change adaptation and is based on a literature review [Tables A8 and A9 Appendix A, [79,89]] contextualised into the variables of the IAD framework affecting interactions and outcomes [69,74], combined with the authors' expertise. These are organised by governance sub-system. The list is non-exhaustive, flexible and can be used as a starting point in the development of assessment criteria. This means that criteria can be added or modified to reflect the particular circumstances of the SES under study. Each attribute or criterion may have different relevance for different policy issues or marine SES selected for the analysis. Therefore, their relative relevance can be assessed by scoring the attributes and/or criteria, which can be performed as an aggregation (e.g. mean values) at the appropriate level (e.g. sub-system, Actors, Interactions and Outcomes).

Table 2 provides governance attributes and assessment criteria for the Resource Allocation and Extraction sub-system, used in the example presented in Section 4 to support a first-pass assessment and illustrate the application of the analytical framework.

3.2.4. Select assessment method

In this study we illustrate the use of a semi-quantitative scoring system [which is a robust approach in other studies, see [90,91]] using standardised metrics that are comparable across different assessment criteria (Table 2) and potential case studies.

The assessment of governance involves assigning scores for criteria characterising interactions (I), actors (A) and outcomes (O) for each sub-system. An overall 'governance' score can be calculated based on the scores of criteria. Scores for individual sub-systems or for individual governance attributes (Actors, Interactions and Outcomes) can also be presented and contrasted to help identify issues and opportunities in the governance system depending on the objectives of the scoring exercise. For example, in the case study (Section 4) the objective of the scoring exercise was twofold: to characterise the governance system and identify constraints and opportunities for adaptation in the Resource Allocation and Extraction sub-system. The scoring system presented in Table 3 has been used.

Assigning semi-quantitative scores to criteria to evaluate different attributes of the SES governance helps identify gaps and opportunities for each policy issue and is useful for comparative analysis. Such

Table 2
Attributes and assessment criteria characterising adaptive capacity of SES for Resource Allocation and Extraction sub-system.

Actors holding authority to control or allocate access to the resource (A)	Authority is allocated to actors that have interest in long-term sustainability of the resource (i.e. motivation to sustain the resource) Authority is allocated to actors that have a knowledge of the resource system or capacity to obtain the knowledge (i.e. learning capacity) Authority is allocated to actors that have the capacity to undertake the role (e.g., availability of human, financial and technical resources) Authority is allocated to actors that are trusted Authority is allocated to actors who have ability to facilitate cooperation and coordinate activities between the various resource harvesters and users
Resource harvesters (A)	Resource harvesting rights are allocated to actors that have interest in long-term sustainability of the resource Resource harvesters are able to switch to harvesting of other resources or other sources of income Resource harvesters have knowledge about sustainable harvest amounts and practices in their area Extractive capacity of resource harvesters matches sustainable resource yields
Management authority allocation (I)	Actors are enabled to control/adjust seasons, zoning or use other instruments to reduce pressures on the resource Actors are enabled to control/adjust resource amount or numbers of harvesters Actors having stake in the resource are enabled to participate in the management of the resource (e.g. co-management arrangements)
Resource allocation and management (I)	Resource allocation processes are transparent and trusted Collection and use of resource access fees is transparent and trusted Effective integration of knowledge that supports resource allocation and management Learning approach to allocation and management
Impacts on the resource (O)	Sustainable extraction levels Sustainable distribution of fishing pressures in the fishing area Sustainable interactions with other systems (bycatch, impacts on other resources and supporting ecosystems)
Socio-economic outcomes (O)	Benefits shared in a way that is perceived to be fair/equitable. Access fees/other industry contributions are invested in the maintenance/improvement of the resource and SES

Table 3
Scoring system for governance assessment.

Score	Meaning
− 2	Extremely ineffective
− 1	Ineffective
0	Neither effective nor ineffective
+ 1	Effective
+ 2	Extremely effective

comparisons are useful to identify particular governance characteristics that help minimise vulnerabilities and are effective in particular contexts (e.g. climate change adaptation), and situations (e.g. in subsistence-based or commercial fisheries targeting external markets) [27]. However, scores are not meant for scaled comparisons to identify 'better' or 'worse' governance arrangements. The categories used for the scoring can be used to support a broad governance assessment but the 'full story' can only be told using the characterisation framework (Section 3).

4. Results: applying the methodological framework on a case study

An example from inshore reefs in Vanuatu was used to illustrate the governance mapping and assessment analytical framework. Note this is 'first-pass' illustrative assessment rather than a comprehensive definitive one (refer to Section 3.2.1 for differences). Only the 'Resource Allocation and Extraction' sub-system (Table 1) is described to illustrate the analytical framework. The description of the sub-system under analysis follows Aswani et al. [66], Love [92], Llewell [93] and the Vanuatu Fisheries Act [94] as well as extensive regional experience of one of the co-authors (S. Aswani).

The policy issue is overfishing in coral reefs in certain customary areas referred to as 'dead' *nakamal*. Vanuatu people define a "dead" *nakamal* as a specific inshore reef area which lacks direct locally and culturally *recognised* sea owner descendants and leaders to govern the use and access to them [66,92].

4.1. Structure of marine SES

The Government (G), through the Vanuatu National Fisheries (VNF) Act recognises customary owners of marine areas, but also provides for a centralised management where the state is responsible for formulation, implementation and enforcement of policies (solid line between management authority (Am) and G) (Fig. 2). Although traditional practices are not explicit in the VNF Act, they are strongly recognised, in the sense that the VNF Act requires customary owners to be consulted about any issues affecting customary areas. In practice, the government (G) works with customary leaders (chiefs; CL) and communities and often give customary leaders some level of management authority (Am) in marine management or conservation initiatives (dashed line between G and CL). These include the power to enforce, distribute and allocate resources according to traditional laws, thus actively incorporating traditional management systems into overall fisheries management initiatives. This kind of co-management initiative reinforces the powers chiefs (CL) have under customary laws, resulting in fisheries regulations co-existing with traditional management mechanisms (with often positive impacts in fisheries resources; Fig. 3A).

Customary or community fishers (CF) must, in principle, abide to both Fisheries regulations (which they often don't) and traditional laws (solid line between extraction authority (Ae) and CF; Fig. 2). They extract marine resources to feed their immediate family, sell or exchange. The overall catch however is affected by decisions made by all fishers extracting the resources in the area (CF) and Other Fishers (OF; e.g. commercial or illegal fishers–details not covered in this 'first pass' analysis). Other fishers are not bound by customary law (voluntary compliance) and their access and interactions with the resource is determined by the Government actions authorising such access (solid line between Ae and OF).

Problems with resource sustainability, however, emerge in dead *nakamal*, where the community fails to appoint (Ap in Fig. 2) the customary leader. As a result, there is no recognised customary leader with authority to support traditional marine resource management. The government alone, who granted rights to customary fishers, is unable to control access or restrict species extraction and season harvests, because customary authority is disputed. In practice, customary authority is absent or contested in dead *nakamal,* which provides strong incentives for inclusive and non-inclusive customary fishers alike to overfish the resource [see tragedy of the commons, [95,96]] (Fig. 3B). In principle, the Fisheries Act allows the government to facilitate a process where fishers could discuss and agree on how to improve resource sustainability (dashed lines between G, Am, CF and OF), but this link is absent in dead *nakamal*.

4.2. Assessment

The resource allocation sub-system in Vanuatu is shaped by relatively recent history, migration, tenure claims, religion and colonisation [66,92]. This indicates that some of the socio-cultural aspects of governance, such as chiefly forms of political hierarchies (or nodal governance), customary management and tenure systems must be understood in order to promote adaptation.

The assessment is based on interpretation of information derived from regulations [94], peer-review [66,92], and grey [93] literature and was undertaken by the authors (details on expertise of assessors is provided in Appendix C). In Vanuatu both government and customary actors have authority to allocate and control extraction rights of coastal marine resources. Therefore, scores were allocated to both 'formal' and 'customary' governance attributes, where applicable. When information about the attribute was not found in the literature the assessment score was given based on the opinion of the assessment team members having expertise in Vanuatu fisheries or fisheries in the Pacific Islands. Scores were subsequently reviewed by co-authors who have broad expertise in fisheries resource management and governance. A risk of bias due to limited literature sources and focus of expertise was minimised via cross checking scores, and collective discussion and justification of scores within the research team.

The scores for the Resource Allocation sub-system are shown in Table 4. The mean score value for the 'Resource Allocation and Extraction' sub-system is -1.1 (Outcomes: -1.8, Interactions: -0.3, Actors: -1.2), which suggests it may fail in maintaining sustainable extraction levels of the resource over time and is vulnerable in terms of facilitating adaptation to changes in the resource system attributable to changing environmental conditions (Table 4). The rationale for the scores is detailed in following sections.

4.2.1. Authority to distribute fishing rights

4.2.1.1. Government. The Vanuatu National Fisheries (VNF) Act provides for a centralised management where the state is responsible to formulate, implement and enforce policies. The purpose of the Fisheries Act is to ensure the government has a *long-term interest in the sustainability of the resource*, but the government also has other (conflicting) interests such as development and mining, which can affect overall resource sustainability, hence the **score: + 1**. The government has *knowledge about the resource system* but it is not as extensive compared to knowledge locals have about the resource (**score: + 1**).

There is no information from the sources used to score about the *capacity of government to undertake their role to distribute fishing rights*. However, as experience working in the region indicate, the Government, through its Ministry of Fisheries, has very little power to enforce legislation due to lack of human and financial resources (**score:**

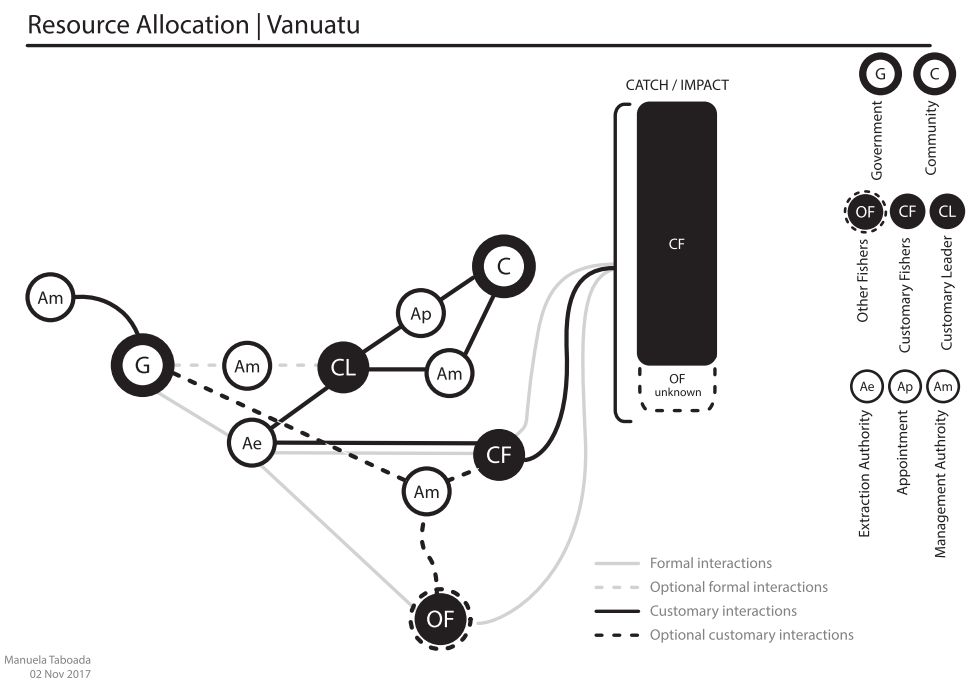

Fig. 2. Non-comprehensive example of governance map for the resource allocation sub-system, showing actors, interactions and outcomes as impacts on fisheries in dead *nakamal*.

-1). Similarly, experience suggests that *trust in government* is low (**score: -1**).

The Fisheries Act gives the authority to the Director of the Department of Fisheries to work cooperatively with other government agencies and fishers on issues related to fisheries. However, in dead *nakamal*, the government is unable to *facilitate sectoral cooperation and coordinate activities between harvesters and users* due to the disputes over customary authority and resource ownership (**score: 0**).

Government authority is weak in dead *nakamal* because of weak/absent customary authority. The government *is not able to learn* because government officials are mostly based in Vanuatu's capital (Port Vila) and are not properly involved in the management of resources in dead *nakamal* **(score: -1)**.

4.2.1.2. Customary leaders. The VNF Act gives people customary rights to land and inshore reefs. Customary authorities have *long-term interest in the sustainability of the resource*. However, dead *nakamal* lack such customary authority due to lack of direct heirs or disputes, which negatively affect the resource because in practice these areas are perceived to be 'open to all' (**score: -2**). Despite the *knowledge about the resource system* and *the capacity to undertake their role* customary leaders have, the lack of customary authority negatively affects the resource **(score: -2 for both criteria)**. The disputes over customary authority in dead *nakamal* highlights the distrust on customary leaders (**score: -2**). Also, the combination of lack of, or disputes over, local authority results in poor *cooperation between sectors (e.g. government, communities, tourism and fishing industries)* and *ineffective coordination of activities* between resource harvesters and users (**score: -2**). Customary leaders have no authority over the resource and therefore, they are unable to learn from undertaking this role **(score: -2)**.

4.2.2. Resource harvesters

4.2.2.1. Customary fishers. The VNF Act gives *resource harvesters, who have an interest in the long-term sustainability of resources,* rights over inshore reef within certain limits established both by customary and national laws. However, given the lack of customary authority to manage access to the resource, dead *nakamal* are 'open to all' and overfished (**score: -2**). Customary *harvesters are able to switch to other resources or sources of income*, when opportunities exist. In some areas, tourism and conservation measures provide opportunities for recovery of certain fish populations when the initiative starts at the family level in consultation with other communities. Such initiatives open-up income opportunities both in the tourism and fishing sectors. However, benefits are limited in dead *nakamal* because of over-fishing (**score: + 1**). Given the open access nature of dead *nakamal* fishers try to extract as much as they can as they perceive others are doing the same, which indicates *harvesters do not have the knowledge about sustainable fishing practices* (**score: -2**). In dead *nakamal* customary fishers have more capacity to fish (number of fishers, fishing gear, etc.) than the resource can sustain, leading to over-fishing (**score: -2**).

4.2.2.2. Other Fishers. Other fishers, such as commercial fishers, do not necessarily *have long-term interest in the sustainability of the resource.* In dead *nakamal*, where resources are over-exploited, other fishers will also attempt to harvest as much as they can, further increasing fishing pressure (**score: -2**). Other fishers are *able to switch to other activities for income* (**score: + 1**). In dead *nakamal* there is no incentive for other fishers to *sustainably extract resources* because the resource is 'open to all' and because there is no pressure from customary fishers and communities to reduce fishing pressure from other fishers **(score: -2).** In dead *nakamal* resources are overfished, which indicates an *over-capacity of fishing* **(score: -2)**.

4.2.3. Authority allocation processes (I)

4.2.3.1. Government authority. The VNF Act give the government the formal *authority to control/adjust seasons, zoning or use other instruments to reduce fishing pressure*. However, the government has other (conflicting) interests, such as coastal development and agriculture (**score: + 1**). The VNF act gives the *authority to the government to control/adjust resource amount or numbers of commercial harvesters* through licenses and landing records **(score: + 1)**. In dead *nakamal* fishers *do not participate in the management of the resources* because they cannot agree on how to improve fisheries management due to the 'open-access' nature of the area and weak or absent customary authority (**score: -2**). The VNF Act allows the government to facilitate a process where fishers could discuss and agree on how to

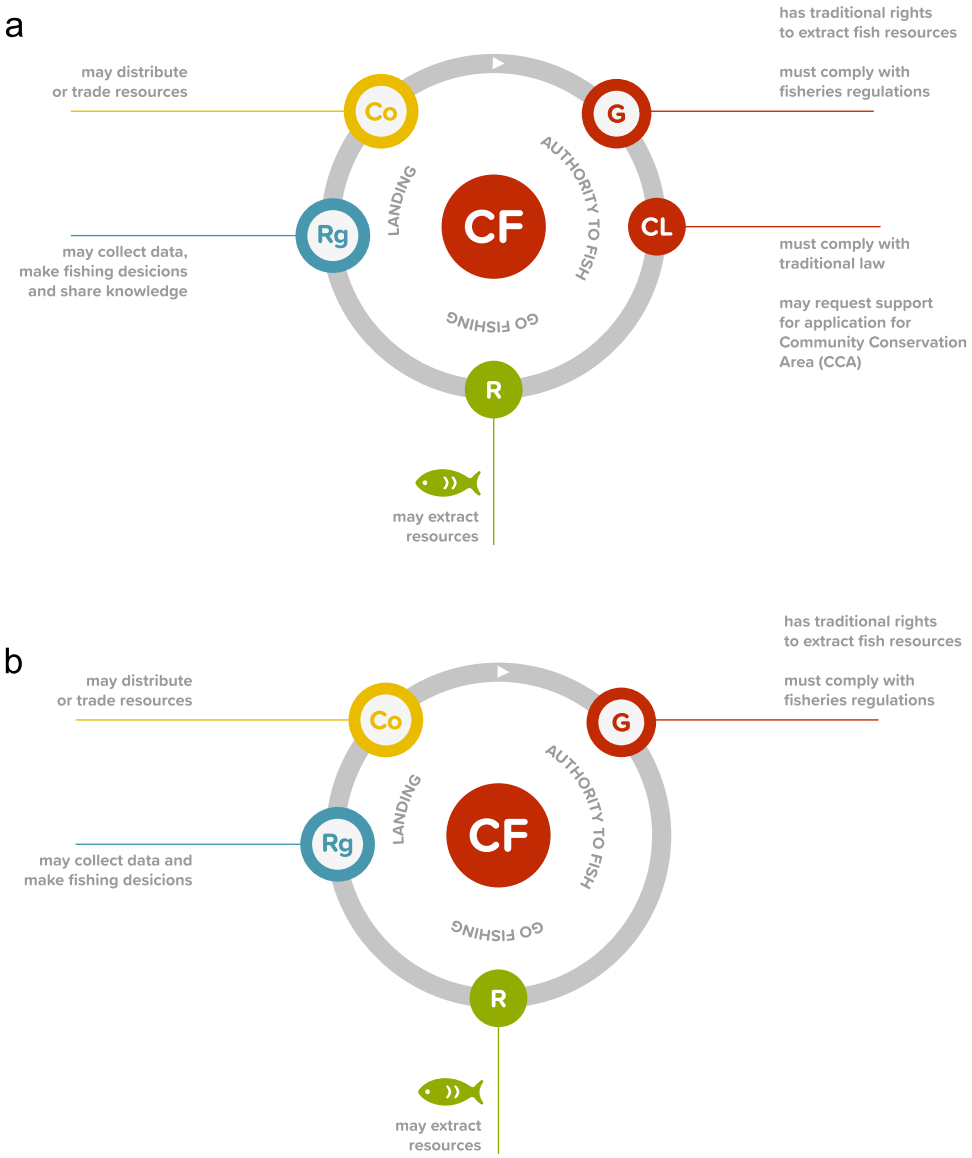

Fig. 3. Story cycle in areas with customary authority (A) and in dead *nakamal* (B) for customary fishers actors in Vanuatu. Key: CF: customary fisher; G: government; CL: Customary leader (chief); R: resource; KE: Resource monitoring and knowledge governance sub-system; Co: Consumption, production, and distribution governance sub-system.

improve resource sustainability, but such capacity is not yet performed by the government.

4.2.3.2. Customary authority. Although the VNF Act does not expressly recognise customary practices, there is high-level recognition of their application in fisheries management in the constitution. Despite the lack of formal recognition, the government do engage with communities and empowers customary leaders to carry on their roles and responsibilities under customary law. Therefore, there is semi-formal authority rule from *the government that enables customary actors to control/adjust seasons, zoning to reduce fishing pressure* but in dead *nakamal* there is no customary leader to receive it (**score: + 1**). Similarly, *customary law gives authority to customary leaders to control/adjust fishing seasons and zoning to reduce fishing pressure*, but in dead *nakamal* there is no customary leader to receive it because authority is either absent (no direct owners) or disputed as some people may still have ancestry relations to the area and stake primary or secondary rights claims (**score: + 1**). Customary fishers cannot agree on how to improve fisheries management and therefore do not *participate in the management of the resources* because they cannot work together or with the government to improve resource sustainability **(score: -2)**.

4.2.4. Resource allocation and management processes

4.2.4.1. Government. No information from the literature was found about *transparency and trust on resource allocation systems and processes*. However, experience suggest that this is likely to be deficient, particularly when money is involved **(score: -1)**.

Similarly, there is not enough information from the literature about *transparency and trust on collection and use of resource access fees*, but experience indicate it is likely to be unfair and distributed asymmetrically **(score: -1)**.

Over the years the Government has been encouraging community-based marine conservation programs, resulting in a strong increase in such initiatives (the number of local-level marine management measures more than doubled from 1993 to 2001) [66]. More recently, the government has introduced the Community Conservation Area (CCA) Act, which gives villagers the power to register a CCA and request the state to enforce rules and improve conditions of registered CCA. These are indicative of *effective integration of knowledge* but its effectiveness in dead *nakamal* is only partially successful as reef fishes are over-

Table 4
Scores for the resource allocation and extraction governance sub-system for case study in Vanuatu.

Governance attributes (actors (A), interactions (I), outcomes (O))		Assessment criteria	Score
Authority to distribute fishing rights and collect access fees (A)	Government	Authority to distribute fishing rights is allocated to governance actors that have interest in long-term sustainability of the resource	+ 1
		Authority to distribute fishing rights is allocated to governance actors that have a knowledge of the resource system	+ 1
		Authority to distribute fishing rights is allocated to governance actors that have the capacity to undertake the role	− 1
		Authority to distribute fishing rights is allocated to trusted governance actors	− 1
		Authority is given to governance actors who are able to facilitate sectoral cooperation and coordinate activities between the various resource harvesters and users	0
		Authority is given to governance actors who are able to learn (knowledge capacity)	− 1
	Customary leaders	Authority to distribute fishing rights is allocated to governance actors that have interest in long-term sustainability of the resource	− 2
		Authority to distribute fishing rights is allocated to governance actors that have a knowledge of the resource system	− 2
		Authority to distribute fishing rights is allocated to governance actors that have the capacity to undertake the role	− 2
		Authority to distribute fishing rights is allocated to trusted governance actors	− 2
		Authority is given to governance actors who are able to facilitate cooperation and coordinate activities between the various resource harvesters and users	− 2
		Authority is given to governance actors who are able to learn and transmit knowledge (knowledge capacity)	− 2
Resource harvesters (A)	Customary Fishers	Resource harvesting rights are allocated to actors that have interest in long-term sustainability of the resource	− 2
		Harvesters are able to switch to other resources or sources of income	1
		Harvesters have knowledge about sustainable fishing harvest in their area	− 2
		Extractive capacity of resource harvesters matches sustainable fishery yields	− 2
	Other Fishers	Resource harvesting rights are allocated to actors that have interest in long-term sustainability of the resource	− 2
		Harvesters are able to switch to other resources or sources of income	1
		Harvesters have knowledge about sustainable fishing harvest in their area	− 2
		Extractive capacity of resource harvesters matches sustainable fishery yields	− 2
Authority allocation processes (I)	Government Authority	Authority enables actor to control/adjust seasons, zoning or use other instruments to reduce pressures on the resource	1
		Authority enables actor to control/adjust resource amount or numbers of harvesters	1
		Resource harvesters participate in the management of the resource (e.g. co-management arrangements)	− 2
	Customary Authority	Authority (formal) enables actor to control/adjust seasons, zoning or use other instruments to reduce pressures on the resource.	+ 1
		Authority (customary) enables actor to control/adjust seasons, zoning or use other instruments to reduce pressures on the resource	+ 1
		Authority enables actor to control/adjust resource amount or numbers of harvesters	+ 1
		Resource harvesters participate in the management of the resource (e.g. co-management arrangements)	− 2
Resource allocation and management process (I)	Government	Transparent and trusted resource allocation systems and processes	− 1
		Transparent and trusted collection and use of resource access fees	− 1
		Effective integration of knowledge that supports resource allocation and management (knowledge transmission capacity)	0
	Customary	Transparent and trusted resource allocation systems and processes	− 2
		Transparent and trusted collection and use of resource access fees	− 1
		Effective integration of knowledge that supports resource allocation and management (knowledge transmission capacity)	0
Impacts on the resource (O)		Sustainable extraction levels	− 2
		Sustainable distribution of fishing pressures in the fishing area	− 2
		Sustainable interactions with other systems (bycatch, impacts on other resources and supporting ecosystems)	− 1
Socio-economic outcomes (O)		Benefits shared in a way that is perceived to be fair/equitable.	− 2
		Access fees/other industry contributions are invested in the maintenance/improvement of the resource and SES	− 2

harvested (**score: 0**)

4.2.4.2. Customary. Customary resource allocation systems and processes are not transparent nor trusted in dead *nakamal* because customary authority is disputed. Another indication of how ineffective resource allocation systems and process are is due to people's attempt to justify access and authority using unusual (from a customary perspective) family links (**score: -2)**.

No information was found from the literature about access fees in customary areas, but when it happens, fees are often kept by chiefs or leaders and may not be distributed to reef owners in general **(score: -1)**.

Despite the sense of ownership some locals have about the resource and the occasional use of customary fishing practices there is limited *integration of knowledge to support resource allocation and management* because neither customary nor western management practices are used and incorporated in dead *nakamal* (**score: 0)**.

Fig. 4. Scores for Resource Allocation governance sub-system in Vanuatu, organised by actors, interactions and outcomes. Legend: 1 full circle = Extremely ineffective and vulnerable governance criteria; 5 full circles: Extremely effective and resilient governance criteria.

4.2.5. Impacts on the resource

Dead *nakamal* are overfished, which means *extraction levels are not sustainable* (**score: -2**). *Fishing pressure is not sustainably distributed* in dead *nakamal* because they are 'open to all' to fish (**score: -2**). No information in the literature was found about *sustainable interactions with other systems (bycatch, impacts on other resources and supporting ecosystems)*, but overall management is poor even in areas that are not dead *nakamals*. Moreover, customary management limits access to outsiders but often not to inclusive stakeholders nor on amounts of resources exploited (**score: -1**).

4.2.6. Socio-economic outcomes

Resources are not equitably shared in a way that is perceived to be fair/equitable due to the disputes over customary authority and unusual attempts to justify access and authority over them (**score: -2**). Resources in dead *nakamal* are over-exploited, therefore there are no benefits to those who use the resource, claim or contest ownership, resulting in *no re-investment (human or financial) to improve the resource and SES* (**score: -2**).

Fig. 4 depicts the inter-play of governance attributes influencing the state of coastal marine resources. Weak points of the governance system (Outcomes and Actors; extremely ineffective, and ineffective, respectively) are potential intervention points to improve adaptive capacity in dead *nakamal*.

5. Conclusion

Over the history of human societies, effective governance arrangements have helped actors cope with and adapt to environmental changes [97]. Climate and other environmental changes generate challenges to achieving sustainable operation of governance systems within marine SES. Appropriate governance is a critical factor in addressing these challenges and understanding governance structures and their operation, strengths and vulnerabilities is essential for the selection and effective implementation of adaptation strategies.

Here, we have presented a transparent analytical framework to disentangle the different components of governance of marine SES. This complements the growing body of literature on operationalising IAD framework [e.g. [14,38]]. The application of the framework assists with gaining detailed understanding of various components of marine governance systems, their interactions and effects on the policy issue under investigation [98]. It may be particularly useful when dealing with complex governance systems that have a broad range of actors who influence, use and manage marine resources and are guided by different sets of rules, ranging from customary systems to national and international laws and regulations. By linking various criteria describing preconditions of adaptive capacity to particular governance attributes, the analytical framework also yields insights into the role particular rules, actors and interactions may play in adaptation process and its outcomes. The framework can also help identify appropriate systems and instruments that can be used to direct SES towards a certain outcome through policy interventions.

The analytical framework has been applied to a particular marine governance system in Vanuatu. In the opinion of the authors, this research developed a robust theoretical framework to characterise and assess governance systems. It proved to be helpful in identifying key governance issues influencing the adaptive capacity of coastal communities in Vanuatu. It also highlighted the importance of sociocultural influences on the ways in which adaptations can be developed and sustained [99]. However, being a new tool, the framework needs to be further tested and refined in other marine resource governance systems and comparative studies. It can also be further expanded to incorporate other governance sub-systems, broaden the range of criteria developed in the study and examine their relative importance and limitations in specific types of marine governance or problem contexts. These are important directions of further research.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2018.12.011.

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