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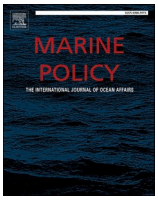

The interplay between top-down interventions and bottom-up self-organization shapes opportunities for transforming self-governance in small-scale fisheries

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ABSTRACT

Small-scale fisheries (SSF) contribute substantially to global food security, sustainable marine ecosystems and poverty alleviation. Yet many SSF face problems of overexploitation and poverty calling for novel governance approaches that enhance human-wellbeing, equity and ecological sustainability. External policies and interventions to support such governance transformations, however, need to take their often self-governed nature into account. Common practices based on informal arrangements between different fishery actors can make existing, mal-adapted structures very persistent and hence difficult to overcome. Here we combine multi-method empirical research on SSF in Mexico with agent-based modeling to analyze if and under which conditions interventions can shift ongoing self-organizing dynamics into directions that support the new governance form. We are particularly interested in the effectiveness of two different types of interventions, financial and social, and their performance under variable social and ecological conditions as commonly found in SSF. Our analysis reveals that a combination of financial and social support during extended periods of time is necessary to ensure persistence of new governance forms in face of competition with established forms, as well as environmental and social uncertainty. The findings highlight the importance of understanding the endogenous self-organizing dynamics created by the interplay between social (e.g. the dynamics of trust) and ecological (e.g. resource dynamics) processes in order to devise policies and measures to initiate a shift towards more sustainable pathways.

1. Introduction

Small scale fisheries (SSF) play an important role for global food security, sustainable marine ecosystems and poverty alleviation [1]. Many of these fisheries, however, face issues of persistent overexploitation and poverty resulting from open access regimes or governance failures [2]. Addressing these challenges and enabling more sustainable and resilient fisheries in the face of global change will often require significant governance transformations. Such transformations are, however, difficult to achieve as complex interactions between diverse actors, institutions and biophysical dynamics across scales may create significant barriers to change [3]. Vested interests, existing power relations and institutional structures for instance may perpetuate path dependencies that are difficult to break. There may be cognitive or cultural barriers or lack of ecological knowledge, human or financial capital [4–7]. Transforming governance towards more sustainable approaches may thus require to first overcome situations that are very resilient but unsustainable [6]. In view of these challenges it is critical to develop a better understanding of the potential of *intentionally* transforming social-ecological systems (SES) through breaking undesirable dynamics and reinforcing those processes that enable more sustainable trajectories [5].

Transformations of marine and other SES have been studied extensively empirically [4,8,9] and the growing body of knowledge has been synthesized in several frameworks [5,6,10–12]. Overall, transformations are complex, multi-level and multi-phase processes that are characterized by the interplay of cognitive, agency and structural features that enable or prevent change at different levels and phases of the process. Here, we focus on one particular sub-process of a governance transformation in a fishery, namely the process of uptake of an innovation, i.e. a novel governance arrangement that seems promising and was successful in an experimental stage [5]. We are particularly

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interested in the potential of social and financial interventions to overcome lock-in of the current regime and reinforce dynamics that lead to the uptake of the new institution. These, external, often top-down interventions can potentially play an important role for triggering transformations, however, little is known about the conditions under which they are effective and how they interplay with ongoing self-organizing processes in a fishery.

Fisheries are complex adaptive systems (CAS) characterized by interactions between multiple actors with competing interests, values and capacities and a dynamic and complex ecosystem which together can bring about non-linear behavior, abrupt change or lock-ins [13,14]. The outcomes of interventions that aim to steer the evolution of such CAS into a particular direction are thus highly uncertain. Studying the emerging dynamics of fishery SES and their response to interventions empirically is, however, challenging. We tackle this challenge by combining synthesis of in-depth empirical research with agent-based modelling to investigate if, how and under which conditions top-down interventions or combinations thereof enable the establishment of a new self-governance arrangement. We do so by extending a stylized, empirically-grounded agent-based model of SSF in Mexico [15]. By combining stylized insights derived from empirical research with a dynamic model we aim to shed light on the causal processes that may move the system out of an entrenched setting and allow a new intuitional form to establish. This allows us to move beyond a static view of individual factors and their effects on outcomes towards an account of the mechanisms that explain how an institutional transformation came about [16]. The purpose of this approach is to use the model as a virtual SES laboratory to experiment with different interventions and environmental settings and analyze underlying mechanisms, not to predict the outcome of a particular policy or develop management recommendations [17].

The agent-based model (ABM) represents a synthesis of insights from more than 15 years of extensive in-depth multi-methods research of SSF in Mexico [18,19]. It captures key interactions between fishers, fish-buyers and fish stocks that determine the self-organization of the fishery into different types of self-governance arrangements, namely patron-client (PC) or cooperative governance arrangements (coops). We contrast two types of interventions: financial subsidies which are common interventions in SSF around the world and social interventions aimed at increasing trust and collective action. Trust is an important factor for successful self-governance in many natural resource management contexts [20,21]. The interventions are targeted to support the establishment of fishing cooperatives, which under certain conditions can transform resource exploitation towards more sustainable and equitable practices. We focus on the critical moment of establishment and adoption of the novel governance form (i.e., a fishing cooperative) against the prevalent form of self-governance, in this case patron-client relationships. We investigate transformative trajectories created by different interventions or combinations thereof under constant environmental conditions and then test successful ones under conditions of increased social and ecological variability and uncertainty due to global change.

2. Transforming small-scale fisheries governance

Many SSF in developing countries are self-governed through informal arrangements between fishers and fish buyers, through fisher cooperatives or co-managed with local authorities [22–26]. Patron-client relationships between fish buyers and fishers (PCs) and fisher cooperatives (coops) are often the main pathways for low-income individuals to secure their livelihoods. They allow them to gain access to capital to afford the upfront costs of fishing trips, to fishing means of production, to property rights to the fishery, and to sell their catch and receive personal loans [27]. Because of the high uncertainty and variability of resource availability, governance arrangements that provide credit and insurance are highly important for reducing risks and providing income. The relationships between fishers and fish buyers are often informal and build on trust and loyalty [28] but can also be characterized by power asymmetries [25,29–31]. At the same time, they have been described as problematic as they may prevent collective action when there are signs of overexploitation [24,32], may gradually undermine the resilience of the SES [25], be exploitative and increase inequalities in communities [e.g., 33].

Cooperative forms of governance can under some circumstances provide for more sustainable resource use [20]. Transforming an existing (self-)governance system can, however, be very difficult as prevailing governance forms are often strongly entrenched and conditions for collective action may be unfavorable [34,35]. Coops are only one possible alternative of a novel governance form that may bring social and ecological benefits to fishers and the environment. In contrast to PCs, coops can provide social security and other collective goods, which reduce uncertainty about the future and incentives for a race to fish, and can create incentives for area-based conservation by protecting areas of high biological productivity from exploitation. Whether coops indeed lead to more equitable and sustainable fisheries remains, however, disputed and most likely depends on the social-ecological context and history in a given location [36].

Transforming an SSF that is dominated by PC arrangements towards self-governance forms that enable sustainable resource use has proven to be difficult and attempts have often failed [37]. Reinforcing feedbacks can make existing arrangements very persistent and thus prevent the establishment and spread of new forms. In Kino Bay, Mexico, for example, the ability of fish buyers to access the market and navigate the bureaucratic process enhances their capture of fishing permits, which legalizes them as fishers. This not only provides them access to benefits of the state provided to fishers, it also can increase overexploitation as fish buyers have less incentives to prevent non-local fishers from exploiting the resource and incentives for collective action among local fishers are reduced [37].

While SSF are often self-governed or co-managed, states frequently intervene through a number of mechanisms such as subsidies, taxes, assistance programs or training [38,39]. The SSFs literature has mostly focused on the analysis of subsidies (particularly fuel) in their economic and biological effects and in comparison to large scale fisheries [40]. Nenadovic et al. [39] highlight that subsides can also take the form of credits or loans and be tailored to poverty alleviation or other social objectives as well as biological sustainability objectives related to fisheries management [41,42]. Such financial or social interventions can play an important role in fishers' adaptive capacity [39].

Investments of social, financial, and intellectual capital are also critical for the establishment and adoption of a novel governance arrangement [5]. These top-down interventions, however, interact with the endogenous, self-organized dynamics of the SSF and can either break or reinforce them, as was the case with the capture of licences by fish buyers that were intended to support fishers and their fishing cooperatives. The conditions under which external interventions can break reinforcing dynamics and enable a transition towards a novel regime is the focus of our model-based analysis. We acknowledge that support for the establishment and adoption of a new governance form in one community is but one step required for a successful governance transformation [43], but a better understanding of this critical sub-process will hopefully help advance our understanding of opportunities but also pitfalls of interventions aimed at triggering or supporting transformations.

3. Methods

3.1. Empirical foundation

The model was constructed based on data and expert knowledge from more than 15 years of multi-methods empirical research on SSF in Baja California, Mexico (see [18,19,31,36] for details of the empirical

data that informed model development). This includes, among others, analysis of a two year journal of all transactions of a major fish buyer, interviews with fishers and fish buyers, and field research in 17 villages around the Gulf of California [19,44]. We synthesized these studies and conducted additional field research to identify factors, actors, interactions and biophysical dynamics that characterize the fishery and may affect the survival of PCs and coops (these interviews are reported in Basurto et al. [19]). As a result, we focused on three key factors influencing the success of PCs and coops alike: loyalty of fishers towards their respective organization (PC or coop), reliability of fishers and the history of working together of coop members [36]. The importance of loyalty/trust and social norms, are representative of small scale fisheries around the world [22–24,28,29].

The establishment and persistence of both PCs and coops depends on their ability to secure enough fish and hence income through their fishers' fishing activities. A fisher's catch depends on the state of the fish population, his fishing skills and willingness and ability to go out fishing. Whether a fisher's catch will benefit the PC or coop that provided the fisher with a loan to go fishing in the first place, however, depends on the fishers' reliability and his loyalty to the buyer or coop. Both organizational forms face the issue of cheating, e.g. that fishers take a loan to go fishing but then sell their catch elsewhere, or use the money otherwise. Loyalty reduces the likelihood of cheating and thus assures that the investment of the coop or PC is not lost. Fishbuyers end relationships with fishers if they do not return their catch to them; a situation that happens frequently. If fishers, however, return their catch regularly strong loyalty between fishers and a fish buyer develops [19,45]. Fishbuyers will try to work with fishers that have a reputation of high loyalty and fishing skills. Coops are less flexible in choosing the fishers to work with. Their collaboration is more formalized which makes it harder for a coop to get rid of a non-loyal or unreliable fisher [19]. Their success thus more strongly depends on the initial composition of their members. Coops whose members have experience in working together from other occasions tend to be more successful [44]. Finally, coops also need to ensure collective action to establish and run their operations which creates high transaction costs, particularly in the beginning [44].

Fisheries are exposed to high levels of environmental variability and uncertainty of resource availability which likely will increase with climate change. Climatic conditions in the Gulf of California are inherently variable, on inter- and intra-annual time scales [46]. While it is unclear in many cases how climate change will affect fisheries in the Gulf, environmental variability is something that fishers face in their everyday lives [47,48]. At the same time, they also need to cope with sudden disruptions in the social environment, such as loss of trust or changes in leadership, resulting from social processes such as conflict. They can be aggravated by increased pressures on resources through globalization [27]. In coops conflicts can emerge when members discover that leaders have created unfair distributions of collective benefits, paid too low prices for the catch of a fisher or paid at too low frequency. These conflicts can lead to frequent turnover among leadership and decrease or collapse of trust within a coop [44].

Policy and development interventions in SSF in Mexico.

In Mexico, the establishment of agricultural and fishing cooperatives was a nation building project after the revolution, where the government incentivized the formation of cooperatives through the granting of property-rights and a variety of state benefits such as subsidies and low-cost loans [45,49,50]. With increasing pressure for liberalisation and concerns about lack of transparency, however, PCs became more prominent. Today in the Gulf of California and Mexico in general, it is estimated that the distribution of coops versus PCs is 49% and 51%, respectively [51]. The re-establishment of coops in recent years has been incentivized by government subsidies and social interventions like facilitated workshops, primarily by NGOs, that are designed to build trust and rapport among a group of people [52]. These interventions can play an important role in providing the financial, emotional and processual means towards lowering the up-front transaction costs of collective action [53]. Examples of such up-front costs can be expressed in terms of the time, financial, or emotional costs of identifying all interested participants, agreeing on a time and place to meet, physically getting all stakeholders to the same place, agreeing on the format of the meeting and who will facilitate. Finding the means to have subsequent meetings, and discussing, and agreeing on the rules under which a new self-governance arrangement (e.g., a fishing cooperative) would operate including formal positions, and responsibilities, etc. Increasingly, local non-governmental organizations bridge between external funders and fishers in the design and delivery of financial and social interventions in SSFs [50,54,55].

3.2. The small-scale fisheries model

The model applied in this study extends the model presented in Lindkvist et al. [15] to incorporate financial and social interventions. The structure of the model, the agent characteristics and causal processes represented are based on the results of the empirical studies and the broader literature on SSF in the region (see Empirical Foundation section). We model a SSF in Mexico consisting of fishers and fish buyers that self-organize in coops or PCs to exploit a fish stock and sell the catch to a regional market [15]. Contrary to [15], the purpose of this model is to study the effect of financial and social interventions in supporting the establishment and persistence of coops in a fishing community that is dominated by PCs. The model captures the challenges for self-governance related to the informality of interactions and need for collective action such as high transaction costs and cheating as highlighted above.

The model consists of 1) the natural environment represented by a regenerating fish stock, 2) the agents who can be fishers or fishbuyers and 3) networks of agents that form coops (maximum of 5 fishers that together form a cooperative) or PCs (maximum of 15 fishers linked to a fish buyer) (Fig. 1, see detailed descriptions of all model processes in the S3). SSF are commonly multi-species fisheries, however, for simplicity and to focus on the social dynamics of self-governance we represent only a single fish stock, modelled using the Gordon-Schaeffer Model (S3.9 – Update stock). We model a sessile species such as pen shells, which are an important target species in many SSF around the Gulf [57]. Fishers are characterized by their reliability, i.e. their ability to stick to an agreement ("do what he said he would do"), loyalty to their patron or coop and fishing skills. Fishers self-organize in coops or work with a fish buyer (PC) (S3.1 – Select fishing crew/Find buyer). The sequence of activities in one time step (day) is represented by the numbers in Fig. 1: fishers (1) get means for fishing (herein monetary loans), (2) go fishing, and (3a,b) sell their catch to their own coop/PC or to a different one (cheating). Empirical observations and informal interviews with fishers indicate that often fishers face strong incentives to cheat on their agreements, particularly if there is strong demand for fish and competition among fishbuyers to increase fish supply [19]. The likelihood of cheating is influenced by the reliability of a fisher and loyalty towards his patron or coop [27,29,58] (S3.4 Cheating). Loyalty increases through successful transactions (a fisher receives a loan and brings back catch to the buyer) and decreases through cheating (S3.6 Update loyalty and capital). We assume that the loyalty between members of a coop increases slower than between a fisher and a buyer reflecting the higher transaction costs of coops who need to engage in collective action to formally set up and organize their fishing operations [27,58]. Members of a new coop can have initial loyalty that represents trust established among members through previous cooperation [44].

We model financial subsidies as an increase in coop financial capital, and social interventions as an increase in loyalty (see S5 Scenario Settings). In practice, financial interventions could be tax breaks on catch produced by the coop, grants to attain administrative, production and commercialization infrastructure such as offices, computers, fishing gear, boats, motors or refrigerated trucks [39]. Social interventions could be training about how to manage coop resources or govern the

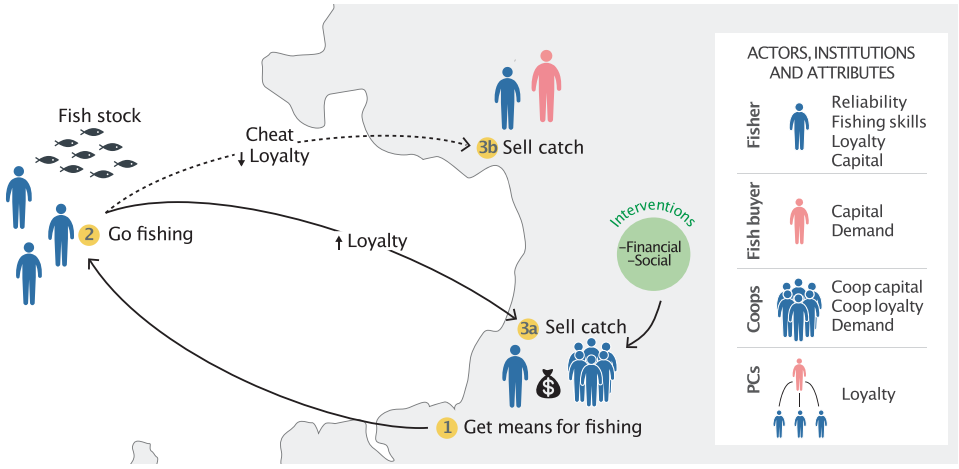

Fig. 1. Conceptual figure of the model entities, their main activities and environment. The agent-based model (SMILI-T [56]) consists of fishers, fishbuyers, coops and PCs that each have a specific set of attributes (see legend). The yellow circles represent the activities that take place on a daily basis, where the fishers acquire means for fishing, go fishing, and sell their fish to a PC or coop. If fishers cheat, loyalty with their coop or PC decreases, otherwise it increases. The financial and social interventions increase coop capital or loyalty, respectively. A detailed description of the model and the model processes can be found in the Supplementary Information S1-S4. Illustration by J. Lokrantz/Azote.

coop, or participatory activities that build a shared understanding of the goals of the coop and build trust.

Environmental variability, i.e., variation in fishing conditions that fishers cannot anticipate or influence (variable fishing conditions), is modeled as stochastic catchability to reflect difficulties of going out fishing and securing catch when weather conditions are bad (see S5 Scenario settings). Social variability is modeled as a sudden loss of loyalty occurring on average once a month (frequent conflict) or once a year (infrequent conflict) as a result of conflict within the coop.

Details of the model including the ODD+D protocol (Table S1), an overview of the sequence of daily activities (Fig. S2), the corresponding processes (S3) and parameter settings (Table S4) can be found in the Supplementary Information. The model has been extensively tested and verified in Ref. [15] (see also S6). In addition, we conducted a sensitivity analysis of frequent and infrequent conflicts, different levels of initial capital for coop members, and different levels of initial loyalty for each coop member which is presented in Figs. S7.1 – 7.4.

Lindkvist et al. [15] have shown that under conditions where coops compete with PCs for the fishers and fish catch, coops can only dominate the fishery when their initial loyalty is intermediate to high and the distribution of fishers' reliability is rather homogenous at an intermediate value (Fig. S6). Here we use parameter values that favor PCs, i.e. low initial loyalty and a distribution of reliability with a standard deviation of 0.3 (intermediate) (see circle in Fig. S6). Under these conditions and competition of the two institutional forms only 23% of the fishers are organized in cooperatives. We start a simulation with a community where all fishers are organized in PCs and then introduce coops in the second and third year following an implicit government intervention that promotes coops [27]; fishers who were previously working with fish buyers now form 10 coops. New fish buyers try to enter the fishery annually and recruit fishers. Over its lifetime a coop cannot accept new members while a fish buyer can cease working with non-loyal members or accept new fishers if he needs more labor. This setup reflects the high barriers of entry and exit resulting from formal coop membership rules [27]. Coops can, however, expel members with whom loyalty has decreased to zero. Coops and PCs whose financial capital falls below zero exit the fishery as do coops who have lost more than two members.

3.3. Simulation experiments

In our exploratory study we depart from the assumption that the need for a transformation has been recognized by state and non-state actors and that coops have been identified as the innovation to achieve a transformation. We apply the model to analyze the effectiveness of the two types of interventions to support the establishment and persistence of coops under different conditions (Table 1). We define a governance transformation as a persistent change of the fishery from a state where the majority of fishers are organized in PC relationships to a state where more than 50% of the fishers are organized in cooperatives. Interventions can be carried out once to support the establishment of the coops, henceforth called startup interventions or repeatedly twice a year over the course of several years, henceforth called repeated interventions. We test the interventions independently and in combination. Finally, we assess the effectiveness of combined and repeated interventions under conditions of environmental and social variability.

4. Results

4.1. Which type of intervention can support a self-governance transformation?

We first test the effectiveness of the two types of interventions when

Table 1
Description of the simulation experiments. Each experiment is repeated many times with the same initial settings to account for stochasticity in the model. The exact number of repetitions is noted in each figure legend.

Experiment/ Settings	Intervention	Fishing conditions	Social conditions	Results
Experiment 1	Single and combined interventions only at startup	constant	No conflict	Figs. 2 and 3
Experiment 2	Single and combined interventions at startup and then repeated over 10 years	constant	No conflict	Figs. 4 and 5
Experiment 3	Combined interventions at startup and then repeated over 10 years	Constant and variable	Infrequent conflicts Frequent conflicts	Fig. 6

introduced at the startup of a coop under constant fishing conditions with no conflicts. Both financial and social interventions enable one or two additional coops to survive (Fig. 2A). The interventions are even more successful when combined. Neither of them, however, leads to a transformation of the fishery where more than 50% of the fishers are permanently organized in coops. When there is no intervention or a financial intervention, coops fail because of lack of loyalty (Fig. 2B). When coops get support for trust building they more often fail because of lack of capital but loyalty is still a factor and becomes more critical again when both interventions are combined (Fig. 2B). Social interventions increase the loyalty in a coop. This can to some extent compensate a lack of reliability of coop members. As a consequence, coops that receive social interventions survive with lower average reliability of their members (Fig. 2C). This result does not change qualitatively when the amount of financial or social support is increased (see Figs. S7.3 and 7.4).

A time series over 30 years of the fishery with a combined intervention at startup illustrates the dynamics of coop establishment (Fig. 3). Coops are formed in the second and third year which leads to a decrease of PCs in the community (Fig. 3A). However, over time only three to seven coops survive because of high levels of cheating by unreliable fishers in the beginning of coop establishment before there was enough time to build loyalty (Fig. 3B). For a coop to persist it is essential that a reinforcing feedback between loyalty and cheating is created such that more loyalty leads to less cheating which leads to more loyalty (see also [15]). The fish stock gets overfished when coops are formed but regenerates when there is less organizations (some coops have dissolved, but only few fishbuyers have been able to establish yet) (Fig. 3C). Over time coops develop high levels of loyalty which allow them to persist when fish resources decline again. Several new PCs manage to establish until the system stabilizes. Contrary to coops, PCs often go out of business, but they are replaced by new fishbuyers that enter the fishery (Fig. 3A).

4.2. *Can a governance transformation be achieved through repeated interventions?*

When interventions are combined and repeatedly provided twice a year over the course of several years a governance transformation can be achieved in more than 50% of the runs (Fig. 4). Similarly, as in the experiment with startup interventions, loyalty remains a bottleneck that financial interventions alone cannot overcome (Fig. S8.1B). When social support is given the lack of financial capital constrains the survival of several coops. Repeated social support allows coops to survive with lower average reliability (Fig. S8.1C).

An investigation of the dynamics of loyalty during the initial phase of coop establishment can help explain why repeated interventions can overcome the lock-in and enable more coops to survive (Fig. 5). Loyalty in coop 1 (yellow) is rapidly increasing, enabled among others by the early exclusion of an unreliable member that cheats often. The initial conditions of this coop in terms of reliability of its members was good enough for it to survive even without social interventions. Coop 2 (blue), on the contrary, would have already dissolved early on without a subsidy at startup (blue dashed line < 0), and while its average loyalty is increasing, some members where dismissed early on because their loyalty was too low. The coop thus dissolved because of lack of members (Fig. S8.2). Coop 3 is struggling with increasing its loyalty, and would have dissolved without repeated social interventions (loyalty - subsidy

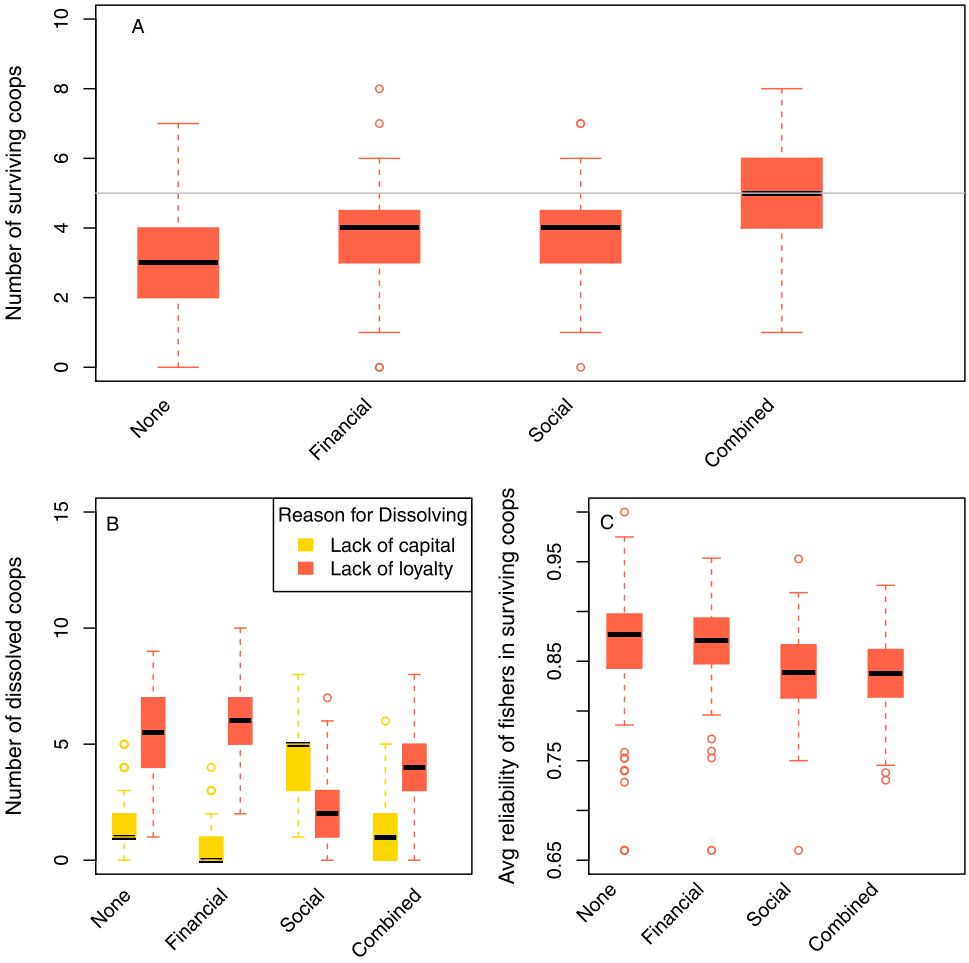

Fig. 2. Different types of interventions at startup under constant fishing conditions and no conflict. Box-and-Whisker plots of results of experiments with financial, social or combined intervention at the moment when coops are formed. The black line in a box is the median, the box represents 50% of the data, the whiskers represent data points outside the middle 50%, dots are outliers. A) Average number of PC and coop organizations that are present in the last 15 years of the simulation. The grey line is the number of coops beyond which they represent $>$ 50% of organizations; B) Reasons for the failure of coops; C) Average reliability of fishers in surviving coops. Coops mainly dissolve because of lack of loyalty. Social and combined interventions at startup of a coop increase the number of surviving coops, however, no intervention or combination results in a transformation of the fishery to dominance of coops. Data is based on 200 simulation runs per experiment.

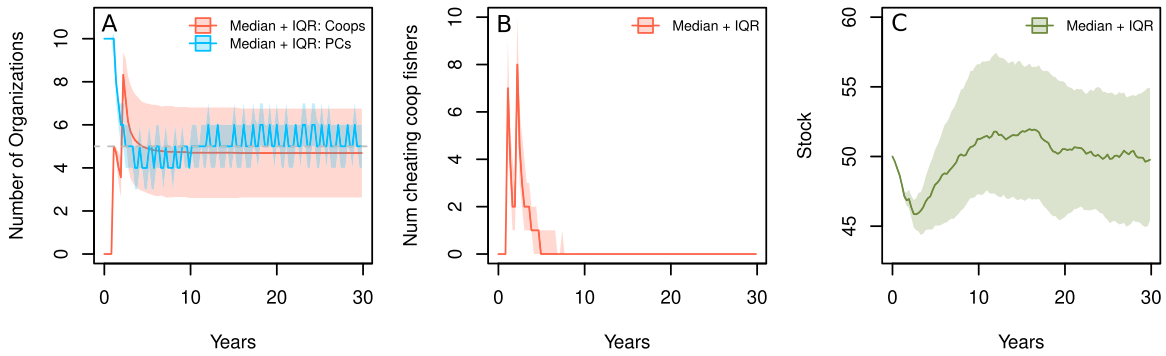

Fig. 3. Time series of 30 year simulations with a combined intervention at startup. A) Number of PC and coop organizations in the fishery over time. 5 coops are introduced in the 2nd and 5 in the 3rd year; B) number of cheating fishers across all coops; C) size of the fish stock. Data is based on the combined intervention in Fig. 2. The figures depict the median and interquartile range.

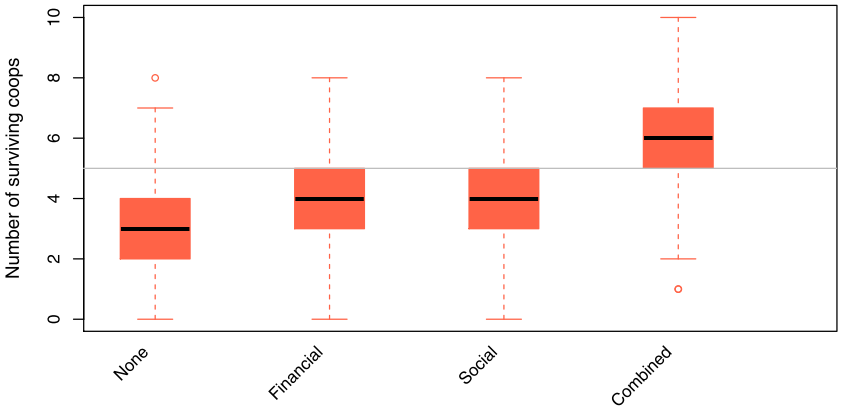

Fig. 4. Different types of interventions repeated twice a year for 10 years under constant fishing conditions and no conflict. a) Number of PC and coop organizations present in the last 15 years of the simulation. The grey line is the number of coops beyond which they represent $>50\%$ of organizations Each experiment us run 500 times. The black line shows the median, the box represents 50% of the data, the whiskers represent data points outside the middle 50%, dots are outliers. Only when interventions are combined and provided repeatedly over the course of several years the majority of fishers remain organized in coops in $>75\%$ of the simulation runs.

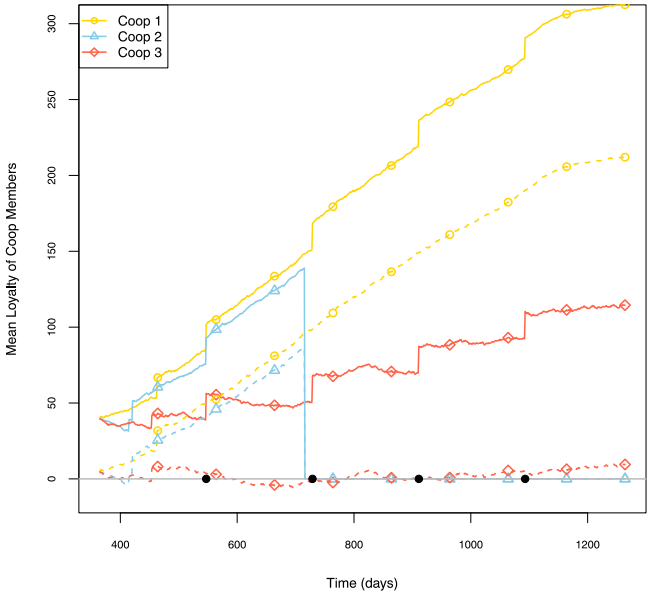

Fig. 5. Individual trajectories of coops during early establishment phase. The mean loyalty (solid line) of fishers in three different coops, and the loyalty with the given subsidies deducted (dashed line) in the first years of coop establishment. Solid dots show when an intervention was given. Depending on the configuration of members' reliability in the coop the development of loyalty takes different pathways.

< 0). The interventions shift the feedback between loyalty and cheating into the direction where an increase in loyalty decreases cheating which increases loyalty (versus a decrease in loyalty leading to more cheating and a further decrease in loyalty). This feedback allows the coop to slowly build up sufficient loyalty. Repeated interventions are thus necessary to enable coops with poor starting conditions (i.e. many unreliable members) to build up sufficient loyalty to reduce cheating and buffer times of high cheating or low resource availability. The timing and duration of an intervention is thus critical. At the same time, it is also critical that social interventions are combined with financial ones in order to overcome the combined and reinforcing effects of limited trust and limited financial resources as social and financial capital are not substitutable.

4.3. Can the success of combined interventions be maintained in an uncertain social and ecological environment?

So far we have assumed that the social and ecological environments of PCs and coops, such as the fish stocks or the strength of loyalty in PCs or coops, change in a constant and predictable manner. In reality, however, SSF are situated in highly uncertain environments characterized by high variability of fish abundance and socio-economic factors as well as the potential for abrupt changes [13]. Climate variability, particularly changing weather conditions, for instance, influences the ability of fishers to go fishing and catch fish (unpredictable fishing conditions). At the same time coops can be affected by conflicts between members or corruption of leaders which can lead to a sudden loss of trust [59] (infrequent or frequent conflicts). In the following we assess the effectiveness of repeated, combined interventions under more realistic and uncertain conditions.

The persistence of coops is radically reduced when they are exposed

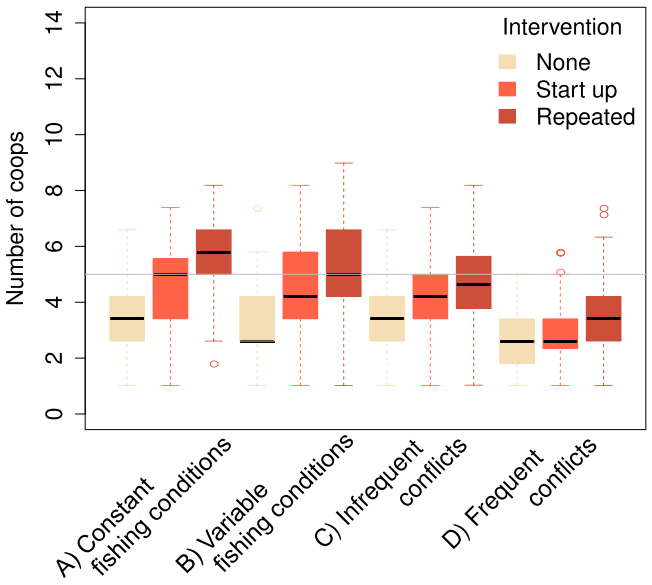

Fig. 6. Survival of coops under three intervention scenarios and different environmental and social conditions. Coops survival increases with interventions, however in the conflict scenarios a transformation cannot be achieved even with repeated interventions.

to stochasticity in their ecological or social environments (Fig. 6B-D) compared to a constant environment (Fig. 6A). Both ecological and social shocks lower the chance of coops to successfully establish, however, the social disruptions, particularly if they happen frequently, have a much stronger effect. Repeated interventions can compensate to some extent for the loss of catch and thus financial capital under unpredictable fishing conditions (Fig. 6B). No transformation, however, is possible when the coop is repeatedly subject to social conflicts as coops cannot cope with the loss of loyalty. As a consequence, most fishers organize in PCs which also fail but they are replaced by new fishbuyers who enter the fishery. The moment at which a conflict happens is critical as the earlier it happens the more devastating it is. Coops only have a chance for survival if there is sufficient time to build loyalty as a buffer against ecological and social conflicts. The number of coops that can survive decreases linearly with an increase in the amount of loyalty lost in a conflict (Figs. S7.1 and S7.2).

5. Discussion

The complex nature of social-ecological systems where outcomes emerge from interactions of diverse actors and ecosystems in given socio-political, economic and biophysical contexts poses particular challenges for transforming governance institutions [60]. Our results show that an injection of financial capital alone, as often practiced when supporting the establishment of new self-governance arrangements in SSF, is insufficient to break the reinforcing dynamics that stabilize the status quo or to help novel forms to overcome multiple, interacting financial and social challenges. Moreover, even if different types of interventions are combined, they do not succeed if given only once. This confirms results found elsewhere in fisheries [22,23], and in other domains, e.g. agriculture. Poverty alleviation in rural landscapes may require a sequence of different types of interventions [61], or different combinations of pathways that lead to the emergence and/or persistence of collective action for biodiversity conservation governance [34]. In addition to other work [12,20,58], our study highlights the need to pay attention to the social dimensions of collective action, particularly the dynamics of trust while at the same time providing financial means for economic well-being. Only when they act together can they push the coop over a critical threshold beyond which it can persist in the face of shocks. A combination of interventions can thus, if provided regularly over a longer period of time, facilitate a transformation to a new governance form.

The picture, however, radically changes when we take account of the often unpredictable nature of complex SES with respect to resource availability and social processes. Under these conditions even combined, repeated interventions fail to facilitate a governance transformation. None of the intervention setups tested with the model are resilient to these uncertainties. Thereby, the loss of trust appears to be particularly critical. As new coops not only have to compete with others over the scarce resources, but also need to cope with unreliable members and high transaction costs for establishing rules and trust for successful collective action, a sudden loss of trust can easily lead to collapse. The flexibility of PCs that allows them to change the fishers they work with [58], reduce their size of operation, and enter a fishery to benefit from an opportunity created by failures of coops, make them a more resilient governance arrangement in highly fluctuating environments.

In our model, the feedback between increasing loyalty and decreasing cheating stabilizes a coop by creating a social norm of acceptable behavior. The disruption of these dynamics through a sudden loss of trust as the result of conflict can shift the coop into the opposite dynamic where a decrease in loyalty leads to more cheating which decreases loyalty even more, ultimately leading to collapse. Once the dynamics have shifted into a downward spiral, a point intervention such as a one-shot measure to build trust will no longer be effective. The interplay between reinforcing feedbacks and policy interventions are an interesting research frontier, particular with respect to how shifts in norms can facilitate transformations [62,63]. At the same time the potential to steer such complex systems is limited and more attention needs to be given to creating the structures and underlying processes that enhance its resilience in the first place [64]. An institutional environment that enables the development of norms and rules within coops, for instance, could provide a mechanism to reduce the impact of shocks such as conflict on trust within the group [20]. Recent work on transformative governance has highlighted the need to build capacity to shape non-linear change in complex SES and actively shift it to a more desirable regime through altering the structures and processes that define the system [12].

Long-term support by the government or civil society to enable transformation towards more sustainable governance is costly. These costs, however, have to be seen in light of the potential benefits enhanced governance can provide to society and the ecosystems people depend on. If one views co-ops not only as business enterprises but as social-ecological institutions that provide services to society by maintaining healthy land- and seascapes, providing continuous support for their stewardship becomes beneficial for societies. At the same time this support needs to be combined with demands for transparency that make coops accountable to society and discourage opportunistic behavior. The lack of the latter has been problematic and led to the weakening of coops in Mexico in the mid-1990s. The Fishing Cooperatives' law was modified to decrease the minimum size of a cooperative [45], effectively reducing incentives to invest in building institutions for collective action beyond a small family group, leading to a boom of 'family-based' cooperatives that exist only in name. Such long-term support could take the form of programs that aim to reduce financial uncertainty and up-front costs of organizing for collective action through a mix of instruments suitable for a given situation combined with those that provide training and ethical values for collective action. At the same time these top down measures need to align with endogenous ways of enhancing the capacity for individuals and groups to cope with variability and change through e.g. diversification of livelihoods [39], among other strategies identified by the fishers themselves.

We have investigated the transformation of a fishing community towards cooperative governance using an agent-based model that is well grounded in decades of empirical research in Mexico. Choices and assumptions made when developing the model need to be taken into

account when interpreting model results for real world contexts. In our model for example coop members cannot divide their labor as has often been observed in successful coops such that some fishers take over organizational tasks of the coop. We have also neglected cultural aspects that may contribute to the persistence of PCs or existing social norms in the community that may reduce the level of cheating. We only test two types of interventions. Ecological measures such as protected areas and the presence of other species will certainly change outcomes. Finally, we have not explicitly modeled mechanisms for the formation of new coops, which is a critical next step to understand how a successful transformation of a single community can scale up to lead to a transformation of fisheries governance and the fishery SES on the regional or national scale. Despite these limitations the model provides novel insights about how the effects of external interventions shape and are shaped by self-organizing dynamics of a complex adaptive SSF. It highlights the importance of accounting for reinforcing feedbacks and path dependencies that may strengthen existing structures or enforce process that stabilize new ones.

The model is not an empirical model of a specific case but builds on a synthetic understanding of many fisheries in Mexico and factors that have proven to be of relevance in fisheries around the world. Our work is an example of combining qualitative, in-depth empirical understanding of key mechanisms and processes with dynamic modelling through a multi-year collaborative and iterative process that allows for experimenting, testing and forecasting developments that are difficult to capture in standard fishery models or in real-world experiments [17,65]. While our insights are specific to the ways we have modeled exchange between the fish buyers, fishers and fishers in coops, these exchange relationships are surprisingly common around the world indicating that our insights may be applicable to other areas [24,29,66].

6. Conclusions

External interventions in form of financial or social support to facilitate the adoption of novel governance arrangements may provide opportunities for transforming SSF governance if they simultaneously target economic and social conditions. They also need to be provided repeatedly to allow sufficient time until a new organization has strengthened social and financial processes and capitals to be able to cope with changing social or environmental conditions such as variable resource stocks or loss of trust. A financial or social intervention at the right time can be critical for turning a dynamic that leads to increasing loss of loyalty into one that increases trust thus stabilizing the coop. If social and environmental conditions become highly variable, however, previously successful interventions fail and no transformation can be achieved. Under such conditions, as commonly found in SSF, additional efforts are needed that build resilience and strengthen capacities to cope, adapt and transform the system. Our findings highlight the importance of understanding the endogenous self-organizing dynamics created by the interplay between social (e.g. the dynamics of trust) and ecological (e.g. resource dynamics) processes in order to devise effective policies and measures to initiate a shift towards more sustainable pathways. Future empirical research is needed to better understand how variable resource dynamics affect the development of the SES by strengthening current pathways or destabilizing them. Modeling can support these field studies by testing hypothesis about changes in dominant social-ecological feedbacks and their consequences for SES outcomes.

CRediT authorship contribution statement

Maja Schlüter: Conceptualization, Methodology, Writing - Original Draft, Writing - Review & Editing, Supervision, Funding acquisition. **Emilie Lindkvist**: Conceptualization, Methodology, Software, Formal analysis, Writing - Review & Editing, Visualization. **Xavier Basurto**: Conceptualization, Methodology, Writing - Review & Editing, Funding acquisition.

Declaration of Interest

None.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2021.104485.

References

[1] FAO, The State of World Fisheries and Aquaculture 2020: Sustainability in action, FAO, Rome, Italy, 2020. ⟨https://doi.org/10.4060/ca9229en⟩Also Available in: Chinese Spanish Arabic French Russian.
[2] J.E. Cinner, Social-ecological traps in reef fisheries, Glob. Environ. Change 21 (2011) 835–839, https://doi.org/10.1016/j.gloenvcha.2011.04.012.
[3] F. Mikulcak, J.L. Haider, D.J. Abson, J. Newig, J. Fischer, Applying a capitals approach to understand rural development traps: a case study from post-socialist Romania, Land Use Policy 43 (2015) 248–258, https://doi.org/10.1016/j.landusepol.2014.10.024.
[4] S. Gelcich, T.P. Hughes, P. Olsson, C. Folke, O. Defeo, M. Fernandez, S. Foale, L. H. Gunderson, C. Rodriguez-Sickert, M. Scheffer, R.S. Steneck, J.C. Castilla, Navigating transformations in governance of Chilean marine coastal resources, Proc. Natl. Acad. Sci. USA 107 (2010) 16794–16799, https://doi.org/10.1073/pnas.1012021107.
[5] M.-L. Moore, O. Tjornbo, E. Enfors, C. Knapp, J. Hodbod, J.A. Baggio, A. Norström, P. Olsson, D. Biggs, Studying the complexity of change: toward an analytical framework for understanding deliberate social-ecological transformations, Ecol. Soc. 19 (2014), art54, https://doi.org/10.5751/ES-06966-190454.
[6] E. Herrfahrdt-Pähle, M. Schlüter, P. Olsson, C. Folke, S. Gelcich, C. Pahl-Wostl, Sustainability transformations: socio-political shocks as opportunities for governance transitions, Glob. Environ. Change 63 (2020), 102097, https://doi.org/10.1016/j.gloenvcha.2020.102097.
[7] D. DeCaro, C. Arnold, E. Frimpong Boamah, A. Garmestani, Understanding and applying principles of social cognition and decision making in adaptive environmental governance, Ecol. Soc. 22 (2017) art33. ⟨https://consecol.org/vol22/iss1/art33/⟩. accessed July 9, 2017.
[8] T. Hahn, P. Olsson, C. Folke, K. Johansson, Trust-building, knowledge generation and organizational innovations: the role of a bridging organization for adaptive comanagement of a wetland landscape around Kristianstad, Sweden, Hum. Ecol. 34 (2006) 573–592, https://doi.org/10.1007/s10745-006-9035-z.
[9] P. Olsson, C. Folke, T.P. Hughes, Navigating the transition to ecosystem-based management of the great barrier reef, Australia, Proc. Natl. Acad. Sci. USA 105 (2008) 9489–9494.
[10] D.J. Abson, J. Fischer, J. Leventon, J. Newig, T. Schomerus, U. Vilsmaier, H. von Wehrden, P. Abernethy, C.D. Ives, N.W. Jager, D.J. Lang, Leverage points for sustainability transformation, Ambio 46 (2017) 30–39, https://doi.org/10.1007/s13280-016-0800-y.
[11] L. Pereira, N. Frantzeskaki, A. Hebinck, L. Charli-Joseph, S. Drimie, M. Dyer, H. Eakin, D. Galafassi, T. Karpouzoglou, F. Marshall, M.-L. Moore, P. Olsson, J. M. Siqueiros-García, P. van Zwanenberg, J.M. Vervoort, Transformative spaces in the making: key lessons from nine cases in the Global South, Sustain Sci. 15 (2020) 161–178, https://doi.org/10.1007/s11625-019-00749-x.
[12] B.C. Chaffin, A.S. Garmestani, L.H. Gunderson, M.H. Benson, D.G. Angeler, C. A. (Tony) Arnold, B. Cosens, R.K. Craig, J.B. Ruhl, C.R. Allen, Transformative environmental governance, Annu. Rev. Environ. Resour. 41 (2016) 399–423, https://doi.org/10.1146/annurev-environ-110615-085817.

[13] R. Mahon, P. McConney, R.N. Roy, Governing fisheries as complex adaptive systems, Mar. Policy 32 (2008) 104–112, https://doi.org/10.1016/j.marpol.2007.04.011.

[14] S. Levin, T. Xepapadeas, A.-S. Crépin, J. Norberg, A. de Zeeuw, C. Folke, T. Hughes, K. Arrow, S. Barrett, G. Daily, P. Ehrlich, N. Kautsky, K.-G. Mäler, S. Polasky, M. Troell, J.R. Vincent, B. Walker, Social-ecological systems as complex adaptive systems: modeling and policy implications, Environ. Dev. Econ. 18 (2013) 111–132, https://doi.org/10.1017/S1355770×12000460.

[15] E. Lindkvist, X. Basurto, M. Schlüter, Micro-level explanations for emergent patterns of self-governance arrangements in small-scale fisheries—A modeling approach, PLoS One 12 (2017), e0175532.

[16] I.M. Sieber, R. Biesbroek, D. de Block, Mechanism-based explanations of impasses in the governance of ecosystem-based adaptation, Reg. Environ. Change 18 (2018) 2379–2390, https://doi.org/10.1007/s10113-018-1347-1.

[17] M. Schlüter, K. Orach, E. Lindkvist, R. Martin, N. Wijermans, Ö. Bodin, W. J. Boonstra, Toward a methodology for explaining and theorizing about social-ecological phenomena, Curr. Opin. Environ. Sustain. 39 (2019) 44–53, https://doi.org/10.1016/j.cosust.2019.06.011.

[18] H.M. Leslie, X. Basurto, M. Nenadovic, L. Sievanen, K.C. Cavanaugh, J.J. Cota-Nieto, B.E. Erisman, E. Finkbeiner, G. Hinojosa-Arango, M. Moreno-Báez, S. Nagavarapu, S. Reddy, A. Sánchez-Rodríguez, K. Siegel, J.J. Ulibarria-Valenzuela, A.H. Weaver, O. Aburto-Oropeza, Operationalizing the social-ecological systems framework to assess sustainability, Proc. Natl. Acad. Sci. USA 112 (2015) 5979–5984.

[19] X. Basurto, A. Bennett, E. Lindkvist, M. Schlüter, Governing the commons beyond harvesting: an empirical illustration from fishing, PLoS One 15 (2020), e0231575, https://doi.org/10.1371/journal.pone.0231575.

[20] E. Ostrom, Governing the commons. The evolution of institutions for collective action, Cambridge University Press, New York, New York, USA, 1990.

[21] M. Nenadovic, G. Epstein, The relationship of social capital and fishers' participation in multi-level governance arrangements, Environ. Sci. Policy 61 (2016) 77–86, https://doi.org/10.1016/j.envsci.2016.03.023.

[22] N.L. Gutiérrez, R. Hilborn, O. Defeo, Leadership, social capital and incentives promote successful fisheries, Nature 470 (2011) 386–389, https://doi.org/10.1038/nature09689.

[23] J.E. Cinner, T.R. McClanahan, M.A. MacNeil, N.A.J. Graham, T.M. Daw, A. Mukminin, D.A. Feary, A.L. Rabearisoa, A. Wamukota, N. Jiddawi, S. J. Campbell, A.H. Baird, F.A. Januchowski-Hartley, S. Hamed, R. Lahari, T. Morove, J. Kuange, Comanagement of coral reef social-ecological systems, Proc. Natl. Acad. Sci. USA 109 (2012) 5219–5222, https://doi.org/10.1073/pnas.1121215109.

[24] B. Crona, M. Nyström, C. Folke, N. Jiddawi, Middlemen, a critical social-ecological link in coastal communities of Kenya and Zanzibar, Mar. Policy 34 (2010) 761–771, https://doi.org/10.1016/j.marpol.2010.01.023.

[25] S. Sudarmono, J. Sulehan, N. Rahamah Hj Abu Bakar, Patron-client relationship of urbanized fishing communities in Makassar, Int. J. Soc. Sci. Econ. Art. 2 (2011) 1–5.

[26] E. Drury O'Neill, B. Crona, Assistance networks in seafood trade – A means to assess benefit distribution in small-scale fisheries, Mar. Policy 78 (2017) 196–205, https://doi.org/10.1016/j.marpol.2017.01.025.

[27] A. Bennett, X. Basurto, Local institutional responses to global market pressures: the sea cucumber trade in Mexico, World Dev. 102 (2018) 57–70.

[28] S. Jentoft, R. Chuenpagdee, Interactive governance for small-scale fisheries. Global Reflections, Springer International, Switzerland, 2015.

[29] D.S. Johnson, Institutional adaptation as a governability problem in fisheries: patron–client relations in the Junagadh fishery, India, Fish Fish 11 (2010) 264–277.

[30] A.G. Merlijn, The role of middlemen in small-scale fisheries: a case study of Sarawak, Malaysia, Dev. Change 20 (1989) 683–700.

[31] B. González-Mon, Ö. Bodin, B. Crona, M. Nenadovic, X. Basurto, Small-scale fish buyers' trade networks reveal diverse actor types and differential adaptive capacities, Ecol. Econ. 164 (2019), 106338, https://doi.org/10.1016/j.ecolecon.2019.05.018.

[32] B. Crona, Ö. Bodin, Power asymmetries in small-scale fisheries: a barrier to governance transformability, Ecol. Soc. 15 (2010) art32.

[33] T. Piketty, Capital in the Twenty-First Century, Harvard University Press, 2014 accessed April 13, 2016, ⟨https://www.google.com/books?hl=en&lr=&id=T8zuAgAAQBAJ&oi=fnd&pg=PR5&dq=piketty&ots=ZiQyJfZxBl&sig=3DPDL9rKd4_8M0MpABGyd4Niypw⟩.

[34] X. Basurto, Linking multi-level governance to local common-pool resource theory using fuzzy-set qualitative comparative analysis: Insights from twenty years of biodiversity conservation in Costa Rica, Glob. Environ. Change 23 (2013) 573–587, https://doi.org/10.1016/j.gloenvcha.2013.02.011.

[35] X. Basurto, Bureaucratic barriers limit local participatory governance in protected areas in Costa Rica, Conserv. Soc. 11 (2013) 16, https://doi.org/10.4103/0972-4923.110942.

[36] B.J. McCay, F. Micheli, G. Ponce-Díaz, G. Murray, G. Shester, S. Ramirez-Sanchez, W. Weisman, Cooperatives, concessions, and co-management on the Pacific coast of Mexico, Mar. Policy 44 (2014) 49–59, https://doi.org/10.1016/j.marpol.2013.08.001.

[37] A. Cinti, W. Shaw, R. Cudney-Bueno, M. Rojo, The unintended consequences of formal fisheries policies: social disparities and resource overuse in a major fishing community in the Gulf of California, Mexico, Mar. Policy 34 (2010) 328–339.

[38] U. Sumaila, V. Lam, F. Le Manach, W. Swartz, D. Pauly, Global Fisheries Subsidies, European Parliament, 2013. ⟨http://www.europarl.europa.eu/RegData/etudes/note/join/2013/513978/IPOL-PECH_NT(2013)513978_EN.pdf⟩.

[39] M. Nenadovic, X. Basurto, A.H. Weaver, Contribution of subsidies and participatory governance to fishers' adaptive capacity, J. Environ. Dev. 25 (2016) 426–454.

[40] J. Jacquet, D. Pauly, Funding priorities: big barriers to small-scale fisheries, Conserv. Biol. 22 (2008) 832–835, https://doi.org/10.1111/j.1523-1739.2008.00978.x.

[41] T. Markus, Towards sustainable fisheries subsidies: entering a new round of reform under the common fisheries policy, Mar. Policy 34 (2010) 1117–1124, https://doi.org/10.1016/j.marpol.2010.03.011.

[42] E. Robles-Zavala, Coastal livelihoods, poverty and well-being in Mexico. A case study of institutional and social constraints, J. Coast. Conserv. 18 (2014) 431–448, https://doi.org/10.1007/s11852-014-0329-9.

[43] F.R. Westley, O. Tjornbo, L. Schultz, P. Olsson, C. Folke, B. Crona, Ö. Bodin, A Theory of transformative agency in linked social-ecological systems, Ecol. Soc. 18 (2013) art27, https://doi.org/10.5751/ES-05072-180327.

[44] X. Basurto, A. Bennett, A.H. Weaver, S. Rodriguez-Van Dyck, J.-S. Aceves-Bueno, Cooperative and noncooperative strategies for small-scale fisheries' self-governance in the globalization era: implications for conservation, Ecol. Soc. 18 (2013) art38.

[45] A. Bennett, The influence of neoliberalization on the success and failure of fishing cooperatives in contemporary small-scale fishing communities: a case study from Yucatán, Mexico, Mar. Policy 80 (2017) 96–106, https://doi.org/10.1016/j.marpol.2016.06.024.

[46] S.E. Lluch-Cota, A. Parés-Sierra, V.O. Magaña-Rueda, F. Arreguín-Sánchez, G. Bazzino, H. Herrera-Cervantes, D. Lluch-Belda, Changing climate in the Gulf of California, Prog. Oceanogr. 87 (2010) 114–126, https://doi.org/10.1016/j.pocean.2010.09.007.

[47] L. Sievanen, How do small-scale fishers adapt to environmental variability? Lessons from Baja California, Sur, Mexico, Marit. Stud. 13 (2014) 9, https://doi.org/10.1186/s40152-014-0009-2.

[48] K.E. Pellowe, H.M. Leslie, Seasonal variability shapes resilience of small-scale fisheries in Baja California Sur, Mexico, PLoS One 12 (2017) 1–15, https://doi.org/10.1371/journal.pone.0182200.

[49] E. Young, State intervention and abuse of the commons: fisheries development in Baja California Sur, Mexico, Ann. Assoc. Am. Geogr. 91 (2001) 283–306, https://doi.org/10.1111/0004-5608.00244.

[50] C. Méndez-Medina, B. Schmook, X. Basurto, S. Fulton, A. Espinoza-Tenorio, Achieving coordination of decentralized fisheries governance through collaborative arrangements: a case study of the Sian Ka'an Biosphere Reserve in Mexico, Mar. Policy 117 (2020), 103939.

[51] Conapesca, Estimaciones de personas fisicas y morales en pesca y acuacultura., Consejo Nacional de Pesca y Acuacultura, Mazatlán, Mexico, 2017.

[52] X. Basurto, E. Blanco, M. Nenadovic, B. Vollan, Integrating simultaneous prosocial and antisocial behavior into theories of collective action, Sci. Adv. 2 (2016), e1501220, https://doi.org/10.1126/sciadv.1501220.

[53] X. Basurto, E. Ostrom, Beyond the tragedy of the Commons, Econ. Delle Fonti Di Energ. E Dell'ambiente LII (2009) 35–60, https://doi.org/10.3280/EFE2009-001004.

[54] X. Basurto, J. Virdin, H. Smith, R. Juskus, Strengthening Governance of Small-Scale Fisheries: An Initial Assessment of Theory and Practice, Oak Foundation, Gland, Switzerland, 2017.

[55] A.C.E. Quintana, X. Basurto, S. Rodriguez-Van Dyck, A.H. Weaver, More than a Fisher: can an ecological monitoring program involving fishers transform participants? Biodivers. Conserv. (2020).

[56] Lindkvist E., Schlüter M., Basurto X., (2021). https://www.comses.net/codebases/5996/releases/1.0.0/.

[57] N. Bueno, X. Basurto, Resilience and collapse of artisanal fisheries: a system dynamics analysis of a shellfish fishery in the Gulf of California, Mexico, Sustain. Sci. 4 (2009) 139–149, https://doi.org/10.1007/s11625-009-0087-z.

[58] X. Basurto, A. Bennett, E. Lindkvist, M. Schlüter, A Beyond-Harvesting Approach to Common-Pool Resources: An Empirical Illustration from Fishing, PLOS ONE. (forthcoming).

[59] B.J. McCay, Oyster Wars and the Public Trust: Property, Law, and Ecology in New Jersey History, University of Arizona Press, Tucson, Arizona, 1998.

[60] L.J. Haider, W.J. Boonstra, A. Akobirshoeva, M. Schlüter, Effects of development interventions on biocultural diversity: a case study from the Pamir Mountains, Agric. Hum. Values (2019), https://doi.org/10.1007/s10460-019-10005-8.

[61] S. Radosavljevic, L.J. Haider, S.J. Lade, M. Schlüter, Effective alleviation of rural poverty depends on the interplay between productivity, nutrients, water and soil quality, Ecol. Econ. 169 (2020), 106494, https://doi.org/10.1016/j.ecolecon.2019.106494.

[62] K. Nyborg, J.M. Anderies, A. Dannenberg, T. Lindahl, C. Schill, M. Schluter, W. N. Adger, K.J. Arrow, S. Barrett, S. Carpenter, F.S. Chapin, A.S. Crepin, G. Daily, P. Ehrlich, C. Folke, W. Jager, N. Kautsky, S.A. Levin, O.J. Madsen, S. Polasky, M. Scheffer, B. Walker, E.U. Weber, J. Wilen, A. Xepapadeas, A. de Zeeuw, Social norms as solutions, Science 354 (2016) 42–43.

[63] C. Efferson, S. Vogt, E. Fehr, The promise and the peril of using social influence to reverse harmful traditions, Nat. Hum. Behav. 4 (2020) 55–68, https://doi.org/10.1038/s41562-019-0768-2.

[64] R. Biggs, M. Schlüter, M.L. Schoon, Principles for Building Resilience: Sustaining Ecosystem Services in Social-Ecological Systems, Cambridge University Press, 2015.
[65] M. Hall-Arber, C. Pomeroy, F. Conway, Figuring out the human dimensions of fisheries: illuminating models, Mar. Coast. Fish. 1 (2009) 300–314, https://doi.org/10.1577/C09-006.1.
[66] B.I. Crona, T. Van Holt, M. Petersson, T.M. Daw, E. Buchary, Using social-ecological syndromes to understand impacts of international seafood trade on small-scale fisheries, Glob. Environ. Change 35 (2015) 162–175, https://doi.org/10.1016/j.gloenvcha.2015.07.006.