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A systematic review of co-managed small-scale fisheries: Social diversity and adaptive management improve outcomes

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ABSTRACT

Small-scale fisheries are an important source of livelihoods, particularly among poor coastal populations. To improve fisheries' condition and maximize their contribution to human welfare, co-management approaches have proliferated worldwide. In this article, we conduct a systematic review of academic literature to examine the context and attributes of co-management initiatives in small-scale fisheries, and their expected outcomes. The review suggests that a supporting legal and institutional framework facilitates the emergence of co-management, because it contributes to clarify and legitimize property rights over fish resources. It is also found that co-management delivers both ecological and social benefits: it increases the abundance and habitat of species, fish catches, actors' participation, and the fishery's adaptive capacity, as well as it induces processes of social learning. Furthermore, co-management is more effective if artisanal fishers and diverse stakeholders become involved through an adaptive institutional framework. However, the review also suggests that more research is needed to discern when co-management initiatives can transform pre-existing conflicts, challenge power asymmetries and distribute benefits more equitably.

1. Introduction

Small-scale fisheries support the livelihoods of many coastal communities around the world (Kittinger et al., 2013). Ninety percent of the world's fishers are directly involved in small-scale fishing, i.e. about 34 million people, and another 100 million are involved in related activities (Béné et al., 2007; FAO, 2016a, 2016b). However, these fisheries face growing threats such as overfishing, competition with industrial fleets, water pollution, destruction of fish habitats, and an increasing human population and demand for land in coastal areas (FAO, 2016b). Increasing fishing pressure is leading to a reduction of marine biodiversity, which will over time make fisheries less resilient in a changing global climate (Brander, 2007). These threats are coupled with a limited capacity of many governments to develop and support management models that suit the multispecies character of small-scale fisheries and the numerous and dispersed landing sites characterizing them (Allison, 2001; Kolding et al., 2014).

The co-management of small-scale fisheries has emerged as a response to these threats and challenges, proliferating worldwide over the last decade (FAO, 2016b). Co-management promotes the joint management of the fisheries' resources by direct users, governments and other actors (Armitage et al., 2007a; Berkes, 2009). It is regarded as a participatory management model able to foster the sustainability of fisheries in biological, social, and economic terms (Costanza et al., 1998; Gutiérrez et al., 2011; Jentoft, 1989; Muñoz-Erickson et al., 2010; Pinkerton, 1989). Co-management can contribute to meet both fisheries and conservation objectives in marine ecosystems (Worm et al., 2009). It has also been shown that co-management can deliver greater benefits to local communities in both terrestrial and marine protected areas because, by strengthening tenure rights and decision-making processes, it can result in increased and more equitably shared economic benefits (Oldekop et al., 2016).

A previous review of industrial and artisanal fisheries (Gutiérrez et al., 2011) identifies a number of co-management attributes that are conducive to positive outcomes, including the presence of community leaders, strong social cohesion, individual or community fish quotas, and community-based protected areas. A meta-analysis focused on small-scale fisheries (Evans et al., 2011) demonstrates that co-

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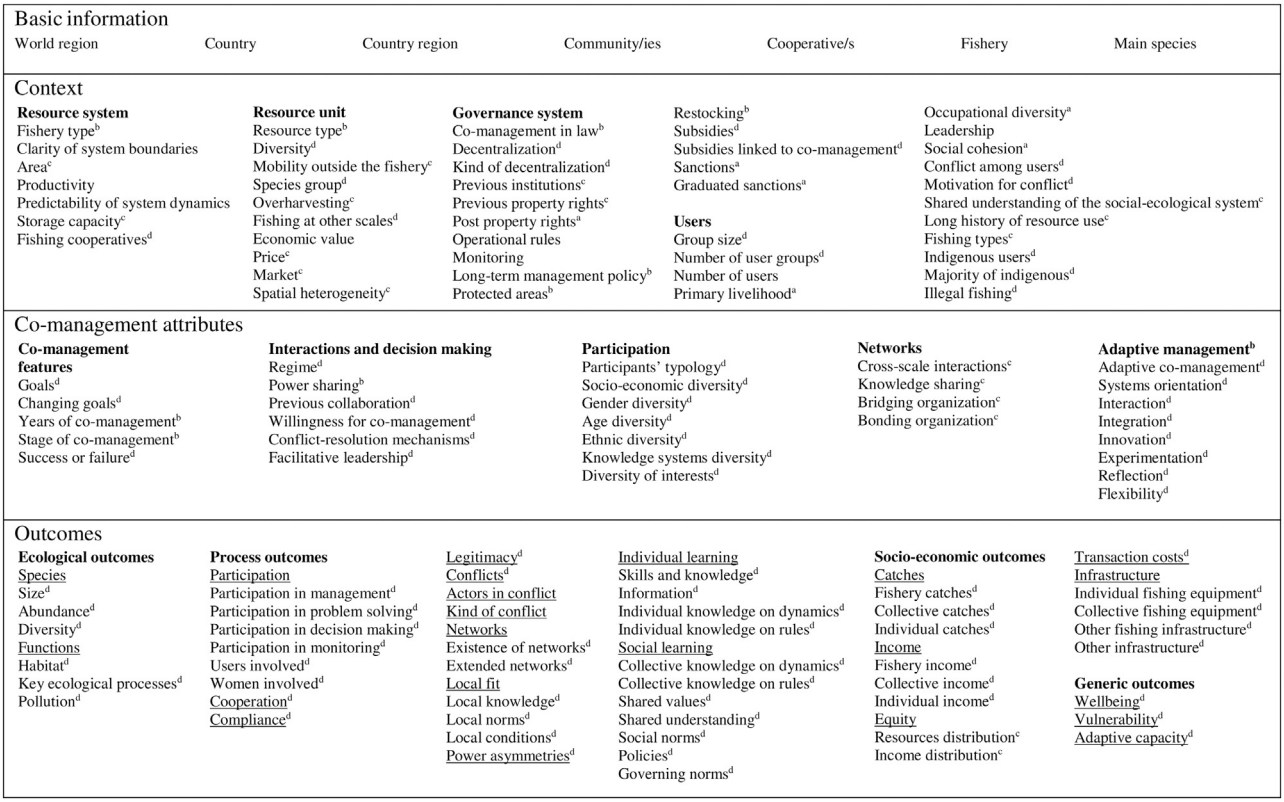

Fig. 1. A framework for the analysis of co-management in small-scale fisheries.
Each of the four variable domains includes variables and may also include categories (in bold). In the *outcomes* domain, underlined words with variables underneath refer to variable groupings. Variables without superscript specify variables from Ostrom's framework (Ostrom, 2009, 2007), superscript [a] specifies variables adapted from Ostrom's framework by other authors, superscript [b] specifies variables included in other works (Basurto et al., 2013; Ernst et al., 2013; Gutiérrez et al., 2011; MacNeil and Cinner, 2013), superscript [c] specifies variables adapted from Ostrom's framework, and superscript [d] specifies our own proposed variables.

management results in positive impacts on fishers' income and other sources of material wellbeing, as well as on the fishery's ecological condition. The study also shows that co-management improves social participation, compliance with the fishery's management rules, and local control over resources while reducing conflict. These findings echo others who previously argued that co-managed fisheries enhanced social equality (Loucks et al., 2003), resulted in more legitimate norms that better fit local conditions (Jentoft, 1989), fostered responsibility among resource users (Nielsen and Vedsmand, 1999), and reduced management costs (Carlsson and Berkes, 2005).

Further, in a context of climatic changes related to sea level rise, ocean temperature change and ocean acidification, which might modify coastal ecosystems and fish species' range and behaviours (Savo et al., 2017; Wong et al., 2014), the adoption of adaptive management principles can be critical for the sustainability of small-scale fisheries in the near future. Flexible, innovative and experimental management practices could in this context strengthen co-management initiatives and improve the capacity of the social-ecological system to better cope with uncertainty and surprise (Armitage et al., 2007b; Olsson et al., 2004).

Our systematic review builds on and contributes to co-management literature by examining the links between context, attributes and outcomes of co-managed small-scale fisheries through the lens of Ostrom's framework for the analysis of social-ecological systems (Mcginnis and Ostrom, 2014; Ostrom, 2009, 2007), which we complement with other indicators from adaptation and co-management literature (Basurto et al., 2013; Cinner et al., 2012; Ernst et al., 2013; Gutiérrez et al., 2011; Partelow, 2015; Plummer et al., 2014, 2012; Plummer and Armitage, 2007a; Plummer and FitzGibbon, 2007). To our knowledge, this is the first review of co-managed small-scale fisheries that includes adaptive management attributes to test how such attributes affect outcomes. Specifically, we ask: Which are the context and attributes of co-managed small-scale fisheries? Which outcomes does the co-management of small-scale fisheries result in? And, how are the context and attributes influencing co-management outcomes? By answering these questions, we contribute to a better understanding of how co-managed small-scale fisheries work as complex social-ecological systems while suggesting ways to improve their performance.

In what follows we introduce the analytical framework, explain the systematic review's protocol, and present our results organized according to our three questions. We first characterise the context and attributes of co-management, and we find that co-management usually develops in contexts of natural resource management decentralization, where co-management contributes to move away from an open access condition and it supports the creation of a new property regime and more legitimate management rules. Second, we show that co-management results in positive social and ecological outcomes overall, while its ability to resolve pre-existing conflicts, address power asymmetries or distribute benefits more equitably is less certain because these issues are scarcely reported in the literature reviewed. Finally, when looking at which context and attribute variables might be influencing co-management effects, we find that involving a diversity of actors and implementing adaptive management practices contribute to more positive outcomes. We discuss these and other findings in the light of relevant literature and we conclude by emphasizing the potential of co-management to foster the sustainability of small-scale fisheries and by highlighting research gaps.

2. Analytical framework and methods

2.1. Analysing co-management outcomes in small-scale fisheries

Ostrom's framework for the analysis of the sustainability of social-ecological systems (Mcginnis and Ostrom, 2014; Ostrom, 2009, 2007) provides a coherent and robust set of variables to analyse how attributes of a resource system, the resource units, the users, and the governance system affect interactions and resulting outcomes. We adapted the framework to better fit the study of small-scale fisheries co-management, following previous related research (Basurto et al., 2013; Cinner et al., 2012; Ernst et al., 2013; Gutiérrez et al., 2011; Partelow, 2015) and including indicators from literature on the adaptive management of social-ecological systems (Plummer et al., 2014, 2012; Plummer and Armitage, 2007a; Plummer and FitzGibbon, 2007; Thiel et al., 2015).

The resulting analytical framework contains: 1) basic information, 2) context, 3) co-management attributes, and 4) outcomes (Fig. 1). Basic information includes key geographical and ecological descriptors of the fishery, while context variables refer to the *resource system*, *resource unit*, *governance system* and *users*. Co-management attributes are split across five categories (including Ostrom's *interactions* variables): *co-management features*, *interactions and decision making*, *participation*, *networks*, and *adaptive management*. Finally, outcomes encompass another four groupings: *ecological*, *process*, *socio-economic* and *generic outcomes*, each containing some self-added variables specific to small-scale fisheries' co-management. We have excluded from our analysis the two sets of variables from Ostrom's framework that refer to *related ecosystems* and *social, economic, and political settings* since almost none of the articles reviewed included information on their respective variables (e.g., climate trends, economic development or demographic trends, among others).

We defined most *context* and *co-management attributes* as categorical variables, deserving either a 'yes/no' or a closed list of given responses during the review process, whereas a few others were numerical variables (e.g. area of the system, number of users). *Outcomes* variables were also considered categorical, most including three possible answers, i.e. '*same*, *increased*, and *decreased*' or '*no*, *positive*, and *negative*', and a few with a '*yes/no*' option. The description of each variable and its possible values are provided in Appendix A.

2.2. Data sources

We grounded this article on well-established guidelines for the development of systematic literature reviews (Collaboration for Environmental Evidence, 2013; Petticrew and Roberts, 2006). To identify relevant research articles and book chapters to be included in the review, we conducted a keyword-informed search in Scopus and Web of Knowledge using the following strings: 1) For Scopus: TITLE-ABS-KEY (co-management OR comanagement OR "collaborative management") AND ALL ("small scale fish*" OR "local fish*" OR "traditional fish*" OR "artisanal fish*" OR "subsistence fish*") AND ALL ("natural resourc*" OR biodiversity OR conservation OR ecosystem OR environment), and 2) for Web of Knowledge: TOPIC: (comanagement OR co-management OR "collaborative management") AND TOPIC: ("Small-scale fish*" OR "local fish*" OR "traditional fish*" OR "artisanal fish*" OR "subsistence fish*") AND TOPIC: ("natural resourc*" OR biodiversity OR conservation OR ecosystem OR environment). These searches targeted all articles and book chapters published until December 2015 (Fig. A.1 in Appendix A). This rendered 544 publications in Scopus and 186 in Web of Knowledge. After bringing them together and eliminating duplicate entries, our dataset encompassed 626 articles and book chapters.

The two first authors screened the abstract of all manuscripts and, when necessary, the full text based on four inclusion criteria: 1) the focus of the case study was a small-scale fishery; 2) the fishery was co-managed, i.e. governed by at least local users and a government actor; 3) the study described a change in at least one variable within the four dimensions of outcomes considered by our analytical framework, i.e. ecological, process, socio-economic, and generic; and 4) the study was empirical and based on first-hand collected data (Fig. A.2 in Appendix A for more information on the criteria appraisal process). As a result of this screening process, 556 out of the 626 manuscripts were discarded and our dataset was reduced to 70 articles.

2.3. Data collection and analysis

The 70 articles were split among the co-authors and the data collected was organized in a shared Excel file, in which each row had the information of one case study, since one article could include more than one case study. The first two columns indicated the article number and reference, i.e. author(s) and year, and the following columns were devoted one to each variable, starting with the variables of *basic information*, and followed by the categories *resource system*, *resource unit*, *governance system*, *users*, *co-management features, interactions and decision-making, participation, networks*, *adaptive management*, *ecological outcomes*, *process outcomes, socio-economic outcomes*, and *generic outcome*. For each outcome category described in the reviewed articles, we also recorded information on the assessment methods.

To ensure consistency in data collection, the first two authors reviewed five randomly selected articles separately. The inconsistencies between the two authors were discussed among all authors and consensus was reached on how to document and code each variable. During data extraction, three articles were discarded because they included repeated case studies that were better described in other articles. The final dataset for the analysis included 67 articles, which in turn referred to 91 case studies (Table A.2 in Appendix A).

Data analysis included three steps. First, categorical variables were quantified, when possible, by assigning to each response a numeric value. Second, we generated absolute frequencies and percentages for each variable. Third, we employed pairwise Fisher exact tests to test associations between co-management context and attributes (independent variables), and outcomes (dependent variables) (Tables A.3 and A.4 in Appendix A). For those variables that showed significant associations in the Fisher exact tests ($p \leq 0.1$), we conducted multinomial logistic regressions to examine their individual and aggregated effects on each outcome variable.

To complement the analysis, we created variable groupings. Within *co-management attributes,* we created a group of variables called '*adaptive management*' by integrating the variables *adaptive co-management*, *systems orientation*, *interaction*, *integration*, *innovation*, *experimentation*, *reflection* and *flexibility*. This group was meant to test whether one or more variables of adaptive management had any effects on *outcomes*. In turn, within the *outcomes* dimension, we created several variable groupings at three levels: 1) a set of 11 groups (see underlined text in Fig. 1) that gathered related variables, 2) four groups that gathered the variables of the four *outcomes* categories, and 3) one broad group of all *outcomes*.

The creation of these variable groupings was aimed at testing whether *context* and *co-management attributes* had any effects on these groupings. For instance, the grouping '*species*' was the result of bringing together the variables *size*, *abundance* and *diversity*, being *species* equal to 1 (improves) if at least one of the variables in this group improved and none of them worsened; equal to –1 (worsens) if at least one of these variables worsened and none improved; and equal to 0 (neutral) if at least one variable did not change and none improved or worsened or one worsened whereas another improved. The grouping '*ecological outcomes*' included the groups *species* and *functions*, being *ecological outcomes* equal to 1 if one group improved and the other one did not worsen; equal to –1 if one group worsened and the other one did not improve; and equal to 0 if one of the groups did not change whereas the other did not improve nor worsened or one group worsened whereas

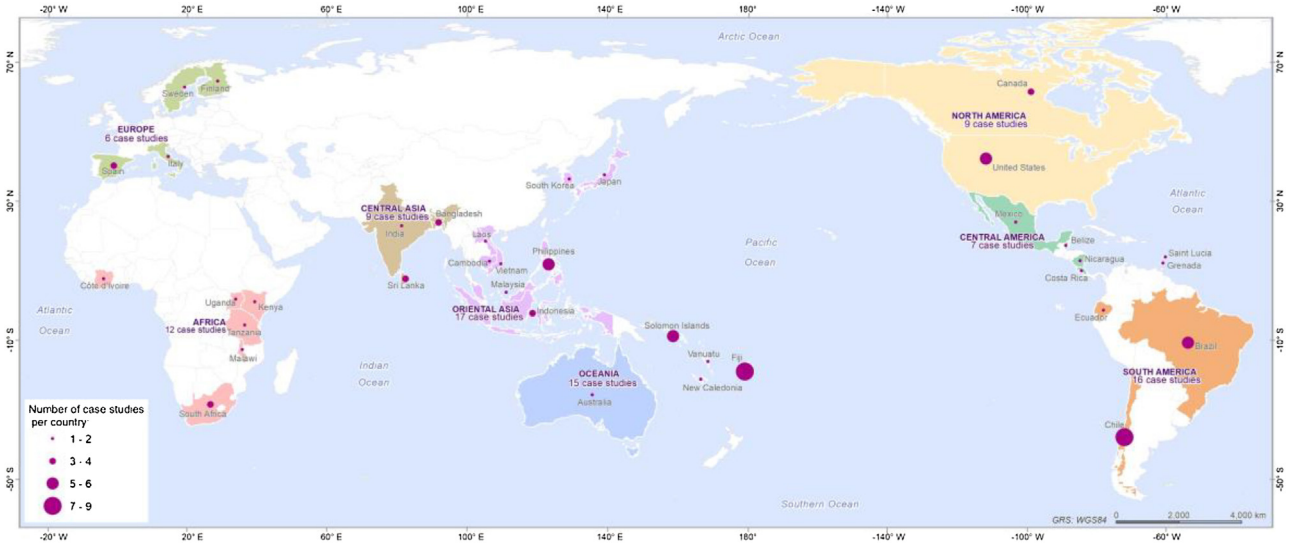

Fig. 2. Location of the case studies in world's regions.
Sources: GADM database of Global Administrative Areas (http://www.gadm.org/) and UN's Standard country or area codes for statistical use (M49) (https://unstats.un.org/unsd/methodology/m49).

the other improved. Likewise, the grouping '*outcomes*' included the four dimensions groups: *ecological*, *process*, *socio-economic* and *generic outcomes*. None of the multinomial logistic regressions with more than one independent variables yielded significant results because of the low number of reported variables in many case studies.

3. Results

3.1. Basic information and context

The 91 cases of our dataset spread across 37 countries, mostly around the Pacific (Table A.5 in Appendix 1). Chile and Fiji have nine and eight cases, respectively, while the Solomon Islands, USA and Brazil have six case studies each and the Philippines, five (Fig. 2).

Although context variables are not evenly reported across case studies (Fig. 3 and Fig. A.3 in Appendix A for a comprehensive list of all context variables), the results of the most reported variables provide an overview of the characteristics of the dataset. Variables reported in more than 75% of the cases are *fishery type* (mentioned in 88 cases), *post access rights* (76), *resource type* (73), *operational rules* (72), *co-management in law* (71), *previous access rights* (70), and *previous institutions* (68). Co-management is most reported in fisheries with a multispecies character, as it is shown in 57 cases versus 16 cases where the fishery only targets one species. Co-management is mostly adopted in coastal (61 cases) rather than in inland fisheries (23), whereas off-shore fisheries are rare as they represent only one case. Co-management initiatives target above all shellfish (39) and finfish (34), although a few cases also report resources such as algae, marine mammals or reptiles (11). Co-management seems more likely to crystalize in countries with favourable national legislation (67) and well-defined operational rules (68). However, there are also four cases where co-management has been established without a supporting legal framework and another four cases where operational rules are lacking.

Most cases report the fishery's previous property rights regime (60 out of 91). Before the establishment of co-management, most fisheries were an open access regime (31 cases), or they were managed through territorial use rights (21) and species fishing permits (8). With the embracing of co-management, 35 cases report the implementation of territorial use rights, nine the use of fishing permits for targeted species, and 12 the combination of both territorial use rights and fishing permits. Among the reviewed cases, one fishery returned to an open access regime after the co-management initiative failed, and seven continued to operate in an open access regime but experienced difficulties to enforce regulations. The reviewed cases indicate that co-management initiatives happen mostly in fisheries that were previously managed by the government (33 cases) or the local community (25), five cases had both governmental and local institutions and five more cases report the absence of previous institutions.

In 50 cases, the authors mention that the co-management initiative has evolved in a context of state-driven natural resource management decentralization. However, only 35 of these cases describe what kind of decentralization has taken place: 20 are inserted in a wider process of resource rights' devolution to local governments; seven are part of ongoing efforts to delegate more resource management powers to local government officers; five represent a transfer of rights to local civil society organizations or private enterprises; and another three consist of transferring management responsibilities to governmental regional and field offices.

There are other context variables defining the characteristics of the co-managed small-scale fishery, but these are less frequently reported and should thus be interpreted with caution. For instance, only 33 cases document the area of the fishery, which usually does not reach 1000 km^2 (26 cases), and 35 fisheries have boundaries that are clearly defined by biophysical conditions, such as fisheries in a lake or around an island. In eight cases, these boundaries are not so clear. Thirty-seven case studies explicitly acknowledge that the co-managed fishery overlaps with a marine protected area while another 13 explicitly indicate that they do not overlap with any kind of protected area.

The presence of fishers' cooperatives or unions is stated in 38 out of 41 cases referring to this variable. Only 32 (out of 40) and 39 (out of 46) cases document enforced sanctions and functional monitoring systems, respectively, which is surprising given the need to monitor co-management initiatives as a means to understand their outcomes. The fish resource was overharvested before co-management in 42 of the 50 cases reporting on this variable. In 13 cases, the resource is only harvested in the fishery under study, whereas in 28 it is also fished outside. In our dataset, only one case reports a fishery without local economic value whereas 55 cases report that fish has economic value -beyond subsistence, and other cultural values-, and 14 of these emphasise that fish is traded in regional and/or international markets.

Whenever mentioned, fishing is the primary income source for users in most case studies (58 out of 61 cases), but there are often other

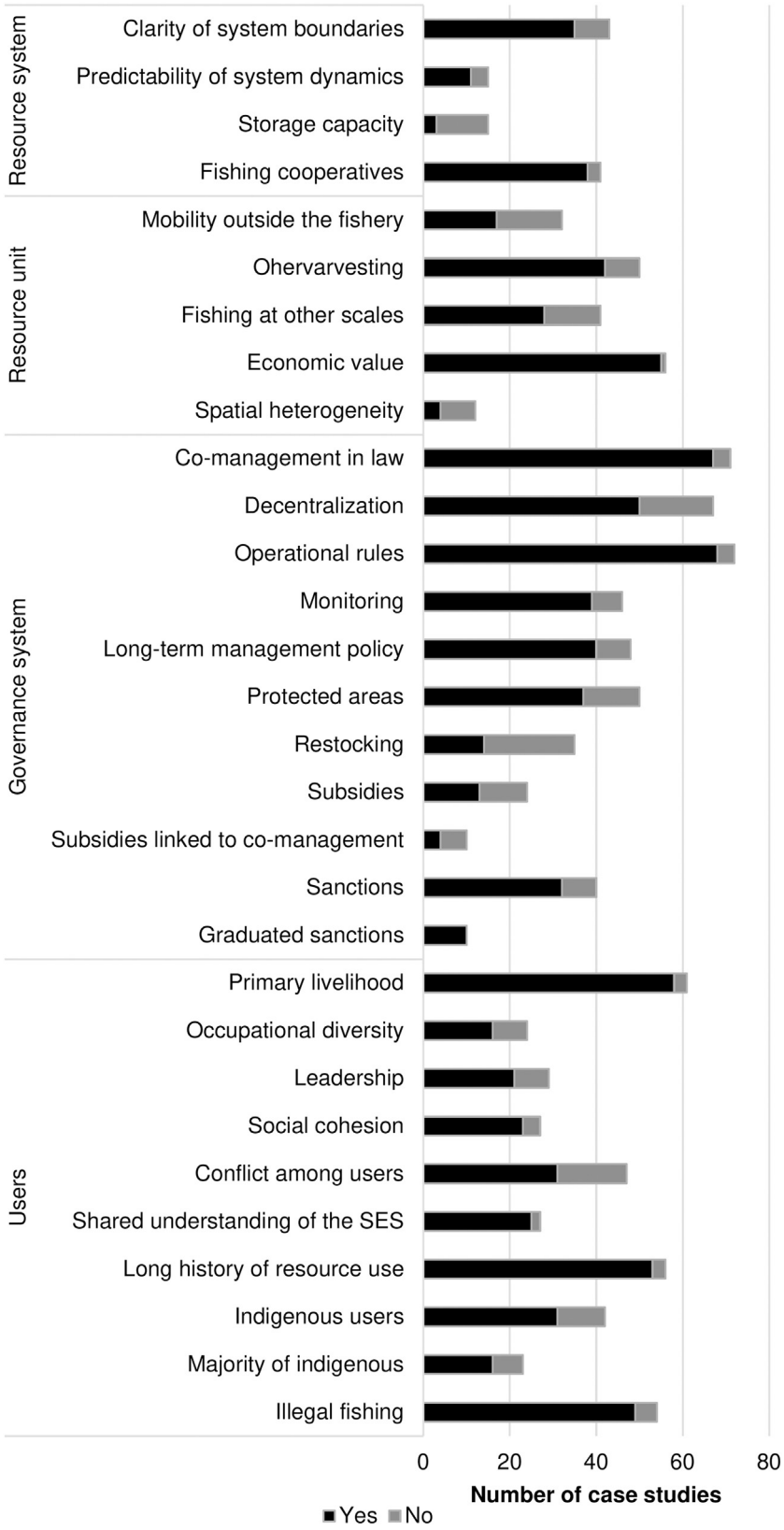

Fig. 3. Number of cases studies reporting context variables with yes/no answers (Fig. A.3 in the Appendix A for the whole set of context variables).

sources of income reported (16 out of 24 cases). Artisanal, commercial and subsistence fishing are the most common fishing practices, mentioned in 63, 55, and 53 cases of our dataset, respectively. Industrial and recreational fishing are reported in only 6 and 9 of the 91 cases. The presence of indigenous fishers is explicitly described in 31 cases whereas 11 cases explicitly report their absence.

Fifty-four cases in our dataset make explicit mention to the existence of illegal fishing practices, and only five highlight the absence of

such practices before co-management was introduced. Conflict is documented in 31 cases and inexistent in 16 cases. Causes of conflict are varied, but these are mostly caused by contested property rights and/or management rules, or by resource competition and uneven decision-making power. By contrast, although relatively few cases mention social cohesion and trust in existing leaders (27 and 29 cases, respectively), most of these cases report the existence of these variables in the described fisheries (23 and 21 cases, respectively). In this regard, users often share a long history of resource use (53 out of 56 cases) and an understanding of the social-ecological system (25 out of 27 cases).

3.2. Co-management attributes

Co-management initiatives usually aim to fulfil between one and four goals. Among the 70 cases reporting goals (77% of the cases reviewed), the most mentioned seek an improvement of the management process of the fishery, namely: *to increase participation in management* (29 cases), *to increase legitimacy and/or compliance with fishing rules* (19), *to define or enforce fishing rights* (19), and *to incorporate customary management norms in formal management* (18). Only one case has the explicit objective of resolving existing conflicts in resource management. Ecological, socio-economic and generic goals are much less reported, with 24, 8 and 8 cases, respectively (Table A.6 in Appendix A for the whole set of objectives). Given the expected adaptive nature of co-management, it is surprising that only 15 cases indicate that goals have changed over the course of the initiative while 21 have maintained the same goals (Fig. 4).

The co-management initiatives included in this review have been established relatively recently. Out of the 79 cases reporting their years of existence (87%), 63 have existed for 20 years or less. The oldest documented initiatives are seven cases in Fiji that have been running for 58 years. Some articles document very young initiatives, such as those in St. Lucia, Brazil and the Philippines which had run for two years.

The stage of co-management is reported in 84 cases (92%): 53 state that co-management is well implemented, 22 report initiatives that are still being implemented and nine describe partnerships that have concluded. Among the latter, five were short-term development projects, another three were not able to continue due to a lack of government's commitment and support, and one could not handle the ecological variability of the fishery, which in turn led to resource depletion after three years of co-management. Half of the co-management partnerships (46 cases) involve only users' representatives and governments, whereas the other half include third party organizations (45), such as NGOs and research centres, which provide expert knowledge (Fig. 5).

Interaction and decision-making attributes are much less reported. The *regime*, or the main actor promoting co-management, is mentioned in 66 cases (73%). Twenty-nine of these have the community as the main promoter, 25 the government, nine an NGO, two a research centre and one a private company. Forty-one cases in our dataset highlight that actors are willing to participate in co-management, whereas in nine cases they are not.

The most common power-sharing scheme is *cooperative*, which has been developed in 17 cases where government and users share, in theory at least, equal power (find the definitions of all variables in Table A.1, Appendix A). An *advisory* scheme is present in another 16 cases, where governments endorse the decisions of the users. *Informative*, *consultative*, or *instructive* power-sharing arrangements are described in four, nine and two cases, respectively. Forty-one cases note that there is a lead actor who supports local involvement in co-management, which is considered lacking in another six cases. Finally, conflict-resolution mechanisms are documented in 31 out of 41 cases.

Although a diversity of actors is theoretically important to nurture the co-management partnership with different perspectives, experiences and knowledge systems, this is scarcely reported in our dataset. In this regard, the most documented variable in the *participation* category is the existence of a diversity of interests (37 cases, 41%), while other sources of diversity, such as knowledge, gender and age diversity are reported in only 23, 22, and eight cases, respectively. In the *networks* category, a bridging organization supporting cross-scale interactions, i.e. vertical links across the involved actors, is mentioned in 38 cases and lacking in three cases (reported by 45% of the dataset cases), whereas a bonding organization supporting cohesion among participants, i.e. horizontal links, is described in 18 cases and lacking in five cases (reported by 25% of the dataset cases). Twenty case studies explicitly affirm that government and users had collaborated before co-management was introduced, whereas in 14 cases they had not (reported by 37% of the dataset cases).

Finally, only 14 cases analysed are explicitly characterised as adaptive co-management, but interestingly 59 of the total sample (65%) describe at least one characteristic of adaptive management. These include initiatives with a *systems orientation* approach, i.e. management that recognises and accounts for human-environment complex interactions (reported in 30 out of 33 cases reflecting explicitly on this variable), *integrating* different perspectives, approaches and knowledges (31 out of 36) and facilitating deliberative *interactions* among actors (29 out of 36). Case studies applying *flexible* norms (21 out of 32) and *experimental* management actions (16 out of 22), which are also key characteristics of adaptive co-management, are less often reported.

3.3. Outcomes

The reviewed cases show an improvement of all outcome groups: *ecological*, *process*, *socio-economic* and *generic*. However, the number of cases reporting each outcome varies (Fig. 6 and Fig. A.5 in Appendix A for the whole set of outcome variables). Ecological outcomes improve in 29 of the 40 cases reporting such outcomes (44% of the cases). The most reported ecological outcomes are *abundance* of species (29 cases), which increases in 20 cases, decreases in five and does not change in four, and *habitat* for nesting, breeding and feeding (15 cases), that increases in 10, decreases in three and does not change in two cases.

Process outcomes are the most reported and improved outcomes. They are stated in 88 cases (97%) and have a positive impact in 72. The single most reported outcome is *participation*, mentioned in 71 cases. *Participation* improves in 67 cases, worsens in 1 and remains equal in 3. Participation increases mostly in what concerns decision-making processes, but it also increases in problem-solving forums and monitoring activities. *Social learning* improves in 41 cases, worsens in three and does not change in four. Most improvements of social learning take the form of strengthened agreement on social norms, increased knowledge of the management rules, as well as of expanded shared understanding. Other aspects of social learning, such as changing policies where unsustainable resource management routines might be rooted, questioning governing norms that might contravene co-management objectives, or improving the ecological knowledge of the fishery across all participant actors, are less reported. *Local fit*, i.e. the congruence of management norms with local knowledge, norms and conditions, increases in 39 cases, decreases in two and remains equal in six. Improvements mostly happen in the form of increased alignment of management practices with local ecological conditions, followed by improved correspondence with local knowledge and with local norms. Finally, 34 cases highlight that compliance has increased with co-management, four mention a decrease and 10 describe no changes.

Socio-economic outcomes are less reported and show the least positive results, only improving in 23 of the 39 cases referring to these outcomes (43% of the dataset cases). The most reported outcome is *catches* (24 cases) either at a fishery, community, cooperative or individual level. After the implementation of co-management, catches increase in 16 cases where this issue is reported, decrease in six and do not change in two. Impacts on income are reported in 17 cases, of which income increases in 14 and decreases in three of these.

Finally, generic outcomes are the least reported, with only 34 cases

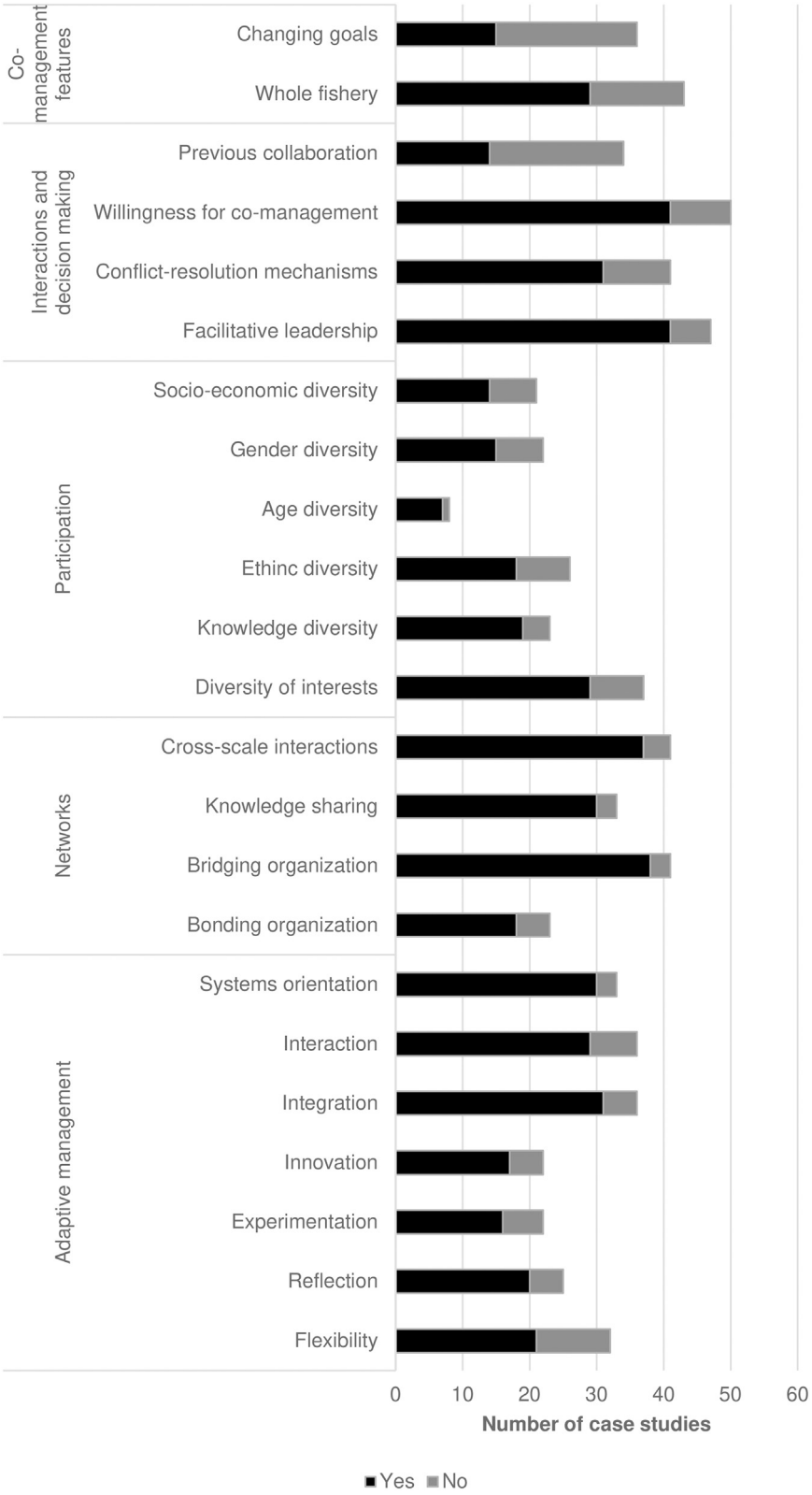

Fig. 4. Number of cases studies reporting key co-management attributes with yes/no answers (Fig. A.4 in Appendix A for the whole set of co-management attributes).

making explicit reference to any of such outcomes (37% of the dataset cases). *Adaptive capacity* is the most reported (22 cases), and it is reported to increase in 16 of these cases and to decrease in 6. *Wellbeing* (16 cases) is reported to increase in 14 of these cases and does not change in two. Finally, v*ulnerability* (7 cases) is reported to increase in 5 of these cases, to decrease in one and to remain the same in one of the cases.

The only three outcome variables reporting more neutral and negative effects than positive are conflicts (42 cases), *power asymmetries* (14) and *distributional equity* (12), yet these variables show low reporting levels. Twenty dataset cases explicitly report that conflicts do not change, 14 describe a decrease of conflicts and 8 report an increase.

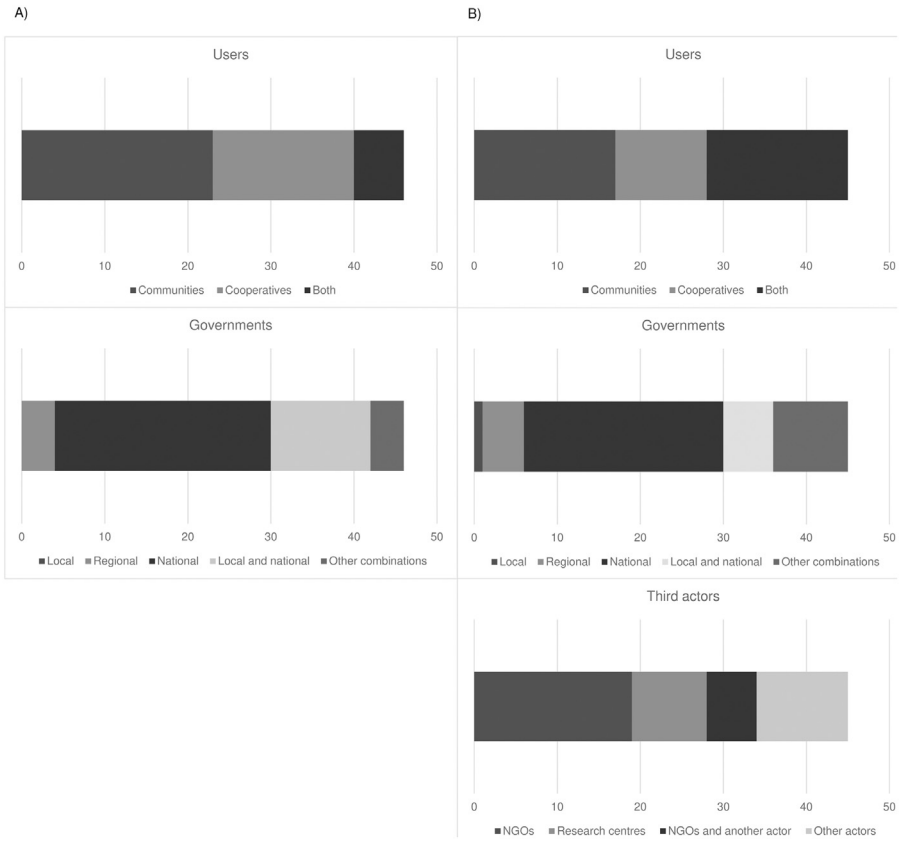

Fig. 5. Co-management partnerships involving users and governments (A) and involving users, governments, and third actors (B).
Numbers on the bottom of the bars indicate number of case studies. *Other combinations* refer to *local and regional* governments, *regional and national* governments, and *local, regional and national* governments. *NGOs and another actor* refers to *NGOs* and an *intergovernmental organization*, a *research centre* or a *company*. *Other actors* refers to *intergovernmental organizations*, *third-country governments*, *multi-stakeholder bodies at regional level*, and *companies*.

Only 29 cases describe the actors involved in these conflicts, including grievances among users (10 cases), users and government (12 cases), users and other actors (two cases), and users, government and other actors (five cases). Existing power asymmetries are reduced in four cases of the dataset, reinforced in three of the cases and ignored by the co-management initiative in seven cases. Finally, distributional equity increases in five cases of the dataset while remains the same or worsens in four and three cases, respectively.

The level of achievement of the goals stated by each co-management initiative is not always measured in the correspondent articles (Fig. 7). The goal *to define or enforce fishing rights* is the most commonly assessed and realised in practice: Nineteen of the cases in the dataset report this goal, with 15 cases indicating positive outcomes and one being neutral. If we exclude the goals stated in only one or two cases of our dataset (i.e. *dealing with conflict*, or *maximising equity*), the following least reported goal is *to address illegal fishing*, with only three of the dataset cases referring to it and indicating a negative result.

Sixty-six cases (i.e. 73%) provide information on research design. Most of them (54 cases) are grounded on an analysis of the fishery's state compared to baseline information, which is commonly collected through users' perceptions (44) and, to a lesser extent, through expert consultation (27). Twenty-three cases collect and contrast data between study sites and control groups and in two cases data are estimated on the basis of past records. Twenty-nine cases use secondary sources of information to complement first-hand empirical findings; these sources are scientific articles (17) and reports and newsletters (24) (Fig. A.6 in Appendix A to find this data disaggregated by outcomes categories).

3.4. Explaining co-management outcomes

Results from both Fisher test and multinomial logistic regressions show some significant results that shed light on existing interactions between co-management context, attributes and outcomes (Table 1 and Tables A.3 and A.4 in Appendix A). The most influential variable in the expected outcomes is the *diversity of interests* represented in the co-management initiative. Engaging a diversity of stakeholders in the co-management partnership is likely to result in more positive *outcomes* overall, and *process outcomes* particularly (13.50 times more likely and 8.67 times more likely respectively) than to remain constant (no change). Also, engaging actors that represent the *socio-economic diversity* of the fishery is related with increased *compliance* ($p \leq 0.05$).

Our statistical analysis also suggests that the existence of *operational rules*, such as quotas and temporal restrictions, can facilitate *social learning* ($p \leq 0.05$). Existing rules are often discussed and refined by co-management participants, resulting in e.g. increased collective knowledge of the dynamics of the fishery, more agreement on rules, more agreement on desirable behaviors towards natural resources, and other characteristics of social learning. Surprisingly, we also observe that the presence of an intergovernmental organization in the co-management partnership hinders the creation of multilevel *networks* ($p \leq 0.05$), and the presence of community representatives lowers the chances of reducing *conflict* ($p \leq 0.05$). The latter might be explained by the fact that conflicts are more likely to surface when community interests are brought to the fore through the interaction of their representatives in the co-management regime. We would suggest that unearthing all existing conflicts in co-management forums is necessary to deal with them successfully over time. The former result is less intuitive, and it may be explained by the fact that our dataset is small and only three cases report the existence of intergovernmental organizations.

The analysis also suggests that if the targeted species is *shellfish, socio-economic* outcomes are more likely to remain constant than to worsen (0.05 times more likely) or to improve (0.10 times more likely). The presence of *industrial fishing* in the fishery constrains *species*' size, diversity and abundance ($p \leq 0.05$), and is also likely to impinge negatively on *cooperation*, which might not increase as a result ($p \leq 0.05$). However, if there is *artisanal fishing*, resource management *legitimacy* is more likely to improve with the establishment of co-management ($p \leq 0.05$). Our analysis also suggests that when *illegal fishing* is

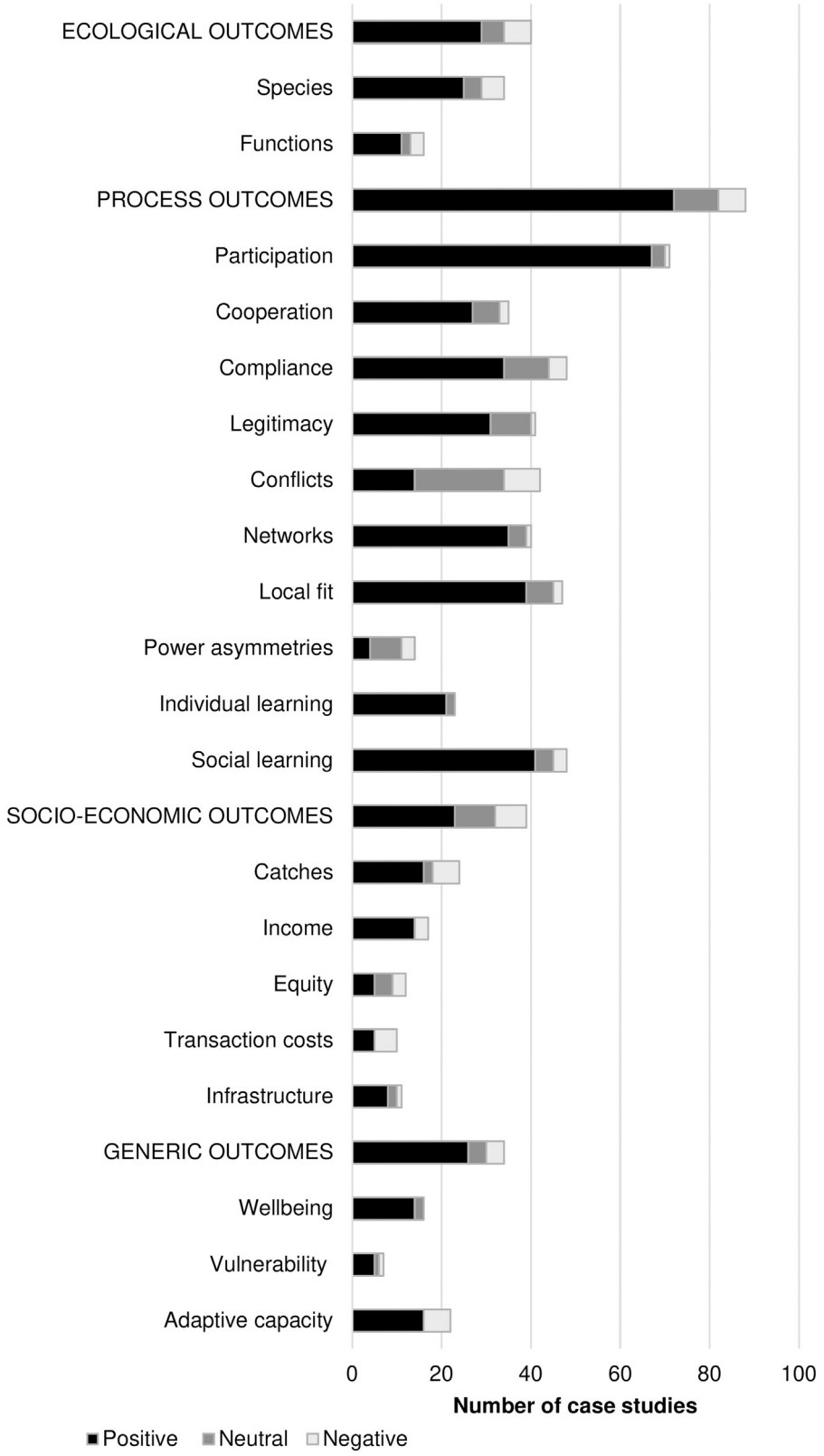

Fig. 6. Number of case studies reporting outcome variables.
Bars indicate how many of the case studies reporting a given variable do so positively, negatively, or indicate no change.

reported, *ecological outcomes* are more likely to improve (29.98 times more likely) than to remain constant. Taken together, these results suggest that involving *artisanal* fishers in co-management may result in more legitimate outcomes, while *industrial* fishers might have fewer incentives to cooperate for the conservation of fish stocks. Finally, when co-management includes one or more practices of *adaptive management,* the *adaptive capacity* of the fishery increases ($p \leq 0.05$) and the likelihood of *conflicts* to appear or increase is reduced ($p \leq 0.1$).

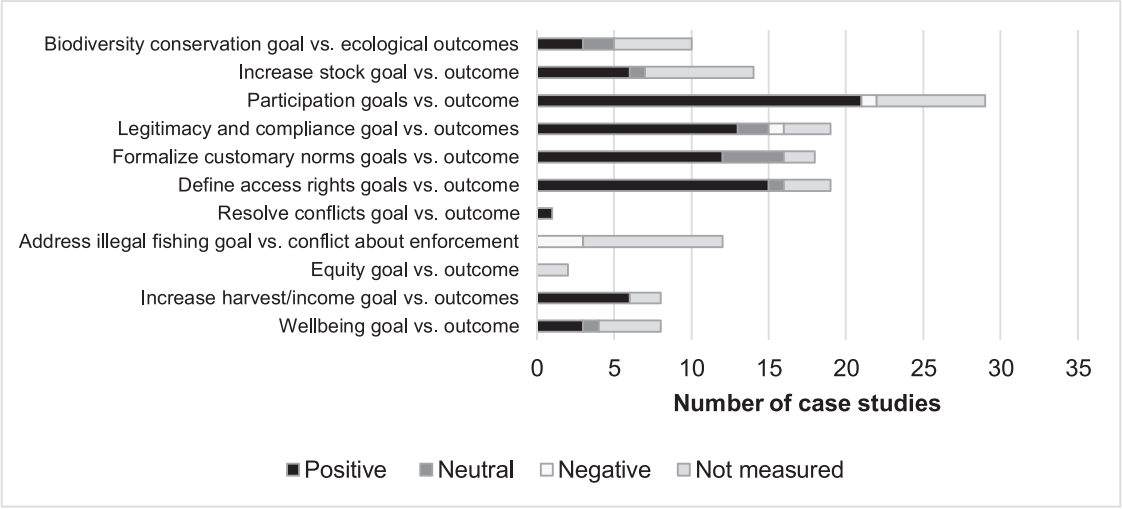

Fig. 7. Number of case studies measuring or not outcomes related to their stated goals, with specification of whether the outcomes are positive, neutral or negative.

When co-management replaces centralized decision-making frameworks, it seems more effective in reducing conflicts and addressing power asymmetries. Co-management might also deepen power asymmetries when it replaces previous community-based systems (Table 2). However, given the reduced number of cases in the dataset that report on these variables, such relationships appear statistically non-significant.

4. Discussion

The results section has provided evidence on the key context and attributes of co-managed small-scale fisheries, their most relevant outcomes and the interrelationships between context, attributes and outcomes. Here we first synthesize and discuss the main findings, and we subsequently reflect on two elements that underpin our systematic review: the spatial distribution of the case studies reviewed and the potential of our review framework to advance the research frontier on the co-management of natural resources.

The most reported context variables in our dataset suggest that co-management often occurs in coastal small-scale fisheries with previous open-access conditions targeting a diversity of species, in a context of decentralized natural resource management, and with a supportive legislative framework that includes clear operational rules, such as quotas and closed-seasons. Most of the initiatives included in the review have been running for 10 years or less, share equal power between government and users or empower users very significantly, while half of them include third parties, usually NGOs and research centres. Communities or government often take the lead in promoting co-management, and throughout the process there is often facilitative leadership provided by a guiding individual or organization. Although not evenly reported throughout the reviewed case studies, it seems that co-management can be a platform for knowledge generation and exchange across scales, as expected from a multi-level governance scheme (Vodden et al., 2005).

Our review also suggests that co-management can be a conduit to the sustainability of small-scale fisheries. Our analysis indicates that 76% of the reviewed cases document one or more positive outcomes, whereas 17% produce mixed results and 7% fail in achieving goals. These findings are in line with other scholarly work, which considers fisheries co-management largely successful in achieving both social and ecological objectives (Cinner et al., 2012; Gutiérrez et al., 2011). Evidence from the few cases of the dataset reporting on ecological outcomes suggests that co-management can make targeted species more abundant and improve their habitat. Combining diverse management approaches and technologies, such as gear restrictions, catch reduction, and closed areas, co-management contributes to the restoration of marine ecosystems and rebuilds fisheries (Worm et al., 2009). In line with co-management theory, a relevant number of the dataset cases report an improvement of stakeholders' participation in management and other process outcomes, such as increased compliance, enhanced social learning, and improved local fit. A reviewed case study, for example, describes how the participation of local users in the design of the management plan of Indonesian coastal fisheries strengthened the congruence of management norms with local ecological conditions and resulted in increased compliance and the banning of very harmful fishing techniques (Crawford et al., 2004).

Other theorized, process-related outcomes of co-management, such as conflict resolution, remain poorly reported and point to mixed results. For example, Ho et al. (2016) show that the Vietnamese government implemented a co-management regime in the Tam Giang Lagoon, where the newly created fishery associations were successful in mediating and improving recurrent conflicts over resource access. This subsequently led to better ecological and social outcomes. In contrast, Nursey-Bray and Rist (2009) show how the incorporation of indigenous cultural aspirations, including traditional hunting of endangered species, into the management framework of Australia's Great Barrier Reef Marine Protected Area resulted in more rather than less conflicts between indigenous peoples, tourist operators and local residents. These two examples suggest that the potential of co-management to resolve or mitigate conflicts should not be taken for granted (Béné et al., 2009; Gelcich et al., 2006).

Only one of the case studies reviewed explicitly acknowledges that the *reduction of conflict* was a key goal of the initiative studied. This is somewhat surprising since co-management should, by definition, bring together different stakeholders in joint decision-making forums and, as a result, unearth existing conflicts or facilitate new conflicts to emerge, particularly when community representatives play a more central role in fisheries' management. This could be regarded as a desirable outcome since conflicts might reflect the fact that historically marginalised management perspectives had been brought to the fore. Furthermore, conflicts can create the conditions for new knowledge and sustainable practices to emerge (Keen et al., 2005; Matulis and Moyer, 2017).

However, conflicts can also destroy long-term collaboration processes, and thus should be taken up and addressed seriously (Lee, 1993). One important source of at-sea conflicts are grievances between artisanal and industrial fishers because the latter are more efficient in extracting the resource and often destroy artisanal fishing equipment (DuBois and Zografos, 2012). In this review, the most reported reason for conflict is competition among user groups and, although only eight cases mention the presence of industrial fishers, who can have a

Table 1
Multinomial logistic regressions in terms of the relative risk ratios of the association between co-management context and attributes with co-management outcomes.

Explanatory variables	Ecological outcomes			Process outcomes			Socio-economic outcomes			All outcomes		
	Worsened	No change	Improved	Worsened	No change	Improved	Worsened	No change	Improved	Worsened	No change	Improved
Fishery type												
Coastal	—	—	—	—	—	—	0.75(1.13)	^	0.94(0.11)**	—	—	—
Off-shore	—	—	—	—	—	—	0.78(4298.36)	^	1111159(4.06x10^9)	—	—	—
Coastal and off-shore	—	—	—	—	—	—	0.78(4293.86)	^	1111159(4.06x10^9)	—	—	—
Shellfish	—	—	—	—	—	—	0.05(0.07)**	^	0.10(0.11)**	—	—	—
Recreational fishing	—	—	—	0.47(0.60)	^	0.17(0.14)**	—	—	—	—	—	—
Illegal fishing	3.02x10^7(5.87)	^	29.98(48.03)**	—	—	—	—	—	—	—	—	—
Stage of co-management												
Implemented	—	—	—	—	—	—	—	—	—	0.11(0.16)	^	0.24(0.26)
Terminated	—	—	—	—	—	—	—	—	—	0.25(0.375)	^	0.05(0.07)**
Diversity of interests	—	—	—	0.00(0.00)	^	13.50(14.81)**	—	—	—	0.00(0.00)	^	8.67(8.83)**

Note: Values represent relative risk ratios with associated standard deviations in parentheses. Base outcomes are highlighted as ^. Statistical significance level is given by ** = $p \leq 0.05$. Non-significant results are not shown and highlighted as —.

negative impact on the fish stocks and prevent users' cooperation. These results call for the inclusion of industrial fishers, when applicable, in the co-management partnerships in order to better handle any potential conflicts, strengthen cooperation, and facilitate user groups to operate under the same governance mechanism and regulations, since artisanal fishers often follow locally established norms whereas industrial fishers operate within the context of formal government rules (DuBois and Zografos, 2012). This would hopefully facilitate the eventual achievement of improved ecological outcomes. Our statistical analysis also suggests that conflict can be prevented and diminished by strengthening users' collective action and community institutions that promote cooperation and equitable outcomes and ensure a more adaptable management system to changing conditions (Ratner et al., 2017).

As for conflict, socio-economic outcomes, such as changes in *income*, *catches*, *power asymmetries* and *equity* are also rarely explored in depth in the dataset cases. And, whereas the few cases reporting *income* and *catches* mostly show an increase of these two variables, case studies reporting on *power asymmetries* and *equity* show rather mixed results. For instance, our review suggests that if power asymmetries within the local community are not addressed by the co-management scheme, the most powerful actors can have greater influence on co-management outcomes (Adger et al., 2005; Davis and Bailey, 1996), leading to the uneven distribution of both income and other benefits (Barnaud and van Paassen, 2013). Whereas equity is theorized to increase with co-management (Plummer and Armitage, 2007b), previous case-based studies show both improved and worsened distribution of co-management benefits among local fishers (Cinner et al., 2012; García Lozano and Heinen, 2016). Therefore, future research needs to provide more evidence on the role of co-management in dealing with conflicts, power asymmetries and equity. Specifically, more evidence is required to test if co-management is more effective in reducing conflicts and addressing power asymmetries when it devolves management rights to local users after the failure of centralized management approaches, or when it replaces traditional systems of resource use and management (Armitage et al., 2007a; Berkes, 2010; Russell and Dobson, 2011).

The scarce reporting on outcomes other than specific *process* outcomes can be explained by the fact that most initiatives reviewed are short-lived, recently implemented or in the implementation phase, which probably made it difficult for researchers to observe significant changes in ecological conditions and fishers' wellbeing aspects that require longer periods to crystallise (Yang and Pomeroy, 2017). Paying more attention to ecological, socio-economic and more generic outcomes, including the status of fisheries' species, changes in income and catches, and users' material, knowledge and political conditions seems paramount. Ideally, these analyses should draw on panel and longitudinal data collected through multi- or inter-disciplinary research.

The results of our systematic review additionally hint at the importance that social diversity in co-management plays in determining co-management outcomes. The statistical analysis suggests that the presence of artisanal fishers and the absence of industrial fishers, as well as the existence of clear operational rules, are the context conditions that support the most successful co-management initiatives. These findings complement, rather than contradict, the other enabling context conditions identified by previous studies which enhance co-management success, including local leadership, social cohesion, governance capacity, quotas and protected areas (Gutiérrez et al., 2011; Selig et al., 2017).

Our review also indicates that partnerships involving all stakeholders and accounting for their socio-economic diversity seem more able to enhance compliance with agreed rules and achieve better management outcomes than those partnerships involving only local leaders. This is consistent with the view that ensuring representativeness, and sharing both power and benefits translates into more sustainable outcomes (Jentoft, 2007; Pascual et al., 2014). A key challenge for co-management theorists and practitioners is developing co-management initiatives involving multiple actors with diverging values,

Table 2
Contingency table between *previous institutions* and the outcomes *conflicts* and power asymmetries.

	Conflicts			Power asymmetries		
Previous institutions	Worsened	No change	Improved	Worsened	No change	Improved
Customary	1	4	1	2	2	0
National	1	4	10	0	1	3
Both	1	2	0	0	2	0

interests and goals, in order to implement more legitimate management arrangements whilst effectively dealing with potential conflict (Ratner et al., 2012). In this regard, our review suggests that partnerships implementing adaptive management practices, such as a flexible co-management structure that can quickly respond to signals of environmental change (e.g. McCay et al., 2014) or experimenting with new management tools to replace previous failed management systems (e.g. Crawford et al., 2010), are better able to prevent conflicts and to increase the adaptive capacity of the fishery.

As for other systematic reviews conducted to evaluate emerging environmental policy frameworks (Plummer et al., 2012; Wamukota et al., 2012), our results should be taken with caution. Our dataset is limited in scope, with case studies selected only from international and English-written peer-reviewed scientific articles. If we had reviewed scientific research published in multiple languages, as well as grey literature published by research programs or the co-management initiatives themselves, we would have probably come up with a much larger and complete dataset of case studies worldwide. Such dataset would have in turn enabled us to test for some multivariable cause-and-effect relationships that we were not able to perform in this article due to the high number of unreported variables.

Our data selection bias also probably explains the gaps observed in the distribution of case studies, with a surprising lack of studies in western and southern Africa, many Central and South American countries, and large parts of Asia, e.g., China and Russia, which might have nonetheless been reported in non-English written academic journals. The rather patchy distribution of the reviewed cases is probably the result of research funding aimed at investigating specific development and policy programmes. In Eastern Asia, co-management research seems to respond to a need to evaluate development projects promoted by international donors. For example, two cases in the Philippines (Baticados and Agbayani, 2000; Kuperan et al., 2008) were developed under the International Collaborative Project on Fisheries Co-management, funded by the Danish International Development Agency, and the case in Laos (Baird and Flaherty, 2005) fell into the Environmental Protection and Community Development in Siphandone Wetland Project, funded by the European Union. In North America, interest in co-management research stems, primarily, from an interest in understanding fisheries management involving First Nations groups: six of the nine cases located in Canada and the USA involve indigenous fishing groups. Seemingly, in Africa, most studies focus on eastern countries' initiatives, with the research being led or organized by USA and UK researchers and funding programs. In turn, the relatively higher density of case studies in Chile and Brazil might be explained by the research interest that arose in response to the Chilean 'management areas for the exploitation of benthic resources' and the Brazilian 'fishing agreements' programs, which respectively promoted co-management in fisheries.

In spite of these methodological caveats, we think that the review results and its underlying analytical framework have considerable value. By innovatively combining insights from existing frameworks for the analysis of social-ecological systems (Mcginnis and Ostrom, 2014; Ostrom, 2009, 2007) and adaptive resource management (Plummer et al., 2017), we have provided a rather comprehensive map of all relevant variables for the study of co-management approaches, which can be further complemented with some additional variables from emerging literature. Selig et al. (2017), for example, have found that variables like the human development index and lower coastal population density can significantly influence the ecological effectiveness of resource management initiatives. This "analytical map" can be used to conduct future reviews, but also to guide fieldwork research in well-established or new co-management initiatives.

5. Conclusions

Small-scale fisheries co-management is a research field of growing interest. This systematic review demonstrates that co-management initiatives are more likely to develop in coastal and multispecies fisheries with an enabling legal and institutional framework, and that co-management is usually a way to clarify property rights. Co-management benefits from involving a diversity of actors, and it faces the challenge of doing so while strengthening cooperation, dealing with conflict and achieving ecological outcomes, particularly when community representatives and industrial fishers are involved. This review shows that adaptive management can contribute to the prevention of conflict and increase the adaptive capacity of small-scale fisheries. The review confirms that co-management can result in more solid management institutions, as well as in positive ecological and social outcomes, including increased fish abundance and catches, the participation of different actors in resource management, and in an increased adaptive capacity of the fishery. However, the review also reveals that empirical research on co-managed small-scale fisheries has to date paid insufficient attention to the social-ecological context underpinning co-management initiatives, as well as the latter's attributes. Additionally, research has been uneven in systematically recording of the outcomes of co-management, with more attention being paid to process outcomes.

We expect that the framework we have developed to conduct this review can guide future research. The use of a multi-variable and multi-dimensional framework to organise the review has allowed us to identify at least three key research domains that require further attention. First, there is a need to investigate the extent to which co-management is effective in resolving existing grievances or buffering against potential new conflicts and in balancing power asymmetries and the distribution of resource management benefits; second, it is critical that future studies shed light on whether the performance of co-management initiatives is sensitive to the nature of the pre-existing management system; and, third, it is important to examine in which ways the involvement of third party actors in co-management affects the type of outcomes and their distribution and sustainability over time. In doing so, future research needs to target case studies where co-management has been implemented for at least 10 years and carefully examine both social and ecological goals. If we expand the evidence base in these three key areas, we will be able to better understand the ways in which co-managed small-scale fisheries benefit both fish species and fisherfolk, now and in the future, in a context of global climate change and increasing pressures on coastal ecosystems.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.gloenvcha.2018.07.009.

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