



Compliance in small-scale fisheries is linked to fisher-trader relations: not fishers alone (Southeast Asian case study)

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Abstract Fisher-trader relations are influential in many small-scale fisheries worldwide. The ability to influence emergent fishing practices has shifted traders into focus of fisheries policy-making. Formal policies could be more effective if they were complementary to and build on an understanding of the role of traders, their interaction with fishers, and how these

contribute to the emergence of compliant or non-compliant fishing practices. Here, we first compared fishing practices with policies to assess the latter's effectiveness in Indonesia, Spermonde. Second, we identified the roles and interactions of fisher-trader relations in shaping emergent fishing practices using the social-ecological action situation framework. We found that 6 out of 7 fishing practices were at least partially non-compliant with formal policies. Second, fisher-trader relations mediated by social norms enabled more fishing practices to emerge than those focused solely on selling and buying fish. Third, traders' interactions with other fishery actors enabled non-compliant fishing practices. These findings comprehensively characterize fishers' and traders' roles and interactions in the emergence of fishing practices. Policy effectiveness could be enhanced by engaging in traders' interactions with other fishery actors.

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Introduction

Globalizing small-scale fisheries (SSF) are increasingly under threat from overfishing and degrading marine environments (Chuenpagdee et al. 2006; Defeo and Castilla 2005; Mills et al. 2011). Fisher-trader relations (FTR) may influence SSFs'

sustainability (Crona et al. 2015; Ferse et al. 2014). The FTR usually centers around selling and buying seafood. FTRs are often referred to as patron-client relations in SSFs (Merlijn 1989). In typical patron-client relations, the FTR is embedded in patron-client normative structures common across the globe (Platteau and Abraham 1987; Wilson 1980). Also, traders' and fishers' interactions expand well beyond selling and buying, including essential socio-economic functions, such as providing loans, gear, and support (Ferrol-Schulte et al. 2014; Russell 1987). Studies have shown the influence of FTRs with patron-client norms on fishing practices (Crona et al. 2010; Glaser and Diele 2004; O'Neill et al. 2019).

Fishing practices herein refer to the fishing behavior exhibiting the fishers' choices and actions for place and time, fishing gear and method used, and the species targeted. Actions and choices interact with the history, traditions, and institutions of SSF. The socio-economic functions of FTRs can generate incentives for change in fishing practices. For instance, access to new markets can promote non-selective capture, and credits can decouple species harvest from environmental fluctuations (Crona et al. 2010; Kininmonth et al. 2017; Nascimento et al. 2017).

The ability to influence emergent fishing practices has shifted traders into focus on fisheries policy-making (Basurto et al. 2020; Ferse et al. 2010; Glaser et al., 2010c; Schlüter et al. 2021). Formal fisheries policies include fisheries laws and regulations implemented through management measures. In- and output restrictions, rights-based, spatial, and temporal management are common fisheries management measures (Cochrane and Garcia 2009). Compliance is a contentious issue in SSFs (Arias et al. 2015; Bergseth et al. 2015). Compliance can be understood as adherence to rules and social norms related to fisheries resource use and conservation (Arias et al. 2015). A recent review found that compliance results from norms, beliefs, economic factors, risk-taking, participation, and marginalization (Arias et al. 2015). These insights are vital to improving compliance, yet, they discount the influential role of traders. FTRs can be a powerful form of informal self-governance (Basurto et al. 2013; Lindkvist et al. 2017). Traders may influence social norms through their key positions of channeling information to local communities (Bodin and Crona, 2009; González-Mon et al. 2019).

Also, traders may devise new rules. For instance, in the case of the Mexican squid fishery, traders have become influential in the fishery due to collusion and have set quotas for fishers that prevent catch discards (Frawley et al. 2019). On the downside, the traders' influence allows them to significantly reduce the beach price fishers fetch for their catch (Elsler et al. 2019, 2021). Finally, fishers cannot contribute to formal decision-making processes like traders because of their limited financial and administrative capacities (Basurto et al. 2012; Maryudi and Myers 2018). Fishing practices in SSFs, governed by FTRs, may contradict or support the objectives of formal fisheries policies. Therefore, there is a need to identify fishing practices related to FTRs and assess their compliance with formal policies.

The effectiveness of formal fisheries management depends on the compliance of fishers (Raakjær Nielsen 2003; Raakjær Nielsen and Mathiesen 2003; Sutinen and Kuperan 1999). Fishers' compliance is central to policy effectiveness, as highlighted by studies of enforcement and monitoring (Bergseth et al. 2015), alongside environmental factors and management capacity (Giakoumi et al. 2018; Melnychuk et al. 2017). Therefore, previous studies have argued that formal policies could be more effective if they sought complementarity with each other or were built on an understanding of existing informal norms and fishing practices that fishers comply with (Bennett et al. 2021; Glaser et al. 2015; Ostrom 1990). Fishing practices can be seen as emergent phenomena within complex social-ecological systems (SES) such as SSFs. They arise from interactions in the SES and feedback to the SES (Preiser et al. 2018; Reyers et al. 2018). Understanding the emergence of phenomena such as fishing practices in SES requires unraveling how dynamic interactions between humans, such as traders and fishers, and non-human actors, such as fish in a fishery, jointly generate them (Schlüter et al. 2019). As such, the emergence of fishing practices does not solely rely on FTRs, but on the interactions amongst and between different actors in the SES. Case studies have previously untangled the factors between FTRs and fisheries sustainability; however, they are often distributed and analyzed with different tools, impeding comparison and generalization (Crona et al. 2015). An important issue is the lack of knowledge about mechanisms, i.e., the combination of relations and interactions leading to the emergence

of different fishing practices. These issues generate a need for studies that make explicit the role of traders, their interaction with fishers, and how these contribute to the emergence of compliant and non-compliant fishing practices.

Here, we assessed the influence of FTRs across compliant and non-compliant fishing practices in an SSF case study. We chose Indonesia, Spermonde, as our case study due to the diversity and spread of FTRs and fishing practices (Deswandi 2012; Ferse et al. 2012) and available social-ecological data collection for more than a decade (Glaser et al. 2022). We used a research process of two stages. We first reviewed existing literature in the Spermonde case and Indonesian law to identify fishing practices and assess their compliance with formal policies. Then, we used expert workshops and literature based on fieldwork from 2001 to 2010 (Jennerjahn et al., 2022; ZMT 2022) and complemented these through open-ended interviews. Our approach allowed us to identify roles and interactions of fisher-trader relations in shaping emergent fishing practices using the social-ecological action situation framework.

Methods

Case study

The Spermonde Archipelago in Sulawesi, Indonesia, consists of fringing reefs and more than 100 coral islands, of which 54 are inhabited (Glaser et al. 2010a). Spermonde's inhabitants depend on marine livelihoods for subsistence and sale (Ferse et al. 2014). Indonesian fishery communities are organized hierarchically (Pelras 2000). Fishing is a predominantly male activity, while women are involved in processing, accounting at landing sites, and selling the catch. The islands of Spermonde seem to have been largely uninhabited until the eighteenth century (Schwerdtner Máñez and Ferse 2010). Except for the Bajau people, few local traditions in marine tenure and protected areas exist (Glaser et al. 2010a). Therefore, involving communities in marine protection can be challenging (Glaser et al. 2015). However, effective management of marine areas, fishing, and species through communities exist, including the temporary or full closure of fishing grounds, territorial

subdivision, and gear restrictions. These emergent rules are diverse in contrast to 'one-size-fits-all' formal fisheries policies (Glaser et al. 2015).

Fisher-trader relations are the predominant form of informal governance in Spermonde (Miñarro et al. 2016). The development of new fisheries has historically been linked to FTRs (Schwerdtner Máñez and Ferse 2010). Traders fueled this development by providing the necessary means to support fishing activities through loans and gear. Traders may compromise the sustainability of fisheries in Spermonde by providing destructive gear and protecting fishers from legal prosecution for infringement of fishery laws (Grydehøj and Nurdin 2016). On the other hand, loans can help reduce income fluctuations for fishers (Ferse et al. 2014).

Similar to many other tropical small-scale fisheries, Spermonde is characterized by a high diversity of fishing grounds and methods in the multi-species reef and pelagic fisheries (Cinner et al. 2012; Kittinger et al. 2013). Some fishers use multiple gears daily, seasonally, or over the year, and complement shorter fishing trips with several month-long migrations (Ferse et al. 2014). Predominant fishing methods typically differ by island; for instance, live reef fishers on one island primarily use fish traps, whereas on other islands use cyanide (Ferse et al. 2014). During the North-West monsoon, when fishing conditions are unsafe in parts of Spermonde, many fishers migrate to distant fishing grounds (Deswandi 2012).

Fishers in commercial FTRs (also referred to as independent or free fishers in the literature) typically use a higher proportion of their catch for subsistence. In contrast, fishers in FTRs with patron-client norms are bound by debt and focus on catching commercial species (Miñarro et al. 2016). Traders have an instrumental role in distributing catches to different trade ports, such as the local market in Makassar (the closest city) or landing sites on the island. The landing site depends on the fish's species, size, quality, and destination (Radjawali 2011). The international trade of fishery products in Spermonde dates back to the seventeenth century (Schwerdtner Máñez and Ferse 2010) when fishers came from mainland settlements to fish in Spermonde. High-value species have long become rare in the reefs of Spermonde (Johannes and Riepen 1995; Massin 1999; Navarrete Forero et al. 2017).

The reefs and fisheries of Spermonde in Indonesia are subject to multiple pressures and a fragmented governance system (Glaser et al. 2022) and are comparatively overfished and degraded (Hoeksema 2004). However, there are also gradients of (over-)fishing and habitat degradation within Spermonde (Plass-Johnson et al. 2015, 2018). One aspect differentiating islands with a relatively higher abundance of species and healthy corals is the limited use of destructive fishing practices such as blast and poison fishing and trawling (Chozin 2008; Deswandi 2012). Destructive fishing includes the use of toxins and explosives; the latter was likely introduced by the Dutch during the colonial occupation of Indonesia (Pet-Soede and Erdmann 1998). Local reef degradation and overfishing (Edinger et al. 1998) in Spermonde, like in many other SSFs, are accompanied by global processes of changing climate and seasonal weather patterns (Cheung et al. 2010; OECD 2017).

Methods summary

This study combines qualitative primary and secondary data in a research process of three stages. First, we conducted open-ended interviews with traders and fishers in Spermonde (Rapley 2001). Second, we gathered and analyzed data through a literature review on Spermonde and Indonesian fisheries policies. Last, we conducted expert workshops structured by the social-ecological action situation (SE-AS) framework (Schlüter et al. 2019). Our insights rely on data collected for the Indo-German research program ‘Science for the Protection of Indonesian Coastal Ecosystems’ (SPICE; For detailed descriptions of the data obtained in this program, see: Jennerjahn et al. 2022). Open-ended interviews with fishers ($n=2$) and traders ($n=3$) were conducted in 2019. Interviews were conducted in Makassarese and Bahasa Indonesia. We obtained written and oral consent from the participants and ethics review approval from the Stockholm Resilience Centre. We provide references for results from the literature review and open-ended interviews; otherwise, we refer to the workshops.

Selection and analysis of fishing practices and formal policies

We first conducted open-ended interviews with fishers ($n=2$) and traders ($n=3$) in Spermonde (Barrang

Caddi island) to identify and learn about existing fishing practices linked to FTRs. The interviews highlighted the importance of patron-client norms and the difference between types of FTRs. We specifically asked about changes in fishing practices and the nature of FTRs in Spermonde from 2010 to 2019 (the post-SPICE period).

Then we gathered information to select fishing practices through a literature review of the Spermonde case study. The articles we reviewed were initially drawn from the publications of the Indo-German research program Science for the Protection of Indonesian Coastal Ecosystems Program (SPICE, 2001–2010). From this initial set of articles, we consulted the references of each article for additional relevant publications. One of the foci of this long-term Indonesian German research cooperation project in Spermonde were FTRs and small-scale fisheries. We selected fishing practices (i) that were documented in the scientific literature, (ii) were present in at least one community in Spermonde, and (iii) were linked to FTRs. For example, we excluded hand-line fishing in the waters surrounding Spermonde because traders are seldom involved in the interactions or relations concerning this practice (Deswandi 2012). We included seven distinct fishing practices in our analysis: blast fishing, cyanide fishing, fishing at fish aggregating devices, fishers’ migration, fishing in marine protected areas (MPAs), selective fishing, and trawl fishing. Fishing practices presented here have been documented by research in Spermonde between 2001 and 2019 (encompassing the SPICE research period and fieldwork in 2019).

We then gathered information to identify measures and tools used in formal fisheries policies of the Republic of Indonesia. We used the SPICE literature reviewed above and the Indonesian Law Database (<https://peraturan.bpk.go.id>). We identified regulations and laws related to the fishing practices in Spermonde—we found six relevant laws. We listed the rules these laws specify and whether the fishing practice complies with the law (Table 1).

The difference between types of FTRs in Spermonde was highlighted as central in the open-ended interviews. We defined two types of FTRs for the purpose of this paper. In FTRs with patron-client norms, social norms determine the roles of traders and fishers. This system of norms is also referred

Table 1 Identified fishing practices in Spermonde and formal fishery laws and regulations

Fishing practice	Formal policy	Compliant	Patron-client norms
<p>Blast fishing refers to the use of explosives to stun and kill fish. It is widely employed in Spermonde and targets mostly schooling reef fish (Crydehoj and Nurdin 2016; Pet-Soede and Erdmann 1998). Explosives can be made of dynamite but are mostly made with artificial (chemical) fertilizers such as ammonium and potassium nitrate (NH₄NO₃; KNO₃). Detonations close to a reef can indiscriminately affect the target species population, other marine organisms, and cause structural damage to the reef framework</p> <p>Cyanide fishing refers to the use of poisons, including cyanide, to stun target fish making their capture easy. Diving equipment used in these practices includes air compressors, locally referred to as 'hookah compressors'. This technique is associated with the live fish industry (Halim 2002)</p> <p>Trawl fishing refers to the use of bag-shaped nets that are pulled by a boat and dragged across the seabed</p>	<p>National law (Republic of Indonesia 2004, 2009a) prohibits intentionally owning, controlling, bringing and/or using fishing gears (fish catching tools) and/or fish catching means (fish catching instruments) on a fishing boat that are not in accordance with standards, fishing gears not in accordance with standards, or standards determined for certain prohibited tools and/or fishing gears, as outlined in Article 8 Paragraph 1, 2, and 4 and Article 9 within the Indonesian Fish Cultivation Territory</p>	No	Yes/ No
		No	Yes/ No
	<p>National law (Republic of Indonesia 2004, 2009a) prohibits possessing, controlling, carrying, and/or using fish catching means and/or fish catching auxiliary means, disturbing and damaging the continuity of fish resources on fish catching ships throughout the Republic of Indonesia Fisheries Management Area. The Indonesian Ministry of Sea and Fisheries prohibits trawls and seine nets (Menteri Kelautan dan Perikanan 2015)</p> <p>National law establishes protected areas and no-take areas which are closed to fishing. Only research activity is allowed after prior approval by the administering body and the communities affected (Republic of Indonesia 2010, 2009b, 2007). In Spermonde, the COREMAP program established protected areas and no-take areas (Glaser et al. 2010a, 2010b)</p> <p>National law prohibits the trade of protected wild fauna according to provisions of Article 21 Law No.5/1990 on Conservation of biological natural resources and its ecosystem in accordance with the UN Convention on International Trade in Endangered Species Appendix I and II (CITES 1975; Republic of Indonesia 1999, 1990)</p> <p>The Spermonde archipelago is formally, with exception of the above-mentioned MPAs, an open access zone (Deswandi 2012)</p>	No/Yes	Yes/No
<p>Fishing in MPAs refers to fishing in areas designated as protected areas with limited access or strict no-take zones</p>		No	Yes/No
<p>Selective fishing refers to differentiating between target species through their choice of gear. In Spermonde, fishers use highly selective hand-line fishing techniques. Fishers in FTRs with patron-client norms typically focus on catching traded species compared to those not involved in commercial trade relations and, therefore, catch a significantly larger proportion of commercially valuable and less diverse species (Miñarro et al. 2016)</p> <p>Fish aggregating devices (rumpun) refer to devices deployed to attract schools of pelagic fishes. In Spermonde, the deployer of such a device is also thought of as the owner. According to social norms, fishers, particularly those who use gear that can be destructive to the FAD, are not permitted to fish in the proximity (Deswandi 2012)</p>		No/Yes	No/Yes

Table 1 (continued)

Fishing practice	Formal policy	Compliant	Patron-client norms
<p>Fishers' migration (<i>sawakung</i>) refer to the temporary relocation of fishers to other fishing grounds lasting multiple days to several months. Fishers typically migrate to areas in Indonesia with higher fish biomass, such as marine national parks and fishing grounds in Eastern Indonesia (Ferse et al. 2014). Fishers' migration areas are well beyond the immediate fishing grounds surrounding Spermonde. Fishers typically hire a 'mothership' to carry small boats to the fishing destination. The small boats are launched at the fishing grounds and picked up at the end of the day. Migrations can be linked to various gear, methods, and target species, such as hookah diving for sea cucumbers and hand-line fishing for yellowfin tuna. They are firmly rooted in Spermonde's local tradition and are common during the monsoon season. In the past decades, fishers' migration have become more common due to increasing fishing competition and reduced catches (Ferse et al. 2014)</p>		Yes	Yes/ No

to as *punggawa-sawi* system (Pelras 2000). Long-term commitments are characteristic of FTRs with patron-client norms. For instance, traders are expected to provide flexible loans, and fishers are expected to sell their catch to the trader (Pelras 2000). In commercial trade relations, fishers and traders interact by buying and selling seafood (Ferse et al. 2014). In these relations, traders have also been referred to as big patrons (Ferse et al. 2014). In the workshops (see Sect. "Application of the social-ecological action situation framework"), we asked, 'Is the fishing practice primarily enabled by FTRs with patron-client norms?'. As a counterfactual, we asked, 'Could the fishing practice not be enabled by commercial FTRs?'. We filled in the answers 'yes' or 'no' in the last column of Table 1.

Application of the social-ecological action situation framework

We aimed to understand the role and interactions of (i) fisher-trader relations and (ii) other social, ecological, and social-ecological relations, and (iii) whether the interactions enabled or restricted emergent fishing practices. We chose the social-ecological action situations (SE-AS) framework as the conceptual foundation for our analysis (Schlüter et al. 2019). The framework organizes knowledge about emergent social-ecological systems (SES) phenomena and helps develop hypotheses about the social-ecological interactions that may have generated them. We view fishing practices as emergent phenomena which re-emerge daily, weekly, or seasonally through continued interactions. The core unit of analysis in the SE-AS framework is the action situation. It is an interaction context in which 'actors', such as fishers, traders, and marine species, interact to produce outcomes such as loaning money or catching fish. Action situations can be social-ecological, social, and ecological, depending on the actors involved in immediate interactions. The action situation does not specify the continuity of interactions but can accommodate short-term interactions and relations.

In SE-AS, social actors engage in interactions based on, for example, their motivations, aims, history, and risk perception (Schill et al. 2019; Schlüter et al. 2019). Interactions in social action situations include exchanging goods and services, solving problems, developing rules, or trading (Ostrom 2011). In

these situations, formal policies and informal rules shape individuals' interactions (Ostrom 2011). Policies and informal rules shape expectations of actions that individuals should or should not take (McGinnis 2011), thus enabling or restricting specific interactions from occurring. Interactions in social-ecological action situations include harvest, cultivation, care, and monitoring. Interactions in ecological action situations include predation, competition, and species-habitat interactions (Schlüter et al. 2019).

We consecutively developed a representation of the emergence of each fishing practice with the SE-AS framework following the protocol Schlüter et al. (2019) provided for implementation. In particular, we recorded the actors, interactions, and characteristics of the relations contributing to the emergence of the seven identified fishing practices. As such, the SE-AS diagrams were our primary tool for mapping raw data in a structured way. The SE-AS diagrams of all fishing practices are provided in SI Fig. 1-6. First, we gathered data through the literature review of the Spermonde case study, as described in Sect. "[Selection and analysis of fishing practices and formal policies](#)". Second, we used expert workshops to complete the diagrams. Finally, we classified interactions as enabling and restricting. In the following, we will discuss the SE-AS workshops in more detail.

The first author conducted workshops with case study experts ($n=6$). Experts were selected that had led the SPICE project for Spermonde or conducted fieldwork related to FTRs in Spermonde. During the workshop, the first author first explained the aim of the study. Then the case study experts were asked to discuss the specific fishing practices they were most familiar with. The experts were then presented with a draft conceptualization of the SE-AS framework of the respective fishing practice. The conceptualizations included interactions the first author had previously identified through the literature review. The experts were asked whether the interactions of the draft conceptualization were correct and which actors and interactions needed to be additionally included. Then, details of the attributes of actors, characteristics of the relations, and systemic drivers were enquired about. After the workshops, the experts were invited as co-authors. In a second round, the first author compared the SE-AS from each fishing practice for consistency. For instance, in the case of blast fishing, the SE-AS contained community-fisher interactions

but not for cyanide fishing. For these cases, the first author returned to the experts with a set of questions and adapted the SE-AS to their final state with approval from the experts. The primary raw data was captured in form of the SE-AS diagrams and as workshop notes which were added to SI Table 1.

In the next step, we classified the outcomes of action situations as enabling or restricting SI Table 1 by answering the question: 'Does the outcome of this interaction enable or restrict the fishing practice?'. An outcome is categorized as enabling if it (i) facilitates or promotes a fishing practice and (ii) directly links to fishers or traders. An outcome is categorized as restricting if it (i) hinders or prevents a fishing practice and (ii) directly links to fishers or traders. An outcome is categorized as N/A if it is (i) not directly linked to fishers or traders, (ii) not the outcome of an action situation (e.g., driver), and it is (iii) a market transaction (i.e., buying and supplying catch). The response is independent of whether the restriction for the fishing practice relates to the FTR or any other fisher because we are interested in whether the fishing practice emerges. Also, if one action situation has multiple outcomes, we list them individually.

The FTR was central to our investigation. First, we placed specific emphasis on the characteristics of the FTR in the workshop. In addition to the question about interactions, we asked about the characteristics of relations and actors. Second, we decided to differentiate between commercial trade relations and FTRs with patron-client norms because of the importance of these different types of relations we observed during the open-ended interviews in Spermonde (see Sect. "[Selection and analysis of fishing practices and formal policies](#)".).

Results

Compliance of fishing practices with formal policies

We identified seven fishing practices linked to FTRs (Sect. "[Interactions between fishers and traders enable fishing practices to emerge](#)"). These are blast and cyanide fishing, trawl fishing, fishing in MPAs, selective fishing, fish aggregating devices, and fishers' migration. The relation to spatial, gear and species-related aspects reflects the diversity of fishing practices. Fishing practices are not mutually exclusive.

For example, fishers' migration is common during the monsoon season and when target species are scarce. A commonly employed fishing practice during fishers' migration is blast fishing.

We found six formal policies corresponding to the fishing practices (Table 1). These used four generic fisheries management measures (Cochrane and Garcia, 2009). Input controls regulate input factors such as the number of vessels and fishing gear. We identified three related policies: a ban on blast, cyanide, and trawl fishing. Output controls regulate catch volumes and species; in the case of Indonesia, the formal policy prohibited trade (but not fishing) of endangered species. Finally, spatial management regulates spatially permanent or temporary closures. In Spermonde, we identified MPAs, no-take areas, and open-access areas.

We found that six of the seven regional fishing practices were partially non-compliant with formal

policies (Table 1). Blast fishing, trawling, and selective fishing provide illustrative examples. First, Indonesian law prohibits destructive fishing methods, including blast fishing (Republic of Indonesia 2004, 2009a). In particular, the law defines that no person may 'intentionally catch or breed fish using chemical substances, biological substances, explosives, tools or means or structures, which may damage or endanger conservation of fish resources or the environment thereof' (Republic of Indonesia 2004). The literature documents that traders provide access, support, and incentives for fishers to use cyanide and blast fishing (Nurdin and Grydehøj, 2014; Radjawali 2011). Thus, the support of blast fishing is in direct opposition to this law.

Second, endangered species are internationally protected through CITES (CITES 1975). CITES prohibits the trade of protected wild fauna and defers violators to be subject to national legislation. Indonesia



Fig. 1 A juvenile humphead wrasse (*Cheilinus undulatus*) was caught by fishers in Spermonde (credit: Gabriela Navarrete Forero)

has implemented CITES into national legislation. Selective fishing is common among fishers in FTRs to repay their debt by catching commercially valuable species (Navarrete Forero et al. 2017). According to the CITES provisions, some commercially valuable species caught in Spermonde are endangered. An example is the humphead wrasse (*Cheilinus undulatus*; Fig. 1). For endangered species, selective fishing is in breach of formal policies.

Third, trawling was rendered not legal several years ago (Menteri Kelautan dan Perikanan 2015). While traders support trawling in some cases, there have been other cases in which traders provided wired fences to sabotage trawling gear. Traders have supported trawling bans if they own permanent installations, such as fish aggregating devices, which can be damaged by trawling gear. The trawl examples show that fishing practices emerging through FTR interactions do not have to contradict formal rules but can support them.

The last column answers the questions: 'Is the fishing practice primarily enabled by FTRs with patron-client norms?' and 'Could the fishing practice be enabled by commercial FTRs?'

Interactions between fishers and traders enable fishing practices to emerge

Traders who engage in FTRs with patron-client norms enable more different fishing practices than those focused solely on selling and buying fish. Specifically, we found that 5 of 7 fishing practices relied on patron-client norms (Table 1). Short-term loans are characteristic of the majority of FTRs in Spermonde. The provision of materials and loans gives fishers the necessary means to go fishing but does not determine the target species or gear used. Long-term loans are characteristic of FTRs with patron-client norms.

The most frequent interactions between fisher and trader were the provision of loans and repayment of loans by fishers selling their catch (SI Table 1). Traders additionally provided access to materials and boats. Fishers have to trust their trader to protect them from prosecution for fishing practices that are banned by regulation. Reversely, for fishers' migrations, traders have to trust their fishers.

Fishers were expected to target specific species and use specific gear for fishing practices associated

with patron-client norms. For instance, fishers are expected to catch commercially valuable species for the trader, leading to selective fishing. Also, fishers were expected to engage in blast fishing if they were part of a trader's fishing group and owned no gear. Fishers who default and catch little or no commercially valuable species increase their debt and may receive fewer loans in the future. In return for targeting specific species and using specific gear, traders are expected to care for their fishers. In the fishing practices we examined, we found support for this. For example, fishers can ask for long-term loans for migrations and help for their families if fishing is challenging due to weather and species abundance. Fishing conditions are not always predictable, and catch volumes could be insufficient; therefore, flexible repayments are crucial. If traders do not provide this flexible loan to fishers and their families, fishers may switch to another trader.

We also found that trust between fishers and traders, due to kin relations, loan dependence, and reputation, was needed to take risks (SI Table 1). There are many risks involved in fishing for fishers and traders. For the fisher, it is risky to use prohibited fishing gear. For instance, blast fishing is not a legal fishing practice in Indonesia and fishers risk prosecution by authorities. Fishers have to trust in the trader to protect them from enforcement and prosecution (Deswandi 2012). Feelings of trust and kinship form are tied to dependence on loans (Gisondo 2014) and reputable traders are trusted (Deswandi 2012). It is risky for traders to provide loans because they have limited means of observing catch and selling once fishers are at sea. For example, for fishers' migration, fishers can leave Spermonde for several months and sell in local markets at their destination. Fishers collect the revenue from these sales to repay their loan at the end of the trip. The traders commit to providing monetary help in the fishers' absence. Loans and family support during fishers' migration are often provided to kin to ensure mutual commitment.

Interactions with other fishery actors

The emergence of a fishing practice is also affected by the interests of fishery actors such as the fishers' families, fishing authorities, and the fishing community. One reason is that many fishing practices impact other fishery actors, fishing methods, and the

environment. Thus, interactions of fishers and traders with other fishery actors can be critical to enabling the use of a fishing practice. Finally, a fishing practice can only be realized within social, regulatory, and environmental boundaries. Traders have developed strategies that allow them to circumvent social and regulatory boundaries. We provide an overview of the interactions between traders, fishers, and other fishery actors that enable and restrict the emergence of our seven selected fishing practices in SI Table 1.

In total, we identified 50 interactions, 8 of which were interactions between fishers and traders (SI Table 1). We identified the fishers' interactions primarily in the seascape, including interactions with other fishers, the fishing community, and law enforcers at sea. The traders' interactions with other fishery actors extended well beyond the seascape to exporters or dealers, the fishers' families, the fishing communities, and authorities.

Apart from interactions between fisher and trader, the emergence of a fishing practice also depends on the interests of other fishery actors. We found 28 interactions between fishers and traders (FTR) with other fishery actors, and we classified nine of them as not applicable (N/A), nine as restricting, and ten as enabling fishing practices (SI Table 1). Thus, there are slightly more enabling than restricting interactions. An example of restricting interaction is that fishing communities prohibit blast fishing in the area surrounding their island. An enabling interaction is, for example, that blast fishers share catches with hand-line fishers. Hand-line fishers, in return, do not dispute blast fishers' rights to fish.

We found that traders' interactions with other fishery actors were critical in enabling fishing practices that were non-compliant with formal policies. From the total ten enabling interactions, nine were between traders and other fishery actors and enabled primarily

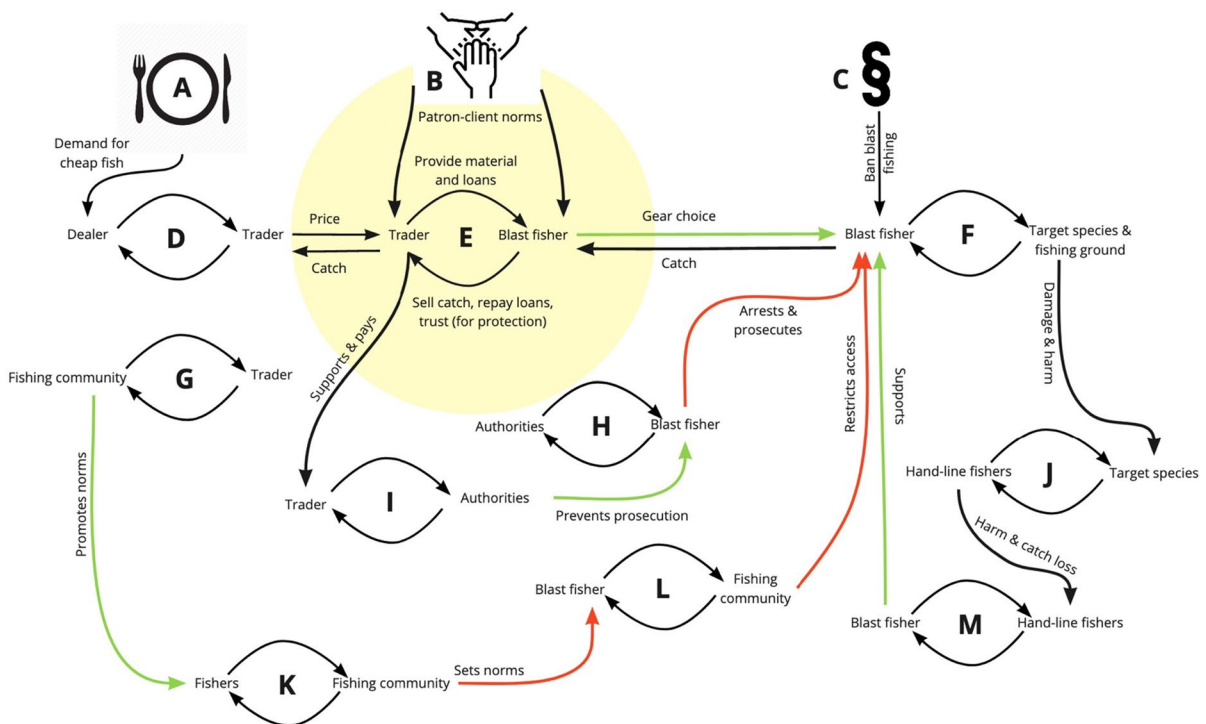


Fig. 2 The illustration shows the social-ecological action situations diagram for blast fishing. Illustrated are action situations (circular arrows) and outcomes from one action situation, which feed into (straight arrows) the following action situation. Arrow colors indicate restrictive (red) and enabling (green) interactions. The fisher-trader relation (E) is highlighted with

a yellow background. We identified three drivers: 'demand for cheap fish' (A), 'patron-client norms' (B), and 'ban blast fishing' (C)—herein indicated by icons. Blast fishing (C) emerges from a series of action situations D–M and interactions between them

non-compliant fishing practices (6 of 9 interactions). Examples include traders paying bribes or supporting local authorities to avoid fishers' prosecution, promoting community norms, and supporting fishers' families. Yet, in one case, traders' interactions restricted (not legal) trawling. Traders working with fishers using passive gear provided their fishers with tools such as barbed wires to sabotage trawling gear because trawls can damage passive gear such as traps.

Figure 2 illustrates the full SE-AS for blast fishing, including enabling and restricting interactions with other fishery actors. Below we reference the action situations in Fig. 2; for content details, please refer to SI Table 1. Traders sell large volumes of cheap reef fish to dealers to supply local markets' demand (Fig. 2E). They also engage with authorities. Formal policies prohibit blast fishing, but traders pay bribes and support high-level authorities in their political campaigns to avoid prosecution of fishers (Fig. 2G). The interactions between traders and high-level authorities have been referred to as a 'prosecution insurance network' in the literature (Nurdin and Grydehøj, 2014; Radjawali 2012). It is effective; many arrested fishers had their court proceedings abated (Fig. 2H) (Grydehøj and Nurdin 2016). The relation between traders and authorities has changed from paying illicit bribes in exchange for protection from prosecution to support for political campaigns in exchange for influence on regional-level policy-making (MN, open-ended interview with trader, 2019).

Traders engage with communities (Fig. 2J) and blast fishers with hand-line fishers (Fig. 2L). The destructive force of blast fishing can affect nurseries, passive gear, and island infrastructure. For example, if large bombs are used in proximity to islands, they have been reported to cause damage to buildings and infrastructure (Deswandi 2012). Also, hand-line fishers may have foregone catches due to the high catch volumes caught with blast fishing (Fig. 2I). In response to these threats, fishing communities and fishers monitor, punish, and dispute blast fishing (Fig. 2K). Thus, blast fishing is (informally but effectively) prohibited in areas considered the community's land and fishing territory and in marine areas where other fishers are actively fishing (Glaser et al. 2015). Traders seek to remedy informal norms, punishment, and exclusion by engaging with and setting social norms (Fig. 2J). In particular, traders can provide financial and religious leadership to improve

their status and leadership in the fishing community. The opinion of influential traders can affect fishers' opinions concerning fishing practices and, in some cases, reduce the monitoring and punishment of blast fishers (Deswandi 2012). Blast fishers seek to alleviate the negative impacts of the habitat and gear destruction they cause by sharing their catches with hand-line fishers (Fig. 2L).

Discussion

Evidence proves that effective formal policies can lead to sustainable fisheries (Costello et al. 2016; Melnychuk et al. 2017). Understanding how policies can be effective in SSF is a critical component of sustainability. We found that in Spermonde, few fishing practices complied with formal policies. FTRs mediated by social norms and characterized by trust enabled non-compliant fishing practices to emerge, a feature that commercial FTRs focused solely on selling and buying fish did not share. Finally, our analysis highlighted that traders' interactions with other fishery actors were critical in enabling non-compliant fishing practices. The FTR and relations with other fishery actors helped overcome formal policy constraints. Compliance is thus linked to relations between fishers, traders, and other fishery actors—not fishers alone. Thus, an increasing focus on the roles and interactions of traders and other fishery actors in policy-making could enhance SSF policy effectiveness.

Sustainability can be low because formal policies are more difficult to enforce in SSF than in industrial fisheries. We found that 6 of 7 fishing practices were at least in part non-compliant with formal policies. Patron-client relations can promote unsustainable fishing practices; examples have been documented across fisheries. For instance, in a comparison of 18 case studies, patron-client relations were associated with declining stocks and conflict amongst fishers (Crona et al. 2015). Similar to selective fishing practices in Spermonde, patron-client relations in Uganda generated incentives to fish selectively compared to 'free fishers' who adapted to the market and environmental fluctuations (Kininmonth et al. 2017). The diversity of practices and the mobility in SSFs present major constraints for authorities that are biased toward

blanket approaches and standardized procedures (Cochrane and Garcia, 2009; Young et al. 2018). The universality of FTRs and patron-client norms may present an opportunity for designing standardized procedures aligned with the activities of the FTR to improve compliance. For example, the multiple types of relations traders engage in might be intervention points for effectively engaging with emergent fishing practices. The relation between traders and authorities has been highlighted in Spermonde before (Ferse et al. 2014; Nurdin and Grydehøj, 2014; Radjawali 2012); however, it might be important elsewhere. For example, the influence of traders on fisheries management has been linked to their participation in meetings with Mexican fishery authorities (Basurto et al. 2020; Frawley et al. 2019). In Spermonde, financial transactions between traders and authorities used to support political campaigns could, for example, be made transparent to publicly denounce support from traders linked to abated prosecution proceedings. This example could be one approach aiming at higher compliance in SSF based on a better understanding of the role of FTRs in compliance. At the same time, blanket policies prohibiting specific fishing gear are inconsiderate of local needs, norms, and traditions (Glaser et al. 2010b). Supporting spatial prohibitions of these gear, as practiced in Spermonde, could be more effective (Deswandi 2012).

We found that FTRs characterized by trust and mediated by social norms enabled more fishing practices to emerge compared to those focused solely on selling and buying fish. Trust and trustworthy behaviors are crucial for cooperation (Milgrom and Roberts 1990), reducing uncertainty (Guiso et al. 2008), and risk (Houser et al. 2010). In Spermonde, fishers who trust their traders to protect them from prosecution used gear that was not legal. A study in Kenya showed that fishers risk losing income because of loans from traders: they extended the fishing season and continued fishing despite low catches (Crona et al. 2010). In Spermonde, there is a trend from FTRs based on traditional patron-client norms toward commercial relations (Ferse et al. 2014, 2012). This trend, *ceteris paribus*, could lead to the disappearance of some prohibited fishing practices discussed here.

Social norms have been recognized as effective entry points for sustainability oriented policy (Abson

et al. 2017). Social norms are behavioral rules based on a shared understanding of acceptable behavior and sustained through social interactions within a group (Ostrom 2000). In Spermonde, fishers' families can always count on traders for flexible loans when fishers are on fishers' migration. Fishers without a trader who can support their family do not migrate for more than a few days. This example underlines the importance of FTRs with patron-client norms, the *pung-gawa-sawi* system, compared to purely commercial relations for fishing practices. Similarly, patron-client relations in Vietnam's *van chai* system are based on a shared understanding that mutual assistance is required (Ruddle 2011). In the Philippino *suki* system, debt of gratitude is expected and sustained through FTR interactions (O'Neill et al. 2019). Thus, policy instruments such as incentives and public communication that shape social norms could be a target to shape the emergence of fishing practices.

Compliance of SSF practice with formal policies and laws is embedded in and supported by social relations between fishers, traders, and other fishery actors. We found that traders' interactions with other fishery actors were critical in enabling non-compliant fishing practices. Traders' relations in Spermonde extended to authorities, fishers' families, other fishers, and fishing communities. The high connectivity of traders in networks related to fishing has also been identified in other SSFs (Bodin and Crona, 2009). However, whereas knowledge brokering has been emphasized in another case (Bodin and Crona, 2009), traders' links to the fisher's family, their spiritual and financial leadership in communities, and other interactions were essential in enabling Spermonde's fishing practices. Traders' relations with authorities, for instance, were essential enablers. Their relation changed over time from paying bribes in exchange for prosecution protection to support for political campaigns in exchange for influence on regional-level policy-making. Fishers are usually the prime target of studies investigating compliance in fisheries (Bergseth et al. 2015). Compliance is expected to be high if the certainty and severity of sanctions are high (Sutinen and Kuperan 1999). Our results indicate that – in addition to individual motivation—fishers' social relations and the roles of other fishery actors are understudied determinants of compliance. Attention to these relations and roles presents an exciting future research direction for SSF compliance.

Globally, SSFs globally suffer from overfishing and degrading marine environments, but it is essential to recognize their crucial role in providing jobs, supporting marginalized populations, and feeding millions of people (Bevitt et al. 2021). Thus, it is worthwhile to invest in the sustainability of SSFs. Achieving policy effectiveness in Spermonde will only be possible by engaging with the relations between fishers, traders, and other fishery actors. Not surprisingly, the major focus in compliance and fisheries norms is on the direct law-breaker, the fisher. Yet, the emergence of fishing practices in Spermonde is linked to relations between fishers, traders, and other fishery actors. As provided in this study, an analysis of fishers' and traders' roles and interactions in the emergence of fishing practices highlights pathways for formal policies to interact with informal relations.

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Data availability SPICE project publications and summaries of the findings are available in the final project reports (<https://doi.org/10.2314/GBV:887785549>; <https://doi.org/10.2314/GBV:719054699>). Data collected in open-ended interviews are not published as previously determined in the ethics review.

Declarations

Competing interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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