Behavior Change Interventions to Reduce Illegal Fishing

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Illegal fishing is a serious problem that threatens the sustainability of fisheries around the
world. Policy makers and fishery managers often rely on the imposition of strict sanctions
and relatively intensive monitoring and enforcement programs to increase the costs of
illegal behavior and thus deter it. However, while this can be successful in fisheries
with sufficient resources to support high levels of surveillance and effective systems
for imposing penalties, many fisheries lack the resources and requisite governance to
successfully deter illegal fishing. Other types of governance systems, such as customary
marine tenure and co-management, rely more on mechanisms such as norms, trust,
and the perceived legitimacy of regulations for compliance. More generally, the absence
of such social and psychological factors that encourage compliance in any fishery can
undermine the efficacy of an otherwise effective and well-designed fishery management
system. Here we describe insights from behavioral science that may be helpful in
augmenting and securing the effectiveness of conventional deterrence strategies as
well as in developing alternative means of deterring illegal fishing in fisheries in which
high levels of surveillance and enforcement are not feasible. We draw on the behavioral
science literature to describe a process for designing interventions for changing specific
illegal fishing behaviors. The process begins with stakeholder characterization to capture
existing norms, beliefs, and modes of thinking about illegal fishing as well as descriptions
of specific illegal fishing behaviors. Potential interventions that may disrupt the beliefs,
norms, and thought modes that give rise to these behaviors, along with those that
encourage desirable behaviors, can be developed by applying principles gleaned from
the behavioral science literature. These potential interventions can then be tested in
artefactual experiments, piloted with small groups of actual stakeholders and, finally,
implemented at scale.

Keywords: illegal fishing, compliance, behavior change, behavioral science, interventions, small-scale fisheries,
social norms

INTRODUCTION

Illegal fishing – defined here as the intentional disregard of fishery regulations – occurs all around
the world, in fisheries of all sizes, and with all types of target species. Many countries and
international bodies (e.g., the Food and Agriculture Organization of the United Nations) have
recognized illegal fishing as an important problem threatening fishery sustainability (FAO, 2002;

Pitcher et al., 2008; Agnew et al., 2009; Le Manach et al., 2012). In some small-scale fisheries and low-governance areas it is among the most significant issues faced by fisheries that are often already stressed by over-harvesting, pollution, and other anthropogenic impacts (Sumaila et al., 2006; Hauck, 2008; Österblom et al., 2011). These fisheries generally have the least capacity to address illegal fishing.

Data on the frequency and degree of illegal fishing are limited (Bergseth et al., 2015), making it difficult to understand the full extent and impact. However, it is clear that highly regulated, well-enforced fisheries have a relatively low incidence of illegal fishing (Agnew et al., 2009) and many achieve high compliance with regulations such as Total Allowable Catch (TAC) limits (Grimm et al., 2012). Other fisheries achieve compliance mainly by imposing social costs (e.g., shame), generating trust in the authorities responsible for regulating the fishery and in the efficacy of the regulations themselves [which depends strongly on how regulators and enforcers interact with fishers: (Hønneland, 2000; McClanahan et al., 2006)], and aligning compliance with ethical or moral values, etc. (Gezelius, 2002, 2004; Nielsen, 2003; Eggert and Lokina, 2010; Jagers et al., 2012), often in the context customary marine tenure or co-management governance systems (McClanahan et al., 2006; Viteri and Chávez, 2007). However, many fisheries lack most or all of these mechanisms to increase the economic, social, and psychological costs of illegal fishing or to motivate compliance with economic, social, and psychological rewards (Kuperan and Sutinen, 1998; Arnason, 2013). As a result, such fisheries typically experience high levels of illegal fishing (Hilborn et al., 2005; Beddington et al., 2007; Agnew et al., 2009). Illegal fishing can be especially devastating for small-scale fisheries where participants are highly dependent on resource extraction for livelihood support and food security (Hauck, 2008; Worm et al., 2009).

We reviewed the literature on the factors that contribute to illegal fishing, and on interventions aimed at changing undesirable behavior in order to examine the potential for such interventions to supplement fishery enforcement efforts and achieve higher compliance with regulations in more fisheries. We also describe a process that has been used to design and implement behavior change interventions in other sectors, modified for developing interventions to reduce illegal fishing.

THE DETERRENCE APPROACH

Illegal fishing is a complex issue, driven by an interacting array of economic, institutional and social factors (Gallic and Cox, 2006; Hauck, 2008). Historically, policy makers and fishery managers have attempted to deter illegal fishing by imposing sanctions on offenders and by strengthening monitoring and enforcement programs (Sumaila et al., 2006; Hauck, 2008; Arias and Sutton, 2013) which increases the cost of illegal behavior or reduces the costs of legal behavior (Kuperan and Sutinen, 1998; Sumaila et al., 2006). The theory of compliance underlying this approach posits that all individuals are rational decision-makers who aim to maximize their utility, and that individual actors break the rules only when the benefits of doing so outweigh

the costs (Becker, 1968; Branch et al., 2006; Sumaila et al., 2006; Keane et al., 2008). This concept was adopted from classical economic theory, and serves as the basis for the deterrence model. Researchers have focused on finding the optimal level of fines or sanctions that should be imposed, given a certain probability of detection (e.g., Sumaila et al., 2006), to reduce the prevalence of illegal behavior.

According to the deterrence model, perfect monitoring, enforcement, and prosecution, coupled with sufficiently severe penalties, should prevent illegal fishing from occurring. A handful of case studies from fisheries around the world with 100% observer coverage and strong enforcement measures have demonstrated dramatically reduced illegal fishing (Ainsworth et al., 2008; Burnett et al., 2008; Alaska and British Columbia groundfish case studies in Bonzon et al., 2013). Moreover, even if monitoring and enforcement are imperfect, illegal fishing should be reduced, as long as sanctions are adequate, the likelihood of getting caught is sufficiently high, and fishermen are acting rationally (Becker, 1968).

However, in many fisheries the fines associated with violating fishing regulations are not large enough to provide a significant deterrent, as courts are typically hesitant to impose sanctions for fisheries violations that may seem excessive in comparison to what are perceived as more serious crimes (Sutinen and Kuperan, 1999). The cost of achieving enforcement levels resulting in the optimal probability of detection is often prohibitive, especially in relation to fisheries revenues. Actual levels of enforcement are often determined largely by this cost of implementation rather than by the levels required to deter illegal behavior (Arnason, 2013). Several studies have found that the actual likelihood of detection while violating a fishery regulation is often close to zero (Kuperan and Sutinen, 1998).

In small-scale fisheries, limited funding and capacity, often in the context of corruption, poverty, and/or organized crime regimes, sometimes leave fishery managers with few effective tools for addressing the problem of illegal fishing. Indeed, in many of the world's fisheries, and particularly in small-scale and/or developing world fisheries, effective, reliable monitoring and enforcement are rare (de la Torre-Castro, 2006; Hauck and Kroese, 2006; Gutiérrez et al., 2011).

If fishermen act only in their economic self-interest, an obvious solution to this quandary would be to seek more cost-effective ways to strengthen enforcement and increase penalties for detection. However, decades of research in several disciplines, including cognitive and social psychology, sociology, biology, anthropology, and behavioral economics, have yielded many important insights into the drivers of human behavior suggesting this approach may not always be effective (Sutinen and Kuperan, 1999; Fowler, 2005; Velez et al., 2005; de la Torre-Castro, 2006; Sumaila et al., 2006; Hauck, 2008; Keane et al., 2008; Mazar et al., 2008; Thaler and Mullainathan, 2008; Bose and Crees-Morris, 2009; Jagers et al., 2012; Kraak et al., 2014; von Essen et al., 2014). Findings from these scientific disciplines challenge the three core assumptions of the standard economic model of human behavior: that humans act and make decisions rationally, have boundless willpower, and are motivated solely by self-interest (Thaler and Mullainathan, 2008). Instead, humans have many

cognitive biases, are influenced by context and social factors, hold individual and cultural values, and are often driven by beliefs and perceptions that do not accurately reflect reality.

Rather, most humans are predictably irrational actors (Ariely, 2008) whose actions are sometimes driven by deliberative reasoning but more often by automatic mental processes or affect, often outside of awareness (Weber, 2013). A more realistic model of compliance (the "behavior change model") based on this understanding of human behavior would posit that a range of factors – including economic self-interest as well as social norms, perceptions, beliefs, and information – influences decisions about whether to engage in illegal behavior, and that the most important drivers of illegal behavior are context dependent. Hence, efforts to increase compliance should address whichever factors most strongly drive illegal behavior in a particular context.

EVIDENCE-BASED STRATEGIES TO COMBAT ILLEGAL FISHING

Illegal fishing behaviors are likely to be more varied and complex than the rational actor model of human behavior would indicate (Sutinen and Kuperan, 1999; Fowler, 2005; Velez et al., 2005; de la Torre-Castro, 2006; Hauck, 2008; Kraak et al., 2014; von Essen et al., 2014). Research into human behavior, decision-making, and compliance indicates that individual levels of risk tolerance, perceptions of regulation legitimacy, levels of trust and mistrust, preferences for avoiding detection, self-perceptions, wealth, knowledge or understanding of the likelihood of being caught, as well as social, moral, and other contextual factors all play roles in determining whether or not an individual will violate a regulation (see literature cited in Keane et al., 2008: Becker and Stigler, 1974; Polinsky and Shavell, 1979, 1990; Kaplow, 1990; Malik, 1990; Bebchuk and Kaplow, 1992; Sutinen and Kuperan, 1999; Hønneland, 2000; Nielsen, 2003; Tyler, 2006; as well as Sumaila et al., 2006; Hauck, 2008; Mazar et al., 2008; Bose and Crees-Morris, 2009; Jagers et al., 2012; Kraak et al., 2014). Modeling and empirical studies have shown that such factors can be at least as important as economic considerations in driving illegal behavior (Velez et al., 2005; Sumaila et al., 2006; Tyler, 2006; Lopez et al., 2012; Kraak et al., 2014).

Several important insights have emerged from research suggesting interactions between fishery actors likewise influence cooperation and rule breaking (see literature cited in Keane et al., 2008: Andreozzi, 2004; Dawes, 1973; Hamilton and Axelrod, 1981; Tsebelis, 1989; Mesterton-Gibbons and Milner-Gulland, 1998; Fehr and Gächter, 2002; Gezelius, 2002, 2004; Fowler, 2005). For example, the ways that enforcement officers interact with fishers can have a strong impact on compliance (Tsebelis, 1989; Hønneland, 2000; Tyler, 2006; Sundström, 2012). One field study, for example, revealed that when fishers perceive enforcement officers to be fair, incorruptible, and respectful, they are more likely to comply with regulations (Hønneland, 2000). Modeling studies have demonstrated that in situations where resource users and enforcers are likely to interact multiple times, increasing the reward to enforcement officers for detecting illegal activity

may not reduce the number of offenses; in fact, it may actually reduce the effort devoted to monitoring (Tsebelis, 1989; Andreozzi, 2004). This counter-intuitive outcome results from the fact that rewarding enforcers for catching violators may incentivize them to reduce their monitoring in order to encourage more flagrant illegal behavior, which enforcers can more easily detect to reap the benefits (Tsebelis, 1989; Andreozzi, 2004).

Under certain conditions – for example, when leadership is strong, trust is high, and social capital is high (Gutiérrez et al., 2011; Turner et al., 2016) – fishers tend to engage in self-enforcement, monitoring and reporting on or otherwise stopping the illegal behaviors of others (Fehr and Gächter, 2002; Fowler, 2005; van Hoof, 2010). Repeated interactions among self-enforcing resource users may increase cooperation (Hamilton and Axelrod, 1981) and empirical studies have shown that repeated interactions also increase community support for punishment of non-cooperators (Fehr and Gächter, 2002; Fowler, 2005). However, some modeling studies suggest that the shared benefits of communal self-enforcement (e.g., stewardship of resources) may not be sufficient to motivate enforcement over the long term without additional payments or incentives to monitor (Mesterton-Gibbons and Milner-Gulland, 1998).

DESIGNING BEHAVIORAL SCIENCE-BASED INTERVENTIONS TO REDUCE ILLEGAL FISHING

Research from behavioral science disciplines has guided successful interventions to change behavior in many sectors, ranging from voting behavior (Issenberg, 2010; Neri et al., 2016), savings and investment behavior (Fertig et al., 2015), to health behavior such as health screenings (Hallsworth et al., 2016; Matjasko et al., 2016), and prejudice (Aboud et al., 2012). These have often been implemented when changes in policy, the law or social structures were not feasible or not effective. In this context, an intervention is an action meant to produce a specified change in cognition, affect or behavior in a target. Here we focus on designing and using such interventions to reduce illegal fishing. Such interventions are not, of course, a panacea for ending illegal fishing. They are not likely to be necessary in fisheries with high levels of surveillance and strong enforcement capacity. Neither are they likely to produce strong enough incentives in the absence of surveillance and enforcement to achieve high compliance. They may be most useful for extending the mechanisms that result in high compliance rates observed in customary marine tenure and some co-management systems (McClanahan et al., 2006; Viteri and Chávez, 2007), such as trust in leadership, perceived legitimacy of regulations, and social norms to fisheries that lack such mechanisms.

Successful behavior change initiatives rely on a deep understanding of what motivates undesirable behavior, as well as of how to identify and overcome any barriers to the desired behaviors (Michie, 2008; Butler et al., 2013; Kraak et al., 2014). Human minds rely on heuristics to interpret information and

to make decisions when information is scarce or cognitive resources are low, which results in cognitive biases (Gilovich et al., 2002; Kahneman, 2003). Thus the way information is framed, the methods through which it is transmitted, and certain contextual attributes can strongly impact how people respond.

Some fishery management systems (i.e., Rights Based Management systems) are designed to motivate compliance by making it possible for fishermen to directly benefit from behaviors such as complying with a catch limit, in addition to the use of surveillance and penalties. Recent studies have shown that well designed rights based management systems can result in higher collective compliance rates (Grimm et al., 2012), behaviors consistent with increasing catch value rather than volume, and other behaviors that result in improved fishery outcomes (Costello et al., 2008; Gutiérrez et al., 2011; Newman et al., 2015). However, cases of unanticipated and undesirable fishery outcomes in rights based fisheries such as excessive quota lease rates (Pinkerton and Edwards, 2009), undesirable levels of quota consolidation (Casey et al., 1995; Grafton, 1996; Eythórsson, 2000; Yandle and Dewees, 2008), and undesirable distributions of benefits (Grafton, 1996; Guyader and Thébaud, 2001; Hauck, 2008; Carothers, 2011; Olson, 2011; Brown et al., 2017) indicate that the full suite of incentives and motivations at play in these systems need to be considered in order for these systems to achieve a variety of conservation, economic, and social goals.

Several other aspects of fishery management are already based on an understanding of human motivation and behavior. For example, fisheries observers are used on board many commercial fishing vessels not only to record catch data, including illegal take, but also to serve as a constant disincentive to engaging in illegal behaviors (Pramod et al., 2014). Participatory, community-based resource science and management can increase compliance by increasing the perceived validity of regulations (Ostrom, 1990; Hønneland, 2000; Nielsen, 2003; Hauck and Kroese, 2006; Tyler, 2006; Viteri and Chávez, 2007). This can be an especially effective means of improving compliance in small-scale and low governance settings (Hauck, 2008; Worm et al., 2009). Thus, fisheries managers are increasingly engaging fishermen in their science and management processes so that they are more likely to understand the importance of maintaining catch limits (Hartley and Robertson, 2006; Armstrong et al., 2013). However, results depend on other contextual variables, including the extent to which laws and regulations in general are deferred to (Anferova et al., 2005; Hauck and Kroese, 2006; Keane et al., 2008; Velez, 2011).

There appears to be substantial opportunity to build on these examples and improve compliance with fishery regulations, particularly in low governance and low capacity fishery contexts. This will require a better understanding of fisher responses to policies and regulation, designing policies and regulations to better elicit desired behaviors, and interventions that can enhance more conventional tools intended to reduce illegal fishing.

ADDRESSING THE DRIVERS OF ILLEGAL FISHING

While there is both a theoretical (Hønneland, 2000; Sumaila et al., 2006) and empirical (Fehr and Leibbrandt, 2011; Velez, 2011) basis for the design of behavioral science-based interventions, cases in which well-established methodologies from the behavioral sciences have been used to design and implement such interventions appear to be rare. In the remainder of this paper, we discuss some of the most powerful non-monetary drivers of illegal fishing that have been documented in the literature. We then describe a generalized process for designing interventions that target these drivers in order to reduce illegal fishing behaviors. In an effort to increase the rigor and robustness of the solutions generated through our process, we combine social science methods with empirical evaluation and testing methods, as has been advocated by other authors (e.g., Tantia, 2017). Because the drivers at play in a given fishery, as well as the interventions that will be effective, will depend to a significant degree on the specific social, economic and political context of the fishery, this process is designed to result context-specific solutions.

We have organized the following behavioral science-based intervention examples into three categories based on the main drivers they aim to address: (1) those related to self-interest; (2) those related to personal perceptions and beliefs, including perceived social norms; and (3) those related to information (or the lack thereof). Within each of these categories, there are two basic types of behavior change interventions: (1) changing internal drivers of undesirable behavior such as beliefs and values; and (2) removing barriers to the expression of desirable behaviors. See **Table 1** for a summary of these categories, along with some example interventions. Existing research on compliance, norms, risk-taking, altruism, and other topics can inform the design of both types of interventions. Behavioral science-based interventions can also improve group dynamics and increase cooperation and social cohesion (Hamilton and Axelrod, 1981; Fehr and Gächter, 2002; Fowler, 2005; Tyler, 2006; Velez et al., 2006; Lopez et al., 2012), both of which are vital features of effective community-based management systems (Gutiérrez et al., 2011).

Self-Interest

Drivers of behavior related to self-interest are those that involve physical or emotional benefits to the individual or their communities. The most straight-forward of these in the context of illegal fishing is the profit motive. Obviously, there are often significant financial benefits associated with illegal fishing which may be challenging to address through behavioral interventions. Here, we review studies that have revealed a number of other types of self-interest drivers that may be more amenable to behavior change interventions.

The relative influence of the profit motive compared with other motivations will likely vary among fisheries. For example, it may be that the social status resulting from financial gains from illegal fishing is as important a driver as the actual profits.

TABLE 1 | Categorized behavioral drivers of illegal fishing, potential methods to investigate, and potential intervention examples.

Illegal fishing driver category	Illegal fishing driver	Potential methods to investigate	Examples of actions based on the behavioral interventions
Self- interest	Increase profits or social status or improve reputation	Using existing data on the communities, or existing information, further more targeted data gathering methods can be used. Informal interviews of representatives of individuals displaying the target behavior (e.g., the actual fishers) and of different stakeholder groups; literature reviews; surveys, especially techniques designed to investigate potentially sensitive topics by maintaining the respondent's confidentiality, such as Randomized Response Technique (RRT) (Lensvelt-Mulders et al., 2005); power mapping; social network analysis; ethnography; town halls; focus groups. See Step 1 in **Figure 1**.	Education campaign making the long-term negative implications of illegal fishing more immediate and salient or reducing social and psychological rewards could potentially alter people's attitudes and behaviors around illegal fishing.
	Safety and protection		Creation of a truly anonymous reporting hotline.
	Resistance to change out of desire to preserve identify or tradition		Campaigns to tap into pride in self/community (Butler et al., 2013). Making legal fishing something to be proud of, or support notion of working for common good (Day et al., 2014).
	Meeting immediate survival needs in the face of poverty		Program to deliver information about the impacts of illegal fishing or to clarify what the regulations that allows individuals to access materials intermittently [including via text messaging (Mullainathan and Shafir, 2013; Castleman and Page, 2016; National Science and Technology Council, 2016), games, or even soap operas (Silberner, 2016; Vansen, 2016)] than extended courses that require high mental bandwidth and large amounts of time.
Perceptions and beliefs	Fishing illegally because of belief others are doing so	To develop and test interventions, a rich methodological history exists in the experimental branches of sociology, psychology, political science, economics and marketing research.	Changing perceptions by highlighting legal fishing activity. Communicating low incidence of illegal behavior.
			Telling stories of where other fisheries have benefited from complying with regulations (Kraak et al., 2014).
	Perceived lack of legitimacy of regulations	Randomized control trials and field experiments can help hone the intervention and adapt them to the sociocultural realities of the targeted communities.	Messaging campaigns to educate about damaging impacts of illegal fishing. Co-creating regulations with fishers to increase legitimacy.
			Highlighting role of fishers in collecting data/designing regulations.
	Lack of trust between enforcers and fishers	See Steps 2 through 4 of **Figure 1**.	Create forum where enforcement agents and fishers can interact.
Information	Lack of knowledge about regulations		Simple, clear rules communicated through appropriate channels.
			Education about purpose of regulations, process for designing them, and mechanisms through which they are intended to work (Pollnac et al., 2010).
	Lack of information about consequences of illegal fishing		Education campaigns designed to make these impacts salient.

Similarly, there may be reputational benefits from illegal fishing. For instance, violating the regulations may allow fishers to catch more or larger fish, thereby making them appear to be more skilled or experienced than their peers. This social status benefit can also prevent community members from reporting violators (e.g., von Essen et al., 2014). Fishers may also take personal pride in maximizing their daily catch, or in coming home with a full boat, potentially driving them to exceed their quotas or otherwise violate fishing regulations.

Another important dimension to consider in self-interest is time. Most people have a well-documented cognitive bias toward prioritizing short-term needs and benefits over long-term costs and impacts (Weber et al., 2007; Gifford, 2011). Thus, making the long-term negative implications of illegal fishing more immediate and salient or reducing social and psychological rewards could potentially alter people's attitudes and behaviors around illegal fishing. Safety and protection are also important self-interest drivers that could potentially influence illegal fishing behaviors (Corbett, 2005). Fishers may experience pressure to engage in illegal behaviors, or at the very least to turn a blind eye to it, lest they be seen as an informant by a powerful individual or group. This can be an especially significant factor in settings where the illegal actors are functioning like an organized criminal group, as opposed to isolated actors (Österblom et al., 2011).

Some fishermen are motivated by a desire to preserve a sense of identity or tradition. Such fishermen may be resistant to changing their behavior in the face of new regulations (Hviding, 1996; McGoodwin and Nations, 2001; Pollnac et al., 2001, 2012; Eder, 2005; Blount, 2007; Gupta, 2007; Weeratunge et al., 2014). Interventions can be designed to either take advantage of such an interest in preserving or reinforcing identity, or to change them where necessary. For example, Rare, a conservation NGO, has designed effective conservation interventions that tap into pride in one's self, place, or community with campaigns and capacity building programs (Butler et al., 2013). Such interventions are being used to improve uptake of the notion that legal fishing is something to be proud of, that one's community is a place where people work together for a common good that is larger than one's self, or that one's knowledge is being used to inform the design and implementation of the regulations may be effective (Day et al., 2014).

Finally, illegal fishing often occurs in communities dealing with poverty; fishers violate rules in an effort to meet the basic needs of their families (de la Torre-Castro, 2006). Poverty has been linked to a set of cognitive processes that have come to collectively be known as the "scarcity mindset," wherein (among other effects) the mental processes necessary to consider and value one's own long-term needs are impeded by the immediate and pressing drive to meet one's short-term needs (Shah et al., 2012; Mani et al., 2013; Mullainathan and Shafir, 2013). Experimental results suggest that the "scarcity mindset" causes people to make sub-optimal or irrational decisions. When individuals are in the scarcity mindset they likely do not have the mental bandwidth to engage in efforts to conserve fish stocks, even if such efforts could generate higher yields in a few years.

While the reduction of poverty is the long-term solution, other measures may be effective in increasing cognitive bandwidth to lengthen planning horizons and/or reduce discounting (i.e., placing a smaller value on future benefits than on current benefits), such as short-term measures to alleviate pressing food security or cash flow issues. This problem of low cognitive bandwidth can also be addressed by improving the way in which programs aimed at increasing compliance with fishery regulations are implemented. Because impoverished people often lack a safety net, engagement in educational or capacity building programs can often be disrupted by small problems such as a sick child (Mullainathan and Shafir, 2013). A program to deliver information about the impacts of illegal fishing or to clarify what the regulations are might be more effective in this context if it allows individuals to access materials intermittently [including via text messaging (Mullainathan and Shafir, 2013; Castleman and Page, 2016; National Science and Technology Council, 2016), games, or even soap operas (Silberner, 2016; Vansen, 2016)] than extended courses that require high mental bandwidth and large amounts of time.

Perceptions, Beliefs, and Norms

Often, the decision to engage in illegal fishing is motivated by individual perceptions, beliefs, values, or social norms (Velez et al., 2005, 2006; Sumaila et al., 2006; Tyler, 2006; Lopez et al., 2012).

Belief in the legitimacy of regulations and of fishery management authorities is a key factor in compliance. If there is no faith in the efficacy of the regulations, or in the science that serves as the basis for regulation – whether as a result of corruption, lack of information, or other factors – compliance is also likely to be low (Sutinen and Kuperan, 1999; Hatcher et al., 2000; Tyler, 2006; Levi et al., 2009; Arias, 2015; Turner et al., 2016). Increasing the perceived legitimacy of regulations is one of the most powerful means for increasing compliance (Hønneland, 1999, 2000; Sutinen and Kuperan, 1999; Tyler, 2006; Viteri and Chávez, 2007). Some factors that may impact the perceived legitimacy of regulations include: involvement of fishers in the regulatory process; similarity of enforcement agents to fishers; effectiveness of regulations; visibility of benefits resulting from regulations; equity of management outcomes; perceptions of corruption in governing institutions; perceptions of efficacy of governing institutions and regulations; and procedural justice (Hatcher et al., 2000; Hønneland, 2000; McClanahan et al., 2006; Levi et al., 2009; Arias, 2015; Turner et al., 2016).

Creating deference to regulations, resulting in voluntary compliance, as opposed to coercing compliance (Tyler, 2006; Viteri and Chávez, 2007), results in greater durability and resilience of legal behaviors over time. For example, if enforcement diminishes due to budget cuts, compliance levels may remain high when there is deference (Tyler, 2006). Others have found that willingness to comply with regulations voluntarily is inversely proportional to the level of top-down control in a system. This is because such control signals mistrust, reducing intrinsic motivations such as reciprocity and the desire to "be a good citizen" (Bowles, 2008; Richter and van Soest, 2012).

Using behavioral interventions to increase deference may help to break the vicious cycle wherein top-down control in response to low compliance results in mistrust, which leads to more violations, thereby leading to calls for even stronger controls and signaling even greater mistrust (Kraak et al., 2014). Creating forums in which enforcement agents can interact with fishers and community members outside of the high-tension atmosphere of an inspection encounter may generate mutual respect and understanding, reducing the perception that the enforcers are "outsiders" or "others," which can in turn increase compliance (Hønneland, 2000; von Essen et al., 2014). Skillful facilitation may be necessary to elicit a constructive dialog (Pollnac et al., 2001).

Likewise, the perception that other fishers are violating fishing regulations can decrease legitimacy and be a strong driver of non-compliance behavior (Kuperan and Sutinen, 1998; Bova et al., 2017; Bergseth and Roscher, 2018). This is particularly true when the payoff from compliance for an individual depends on the assurance others will also comply (Nielsen, 2003). Chronic violation of regulations may decrease the perceived legitimacy and effectiveness of the regulations, weakening the moral and social obligations of those fishing legally to continue doing so (Viswanathan et al., 1997). One study found that fishers who perceived that other fishers were violating fisheries regulations were themselves 8% more likely to violate (Hatcher et al., 2000).

Social norms – people's perceptions of what other people do or should do (Cialdini et al., 1990; Miller and Prentice, 2016) – are considered to be among the most powerful drivers of human behavior (Cialdini et al., 1990, 1991; Reno et al., 1993; Cialdini and Trost, 1998; Sober and Wilson, 1998; Kallgren et al., 2000; Boyd and Richerson, 2006; Schultz et al., 2007; Goldstein et al., 2008; Allcott, 2011; Gneezy et al., 2016) and have been identified as important drivers of legal and illegal fishing behavior (van Sittert, 1993; Hatcher et al., 2000; Sumaila et al., 2006; Hauck, 2007, 2011; Thomas et al., 2016; Bova et al., 2017). Fishers who have been complying with regulations may engage in illegal fishing when they perceive that their peers are doing so. There may be a high degree of community acceptance or even support of illegal behavior, based on, for example, a belief that this type of behavior is part of what defines the community, or that it is a form of protest against illegitimate regulations or corrupt enforcement actors. Fishers may be motivated by a desire to rebel against laws and regulations that are perceived to be oppressive (Nielsen and Mathiesen, 2003; Fabinyi, 2007; Hauck, 2007, 2008; von Essen et al., 2014). Educating individuals about the damaging impacts of illegal fishing can be improved by focusing on how these behaviors can negatively impact the whole community and future generations. It may be that community members and fishers believe illegal fishing to be a "victimless crime" (Smith and Anderson, 2004; Hardin, 2009), especially if stocks are still relatively healthy. Thus, clearly identifying the victims as the fishers' own friends and neighbors may be a powerful intervention.

In addition, community members and other fishers who are friends, family, and neighbors of fishers who engage in illegal fishing may not wish to turn them in because they see these illegal actors as members of their own group. This in-group dynamic can be especially problematic if enforcement agents are also members of the same communities as illegal fishers. If these attitudes have persisted long enough, this may result in permissive social norms and a "culture of rule breaking," in which breaking the rules is acceptable (Branch et al., 2006).

Just as they can drive illegal behavior, replacing social norms that reinforce illegal behavior with norms that strengthen legal fishing can be among the most effective and long-lasting interventions (van Sittert, 1993; Kuperan and Sutinen, 1998; Sutinen and Kuperan, 1999; Eder, 2005; de la Torre-Castro, 2006; Sumaila et al., 2006; Hauck, 2007, 2011; Weeratunge et al., 2014). Because the perception of the norm drives behavior (as opposed to the actual conditions in the fishery) (Prentice and Miller, 1993; Miller and Prentice, 2016), interventions may need to focus on increasing alignment between perceived norms and reality. For example, if the vast majority of fishermen in a community actually comply with their catch limits but there is a widespread perception that most people do not, individuals may exceed their quotas even if their individual preference is to comply. Communicating and making salient the actual low incidence of the illegal behavior would disrupt this perception and perhaps prevent this kind of illegal fishing.

Messaging campaigns using social norms which describe a desired behavior as common among a target audience's peers can effectively motivate that behavior in the target audience (Goldstein et al., 2008). Behavioral interventions designed to change this perception may highlight the prevalence of legal fishers or the scarcity of illegal fishing in a given community. Framing new regulations as "tried and tested" in other, similar governance contexts, such as telling stories of similar fisheries where complying with regulations has led to benefits for communities, may be a successful strategy (Kraak et al., 2014).

Information and Knowledge

Many fishery management initiatives are based on the assumption that the provision of information will result in desired behaviors. This assumption that information will alter behavior is sometimes referred to as the information deficit model. This is probably seldom the case, because there are many other factors that determine behavior (Butler et al., 2013; Sutton and Rao, 2014). In fact many efforts to change behavior solely by providing information have failed, and sometimes result in perverse outcomes such as increased poaching (Bergseth et al., 2017). However, strategies that provide information are often important components of behavior change strategies and there are many insights from behavioral research that can be applied to improve the effectiveness of communication.

Simple, clear rules communicated to fishers through the appropriate channels are more likely to be followed (for example, summaries of rules printed on waterproof cards handed out at sea; articles in fishing magazines or local newspapers) than are complex rules communicated through channels that

are ignored by fishers (for example, posted on government websites or published in lengthy reports) (Bose and Crees-Morris, 2009; Jagers et al., 2012; Thomas et al., 2016). Some illegal fishing behaviors are also motivated by unfounded beliefs or misinformation. For example, fishers may believe that catching more fish will always result in higher revenues and profits, when in fact this is often not the case: fishing too hard can create market gluts that drive down the price of each individual fish caught, and overfishing for an extended period can cause the stock to collapse. Participatory processes in which stakeholders identify such dynamics together can result in improved common understanding, which in turn can result in the co-creation of interventions to disrupt the adverse dynamics. For example, in 2012 a participatory systems-mapping exercise revealed that high catch rates – which were believed by many fishers to be essential for maintaining sufficient fishing revenues – were causing price collapses in the Upper Gulf of California curvina (croaker) fishery. Based on this information, community purchase agreements and a price floor were implemented to regulate catch volumes and boost compliance with the quota system, which in turn stabilized prices and increased overall revenues (EDF de Mexico, 2015).

Education about the purpose of regulations, the process through which they were designed, and the mechanisms through which they are intended to work can increase compliance (Pollnac et al., 2010). Participatory processes in which fishermen co-create the regulations may be even more effective (Ostrom, 1990; Hatcher et al., 2000; Keane et al., 2008; Karr et al., 2017). If fishers are included in the process of collecting data and/or designing the regulations, an education campaign that highlights this role and the value of their input may significantly increase the perceived legitimacy of the management system and instill a sense of ownership in it.

Fishers and community members may also lack information on the likely consequences of illegal fishing, and how illegal behaviors may impact themselves and their communities. Some forms of common illegal fishing practices, such as dynamite and cyanide fishing, can have immediate and visible negative impacts on the target ecosystem and community. Other forms of illegal fishing, however, such as exceeding individual quotas or fishing in key habitat areas, may have negative impacts that take longer to manifest, or that only arise from the aggregate behavior of many individuals. These types of impacts can seem abstract or intangible; people often struggle to make optimal decisions about abstract concepts or with imperfect information (Gilovich et al., 2002; Weber, 2006). Education campaigns that make these types of impacts more salient may help reduce illegal fishing. However, as mentioned above, the provision of information alone is rarely sufficient to change behavior (Butler et al., 2013; Sutton and Rao, 2014), and must be presented in ways that inspire emotional responses to the problem (Weber, 2006; Butler et al., 2013). Coupling information provision with other interventions aimed at producing motivation to engage in the desired behavior and at removing barriers to behavior change may also be necessary.

DESIGNING AND IMPLEMENTING BEHAVIORAL INTERVENTIONS TO REDUCE ILLEGAL FISHING

The prevalence of illegal fishing in small-scale fisheries lacking the resources and systems to implement traditional deterrence methods, along with the failure of those methods to deter illegal fishing in many fisheries in which they are implemented, calls for new approaches and tools. Here, we draw on several design processes[1] that have been used to change behavior in other sectors (e.g., healthcare, finance, public policy, international development, ethics, and advertising) to describe a step-by-step process for designing empirically supported behavioral interventions specifically targeted to reduce illegal fishing.

The process can be summarized in the following five steps (and see **Figure 1**):

(1) Gain an in-depth understanding of the community and context in order to identify relevant actors, types of problematic behaviors, and possible drivers.
(2) Develop hypothetical interventions.
(3) Experimentally test hypothetical interventions.
(4) Pilot interventions based on the mechanisms identified.
(5) Scale-up tested interventions, and set up systems to monitor, evaluate, and adjust.

Step 1: Gain an In-Depth Understanding of the Community and Context to Identify Relevant Actors, Types of Problematic Behaviors, and Possible Drivers
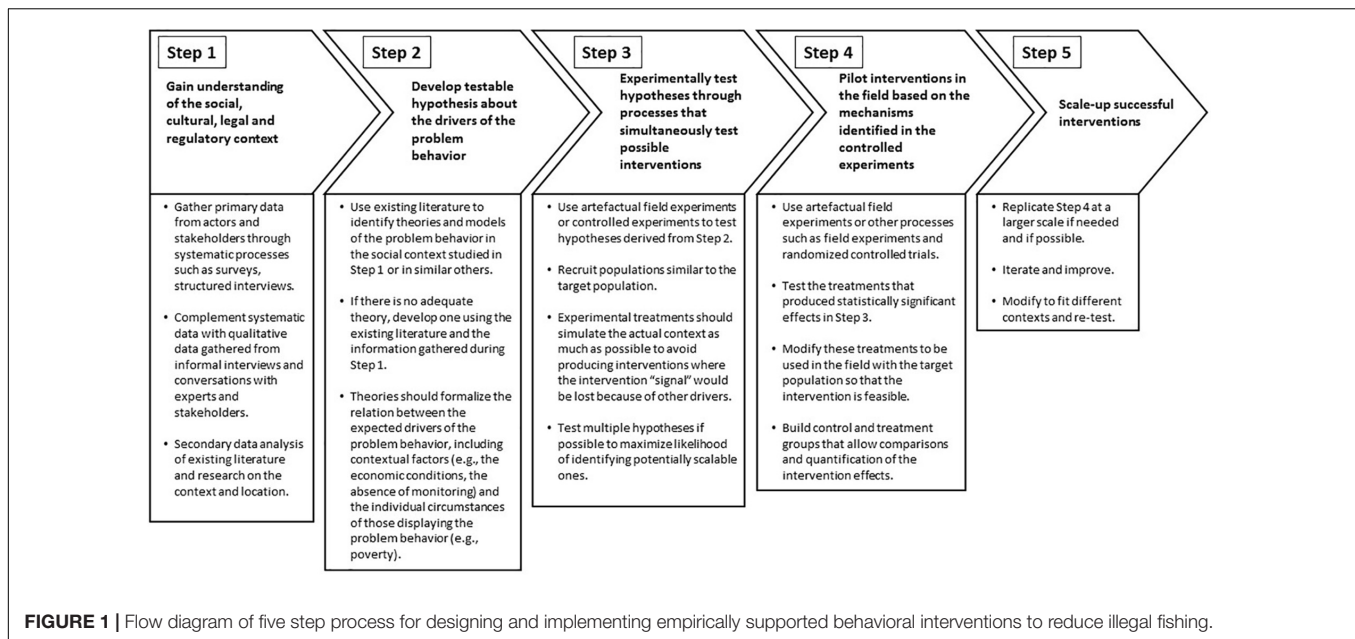
Understanding the context of illegal fishing is essential for identifying conditions that enable illegal fishing and for interpreting the results of surveys and experiments. Important contextual attributes include the manner in which policies are implemented, how relevant actors interact, how decisions are made at various levels of society, the role of fishing in the community's political, economic, social, and cultural spheres, the values, beliefs, and behaviors of all relevant stakeholder groups, and the general scope of illegal fishing.

There are a variety of methods for gaining an understanding of community context. Informal interviews of representatives of different stakeholder groups may suffice. This information can be supplemented with a literature review. Surveys, power mapping, social network analysis, ethnography, town halls, focus groups, and other social science methods can also be used if time and resources allow[2].

These same social science methods can also be used to gather information on the relevant illegal fishing acts and each actor group's contributing behaviors. Survey techniques

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[1] Including the Behavioral Design guidance presented in (Tantia, 2017); the REVISE principles to change unethical behavior (Ayal et al., 2015); the Behavioral Economics Guide (Samson, 2017); the MINDSPACE mnemonic (Dolan et al., 2010, 2012); the Field Guide to Human Centered Design (Brown, 2009; IDEO, 2015); and the Root Solutions process (root-solutions, 2017).
[2] The "Field Guide to Human Centered Design" (IDEO, 2015) provides an extensive set of tools and methods that may be useful in conducting effective and comprehensive community surveys/interviews.

FIGURE 1 | Flow diagram of five step process for designing and implementing empirically supported behavioral interventions to reduce illegal fishing.

designed to investigate potentially sensitive topics (like illegal fishing) by maintaining the respondent's confidentiality, such as Randomized Response Technique (RRT) (Lensvelt-Mulders et al., 2005), will be especially useful in this step.

Illegal fishing is typically comprised of many different behaviors with many different drivers. Illegal behaviors may include fishing without a permit, fishing in restricted areas or at restricted times, fishing for protected species, fishing with illegal gears, failing to report or underreporting catches, among others.

Relevant actors include fishermen and those who may influence fishing behavior. Vessel or gear owners may condone, encourage, or even demand that their boats participate in illegal fishing. Those involved in transporting, distributing, and selling fish may help deliver protected species or illegally sized fish to market. Enforcement officers may not report illegal fishing they witness taking place, or may simply avoid witnessing such illegal activity. Judges may reduce fines to a negligible amount. Family and community members may not report illegal activities to authorities. Each of these actor groups and their relevant behaviors should be considered in the design of interventions. Targeting an intervention at a group other than the fishers themselves could possibly be the most effective means of eliciting the desired change.

Survey results and literature review can illuminate the drivers of specific illegal fishing behaviors. The next step will be to determine which behaviors to prioritize, given available resources and the desired scope of the intervention. Workshops designed to describe specific illegal behaviors and assign potential drivers to them can be effective.

Step 2: Develop Hypothetical Interventions

To generate hypothetical interventions, a theory (or theories) of change can be developed that describes how the behavioral drivers identified in Step 1 can be addressed to ultimately reduce illegal fishing. Developing theories of change helps ensure that those designing a hypothetical intervention share an underlying understanding of the relevant context and various dynamics at work. It is an important step, because interventions that seem generalizable may fail to remain relevant in a particular fishery upon closer examination of the theory of change (Margoluis et al., 2013).

Theories of change can be informed by a literature review, information gathered in Step 1, and local knowledge. Several types of interventions have been shown, either empirically or via modeling studies, to be effective for reducing illegal behaviors (e.g., Hamilton and Axelrod, 1981; Tsebelis, 1989; Sutinen and Kuperan, 1999; Fehr and Gächter, 2002; Gezelius, 2002, 2004; Andreozzi, 2004; Fowler, 2005; Velez et al., 2005; Sumaila et al., 2006; Tyler, 2006; Lopez et al., 2012; Kraak et al., 2014; von Essen et al., 2014). In addition, certain principles for changing behavior have been articulated based on experiments and field experience (e.g., Dolan et al., 2010; Ayal et al., 2015; Samson, 2017). Thus, there is an abundant and growing body of research that can be drawn from to identify a compelling theory of change and develop hypothetical interventions.

Step 3: Experimentally Test Hypothetical Interventions

Once potential interventions have been developed to address a particular behavior associated with illegal fishing, the next step is to experimentally test the efficacy of those interventions. To do so, artefactual field experiments [wherein samples are drawn from the population that would be used in a larger field study (Velez et al., 2006; Fehr and Leibbrandt, 2011; Lopez et al., 2012; Gneezy et al., 2016)], or laboratory experiments that use samples of individuals from each target actor group can be conducted to test the effectiveness of each

intervention – compared to each other as well as a control treatment if possible – at modifying attitudes and changing behaviors. If it is not possible to test experimental interventions on the target audience (due to concerns about influencing the target audience ahead of the full implementation of the intervention, for example), then an alternate but highly similar audience can be used (Samson, 2017). In addition, given available time and resources, preliminary experiments with small numbers of participants can be conducted in a separate community to test intervention variations and refine experimental protocols before implementing the full-scale experiment in the target community. Behavior change might not be captured as a change in actual illegal fishing, but rather through an analogous behavior in a simulation; for example, through reductions in cheating behaviors in a game-based experiment. Common pool resource (CPR) games are often used to test the effects of hypothetical interventions on participants in a simulated fishery. Experimental interventions could include mock fishing scenarios, simulated framing and messaging campaigns, the provision of feedback on the effects of illegal fishing, or many other types of interventions designed to address drivers identified in surveys and interviews. Experimental treatments that simulate real world variations and challenges can be used to test the robustness of interventions to some extent.

Step 4: Pilot Interventions Based on the Mechanisms Identified

Once interventions have been tested experimentally, those with demonstrated efficacy (in the experimental setting) at shifting behaviors in the desired direction should be piloted with small groups under real-world conditions in the target community. This step is crucial because behavioral interventions that are effective in experimental settings may not be effective in real-world settings, where efforts may be undermined by countless confounding factors that were not accounted for in the experiment. For example, it is easy to convey information, such as the aggregate catch of all fishers, to the participants in an experiment. It may, however, be significantly more difficult to get that same information to all members of a fishing community within the requisite amount of time. Similarly, experimentation may reveal that allowing participants to generate their own fishing rules is effective in reducing illegal behaviors, but it might not be politically possible to implement an intervention that involves having fishers re-design the actual regulations with which they must comply. The purpose of the pilot stage, therefore, is to clarify how the interventions that worked in the experimental phase can be implemented in the real world, and to identify problems that arise in the field before they are implemented at a larger scale, requiring more resources and capacity.

Depending on the intervention and the results of the experiments in step 3, piloting may require multiple "conditions" to test different versions ("treatments") of each intervention in the real-world environment. Depending on available resources,

each version of the intervention should be replicated on multiple sample populations as well, if possible. In addition, control groups should be included (Martin et al., 2012; Monitoring Design Before-After Control-Impact, 2017). At this step, the efficacy of the interventions can be measured directly with surveys conducted before and after interventions are carried out, and with direct observations of behavior, although it is likely that only short-term process indicators can be measured during this pilot phase (e.g., immediate reductions in the presence of non-permitted fishers on the water, or indicators of earlier steps in the theory of change, such as shifts in knowledge or attitudes). Longer-term outcome indicators (e.g., community-level metrics such as reductions in seasonal catch above quotas or official reports on the prevalence of illegal fishing) should be used to measure success of the large-scale implementation (in the next step).

Step 5: Scale-Up Tested Interventions, and Set Up Systems to Monitor, Evaluate, and Adjust

If the pilots demonstrate efficacy, and after any necessary modifications are made to the design based on the results, then the interventions are ready to be implemented on a broad, community-wide scale.

A deliberate scaling strategy should be developed, rather than simply depending on the effectiveness of the intervention to result in broader uptake (Battista et al., 2017). A key step will be to determine what scaling up interventions will entail in terms of actual logistics and policy. These will vary greatly among interventions: for example, they may be minimal if the intervention consists of participation in a CPR game that illustrates dynamics that lead to illegal fishing in order to change beliefs about illegal fishing. Some interventions can be scaled very simply, for example by increasing the number of monitors showing aggregate catch at landing sites. However, some interventions such as campaigns to change social norms or the use of more participatory processes to increase the legitimacy of regulations may require many more resources, policy changes, and even the formation of new relationships or changes in existing relationships.

These kinds of changes may lead to unforeseen challenges. For example, if interventions involve the implementation of a program that rewards community members who report illegal fishing, conflicts may form between adjacent areas of the community that failed to emerge in the pilot stage (e.g., if one part of the community has a disproportionately large number of illegal fishermen).

Thus, except in limited circumstances, scaling up interventions from pilots to the entire community is likely to lead to unexpected dynamics (World Health Organization and ExpandNet, 2011; Management Systems International, 2012; Sutton and Rao, 2014; Battista et al., 2017). This is generally an unavoidable part of changing a social and economic system. When challenges do arise, it is critical to document them and any changes made to the intervention in order to accurately

evaluate its efficacy in the following step. Changing interventions prematurely will confound efforts to analyze the efficacy of the intervention, but may be necessary depending on context.

Evaluation of the performance of behavior change interventions is critical, from beginning to end (Woodhouse et al., 2016; Battista et al., 2017). Measurable indicators of the desired behavior changes should be chosen and evaluated prior to implementation to generate baseline data. Many of the same indicators used for evaluating the efficacy of interventions in experiments and pilot projects can be used to assess the efficacy of community-wide interventions. These can include process indicators that reflect intermediate changes that precede actual outcomes such as reductions in illegal fishing (e.g., increased cooperation in reporting and monitoring programs, or the purchase of legal fishing gears). In addition, indicators of actual outcomes (i.e., reductions in illegal fishing behavior) should also be measured at the community-wide scale to ensure illegal fishing has actually been reduced. It is important to measure changes in similar communities not receiving interventions, if possible.

Reductions in illegal fishing can often be measured using standard fisheries data collection methods, including catch logs, reports from patrols, at-sea or electronic observer data, etc. In some cases, new data streams will be required to measure behavior change; for example, individual catch records would be necessary for measuring the efficacy of an intervention aimed at changing individual fishing or reporting behavior. These can be complemented by social science techniques, e.g., surveys with fishermen and community members regarding the frequency and intensity of the illegal fishing taking place. Progress should be measured against specific, quantitative objectives for each indicator that are established before implementation. If these objectives are not being met, project managers can then investigate what is undermining the intervention's effectiveness, and propose solutions to get them back on track.

DISCUSSION AND CONCLUSION

There is an urgent need to reduce illegal fishing, especially in fisheries where illegal fishing may be threatening livelihoods and food security in dependent communities, and where resources for bolstering surveillance and enforcement are limited. Moreover, corruption, lenient penalties, and other problems constrain the efficacy of enforcement systems in many fisheries around the world. There is evidence that behavioral factors related to perceptions and beliefs, self-interest, and information or the lack thereof can also drive illegal fishing activities. Hence, interventions aimed at addressing these drivers can supplement enforcement efforts or prompt compliance where enforcement is inadequate to reduce illegal fishing activity. Furthermore, such interventions may prove to be even more effective if implemented in concert with each other, so that multiple drivers of the behavior are targeted at once. For example, efforts to improve access to information can be paired

with messaging/framing campaigns targeted toward relevant perceptions and beliefs in order to increase knowledge while simultaneously generating motivation, a technique which has proven effective for eliciting change (Butler et al., 2013; Sutton and Rao, 2014).

Significant research has been conducted on behavioral science-based interventions that may be useful to marine conservation and management (Reddy et al., 2017), and there is much room to improve outcomes through the application of these lessons. However, as behavior change is context- and actor-dependent, a systematic process for developing solutions to illegal fishing tailored to specific fishery contexts is needed.

We posit that effective interventions to reduce illegal fishing behaviors in any setting can be developed and implemented by using the 5-step process described here, which is derived from well-established methods that have been used to change behavior in many other sectors. This process entails developing a deep understanding of the target communities and includes steps to characterize illegal fishing behaviors and their drivers, develop theories of how undesirable behaviors can be changed, test potential interventions with experiments, pilot and adjust interventions, and fully implement interventions, as well as to monitor, evaluate, and adjust interventions to ensure their ongoing effectiveness.

We are not recommending that conventional, command-and-control regulations and enforcement systems designed to deter illegal fishing, where they already exist, be replaced by a behavioral approach. Instead, we seek to highlight the conditions under which deterrence methods can be complemented through the application of behavioral science, and suggest approaches to improve compliance. Behavioral science-based interventions can improve the efficacy and uptake of conventional regulations, improving the levels of compliance and deference, as well as their resilience over the long term (Tyler, 2006). Combining behavioral interventions with increased surveillance to increase detection probability, for example, may be highly effective for reducing illegal fishing because both the monetary and non-monetary drivers of the illegal behaviors are targeted (Hønneland, 2000; Sumaila et al., 2006; Velez et al., 2006). Furthermore, efforts to reveal and reduce corruption, which can themselves benefit from the lessons of behavioral science, can go a long way toward reducing the systemic drivers of illegal fishing (Becker and Stigler, 1974; Hønneland, 1999, 2000; Sutinen and Kuperan, 1999; Dietz et al., 2003; Sumaila et al., 2006; Tyler, 2006; Hauck, 2007; Österblom et al., 2011; Sundström, 2012; von Essen et al., 2014). For these reasons, behavioral interventions may be particularly useful in small-scale and low-governance fisheries that lack resources for high levels of surveillance and enforcement.

AUTHOR CONTRIBUTIONS

WB contributed to the development of the novel method presented in the manuscript and also was the lead author of the

manuscript. RR-C was the lead in developing the novel method presented in the manuscript, and provided multiple reviews and edits of the manuscript text. SS contributed to the background literature review presented in the manuscript, and also provided a number of complete reviews. JF, ME, and DL-K contributed to the development of the novel method presented in the manuscript and the initial draft. RF contributed to development of the novel method presented in the manuscript and the initial draft, and provided multiple reviews and edits.

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