



Original Article

Deterrents and nudges improve compliance in Greenland's Atlantic salmon (*Salmo salar*) fishery

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Fishers reporting all of their catch is key to estimating population viabilities of vulnerable, highly migratory fish stocks. However, fishery managers find it difficult to ensure that this reporting behavior takes place consistently. Wild Atlantic salmon (*Salmo salar*) are a highly migratory and internationally contested species with a threatened conservation status. Greenland manages a fishery for Atlantic salmon, and its coastline serves as a key feeding ground in the life history of Atlantic salmon. However, salmon catch is underreported by fishers, even though they are required to report. Deterrenting noncompliant behavior with penalties and sending short message service (SMS) messages have been shown to increase compliance, but no known studies test their effect on compliance with catch reporting requirements. We evaluated two interventions for their effect on salmon catch reporting behavior among Greenland's salmon fishers. Salmon fishers were 41% more likely to report ($p < 0.00$) once a deterrence-based intervention was implemented. Fishers who received SMS reminders were 6% more likely to report salmon catch ($p < 0.1$). These results highlight the complementarity of nudges and command-and-control interventions to increase compliance with catch reporting requirements.

Keywords: Arctic, compliance, conservation social science, fisheries governance, recreational fisheries, salmon, transnational fisheries management

Introduction

Greenlanders are known to have fished for Atlantic salmon (*Salmo salar*) for centuries and, as part of the Greenlandic economy, for nearly 60 years (Stein, 1984). In 1971, harvests peaked, with more than 2500 t of salmon landed (ICES, 2020a). Greenland's salmon harvests began to slowly decline in the decades that followed (Figure 1), and conservationists grew concerned about the status of Atlantic salmon stocks throughout the North Atlantic region. As a result, stakeholders formed the North Atlantic Salmon Conservation Organization (NASCO) in 1984. Greenland's harvests of salmon and the accuracy of salmon catch reporting have remained a controversial discussion point for NASCO members.

Accurate salmon catch reporting is important for identifying the drivers of salmon declines and for developing sound salmon fisheries management. Greenland has legislation that requires reporting of salmon, but not all fishers comply. Our research objective is to evaluate two interventions designed to improve salmon catch reporting. In so doing, we outline the benefits and limitations of a deterrence-based, command-and-control intervention, and an alternative, nudged-based intervention for improving salmon catch reporting.

The reason for concern over the ecological status of Atlantic salmon in the North Atlantic and neighboring waters is because much of the Atlantic salmon harvested off Greenland's coastline migrate from stocks along the North American and northern

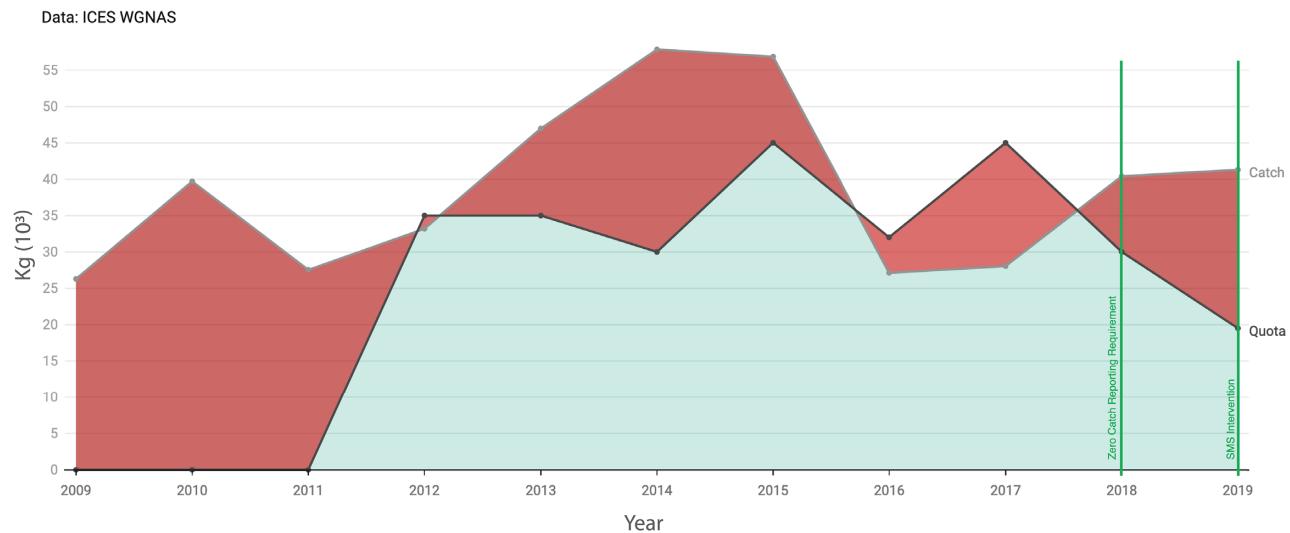


Figure 1. Shaded line graph of Greenland's annual quota and catch (kg) of Atlantic salmon (*Salmo salar*), and timing of Zero Catch Reporting Requirement and SMS Intervention, 2009–2019. Data: ICES WGNAS.

European coastlines, including, but not limited to, stocks in or adjacent to the Gulf of Maine, Bay of Fundy, Nova Scotia, Newfoundland and Labrador, Quebec, as well as the United Kingdom, Ireland, France, Spain, and Denmark (ICES, 2020a). All salmon stocks under the jurisdiction of NASCO are classified as suffering reduced reproductive capacity and have a threatened conservation status (ICES, 2020b). Given the life history of Atlantic salmon, which feed in the waters off Greenland and return to their rivers of origin to spawn, reduced reproductive capacity has been argued to be driven in part by salmon harvesting in Greenland (Atlantic Salmon Federation, 2013, 2018).

Greenland's salmon fishery is understood by NASCO to be a subsistence, domestic fishery, meaning that salmon catch can only be consumed in Greenland with no commercial exports allowed. In this subsistence fishery, salmon fishers are classified as either private or professional. The segment of professional fishers differ as they land and sell their catch in limited venues (e.g. open-air markets, nursing homes, cafeterias), and they are permitted to use up to 20 gillnets (Government of Greenland, 2020). Not all Greenlanders can become professional salmon fishers, as salmon licenses are granted only to previously established professional fishers, which includes persons fishing in fisheries other than salmon. Professional salmon fishing takes place on a small scale and is still an economic activity (Bubier, 1988). We argue that literatures on drivers of compliance and in particular instrumental motivations in commercial fisheries can explain professional fishers' compliance with catch reporting requirements (Sutinen and Kuperan, 1999; Hatcher et al., 2000).

Private salmon fishers exhibit many of the same characteristics as recreational fishers or anglers, given that they develop social capital through the sharing of Greenlandic foods, their interest in consuming harvested catch, and their interest in connecting with nature (Snyder et al., 2020). Private fishers have only been required to have a license since 2018. Before 2018, private persons could freely fish for salmon and could voluntarily report salmon catch. Private salmon license holders differ from the professional license holders as they do not have the right to sell their catch and are limited to the use of one gillnet. Historically, salmon fishers are primarily distributed throughout the southwest and central western coastline of

Greenland and, to a smaller extent, along the east coast (Figure 2). The timing of the salmon season and distribution of salmon does not facilitate fishing in more northern localities. Salmon are known to be distributed primarily below Qeqertarsuaq and lower latitudes.

While the majority (417 of 720) of 2019 salmon fishers were private, the majority of the catch (21.9 of 29.8 t) came from professional fishers (Government of Greenland, 2020; ICES, 2020a). A history of noncompliance with salmon catch-reporting requirements is the basis for testing and evaluating the effectiveness of a deterrence-based and nudge-based intervention. They were designed to enact behavior change in Greenland's salmon fishery, address unreported salmon catch, and improve salmon fisheries management.

Compliance, nudges, and deterrence-based interventions

Economically insignificant fisheries worldwide tend to persist in cycles of non-compliance. They are deceptively difficult to control because comparatively few management resources are allocated to address non-compliance within them (Arnason et al., 2000; Sutinen and Johnston, 2003; Rudd and Branch, 2017). Less comprehensive policy design as well as fewer monitoring, control, and surveillance resources are made available for them because the value proposition and ecological stake is assumed to be lower than for profit-generating commercial fisheries (Hickley and Tompkins, 1998; McPhee et al., 2002; Arlinghaus et al., 2007). Little attention results in an incomplete appreciation of their impacts, which, in turn, fosters a false sense of assurance that they pose little or no threat to fish stocks (Cowx et al., 2010). In such a cycle, non-compliance persists. Given that fisheries management regimes face financial constraints (Government of Greenland, 2020; ICES, 2020a), cost-effective interventions that improve compliance are needed to help break the cycle of non-compliance and to ensure that fishers have continued access to living marine resources.

A nudge is one tool that may be used to increase compliance in such a setting. Nudges are broadly defined by Thaler and Sunstein (2008) as factors that influence human decision-making by changing the choice environment without imposing undue constraints on

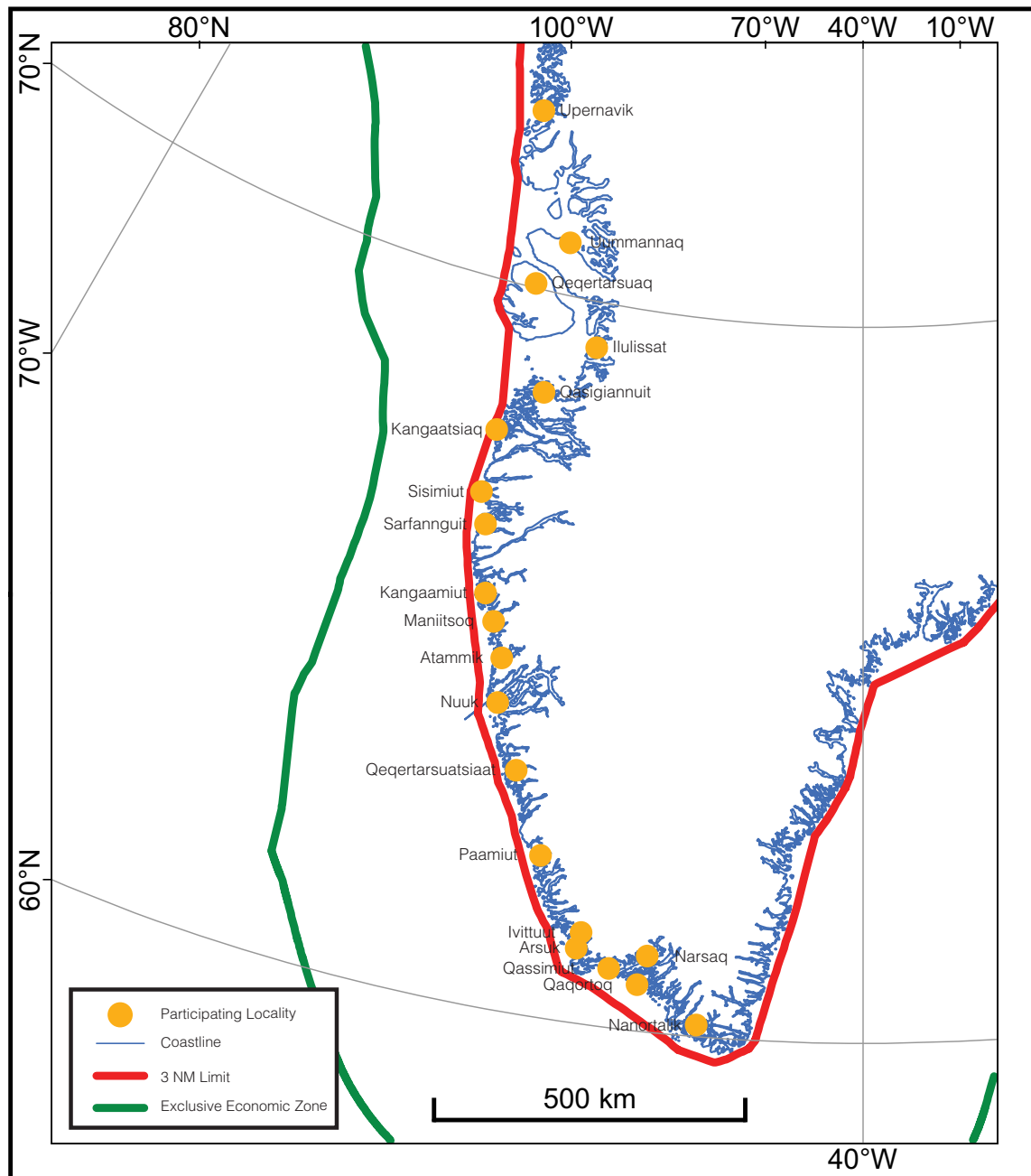


Figure 2. Historic participating localities in Greenland's Atlantic salmon (*Salmo salar*) fishery. Data: ICES WGNAS.

decision-makers. Choice designers, as Thaler and Sunstein refer to them, consider possible outcomes when designing a nudge. Scholarship on nudges in natural resource settings is increasing (Allcott, 2011; Costa and Kahn, 2013; Allcott and Rogers, 2014; Mackay *et al.*, 2019). Among the few empirical studies, researchers found that short message service (SMS) messages are more cost-effective than phone calls (Ou-Yang *et al.*, 2020) for encouraging behavioral changes in contacted subjects, especially if the subject was already known to be motivated to act (Santo *et al.*, 2018). This specific finding bears relevance for Greenland's salmon fishery, where the response pool has already demonstrated motivation to act by applying for and receiving a license to fish for salmon.

In other studies, SMS campaigns did improve knowledge among subjects, but changes in behavior were only mildly positive and, in rare cases, negative. In a study of forest use in Uganda, SMS reminders of the rules improved knowledge, but did not drive sanctioning among villagers, nor did the SMS reminders improve villages' compliance with their forest rules (Eisenbarth *et al.*, 2020).

An SMS intervention for salmon fishing should not be designed to merely provide information. The Government of Greenland has provided information campaigns on salmon fishing regulations through radio and television for over a decade, and the above studies suggest that SMS campaigns designed for knowledge transfer may not be sufficient to change user behavior and that knowing

more does not necessarily change behavior (Ehret *et al.*, 2017). Instead, the nudge should alter the fishers' choice environment by withholding information that is not specifically relevant to them, by embodying normative motifs, and by using positive language. There is an opportunity to help resource users make deliberate choices from a narrowed set of options, which differs from merely transferring knowledge.

The second and more common intervention for managing fisheries is to employ a command-and-control approach. Establishing rules to guide resource-user behavior and setting penalties for non-compliance is often the primary course of action for managing natural resource users (Holling and Meffe, 1996; Cox, 2016). The success of natural resource management often hinges upon the level of compliance with the rules (Kuperan and Sutinen, 1998). Given that compliance can be driven by normative, legitimacy-based, and moral factors (Hatcher *et al.*, 2000; Hatcher and Gordon, 2005; Oyanedel *et al.*, 2020), fishery managers may benefit from the evaluation of command-and-control interventions as well as interventions that account for non-instrumental factors. This focus on non-instrumental factors is especially relevant in Greenland's salmon fishery where economic drivers are less prominent (Government of Greenland, 2020). Fortunately, Greenland's salmon fishery is structured in such a way to evaluate the effectiveness of a nudge and a deterrence-based intervention for improving salmon catch reporting.

Research design and methods

Our research seeks to evaluate the effectiveness of nudge-based as well as deterrence-based interventions for improving salmon catch reporting. We specifically ask if it is possible to detect changes in catch reporting behavior when resource users are nudged to report with SMS reminders, and if a deterrent has an effect on catch reporting behavior.

We evaluated two interventions by the Government of Greenland to improve fishers' reporting of their salmon catch. The first intervention is called the Zero Catch reporting requirement (Zero Catch). If fishers do not report their salmon catch, even if they caught zero fish, fishers risk the penalty of losing automatic renewal of their license for the following year. The second intervention is called the SMS notification program (SMS). Because the SMS intervention can be studied experimentally and the other cannot, we cannot evaluate the interventions within the same model (The Zero Catch intervention could not be studied experimentally and is without a control group because the Government of Greenland would have no legal basis to subject a random sample of salmon fishers to a regulation).

Zero Catch research design

The Zero Catch requirement was designed by the Government of Greenland and written into legislation in 2018. Under Zero Catch, salmon fishing license holders who receive a license must notify Grønlands Fiskerilicenskontrol (GFLK) of their fishing activity for the season, even if they did not catch any salmon (hence the "Zero Catch"). The rationale requiring fishers to notify GFLK, even if they have caught zero salmon, stems from a track record of few salmon fishing license holders reporting salmon catch. Under the Zero Catch requirement, the penalty and the deterrent for not submitting report catch, even if zero were caught, results in no auto-

matic renewal of the fisher's salmon fishing license in the following season. GFLK monitors catch reports throughout the season; if any license holder has not complied, their license is flagged for the upcoming year.

SMS research design

The SMS intervention was developed in 2019 by the authors in consultation with GFLK and the Fisheries Department, reviewed by the Center for the Protection of Human Subjects at Dartmouth College, and then implemented by GFLK. Before the salmon fishing season began in August 2019, we worked with GFLK to draw a random sample of salmon fishing license holders from the total salmon fishing license holder population ($N = 719$). The sample included their license status (private or professional fisher) and their phone number. In Greenland, mobile phone usage is very high, with Greenlanders having more than one cell phone plan per person, for the last five years (TELE Greenland, 2019). The objective of the SMS intervention was to provide relevant information and a clear choice environment where license holders would choose to report their salmon catches.

GFLK then sent SMS text messages to approximately 50% of license holders, leaving the other 50% as the control group. To avoid sampling bias and a skewed sample, license holders were block sampled according to their license status as either private or professional, and their locality (Kish, 1965). One challenge to a balanced sample was that GFLK is legally required to continue issuing salmon fishing licenses even after the season begins. This meant that the license holder population was a running sample and increased throughout the season. The outcome was that the total population could not be treated exactly 50/50, and that some new license holders may not receive the first message. This timing also explains why no person received just one or two messages (Figure 3). Ultimately, 42% of license holders were treated with SMS messages and 58% were not.

We protect fishers' identities while also maintaining a non-traceable proxy identifier. GFLK served as an honest broker, with a member of staff anonymizing individual fishers' fishing records and sending them to the authors. They anonymized records by scrambling either an individual's salmon fishing license number (e.g. fisher "A-19 873" scrambled into "zatbcyq") or their CPR number (e.g. 77-987-1990 to "xuyraxnc") (A CPR number, also known as a civil registration number, is a state-issued, unique identification number for all citizens within the Kingdom of Denmark. It is similar to a social security number or a passport number). This method of scrambling not only allowed the authors to protect fishers' anonymity, but it also allowed them to review salmon fisher behavior in 2017, during which license numbers were not issued to individual, private fishers. Salmon fishers' identity remains further protected because the authors and GFLK are not capable, by design, of providing a "key" to re-identify salmon fishers.

The design of the SMS messages avoids pitfalls that have been identified in previous lab and field-based experimental work on nudges and in SMS message campaigns. We avoided cost-benefit-focused messages in recognition that this tone may not be effective in compelling resource users to comply (Lebel *et al.*, 2018, p. 201). Three short messages were drafted and sent to avoid information overload (Ou-Yang *et al.*, 2020). The second short message was sent to recipients twice due to a technical error, which is why Figure 3 depicts a count of four messages, of which three were unique. Mon-

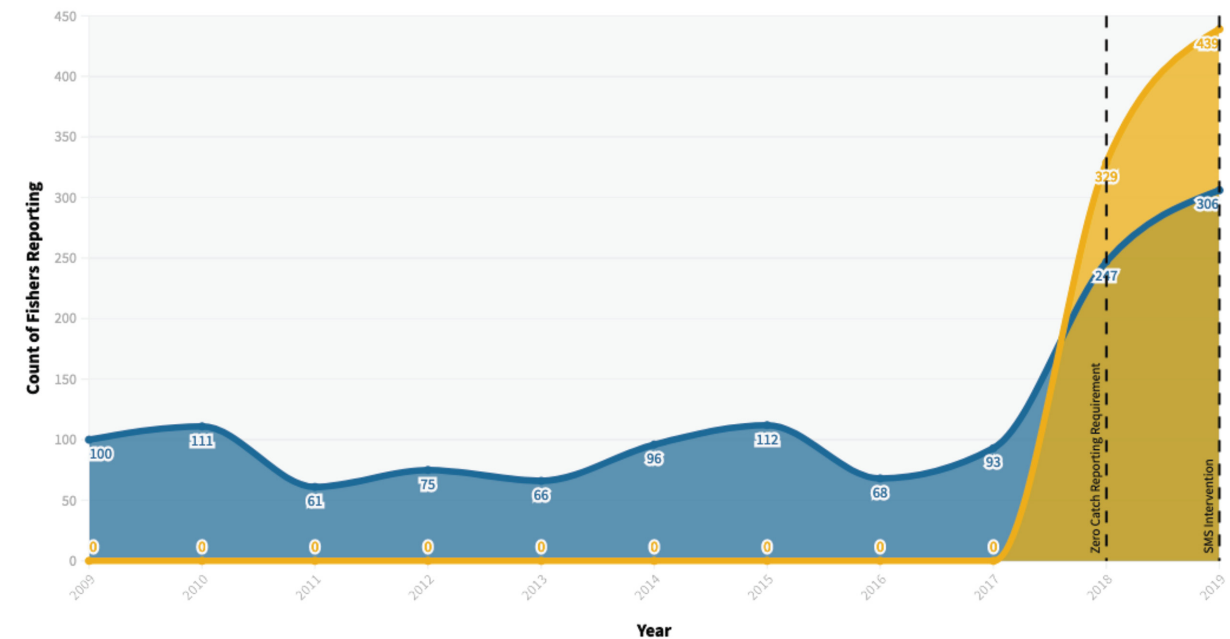
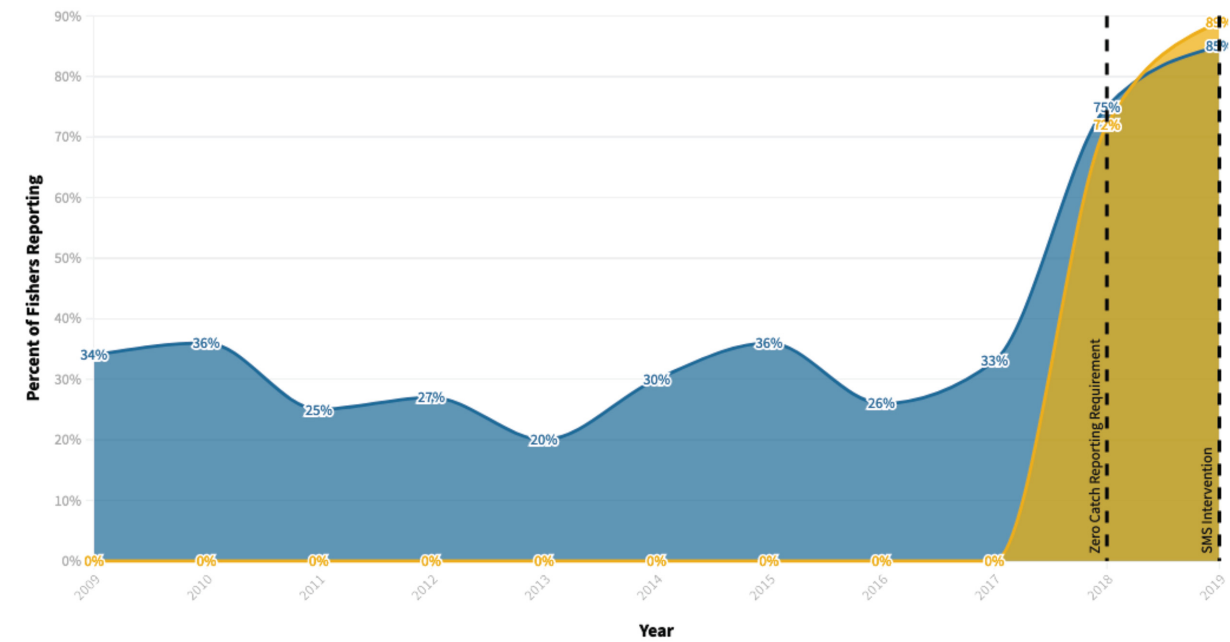


Figure 3. Catch reporting among salmon fishing license holders, by license type, 2009–2019. Data: Greenland Fisheries License Control Authority (GFLK). Note: no private licenses were issued before 2018.

Table 1. SMS Messages used in SMS nudge intervention.

Message	Message description	Message text (English translation of Greenlandic/Danish message)
1	The first message thanked fishers for applying for and receiving a license and wished them luck with their salmon fishing.	"We wish you success with your salmon fishing this season. Last year 73% of all fishers reported their catch, which allows Greenland to fish for salmon into the future."
2	The second message provided a real-time update on uptake of the salmon fishing quota and congratulated them on their harvesting efforts to date. The second message also included information on how to report salmon catch.	"Good work. Salmon fishers have caught XX of XX tons. The season will close on ~INSERT DATE~. It is easy to report your catch. Fill out a formula at the municipality office and they will email it for you or download the formula at www.sullissivik.gl and email it to gflk@nanoq.gl ."
3	The third message provided a final real-time quota uptake, notified them that the season would close the following day, and reminded fishers about how to report their catch.	"The season closes tomorrow. Thank for your not fishing for salmon after ~INSERT DATE~, which allows salmon stocks to grow. Report your catch now to secure a license for next year."

Table 2. Overview of tested interventions, model variables, and descriptions.

Intervention	Variable name	Description	Model
Zero Catch Reporting Requirement	<i>reportstatus</i>	Dependent variable, binary	Zero Catch model
Zero Catch Reporting Requirement	<i>zerocatch</i>	Independent variable, binary	Zero Catch model
SMS Nudge	<i>reportscount</i>	Dependent variable, continuous (count)	SMS Model 1, SMS Model 2
SMS Nudge	<i>treatmentsum</i>	Independent variable, continuous (count)	SMS Model 1
SMS Nudge	<i>treatmentstatus</i>	Independent variable, binary	SMS Model 2

etary incentives were also avoided; instead, the messages that were sent were altruistic and encouraging, and they leveraged normative motifs and positive language (Czap *et al.*, 2015).

All messages were sent by an unlisted number, but identified as coming from GFLK. Trust in the governing body is known to drive the success of fisheries interventions (Battista *et al.*, 2018), and GFLK was known to be trustworthy and legitimate among salmon fishing license holders (Snyder *et al.*, in preparation). The authors and GFLK took extra care with the tone of messages (Table 1). Instead of threatening fishers with losing their license if they did not report or writing that fishers must report their catch to receive a license for the following year, recipients were instead reminded of where they could report catch and that in so doing, they would receive a license for the following year. Messages were sent using a vetted SMS messaging service, with content written and sent in Greenlandic and in Danish, and in that order. The messages that private and professional fishers received were the same.

Data analysis

For both Zero Catch and SMS interventions, the unit of analysis is the individual salmon fishing license holder. The analytical approach for the Zero Catch intervention differs from the SMS intervention because of how and when it was implemented. Unlike the SMS intervention, all fishers from 2018 onwards were required to comply with the Zero Catch requirement. While evaluating behavior within a year is not possible, it was possible to evaluate differences between fishers' reporting behavior between the 2017 and 2018 seasons. To evaluate the effects of the Zero Catch intervention, we fit a multilevel linear regression with fishers as random effects using the STATA *xtreg* command. The independent variable is *zerocatch* and the dependent variable is *reportstatus* (Table 2).

To evaluate the effect of the SMS intervention on salmon catch reporting at the end of the 2019 salmon fishing season, we constrained observations to those that took place in 2019, given that the SMS messages were sent only during the 2019 season. The dependent variable was the number of salmon catch reports a fisher submitted within the season (*reportscount*), and the independent variable was available in either binary or count format (Table 2). The number of SMS messages fishers received throughout the season (*treatmentsum*) was used in SMS Model 1. Whether or not fishers received an SMS message was also formatted into a binary variable (*treatmentstatus*) for SMS Model 2.

We hypothesized that behavioral changes could be detected and the number of catch reports a fisher submits (SMS Model 1) is a function of how many SMS messages they received. For SMS Model 2, the same hypothesis applies, but it is instead fit to the binary variable. We first created descriptive statistics to observe whether fishers treated with SMS messages were associated with larger mean salmon catch reports. Noticing a difference in means, we estimated a Poisson regression. To test whether the model violates the *deviance = means* criterion, we evaluated the deviance goodness-of-fit, finding the values excessively high and the model unsatisfactory. Because the dependent variable is a count variable and fishers are required to report after each trip, we fit a negative binomial regression to *treatmentsum* (SMS Model 1) and *treatmentstatus* (SMS Model 2) as the independent variable and *reportscount* as the dependent variable.

Results

Zero Catch results

Following the Zero Catch intervention from 2017 to 2018, we observed an increase in reporting percentages among professional salmon fishing license holders. In 2017, only 33% of professional

Table 3. Negative binomial models for SMS Program (private and professional, 2019 only).

Variable name	SMS Model 1	SMS Model 2
<i>treatmentsum</i>	0.04 (−0.00 to 0.08) $p = 0.064$	
<i>treatmentstatus</i>		0.013 (−0.04 to 0.3) $p = 0.135$

salmon fishing license holders reported their salmon catch, whereas approximately 75% of them reported in 2018 (Figure 2). The results of the multilevel linear probability model support this, with the coefficient for the *zerocatch* variable being 0.41 ($p = 0.00$, 95% CI = 0.3 173 789 to 0.5 022 584). This marginal effect indicates that the probability of a professional fisher reporting increased by 41% from 2017 to 2018.

SMS results

Following the SMS intervention, output from the negative binomial model suggests that the number of SMS messages a salmon fisher received in 2019 had a significant, but small, effect on the number of catch reports (Table 3 and Figure 3). For each SMS message received, the probability of a fisher reporting salmon catch increased by 6%.

Discussion and conclusion

While it is uncertain what drives salmon declines in the North Atlantic, improved salmon catch reporting will augment estimates of fishing-based mortality on stocks, which creates more accurate scientific advice for management authorities that govern salmon fishery access throughout the North Atlantic region. There was significant improvement in salmon catch reporting overall between 2017 and 2019—up from about 33 to 84% in 2019. Our results are significant and suggest that increases in salmon catch reporting are associated with the Zero Catch and SMS interventions. We caution that it is not possible to confidently infer causation, given that we were unable to account for every factor that could potentially confound these relationships (King *et al.*, 1994; Ferraro *et al.*, 2019). We know that economically motivated fishers comply when the fear of a fine or a penalty exists (Becker and Landes, 1974; Kuperan and Sutinen, 1998; Sutinen and Kuperan, 1999), so it makes sense to see a detectable, significant response among professional fishers to the Zero Catch intervention.

Given that causation cannot be inferred with these model results alone, we conferred with the Government of Greenland as well as the Association of Hunters and Fishers in Greenland (KNAPK) about factors that could confound the relationship between the interventions and fishers' salmon catch reporting. We posited that regulatory changes, such as implementation of a new or additional management instrument, environmental events such as a late return of salmon to Greenland's waters, or economic changes, such as increased domestic demand for salmon, from 2017 to 2019, could have had a role. However, none of these were said to have been a factor, and it is unlikely that there were other factors that would plausibly impact our dependent variable.

There are no plans to discontinue the Zero Catch reporting requirement, and there is no known opposition to this intervention among salmon fishing license holders. The most recent revision to the 2020 Executive Order on the Fishing of Salmon includes this regulatory provision. While the Zero Catch reporting requirement

can result in a noncompliant fisher losing an automatic renewal of their license, fishers are still able to reapply for a license in the coming year. Their reapplication presents an opportunity for fisheries control officers to familiarize the applicant with how they can more easily comply with salmon fishery regulations in the forthcoming season.

The outcome of the Zero Catch intervention is also consistent with what we have known to be true conceptually and empirically about compliance behavior when a deterrent is present in general (Becker and Landes, 1974; Tyler, 1990) and in a fishery (Kuperan and Sutinen, 1998; Hatcher *et al.*, 2000; Eggert and Lokina, 2010). Deterrents, such as the risk of losing one's license, have been shown to encourage compliance, which explains why managers of natural resources continue to govern by command and control (Cox, 2016). Because the interventions differ in their research design, it was not possible to test the effects of the interventions within the same model; therefore, we cannot suggest that nudges in the absence of command-and-control mandatory reporting would have had a greater effect. Nonetheless, it was possible to detect the effects of each intervention on salmon catch reporting.

Results of the SMS intervention provide a small but novel case for nudges in achieving compliance in fisheries. First, normative factors historically were not able to be confirmed as factors in fisheries compliance (Hatcher and Gordon, 2005), but recent studies show that normative, legitimacy-based, and moral factors do play a role (Oyanedel *et al.*, 2020). The SMS intervention further illustrates this association, and in particular how framing and language that focus on normative and moral factors could be used to improve compliance (Mackay *et al.*, 2018, 2019). Second, the SMS intervention results exemplify a potential solution to a common scenario. In a fishery where command-and-control interventions and conventional information campaigns have already been reasonably exhausted, we show that a nudge may be used to achieve a marginal improvement to already high levels of compliance (See Figure 4).

The rapport among fishers, conservationists, and fishery managers makes Greenland's salmon fishery an ideal site for further work. With this level of rapport, it was possible to co-identify the research problem, objectives, and design, and to collaboratively carry out the study and analysis. The study ultimately culminated in improved reporting of salmon catch, which is key to Atlantic salmon conservation. Collaboration on this scale may also make it possible in the future to enroll a larger, more balanced randomization pool of salmon fishers, or to conduct the study over several years, which could make it possible to detect the significance of the SMS intervention at a lower alpha threshold. Surveying salmon fishing license holders about their attitudes toward regulations, regulatory authorities, and how they report may also help identify what motivates fishers to not report salmon catch.

Despite the SMS intervention having a significant but small effect, we argue that it may still be acceptable practice for the Government of Greenland to contact salmon fishers via SMS message. During consultations along the Greenland coastline in 2019, several fishers shared with the Association of Hunters and Fishers in Greenland that they were "proud and happy" to be contacted about

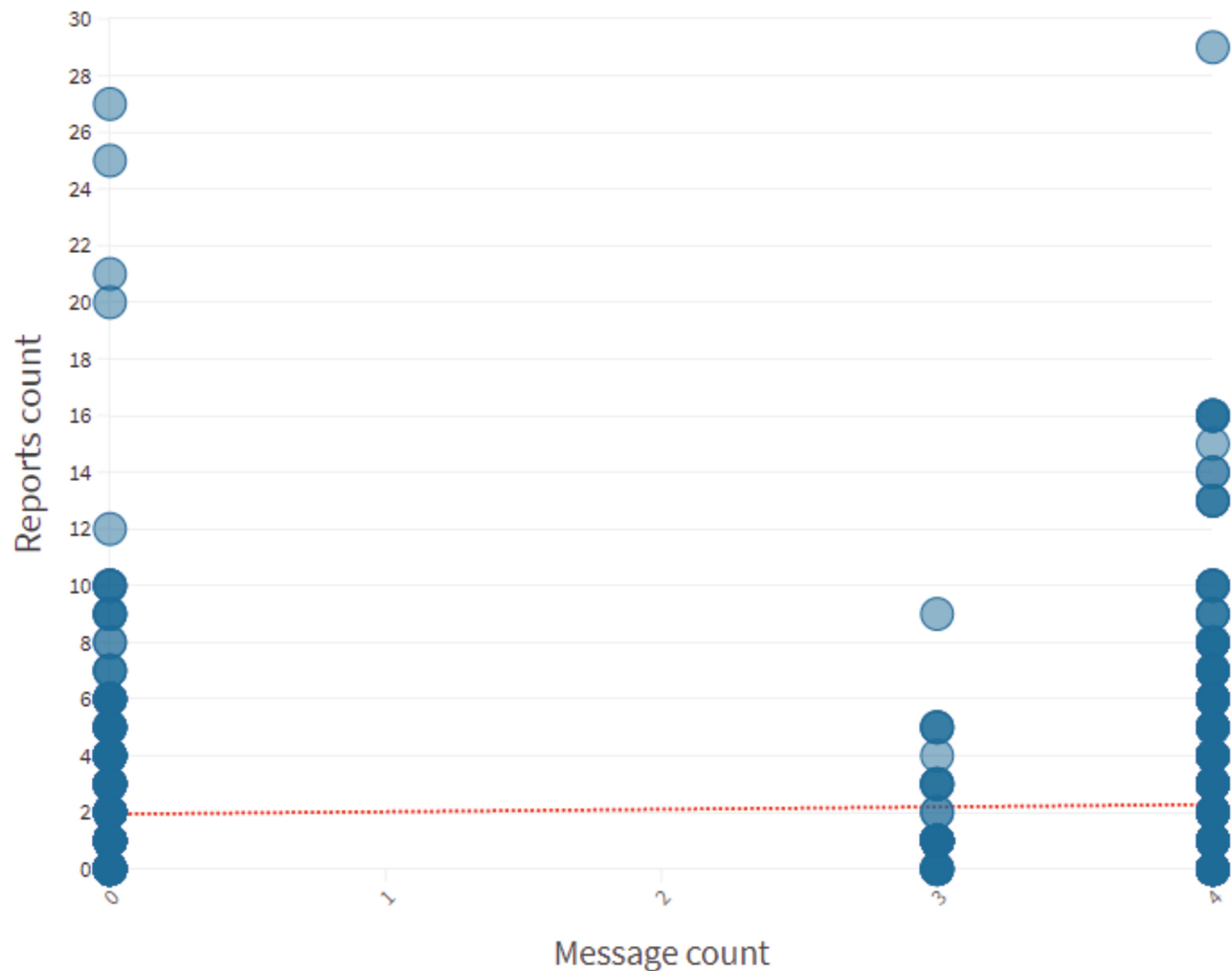


Figure 4. Scatterplot of message count and reports count, with trend line.

their salmon fishing. In a nationwide survey of salmon fishers, there were also no reports of the notifications perceived as an annoyance (work in progress by Snyder), further reassuring the ethical use of such information-sharing techniques.

Our study provides the empirical evaluation of deterrence-based and nudge-based interventions. It underscores the methodological challenges and the needs for further research on the effects that SMS nudges have on behavioral change in fisheries. Interventions such as SMS nudges can help build rapport between resource users and managers, which maintains and fortifies institutional legitimacy in fisheries (Grafton, 2005; Gutiérrez *et al.*, 2011; Snyder *et al.*, 2020). We anticipate that our evaluation may encourage fisheries managers to maintain carefully designed deterrence-based management approaches while also considering that nudges can help them more effectively and inclusively govern access to living marine resources.

Data availability statement

The data underlying this article will be shared on a reasonable request to the corresponding author.

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