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Behavioral responses to competing incentives and disincentives: Compliance with marine mammal protection

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ABSTRACT

In 2010, the Northeast U.S. sink gillnet fleet faced threats of indefinite closures to fishing if compliance rates with acoustic deterrent devices did not increase. Simultaneously, a catch share program with multiple "sectors" was implemented for groundfish, an important target for this fleet. This research examines whether the threat of closures, the transition to sectors, or both, influenced the increased compliance rate after 2010. We learned in focus groups [9], that some fishers left off one pinger for safety reasons. A multinomial logit model using deterrent (perceived likelihood of the detection of non-compliance), economic, and normative (social, cultural, legitimacy) factors was developed to understand three responses: full compliance, non-compliance (multiple pingers missing), and non-compliance presumed to be related to safety (single pinger missing). At-sea observers collect compliance data. Results suggest observed vessels in the single-pinger-missing violation group were not responsive to the threat of consequence closures, while the multiple-pingers-missing group were. This reveals the importance of fisher input in constructing models. The model did not find sector membership to be significant. We suspect there may be an influence that varies across sectors. Non-compliant vessels with lower inconsistent observer coverage were more likely to be non-complaint, suggesting compliance overall may be increased through "nudging," a behavioral economics concept, via increased observer coverage. Increased observer coverage may be more cost-effective than increased enforcement. It is important to understand that regulatory change can introduce multiple incentives and disincentives influencing behavioral responses, as implemented in the 2010 Northeast U.S. groundfish gillnet fleet.

1. Introduction

Marine mammal bycatch in commercial fisheries is one of the leading causes of cetacean mortality [40]. In 2010, the Northeast U.S. gillnet fleet (NEGF) faced threats of indefinite "consequence" closures to fishing, under the Marine Mammal Protection Act (MMPA), if compliance rates with acoustic deterrent devices (pingers) designed to reduce incidental take of harbor porpoise (*Phocoena phocoena*) did not increase (75 Federal Register 7383, 19 February 2010). The Harbor Porpoise Take Reduction Plan (HPTRP) under the MMPA has required the use of pingers in specific fishing areas since 1999 [53,54]. Pinger compliance rates did increase after 2010 [33]. However, simultaneously in 2010, a type of catch share (quasi property rights) program based on multiple "sectors" (similar to harvest cooperatives) was implemented under the Magnuson-Stevens Fishery Conservation and Management Act (MSA) [26] to end overfishing, rebuild overfished regulated groundfish stocks, and mitigate the adverse economic impacts of the previous regulatory tool – effort controls (75 Federal Register 18356, April 9, 2010). This research discusses incentives and disincentives introduced by these two regulatory actions. Understanding factors that may have influenced the increased compliance rate after 2010, i.e., our model results, can identify factors to consider when designing future policies to reduce marine mammal/fishery interactions.

Avoiding or reducing marine mammal bycatch in commercial fisheries can be encouraged through the use of incentives and/or deterrents (disincentives) [24,41,44]. However, objectives (such as lowering marine mammal bycatch) cannot be achieved through any method without both effective regulatory design and fisher compliance with the regulations. Making the distinction between failures to reach goals (here, to reduce marine mammal takes) due to violations versus due to ineffective

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policy instruments is important. If anticipated reduction goals are not met and compliance is high, for example, it may indicate that the policy instrument is ineffective. Choosing a policy instrument is a strategic choice. Regulatory instruments *direct* individuals how to behave. Economic instruments, which are usually market based, can be designed with incentives to *influence* an individual's behavior. Economics links changes in behavior to changes in outcomes. Assigning property rights, for instance, is considered a positive incentive, while negative incentives include taxes, fines or sanctions [44]. Recent work in behavioral economics suggests the use of "nudges" (re. [1,25,49,56]). This relies on finding ways to "push" the regulated (here, fishers) toward individual decisions that nonetheless achieve the outcome desired by the regulators, thus linking changes in behavior to changes in outcomes.

Most policy instruments that NOAA has implemented for marine protected species under its authorities have been a "command-and-control" approach directed toward fishers [8,13]. In general, time and/or area closures reduce or shift fishing effort out of a high bycatch area by prohibiting fishing completely; gear standards meanwhile reduce the bycatch rate and allow vessels to continue fishing. Pingers are a gear requirement where pingers must be attached to gillnet gear to legally fish in designated times and areas to reduce harbor porpoise bycatch. If vessels do have the correct number of pingers attached, they are in violation of the MMPA.

This study is part three of a series of research papers on pinger compliance in the NEGF [7,9]. In this paper we investigate two violation types, on the one hand vessels that chose to be in the single pinger missing group (i.e., only 1 pinger missing, that some fishers told us they left off for safety reasons [9]) and vessels that chose to be in the multiple pingers missing group versus those that had no pinger violations. We examine pinger compliance levels across these three different sub-groups of the NEFG. Our multinomial logit model is used to investigate economic, deterrent (e.g., perceived likelihood of the detection of non-compliance) and normative (e.g. social, cultural, legitimacy) factors that may have an influence on the pinger violation choice a gillnet vessel makes. We examine whether the threat of consequence closures, the onset of sector management, or both, influenced the increased pinger compliance rate after 2010.

2. Background

2.1. Regulatory background

Since 1999, NEGF fishers have been mandated to attach a set of pingers (acoustic deterrent devices) to each of their nets while fishing in designated Pinger Management Areas (PMAs) (Fig. 1). A pinger must be attached to each end of a net in a fishing string. For example, a gillnet string consisting of 10 nets requires 11 pingers to be compliant [33]. In 2007, despite pinger regulations, the incidental take of harbor porpoise in the NEGF exceeded the Potential Biological Removal (PBR) rate, the allowable level of human-induced mortality for a marine mammal stock ([27] section 1386, [51]).[3] Based on gear configuration data collected by at-sea biological technicians (observers) who operate on board fishing vessels under the Northeast Fisheries Science Center's Northeast Fisheries Observer Program (NEFOP), hereafter NEFOP observers, compliance with pinger regulations for harbor porpoise from 1999 to 2007 ranged from 10% to 77% by fishing area ([38]:2); non-compliance was a driver of porpoise bycatch exceeding the PBR rate. In response to the pinger non-compliance problem, regulatory changes under the revised HPTRP included disincentives in the form of "consequence" closures (see [8] for additional background about the sink gillnet fleet). Starting in 2010, "consequence closures" would be implemented if the calculated harbor porpoise bycatch rate observed in designated PMAs exceeded a benchmark harbor porpoise bycatch rate for two consecutive years (75 Federal Register 7383, 19 February 2010). If consequence areas were triggered (i.e. compliance did not reach the target level), large fishing areas would be closed indefinitely (or until the Zero Mortality Rate Goal (ZMRG) was reached); ZMRG is defined by NMFS as less than 10% of PBR (69 Federal Register 43338, July 20, 2004) (Fig. 1, HPTRP Consequence Closure Areas).

Simultaneously, the catch share regulations under Amendment 16 to the Northeast Multispecies (groundfish)[4] Fishery Management Plan (75 Federal Register 18356, April 9, 2010), introduced a voluntary "sector" system. Under this program, fishers could self-organize into "sectors" (similar to harvest cooperatives). Approximately 55% of the sink gillnet fleet joined one of the initial 17 groundfish sectors created under Amendment 16 (see [11] for more background on sectors). Those who did not join a sector became part of the "common pool" which is governed by the previous days-at-sea limitations. Both sector and common pool are governed by an overall Annual Catch Limit (similar to Total Allowable Catch). Formal institutions such as sectors can create peer pressure and may influence an individual's attitude towards compliance [2,35]. Abbott et al. ([2]:191), specifically note a mechanism by which this happens when they state that "changes in management institutions altered the incentives of fishers."

Compliance with pinger regulations increased after 2010. By 2012, 79% of the observed gillnet strings in PMAs were in compliance with pinger regulations [33].[5] We thus have low compliance during the pre-rules era of 2007–2010 and high compliance during the post-rules eara of 2010-2013 (the rules being the HPTRP's threat of consequence closures and the creation of sectors under Amendment 16, both implemented in 2010). Here we examine factors that may have an influence on the violation choice a gillnet vessel makes with regard to pinger regulations, and whether sector regulations are a factor as well, to begin disentangling the impacts of multiple incentives and disincentives on the NEGF fleet beginning in 2010.

2.2. Theoretical background

Regulators often rely on strict enforcement[6] and penalties to achieve high levels of compliance. Economic theory suggests an individual will violate a regulation if the expected illegal gain exceeds the penalty, which is a function of the size of the fine for non-compliant behavior and the detection rate of a violation [5]. Sutinen and Anderson's [45] seminal conceptual work on law enforcement was followed with empirical papers confirming Becker's original hypothesis [4,14,16,22,23,42,46,47], and demonstrating that the economic gain often outweighs the penalty. Potential economic benefits of compliance may be perceived as being lower than those for non-compliance. However, evidence in some fisheries indicates the majority of fishers comply even when the

[3] Under the amended MMPA in 1994, when the 5-year average annual bycatch estimate is greater than PBR the National Marine Fisheries Service (NMFS) must convene a Take Reduction Team (TRT), which then has 6 months to develop a plan that will reduce bycatch below PBR within 6 months of its implementation.

[4] Sink gillnet gear targets commercially sought groundfish species. The Northeast Multispecies Fisheries Management Plan was implemented to reduce fishing mortality of heavily fished groundfish stocks. Thirteen species are managed under this plan. NEGF gear target Atlantic cod (*Gadus morhua*), pollock (*Pollachius virens*), and various flounders (*Pleuronectiform*), which are among the thirteen species. See for details: https://www.nefmc.org/management-plans/northeast-multispecies.

[5] Compliance assessments by Orphanides [33] and Palka et al. [38] are based on NEFOP observer data, the same data source for the compliance research presented here. More details are provided in the Section 3.2, Data.

[6] Recognizing the broad nature of enforcement, [21]:75) note: "Enforcement – monitoring adherence to rules and agreements and punishing infractions when they are detected – is an essential part of successful conservation and natural resource management. Punishments may take various forms, from fines and prison terms to social sanctioning, depending on the enforcement system."

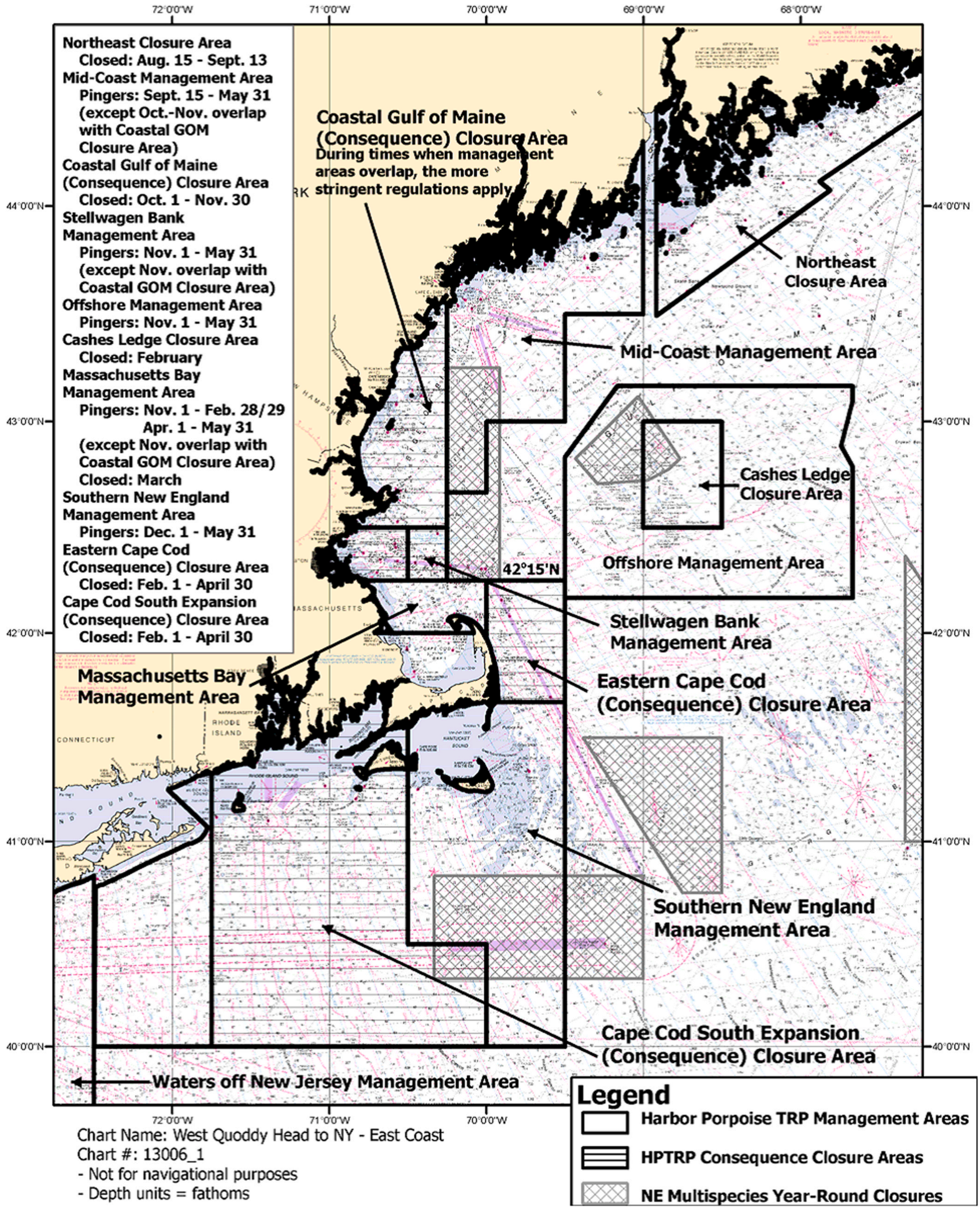

Fig. 1. New England Harbor Porpoise Management Areas for gillnets (upper left legend lists closures to fishing and dates for pinger requirements; bottom right legend presents the spatial demarcation), including Consequence Closures (management measures that would be required if the target bycatch rate was exceeded) (US Department of Commerce 2009). Sectors are not spatially defined. As such, sector membership alone does not prevent fishing in any of these areas.

expected illegal gain exceeds the penalty (see e.g. [23,48]), meaning Becker's hypothesis is not universally true; normative factors may explain such behavior, motivating fishers to comply with regulations. On a very broad level, the existence of the MMPA and ESA imply that society values these animals (i.e., protected species) and may be an influencing factor on pinger compliance decisions. And evidence from focus groups of NEGF members also indicates this may be so for pinger regulations [9].

Normative factors are an individual's a) ethical (cultural) norms, b) social influences and c) attitudes regarding the legitimacy of i) the problem, ii) the solution and iii) the agency implementing the rules (here, NOAA Fisheries – the National Marine Fisheries Service) (for more details see [9]). Ethical/cultural norms can lead a person with principles of right and wrong behavior (which are based in cultural norms) to feel obligated to obey the law, and thus gain a greater sense of satisfaction by behaving in an honorable way. Social interactions can also influence an individual's attitude toward compliance. Social factors here are about formal laws and rules,[7] and institutions, including governments, fishing associations, and sectors. Legitimacy, a fishers' perception of the problem and solution, is considered to be a cultural norm related to a social factor. For example, a harbor porpoise TRT (HPTRT) member may have an affiliation with a vessel's port. The effectiveness of a regulation often depends on its perceived legitimacy ([19,20,23,29,48], see [43] on subjective (perceptual) vs. objective influences on behavior). As such, legitimacy is a key factor in compliance [20,23,29,36,50]. Multiple types of factors need to be examined to understand compliance.

This use of normative factors is in line with work in behavioral economics (re. [57][8]), which suggests that people often do not behave rationally in calculating benefits and losses associated with specific behaviors. Rather they tend to use cognitive "shortcuts" (ICES 2014) based, for example, on the behavior of those around them or their internalization of rules of appropriate or moral behavior (e.g., [58,59]). From a normative perspective, people are often susceptible to a variety of different types of "nudges" that subtly invoke the idea that most people are following certain rules or that remind them of content of these rules of behavior (see [1,25] for fisheries examples).

2.3. Project background

This study is part three of a larger compliance research project. Bisack and Das [7] followed Sutinen's seminal work, along with others, in considering normative factors to explain compliance behavior. The Bisack and Das [7] model was inspired by the Hatcher et al. [17] binomial probit empirical compliance model that sought to move beyond financial deterrents by examining the role of non-monetary values such as "social influence, moral values, and perceived legitimacy" (p. 448). However, while Hatcher et al. [17] used coded face-to-face interview survey data to investigate factors that influence compliance decisions, Bisack and Das [7] relied on historical data recorded by NEFOP observers, i.e. recorded history vs. an individual's perception of their history. Proxy variables replaced survey data for normative variables. The Bisack and Das [7] behavioral model incorporated deterrent (e.g., perception of likelihood of detection), economic and normative (e.g., cultural, legitimacy, and social influences) factors within a probit framework to investigate fishers' compliance decisions, with a focus on the 2010 fishing year. Model results indicated that fishers who previously violated pinger regulations, who were not completely dependent on gillnet gear, and who faced a lower chance of being detected by an observer, were more likely to violate pinger regulations [7].

In 2012 and 2013, research funding was received to ground-truth these initial Bisack and Das [7] compliance model results by conducting focus group research with a self-chosen subset of a representative sample of 123 NEGF vessel captains who had fished in areas requiring pingers within the 12 months prior to the focus groups and who resided from Maine to Connecticut [9]. The timing (May 2012-April 2013) includes a lag between the implementation year (May 2010-April 2011) and the focus groups, to allow time for fishers to be settled into their post-rules behavior for both pinger compliance and sectors; focus group findings thus encompass these two regulatory shifts. In the initial meetings Bisack and Clay [9] received feedback on the revised HPTRP and the new groundfish sector management. Our findings spoke to the themes of deterrence, legitimacy, governance, and reports of and responses to compliance/non-compliance. Apart from the standard rule-following and rule-breaking groups, a third group became apparent. These fishers modified mandatory pinger requirements for operational safety reasons. Participants stated that they purposely left off one of the required pingers at the end of each gillnet string because the standard pinger on the end of the string, with no net behind it to weigh it down, often emerged from the water swinging wildly and sometimes hit the nearest fisher on the head. Removing the last pinger seemed sensible and obvious, yet having that pinger was mandatory. A realization that this unwritten safety rule practice seemed common across the fishery led in part to phase three, this paper, a restructured compliance model breaking out the non-compliant group into those missing only one pinger versus those missing multiple pingers. Combining focus group findings [9] and initial compliance model results [7] allowed us to create hypotheses that we tested in this paper with observer data. We also tested the influence of sectors on compliance, as some fishers reported sector support for pinger compliance.

The overall project used a behavioral model to examine deterrents and economic and normative factors to examine compliance decisions in relation to policy instrument choices. All are critical factors to consider in policy instrument design in order to support greater success in achieving marine mammal management objectives. Our conceptual model is similar to Bisack and Das [7]; however, based on Bisack and Clay [9] we are interested primarily in examining pinger compliance behavior among three versus two distinct groups of individuals: (1) those with no violations, (2) those with only "safety" violations (i.e., one missing pinger), and (3) those with violations due to multiple missing pingers. A multinomial logit model framework is used to investigate how deterrent, economic and normative factors influence a vessel's compliance choice for different pinger violations, pre- and post-rule. Secondarily, we examine NEGF fishers who belonged to sectors versus those that did not. We thus ask, did the threat of consequence closures, the implementation of sector management, or some combination of both influence the increased compliance rate after 2010?

3. Methods

3.1. Conceptual framework

Under the current NOAA Fisheries institutional structure, a systematic way to monitor compliance by all vessels does not exist. However, data on gear configurations (including number of pingers on gillnets) are collected by NEFOP observers for a subset of the fleet. Between 2007 and 2012, on average, 10.5% of the total NEGF fishing trips were recorded by NEFOP observers [15,52]. NEFOP observers collect information, including data on gear violations, for use in scientific research (per MSA sec. 403(b)) [33,34,37]. Recorded violations by NEFOP observers are used by researchers to assess pinger compliance; however, NEFOP

[7] The key rule here, leaving one pinger off a 10-net string of gillnets, is closer to what Schlager and Ostrom [35] might call an operational activity than an operational rule, since it is not decided upon by a formal collective act.

[8] Tyler, [57] would call the traditional economic view "instrumental" and the behavioral economic view "normative."

observers do not report violations to enforcement.[9]

Further, self-policing (suggested in an early HPTRP) does not appear promising, as a plurality of focus group participants, when asked what they would do if they saw another fisher violating a regulation, chose "I would do nothing" (57%), followed by "confront the individual" (36%), and "contact the authorities" (7%) ([9]: Table 2, Q12). Additionally, at the time of this case study, gillnet vessels prosecuted for pinger violations faced a maximum MMPA fine of $8000, according to the NOAA Office of Law Enforcement (OLE) penalty matrix [30], though potentially only an "unintentional first offense" fine of $200 (*ibid.*). Given that the maximum MMPA fine is equivalent to the initial cost of pingers [31], there may be an incentive for fishers to wait and see if they will be levied the $200 fine first rather than spending $8000 on pingers, to the extent they are even aware of the fines.[10] Finally, the likelihood of receiving a penalty was low, based on fisher reports in the focus groups. In addition, the OLE recorded only two cases that were prosecuted for pinger violations from 2010 to 2018.[11] So economic deterrence due to penalties is low. This means economic incentives for pinger non-compliance are high, due to potentially low detection rates (more on this below), low value fines, and the fact that violations resulting in fines appear to be rare events.

At the same time, a common belief shared by some fishers was that attaching pingers to their gillnets lowers their catch and thus revenues. This is supported by the 2007–2010 NEFOP observer data which show significant differences in cod and pollock catch rates between gillnet strings with 100% and zero pingers present. Revenues were lower when fishing with the correct number of pingers [7]. Participants in the focus groups, meanwhile, reported that seals found pingers to be a dinner bell for warm bellies of cod caught in the gear [9], and the literally-gutted and worthless cod carcasses counted against a sector's cod quota. Thus there are high incentives not to comply. Yet some fishers still comply.

Under this environment a fisher's compliance behavior may be explained by normative factors such as the legitimacy of the problem and the solution, legitimacy of the process, and ethical (cultural) norms. These were investigated via proxy variables in the initial compliance model [7] and further investigated and discussed in Bisack and Clay [9]. Legitimacy of the problem/solution: A majority of focus group participants agreed that the sound made by pingers repels harbor porpoise and that pinger regulations are an effective solution for reducing harbor porpoise bycatch in sink gillnets (62%). Very few, however, believed the accidental take of harbor porpoise in the sink gillnet fishery is a real problem (4%). Legitimacy of the process: While, under the MMPA, stakeholders (e.g. fishers, non-governmental organizations, federal and state representatives) convene in a Take Reduction Team to develop proposals to reduce the take of marine mammals in commercial fisheries, ultimately it is NOAA that must approve the final proposal. And many fishers believe their views are not taken into account [9]. Cultural norms: The majority of participants felt that pinger regulations are not fair (65%). Nonetheless, most participants believed even if regulations are not fair, they should be followed (65%) (ibid.). All of these types of factors have been shown to influence compliance decisions [3,19,23,29,48].

This focus group research to ground-truth the Bisack and Das [7] model, which compared two groups – those with any violations and those with no violations, led us to restructure the empirical compliance model presented here. We examine a combination of vessel characteristics, deterrence factors and normative variables to determine their influence on compliance decisions. We include a variable that indicates whether other vessels in the port had a pinger violation (Table 1) as a proxy for whether peer pressure is an influence and another for belonging to a sector to see if sector involvement affects violation behavior.[12] In addition, we shift from a binary choice probit model (violation or not) to a multinomial logit model to evaluate the relative influence of different factors on a vessel belonging to each of two groups of violators; those that had a single missing pinger (with the assumption that this is for human safety) and those with multiple missing pingers [9].

Our data are for a six-year period (2007 – 2013), covering the period before and after the May 2010 regulatory changes. Our independent variables include a set of normative variables, vessel characteristics, and deterrence factors. Additional details about the variables and rationale for proxy selection used in this model can be found in Bisack and Das [7]. A set of exogenous explanatory variables captures a vessel operator's (i.e., captain's) behavior two years prior to the pre-rules year and two years prior to the post-rules year. Behavior in the 2-year period of May 2007 – April 2009, for example, may influence a vessel's compliance choice in the pre-rules year (May 2009-April 2010) ([7]). Similarly, a vessel's compliance choice in the post-rules year (May 2012-April 2013) may be influenced by factors from the previous 2-year period (May 2010 – April 2012). A 2-year period prior to the post-rules year, allows for lag in the time for regulations to take full effect.

3.2. Data description

Multiple data sources are accessed to build the dataset for the compliance model. In the Northeast U.S., the National Marine Fisheries Service (NMFS) collects vessel trip reports (VTR); these records were used to identify the quantity and location of fishing trips taken by the NEGF. NMFS also collects first-sale data for federally managed fish from entities that buy fish directly from federally-permitted fishing vessels; these data are referred as "dealer" data. A vessel's gross revenue and the number of different gear types used within a fishing year are recorded in

Table 1
Description of independent variables.

Variable	Description
CYRS	Number of captain years fishing
HPLEN	Ratio of engine horsepower to vessel length
GREV	Gross revenues of vessel in the previous years (in $1000)
GGE	Fish gillnet gear exclusively yes= 1; no= 0
DETECT	Perceive probability of detection (observed in each of the previous two years at least once = 1; else =0)
V_OLD	Previous violations (at least 2 observed violations in the previous two years = 1; else = 0)
SECTOR	Member of *any* sector = 1; else = 0
PBEHAV	Port behavior of other vessels (yes, others had a violation = 1; else =0)
TRT	Harbor porpoise TRT member had an affiliation with this port (yes =1; no=0)
POST	Vessel observed in NEFOP during the post-rules period = 1; else 0

[9] Only authorized officers, such as NOAA Office of Law Enforcement (OLE), perform enforcement functions (MSA sec. 311(b)). Though not reported by observers to OLE, OLE can and does request NEFOP data to assess regulatory non-compliance.

[10] Focus group findings showed only a few participants were aware of the existence, or the size, of an MMPA fine (12%) [9]: Table 2, Q 14). This suggests penalties (economic factor) may not be a large factor in fishers's daily decisions related to pinger compliance.

[11] Between 2010 and 2018, NOAA's Office of Law Enforcement prosecuted only two pinger violation cases: (https://www.gc.noaa.gov/enforce-office7.html; see case #14 in 2012 and #24 in 2014). One involved "fishing in a commercial fishery in contravention of applicable regulations designed to prevent harbor porpoises from interacting with fishing gear." A $4000 notice of violation and assessment was issued. The other case prosecuted a gillnet vessel for fishing within the offshore closed area without pingers. A written warning was issued.

[12] Humans are known to be more likely to take collective action in situations where the players know each other (ICES 2014).

Table 2
Total number of U.S. Northeast gillnet fleet (NEGF) vessels and the number of vessels fishing in pinger management areas (PMAs) according to the Vessel Trip Reports (VTR), and the number of vessels observed fishing in PMAs according to the Northeast Fisheries Observer Program (NEFOP) during the pre-rules year (May 2009 – April 2010) and the post-rules year (May 2012 – April 2013). Included is the percent of vessels fishing in PMAs according to the VTR and, of those vessels, the percent observed by the NEFOP in PMAs and included in the compliance model.

Time period	VTR			NEFOP PMA	Percent of vessels in model
	North of 40^0	PMAs	Percent in PMA		
Pre-rules	248	107	43%	56	52% (=56/107)
Post-rules	176	123	70%	56	46% (=56/123)

these databases. The NOAA Fisheries Greater Atlantic Regional Office's vessel permit database identifies a vessel's physical characteristics such as horsepower, length and gross registered tons. Additionally, some more detailed data is recorded by the NEFOP observers, including data to estimate pinger compliance.

The first step for creating the dataset required selecting all NEGF vessels that were recorded fishing in PMAs by NEFOP observers during the pre-rule year (May 2009 - April 2010, post=0) or post-rule year (May 2012 - April 2013, post=1). All NEGF vessels fishing in PMAs that carried observers during either the pre- or post-rules year are included in the compliance dataset. Using a unique vessel identifier, these vessels are tracked across all years to estimate a vessel's violation and detection history. All databases are accessed to construct our set of independent variables to statistically identify a set of factors that may explain a vessel's compliance choice in the pre- and post-rules years (dependent variable).

Using the VTR and dealer database, we assess the size and revenue earnings of the entire NEGF. A total of 248 (pre-rules year) and 176 (post-rules year) NEGF vessels fished north of the 40-degree latitude line (Table 2), earning revenues of $45.6 and $31.7 million dollars, respectively. The 40-degree latitude line is the southern limit of fishing areas where pingers are required (see Fig. 1), though the entire area above 40-degrees latitude is not a PMA. Rather, the only PMAs are found above that latitude.[13] Of the 248 vessels in the pre-rules year, the 107 vessels that were recorded in the VTR as fishing in PMAs earned 18% (=$8.3 M/$45.6 M) of the total NEGF revenues. Of the 176 vessels in the post-rules year, the 123 vessels that were recorded in the VTR as fishing in PMAs earned 23% (=$7.4 M/$31.7 M) of total NEGF revenues in PMAs.

Our independent variables include fishing history related to our dependent variable, an operator's violation choice. As in the previous model [7], it is assumed that the individual making the compliance decision is the vessel operator. Our model required the vessel operator during the pre-rules year (May 2009 – April 2010) be the same operator during the previous 2-year period (May 2007 – April 2009). Similarly, the vessel operator in the post-rules year (May 2012 – April 2013) must be the same operator in the previous 2-year period (May 2010 – April 2012). In other words, the set of vessels recorded fishing in the NEFOP and included in our compliance model must have the same operator all three years (either May 2007 to April 2010 or May 2010 to April 2012). For our compliance model, we have a *sample* of vessels (those recorded by the NEFOP observers) versus compliance data for the NEGF as a whole. While our compliance model data is not a census of the entire fleet, with this vessel operator decision rule, our sample data and model results represent 52% (=56/107) and 46% (=56/123) of the NEGF fishing with pingers in PMAs in the pre-and post-rules years, respectively (Table 2).[14]

Our empirical model presented below evaluates general vessel behavior between groups (no pingers missing or NPM, single pinger missing or SPM, and multiple pingers missing or MPM) while identifying the effect of a regulatory shift that occurs between the pre- and post-rule years.

3.3. Empirical model

A multinomial logit model is used to investigate a fisher's compliance decision behavior, i.e., their violation choice. A vessel operator chooses from J outcomes (different types of violations), which are indexed $j = 0\ldots J$. The outcomes are not ranked in order of preference. The model for determining the probability of outcome j is:

$$Pr_{ij}(y = j|x_i) = \frac{\exp(\beta_j x_i)}{1 + \sum_{k=1}^{j} \exp(\beta_k x_i)}$$

where the Pr_{ij} $(v_i = j|x_i)$ denotes the probability that vessel i chooses outcome j, x_i represents the exogenous variables, and β_j are the parameters to be estimated. This type of model allows us to characterize the probability of a vessel's compliance decision for a particular multinomial discrete choice, conditional on the values of the explanatory variables. Independence of Irrelevant Alternatives (IIA) is assumed; the odds of any two choices (outcomes) is unaffected by any other alternative choice [28]. Rejection of the independence assumption implies that biased predictions of probabilities will be obtained by the multinomial logit model.

Insight on the effect of the explanatory variables on the compliance decision can be captured by examining the derivatives of the probabilities with respect to the k^{th} element of the vector of explanatory variables. The marginal effects are derived by differentiation [55]:

$$\frac{\partial Pr_{ij}}{\partial x_{ik}} = Pr_{ij}\left[\beta_j - \sum_{k=0}^{J} Pr_{ik}\beta_k\right]$$

Violation choices (i.e., outcomes) are modeled by the dependent variable; vessel operator i chooses one of the following violation options: (1) a single pinger missing (SPM), (2) multiple pingers missing (MPM), or (3) no pingers missing (NPM).

The independent variable vector, x, includes a set of vessel characteristics, deterrence and normative variables (Table 1). Vessel characteristics variables include the vessel's ratio of engine horsepower to vessel length (representing the vessel's capital stock), the number of years the vessel operator (captain) has been fishing with gillnet gear, and the gross revenues the vessel earned within the previous year. We assumed expected fines may be less of a deterrent to high revenue earning vessels and examined whether the probability of violating pinger regulations is related to revenue. We also examined whether vessel operators may be more likely to comply if they have *less* flexibility to adjust their behavior in response to changes in regulations specific to gillnets (defined here as exclusively fishing gillnet gear). For this reason, we tracked whether the vessel operator fished exclusively with gillnet gear during the previous years.

Fishers that perceive low detection probabilities may factor this into their compliance decision and be less strict about following regulations.

[13] This decision rule excludes from the analysis vessels that fished only below the 40-degree latitude line and therefore would never have had the opportunity or need to enter a PMA.

[14] While the number of vessel operators is the same in both the pre and post-rules years (i.e. 56 operators on 56 vessels), the set of individual vessels and operators in each period is not the same. Although some vessels do appear in both the pre- and post-rules years.

We considered the idea that NEFOP observers can be a substitute for or complement to enforcement. That is, does the presence of an observer deter non-compliant behavior? Here we considered whether vessels with lower observer coverage may be more likely to violate pinger regulations. The detection variable equals one if a NEFOP observer was aboard the vessel while fishing in PMAs, at least once in *each* of the previous 2-year period for the pre- and post-rules periods and zero otherwise. The requirement of being observed in two consecutive years for our detection variable tests whether consistent annual observer sampling of a vessel influences a vessel's compliance choice.

Due to the lack of observed data (e.g., interview or survey data) for the normative variables, we constructed proxy variables. Our ethical behavior variable uses a history of repeat violations to represent the likelihood of future offenses. The NEFOP data were used to determine whether a vessel had two (2) or more observed pinger violations of any kind (i.e., single or multiple pingers missing) [15] in *either* of the previous two years. Individuals observed in consecutive years and having a total of two or more observed violations (DETECT=1 and V_OLD=1), may be lackadaisical about regulations and were classified as repeat violators.

Social influences can affect a vessel's compliance choice. We considered social influences related to the vessel's landing port and whether they belonged to a sector. The variable "port behavior" acknowledges that vessels fishing from the same port of landing likely have more opportunities to communicate about prices, regulations, etc. and indicates whether another vessel in an individual's landing port had any pinger violations (single and/or multiple pingers missing).[16] Vessels landing in multiple ports were assigned to the port with their highest revenue. Similarly, sector members, in at least some sectors, face expulsion from their group for non-compliance with pinger regulations [9]. Vessels belonging to a sector during the pre-rules[17] and post-rules years were identified in our model, to investigate whether belonging to a sector was an influencing factor for pinger compliance choice.

The proxy legitimacy variable tests whether a fisher's involvement in the management process influences a vessel's compliance choice regarding pinger regulations. We determined whether a HPTRT member had an affiliation with a vessel's port. Having direct access to a HPTRT member might allow information sharing, cooperation, and potential collaboration with the development of the HPTRP. We therefore considered whether a vessel is more likely to comply if they have an active HPTRT member in their port. HPTRT members include gillnet fishers from Maine to Rhode Island, though there is not a HPTRT member in every port.

Finally, the variable POST is equal to one if the vessel was sampled during the post-rules year, else zero for the pre-rules year.

[15] Here we are looking specifically at repeat violations over time to elucidate the broad issue of compliance in relation to the frequency of on-board observers.

[16] Similar to the repeat violations variable, we are looking at port communication in general to reveal the broad issue of compliance in relation to communication with other peers in a port setting. Dividing the port behavior and old pinger violation variable by violation group begins to create such small sub-groups, due to the many ports involved, that we feel valid conclusions cannot be drawn. In this study, we are interested in whether they are, or are not communicating, versus what they are communicating about. This type of connection may be better explored through a method like ethnographic interviews that would provide in-depth information about the types of information people receive from a variety of sources [6]:210–250).

[17] A vessel list was available of those committed to joining a sector when it went into effect in April 2010. While not officially operating yet under sector management till after April 2010, we identify these vessels in our pre-rules year.

4. Results

4.1. Summary statistics

During the pre- and post-rules years, of the 112 vessels recorded by NEFOP observers as fishing in PMAs, 46% were recorded as having no pingers missing, 35% were recorded as having multiple pingers missing and 19% were recorded as having a single pinger missing (Table 3). Further, approximately 64%, 33% and 48% of vessels in the NPM, MPM and SPM group were in the post-rules year, respectively. On average, vessels fishing in PMAs measured 7.8 horsepower per vessel foot, earned $267,550 in annual revenues the previous year, and had vessel operators with 22.7 years of experience gillnetting. Revenues for vessels choosing the SPM group ($366.1 K) were higher compared to the NPM group ($233.4 K) and the MPM group ($260.0 K). The data indicate 77% of the vessels fished gillnet gear exclusively the prior year, ranging from 57% for those belonging to the SPM to 85% for the MPM group (Table 3).

Based on a vessel's 2-year history prior to the pre- and post-rules years, of the 112 vessels in our compliance model, 58% of the vessels in the study were observed in consecutive years (Table 3, DETECT=1). The normative ethical behavior variable, using the history of repeat violations as a proxy, indicates that 58% of all sampled vessels had two or more pinger violations of any kind in either of the two prior years (*V_OLD=1*); vessels belonging to the SPM group had the greatest proportion of vessels with previous violations (71%). The proxy social variables show 54% of all sample vessels belonged to a sector and 67% resided in a landing port where other vessels had a pinger violation of any kind. The proxy legitimacy variable indicates 34% of vessel operators had an HPTRT member affiliated with their port.

4.2. Empirical model results

A multinomial logit model is used to examine the determinants of a vessel's choice among the three pinger violation options. Maximum likelihood estimation is used to estimate the model. This method assumes the data satisfy the critical assumption of "independence of irrelevant alternatives" (IIA), meaning the odds ratio between any two choices is unaffected by any other alternative choice. The three distinct compliance choices are represented by three distinct groups: vessels with no pingers missing (NPM), with a single pinger missing (SPM), and with multiple pingers missing (MPM). To test the validity of the IIA assumption, a step-wise regression is conducted where explanatory variables that are not significant at the $p = 0.10$ level are removed. A likelihood ratio (LR) test of the hypothesis, H_o: $\beta_i = 0$ for all β, was performed where the test statistic is defined as $2\ (L_1 - L_0)$, and L_0 is the value of the log-likelihood function with just the constant term, and L_1 is the log-likelihood value when all explanatory variables are included.

Table 3
Summary statistics (mean, standard deviation (SD) and number of vessel (*n*)) of exogenous explanatory variables by violation group (vessels with no (zero) missing pingers = NPM; multiple pingers missing = MPM; single pinger missing = SPM).

	NPM ($n = 52$)	MPM ($n = 39$)	SPM ($n = 21$)	Total (n = 112)
Variable	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
CYRS	22.37 (10.662)	25.04 (9.575)	18.90 (7.762)	22.65 (9.924)
HPLEN	7.97 (2.046)	7.67 (1.67)	7.79 (2.227)	7.83 (1.941)
GREV	233.42 (130.844)	260.00 (141.284)	366.10 (240.449)	267.55 (165.547)
GGE	0.79 (0.412)	0.85 (0.366)	0.57 (0.507)	0.77 (0.424)
DETECT	0.64 (0.486)	0.51(0.506)	0.57 (0.507)	0.58 (0.496)
V_OLD	0.52 (0.505)	0.59 (0.495)	0.71 (0.463)	0.58 (0.496)
SECTOR	0.54 (0.503)	0.46 (0.504)	0.71 (0.463)	0.54 (0.501)
PBEHAV	0.50 (0.505)	0.80 (0.409)	0.86 (0.359)	0.67 (0.473)
TRT	0.31 (0.466)	0.41 (0.495)	0.27 (0.463)	0.34 (0.476)
POST	0.64 (0.486)	0.33 (0.471)	0.48 (0.512)	0.50 (0.502)

The null hypothesis (H_o: $\beta_i = 0$) was rejected ($\chi^2(7) = 16.13$; $p < 0.015$), meaning that the explanatory variables' contributions explain the difference in compliance decisions between the three groups. The IIA assumption was confirmed, meaning the odds of two choices are independent of other choices.[18]

Table 4 includes the estimated logit coefficients for the incidence of pinger violations for vessels that chose NPM, MPM, and SPM. The log–likelihood test rejects the zero-coefficients hypothesis, implying that the model fits the data well ($p < 0.001$). Variables related to the horsepower-length (vessel capital), revenues (flexibility), use of gillnet gear exclusively (flexibility), detection (deterrent), old violations (ethical norm), port behavior (social norm) and post- (time period) were significant at the 95% level. The multinomial logit model allows relative comparisons between the MPM and SPM group to the NPM group (Table 4). It should be noted that the coefficients of the model correspond to the effects of explanatory variables on a log-odds ratio ln [Pr (yi=j)/Pr(yi=1)] for j = 2…J. They should be interpreted in relative terms, i.e., compared to the alternative of NPM. It is easier to interpret the marginal effect on individual probabilities. Table 5 reports the marginal effects for all variables which are evaluated at means of the data. The marginal effects show a particularly strong influence on violations for the explanatory variables DETECT, GGE, V_OLD, PBEHAV and POST.

Model results show that in terms of *vessel flexibility and capital*, vessels were more likely to belong to the MPM and the SPM groups as opposed to the NPM group if they had higher revenues and were underpowered, as suggested by the positive and significant revenue factors and the negative and significant horsepower-to-length factors (Table 4). While the marginal effects are significant, the magnitude is less than 1% for revenues and 4% for horsepower-to-length for vessels belonging to the MPM and SPM group. The negative significant factor for fishing gillnet gear exclusively suggests vessels were more likely to choose the SPM group if they fished multiple gears compared to the NPM group. Marginal effects are negative and significant.

Table 4
Estimation results of the multinomial logit model for pinger violations (*compare vessels with* no (zero)-pingers-missing = NPM *to* multiple pingers missing = MPM and a single pinger missing = SPM). Coefficients (Coeff.; β) and standard errors (SE) are reported where a *** denotes significance at 1%, ** at 5% and * significance at 10% level.

Variable	NPM	MPM Coeff. (SE)	SPM Coeff. (SE)
Intercept		0.177 (1.614)	2.148 (2.094)
Vessel Capital			
CYRS		0.028 (0.026)	-0.044 (0.036)
HPLEN		-0.248 (0.146)*	-0.583 (0.211) ***
Flexibility			
GREV		0.004 (0.002) *	0.007 (0.002) ***
GGE		0.021 (0.704)	-1.811 (0.861)**
Deterrent			
DETECT		-1.337 (0.651)***	-1.946 (1.040) *
Normative			
V_OLD		0.952 (0.624)	2.190 (1.074)**
SECTOR		-0.252 (0.603)	0.130 (0.794)
PBEHAV		1.489 (0.621)**	2.935 (0.961) ***
TRT		-0.355 (0.583)	-1.101 (0.759)
Time Period			
POST		-1.236 (0.573) **	-0.790 (0.750)

Log-likelihood = −87.73; Likelihood-ratio test for model's significance, $\chi^2(20)$= 56.93, *Prob* > χ^2= 0; Pseudo R^2 = 0.25.

Table 5
Marginal effects of multinomial logit model evaluated at means of the data for vessels (with no (zero) pingers missing = NPM to multiple pingers missing = MPM and a single pinger missing = SPM), where *** denotes significance at 1%, ** at 5% and * significance at 10% level.

Variables	NPM Coeff. (SE)	MPM Coeff. (SE)	SPM Coeff. (SE)
Vessel Capital			
CYRS	-0.003 (0.006)	0.009 (0.006)	-0.005 (0.003)*
HPLEN	0.080 (0.035) **	-0.035 (0.033)	-0.045 (0.019) **
Flexibility			0.001 (<0.001) **
GREV	-0.001(0.001) **	0.001 (0.001)	
GGE	0.093 (0.163)	0.083 (0.156)	-0.175 (0.077) **
Deterrent			
DETECT	0.367 (0.159) **	-0.237(0.143)*	-0.130 (0.090)
Normative			
V_OLD	-0.304 (0.153)**	0.134 (0.138)	0.170 (0.091)*
SECTOR	0.042 (0.144)	-0.066 (0.131)	0.023 (0.067)
PBEHAV	-0.449 (0.145)***	0.231 (0.140)*	0.219 (0.080) ***
TRT	0.129 (0.138)	-0.038 (0.128)	-0.091 (0.067)
Time Period	0.285 (0.135) **	-0.262 (0.127) **	-0.023 (0.066)
POST			

Results show for the *deterrent* factor, vessels were more likely to belong to the MPM and the SPM groups as opposed to the NPM group if they had lower detection rates. The detection factor suggests a higher expectation of being observed will reduce the likelihood of choosing to violate with either a single or multiple pingers missing. The marginal effects for DETECT are positive, significant and large for individuals that chose the NPM group and negative for those that chose the MPM group (Table 5). This estimation result suggests that, for a vessel with average levels of the explanatory variable, having consistent observer coverage in previous years has a significantly positive effect on the probability of choosing to be in the NPM group. Thus, the expectation of being observed impacts compliance decisions.

For our *normative variables*, the positive significant factor of old violations suggests vessels are more likely to choose the SPM group if they had old violations as compared to the NPM group. Marginal effects have a negative significant coefficient for the NPM group and positive significant coefficient for the SPM group. The significant positive coefficient on our port behavior variable suggests vessels were more likely to belong to the SPM and MPM group compared to the NPM group if other vessels in their port had pinger violations (either single or multiple missing); marginal effects are significantly positive and large for SPM and MPM group and significantly negative for the NPM group.[19]

In summary, vessels were more likely to choose the MPM group if they did not have consistent sampling, higher revenues, were underpowered and had other vessels with violations in their port as compared to vessels that chose the NPM group. Similarly, vessels belonging to the SPM group were more likely to be under sampled, be under-powered, have higher revenues, fish multiple gears, have old violations and have other vessels with violations in their port compared to vessels that chose the NPM group. Consistent with these results is the

[18] Using the approach of Hausman and McFadden [18] and Cheng and Long [10], we also test this assumption by comparing the coefficients of the multinomial logit model with 2 alternatives (i.e. one alternative is deleted from the initial set of three alternatives). Under the null hypothesis, the statistic follows a $\chi^2(20)$ distribution. Computed statistics are equal to 16.81, 15.75, 15.43. All of them were much lower than the critical value of a $\chi^2(20)$ at the 5% level, 31.41

[19] At the request of an anonymous reviewer, variables port behavior and old violations were split by single and multiple pinger violations. Results with the split port behavior variable was driven by SPM and not interpretable; factors related to old violations were statistically insignificant. There was no statistical difference in the model fits according the likelihood ratio test, which may speak to sample size issues. We feel valid conclusions cannot be drawn by splitting these variable further, suggesting the need for more qualitative research as mentioned in fn (14) and fn (15); and while more data would improve the strength of the results, the study as it stands does provide useful results for management.

finding that an average vessel would more likely fall into the NPM group if they had higher horsepower, lower revenues, consistent observer sampling, did not have old violations and other vessels in their port did not have a violation.

Lastly, the negative significant factor for POST indicates that vessels belonging to the MPM were affected by the regulation shift, compared to the NPM group (Table 4). Vessels were more likely to fall in the MPM group during the pre-rules year, and the positive significant marginal effects (Table 5) suggest vessels were more likely to fall in the NPM group in the post-rules year. This implies vessels choosing to belong to the MPM group may have responded to the threat of consequence closures. In line with this finding is the fact that fewer observed vessels chose the MPM group in the post-rules year compared to the pre-rules year, and there was an increase in pinger compliance in the post-rules year [33]. In contrast, the POST factor was insignificant for vessels belonging to the SPM group. This points to vessels selecting to be in the SPM group not being responsive to the threat of consequence closures.

5. Discussion

The main aim of our study is to provide insights into the factors that may influence an individual's compliance choice. Pinger compliance increased after 2010 compared to previous years. Primary findings suggest the importance of having an observer present in the choice of NPM, that the efficacy of the imposed regulations in improving compliance behavior varied by violation choice (SPM vs. MPM), the importance of port-level compliance behavior patterns (an individual vessel is more likely to belong to the SPM and MPM compared to the NPM group if other vessels in their port had pinger violations (SPM or MPM)), that vessels were more likely to violate if they earned higher revenues, had previous violations (SPM group), fished multiple gears (SPM group), and, unexpectedly, were underpowered (as measured by horsepower to length ratio for the SPM group).

Using an empirical compliance model, this paper investigated whether the threat of consequence closures, the onset of sector management, or both, were influencing factors in the change in compliance rates. It also introduced a new way to measure compliance, by sorting vessels with missing pingers into two groups based on focus group discussions [9]. The focus group discussions indicated two distinct groups of violators: vessels with a single missing pinger (described as being for safety reasons) and vessels with multiple missing pingers. Model results using this insight suggested vessels belonging to the MPM group responded to the consequence closure rule, while vessels in the SPM group were not responsive. The observed overall increase in compliance was thus likely the result of behavioral changes by those violators with multiple missing pingers. Focus group discussions also provided information that some sectors provided support for buying pingers and even threatened expulsion for those that violated pinger requirements. However, being a member of a sector was not found to be statistically significant in influencing compliance. It may be that the focus group members were not a representative sample of sector membership, e.g., participants were members of sectors that do provide support for pinger use, while the majority do not. This contrast between focus group and model results may suggest that the *specific* sector that gillnet vessel owners join matters; it is not merely a question of being in a sector or not. This is an area for further research.

Research results also show that factors beyond economic considerations influence compliance decisions. Becker's classic crime model (1968) suggests one must be aware of *the size of the fine* and the *detection rate* of a violation to determine if the expected gain for a violation is greater than the penalty (i.e., worth the risk). Focus group findings show only a few participants were aware of the existence, or the size, of an MMPA fine (12%) [9]. Thus, penalties, or fines, were not important to participants' decision making process. However, our model results indicate vessels with lower observer coverage were more likely to violate pinger regulations, a deterrent factor. These results support earlier findings [7] which suggest regulators may be able to increase compliance via increased observer coverage. Meanwhile, the variation in violation behavior in ports may suggest the possibility of nudging groups via port-level campaigns, perhaps highlighting the fact that fishers are at heart ocean stewards. The design of such a campaign would require further research to determine the most effective focus.

Focus group findings suggest that vessels with a single missing pinger did not consider their actions to be a violation (*ethical norm*). A participant asked, "You would not penalize a guy for one missing pinger, would you?" Therefore, from their perspective, they did not need to adjust their fishing behavior under threats of closures after 2010 and would not be susceptible to nudges. Our model results confirmed that the single-pinger-missing group did not change their behavior post-2010. Furthermore, the significance of the port behavior variable for vessels belonging to the SPM or MPM group compared to NPM vessels suggests a sharing of information among ports can influence compliance decisions. Some sectors are port-based, though many are not. This suggests that, in the future, when examining sectors that provide support for pinger compliance we should also pay attention to whether they are port-based or not. In general, when individuals find a better way to do something they tend to share the information, while they may be less likely to share information if they believe they are doing something potentially illegal.

This work started with Hatcher's et al. [17] empirical compliance model which led to other research including Sutinen's seminal compliance research [16,17,23,47]. One major difference is, the compliance data in our model is not based on face-to-face interviews of participants' *perceptions* of their compliance behavior, but rather *observed* use of pingers by at-sea observers. The same is true for the normative variables; proxies are created for normative variables using the NEFSC NEFOP data. Both types of data, observer and interview, are important and add value to overall research findings (see [9] for more on this point). While focus group participants provided insight into their daily decision making, our formal compliance model allowed us to statistically test hypotheses for the population of observed vessels. Furthermore, focus group research (see [9] for more on this point) can be used to develop formal surveys that can in turn increase our understanding of how the various decision factors impact policy instrument performance, a critical component in policy design.

Beyond the importance of multi-method research is the need to understand that multiple incentives and disincentives (deterrents) influence behavioral responses to regulatory changes, such as those implemented in the northeast groundfish gillnet fleet in 2010. Failure of current policy instruments to meet marine mammal management goals such as reduced bycatch cannot always be fixed by introducing new instruments. This research suggests non-compliance with existing regulations should be assessed first. If there is a high level of compliance, then the instrument itself may be ineffective and a new or fundamentally different instrument may be required. If there is non-compliance, it may be more cost-effective to address non-compliance issues first. Research findings, for example, suggest there is a lack of awareness about fines among fishers. Additionally, low fines appear to have little impact on fishers' behavior (re. [9]) and may also provide low incentives for enforcement officials to take borderline cases to court for convictions. At the same time, beliefs in the importance of following rules or higher rates of observer coverage may provide incentives for compliance. It seems clear these interactions deserve further research attention.

Currently, enforcement is the traditional solution for non-compliance. Model results suggest that fishers who have consistent and more frequent observer coverage may be more watchful about their behavior. Enforcement trips address one question, compliance, while NEFOP observers primarily record economic and biological research data that provide data for many research questions beyond compliance. Perhaps more observers could substitute for and complement enforcement. More research is needed on the level and consistency of observer coverage that may nudge fishers toward full compliance, as well as on the relative cost of observer versus OLE trips. Based on the results of this research, it may be both cost-effective and provide improved compliance to substitute some OLE trips with observer trips. A further issue, however, is that NEFOP observers and the Office of Law Enforcement are funded under separate budgeting authorities which may make this type of substitution more challenging.

Lastly, layers of increasingly restrictive regulations can put additional pressure upon fishers that may result in more risk-taking trips that compromise safety for profit, such as fishing in poor weather. Though to this point, for example, while Pfeiffer and Gratz [39] showed a switch to catch shares (in this case Individual Transferable Quotas) resulted in the average annual rate of fishing on high wind days to decrease by 79%, Olson [32] found safety impacts in catch share fisheries overall to be mixed and related not just to weather but factors such as whether the vessel is captained by the quota owner or a fisher leasing the quota. The requirement for 100% pinger compliance may have added unintentional risk to the fisher tending the gear coming aboard the vessel, though further research is needed to quantify this risk; in response, fishers took what to them seemed a reasonable safety precaution, removing one pinger, an action that they seemed to expect would have little to no impact on harbor porpoise bycatch and that had been allowed through the spring of 2008 ([34]:259); for more on this poing see [9]:6. Because it had previously not resulted in a violation they did not expect this action to increase the odds of a long term closure due to fleet non-compliance. Thus institutional changes can inflict unintentional stressors. The results in this paper are evidence of how understanding behavioral responses to institutional changes can lead to designing more successful policy instruments to achieve management goals.

CRediT authorship contribution statement

Kathryn Bisack: Methodology, Formal Analysis, Investigation, Writing. **Patricia M. Clay:** Investigation, Writing.

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