i. Title: Effects of increases in fishery resource abundance on conservation compliance

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1. Introduction:

Overfishing is a problem throughout the world, often due to fisheries management failures. However, some fisheries are sustainably managed partly because of high compliance with conservation measures. Understanding stakeholder perceptions about conservation practices is valuable for the effectiveness of environmental management, including fisheries management [1-4]. To better inform adaptive management, more needs to be understood about fishers' behavior and compliance [5]. Understanding conservation compliance, or fishers' compliance with conservation measures, is especially critical when measures cannot be easily enforced [6]. To anticipate the potential of non-compliant fishing behavior, it is important to understand the quality and diversity of motivations for compliance rather than simply the lack of presence of compliance [7].

Conservation compliance depends on many factors, including benefits, costs, and norms [8]. Most notably, resource users are more likely to comply with conservation measures if they benefit from them [9]. Fishers will not comply with conservation if the net benefits from not complying are large enough [10]. Compatibility between conservation measures and fishing practices also influences conservation compliance [8]. This 'rationalist' model assumes that resource users consider costs and benefits of their actions [11]. However, conservation compliance is also influenced by a variety of interrelated social, cultural, and psychological factors [2,4]. This 'normative' model assumes compliance is influenced by norms, morality, legitimacy, and social and cultural factors [11].

Resource users can learn to practice conservation through a multitude of pathways [12]. By understanding the environment (ecological understanding), resource users can learn to practice conservation without a collapse in the resource abundance (depletion crisis) [12]. Under

the depletion crisis mode of conservation emergence, fishers will practice conservation when the resource is scarce. Under the ecological understanding mode of conservation emergence, fishers will practice conservation not because of a depletion event, but because of ecological knowledge and lessons passed between fishers and generations. Resource users can develop an ecological understanding by learning from lessons and experiences of others [12].

In this paper, we examine how conservation compliance can change in a fishery under changing resource abundance. The study examines conservation compliance in the American lobster fishery in Maine, where an important conservation measure, known as v-notching, protects spawning female lobsters. This conservation rule has long been considered a norm, but as we illustrate, the perceived benefits and costs of this practice have changed with increasing abundance, potentially impacting compliance and the future sustainability of the fishery.

2. Materials and Methods:

2.1. Maine lobster fishery background

The American lobster fishery is the most valuable single-species fishery in the United States [13]. Around 82% of the American lobster landings come from the Maine lobster fishery [14], which is co-managed by lobster fishers[1] and the Department of Marine Resources (DMR). The fishery is globally recognized for its sustainable conservation practices and high levels of compliance and self-enforcement of regulations [16]. The fishery is known to take collective action to improve the lobster fishery [17]. A trap only fishery, lobsters are managed with gear restrictions, limited entry into the fishery, trap limits, legal sizes, and protection of egg-bearing lobsters. Maine lobster landings, abundance, and value have increased dramatically in the past

[1] The gender neutral term ‘fisher’, which highlights the diversity in fisheries [15], is used.

few decades [18]. Understanding conservation compliance in this fishery is timely given that conservation can improve the resilience of the fishery to climate change [19] and since changing resource abundance can affect conservation compliance [20].

Specifically, the focus of this analysis is on what is perhaps the most important conservation measure in this fishery, the practice known as v-notching, which is a key part of the lobster fishers' conservation ethic [21]. When a lobster fisher catches an egg-bearing lobster in a trap, the lobster fisher can choose to cut a 'V' shaped notch in her tail with a v-notching tool, legal measure, or knife and release her back to sea. Other lobster fishers that catch these v-notched lobsters must release them as well because it is illegal to land v-notched lobsters. Acheson [16] describes v-notching as a conservation norm. This social norm was formed to help solve a collective action problem, which can happen when resource users develop their own rules [22]. V-notching was developed after the low catches in the 1930s, and lobster fishers are proud of their efforts to get the v-notching conservation measure passed by the legislature in 1947. Previous research has shown that Maine lobster fishers usually comply with and self-enforce this measure because they believe it is essential to the sustainability of the fishery, the most important conservation measure in the fishery, and one of the reasons for the high landings [21]. Before lobster fishers receive their licenses, they need to lobster fish for a certain amount of days with a licensed lobster fisher or a sponsor [23], and it is during this time that many fishers learn their responsibilities to the lobster resource and other fishers, including the practice of v-notching.

Other lobster fisheries, such as Canadian, Irish, and Scottish lobster fisheries [24-26], began practicing v-notching decades after the Maine lobster fishery. Other fisheries have had changes in v-notching compliance. For example, Scottish lobster fishers v-notched less often when the lobster price per pound was higher [26]. This conservation measure has been found to

have positive impacts on lobster fisheries. For example, v-notching has an important role in the Maine lobster fishery; it has contributed to the drastic increases in lobster biomass and landings [27]. Additionally, Daniel et al. [28] and Tully [25] found that the v-notch conservation measure increased the reproductive potential of lobster populations off the coasts of Maine and Ireland, respectively.

Although research on Maine lobster fishers' perceptions of v-notching has shown that Maine lobster fishers view v-notching as effective and the most important conservation measure in the fishery [21], a recent analysis is in order. The Maine lobster fishery is facing a variety of social and environmental threats, such as climate change [19] and graying of the fleet [29]. Such changes can affect fishing behavior and the compliance rate of v-notching, which may be declining [30]. There are concerns about lobster fishers' social resilience to future threats [31].

2.2. Interviews and analysis

First, semi-structured interviews (n=5) [32] were conducted with key-informants in the lobster industry, including managers, scientists, and lobster fishers. Topics included in the exploratory, semi-structured interviews were the strengths and threats related to the fishery and its co-management system.

Next, oral history interviews (n=32) [33] were conducted with Maine lobster fishers. Analysis of the semi-structured interviews and prior research [31,34] helped to develop a semi-structured, oral history interview guide that investigated environmental, social, and regulatory changes and concerns in the fishery. Themes that arose from the semi-structured interviews and were incorporated in the oral history interview guide included the industry's conservation ethic, v-notching, and resilience. This study is a part of a larger project focusing on resilience in the

Maine lobster fishery, and finding from prior research [31,34] on resilience in the Maine lobster fishery informed the oral history interview guide. Oral history interviews preserve social memory and capture the lived experience of an individual and can be used to understand ecological history, resource use, and management [35], including fisheries management [36,37].

A snowball sampling approach [32] was used to collect oral histories from a purposive sample of Maine lobster fishers from March 2017 to March 2018. We asked interviewees if they know of any other lobster fishers that would be interested in being interviewed. We sought a sample of lobster fishers with diverse experiences (e.g., years in the fishery, size of boat, age, and lobster zone) (Table 1). We continued to conduct interviews until we had participants with diverse characteristics. All lobster fishers invited agreed to participate. The mean age of interviewed lobster fishers was 46.31 (Table 1), which is slightly younger than the mean age (49.5) of lobster fishers in 2015 [29]. The state of Maine lobster fishing area is split into seven zones from the east to west (zones A – G). Lobster fishers that were interviewed were from five of Maine's seven lobster fishing zones (zones A - E) (Table 1). Since most of the lobster fishing occurs off mid-coast Maine, most interviewed lobster fishers were from the mid-coast in zones B (n = 11), C (n = 7) and D (n = 7). However, there were only male lobster fishers in our sample. Most Maine lobster fishers are male, and most likely as a result, all of the recommended interviewees through snowball sampling were male. Although the sample cannot be considered representative of all experiences in the lobster fishery, it was sufficient for documenting fisher experiences and perceptions examined in this study.

Table 1. Attributes of interviewees.

Attribute	**Mean**	**Mode**	**Range**

Years in lobster fishery	30.74	47	5-61
Size of boat (ft.)	36.26	40	20-46
Age (yrs.)	46.31	N/A	18-83
Lobster zone	N/A	B	A-E

Oral history interviews ranged from 20 to 150 minutes and followed a semi-structured guide that still allowed participants to share what was most important to them. Topics such as participants' experience in lobster fishing, changes in the lobster fishery and marine ecosystem, threats to the fishery and marine ecosystem, fishery management, and changes in fishing behavior were included in the interviews. Since v-notching emerged as an important topic in the key informant interviews, additional questions were asked about this practice. All oral history interviews were audio recorded and transcribed verbatim by a professional transcription service. The interviewer then reviewed and corrected errors with the transcriptions to further ensure accuracy.

NVivo 11 software was used for qualitative analysis of the oral history interviews following an inductive coding strategy [38]. Interview codes examined in this paper focused on v-notching and reasons why lobster fishers v-notch or do not v-notch. For second cycle coding, we followed a pattern coding strategy. As a result, reported themes were overlying themes that relate to individual codes. Codes included sustainability, preventing free riding, codes relating to lobster abundance, codes relating to lobster health, enforcement, and generational differences. Individual inductive codes were grouped into themes as reflected by the sub-sections in the results.

3. Results:

Five main themes that arose and will be addressed are: 1) maintaining conservation through ecological understanding, 2) decrease in conservation compliance, 3) specific factors affecting compliance, 4) variation in viewpoints on compliance factors across generations, and 5) non-compliance related themes.

3.1. Maintaining conservation through ecological understanding

Although ecological understanding plays a role in conservation emergence, in this case ecological understanding was also important for maintaining the conservation ethic. In general, lobster fishers interviewed expressed positive views about v-notching. All lobster fishers interviewed thought that v-notching was important, with some lobster fishers specifically describing it as the most important regulation in the fishery. One lobster fisher described: "The most important thing, I think, is the v-notch. It's what sustains the catch. It's got to be." Most lobster fishers described having always supported and complied with v-notching since they started fishing.

The importance and practice of v-notching is something that fishers are typically taught very early on in their career. One lobster fisher who was 41 years old recalled how he was taught to v-notch by his father:

> I know that I was kind of raised that way. I remember before there was the mutilation law, people would keep lobsters that were missing half a fin, and my father would never let me. As a kid, he didn't want anything to do with them, and so I always kind of followed that rule anyway because that was the way I was taught.

Many of the lobster fishers interviewed reported that they continue to encourage their children and other lobster fishers to v-notch. As one lobster fisher explained, "I'm gonna continue preaching v-notch 'til I die because I think it's the most important thing we can do to sustain this fishery." Other indicators of the importance of v-notching are stories heard from captains who report that they instruct their crew to v-notch and will re-notch lobsters caught with a v-notch, ensuring the lobster remains protected for longer.

3.2. Decrease in conservation compliance

However, interviews also indicate a decline in the v-notching practice in recent years. When asked if they always v-notch every egg-bearing lobster caught, some lobster fishers reported that they v-notch less than they used to or do not v-notch at all and provided reasons for this in the interviews. One lobster fisher explained: "A lot of guys don't do it. They just think it's a waste of time." One lobster fisher explained how the significance of the practice has changed dramatically:

> I can remember in the '90s again, you did a female loaded down with eggs and it was almost a reverent moment. You took the time. My grandfather would practically stop the boat, and put a huge notch in it and cradle it back into the water.

This lobster fisher went on to lament that while he still tries to v-notch today, he is not actually able to v-notch every egg-bearing lobster when he is busy.

3.3. Factors affecting compliance

Factors positively or negatively affecting v-notching compliance identified in the interviews were related to either ecological understanding or the rationalist model (Table 2).

Although ecological understanding maintained conservation, some aspects of ecological understanding changed, which affected compliance.

Table 2. Factors affecting v-notching compliance and the direction of the effect.

Factors affecting v-notching compliance	**Effect**
Rationalist factors	
Resolving the free rider problem	Positive
Limited time/resources	Negative
Threat of sanctions	Negative
Ecological understanding	
Sustainability benefit	Positive
No sustainability benefit	Negative
Risk to resource	Negative

3.3.1. Rationalist factors

3.3.1.1. Compliance incentive: Resolving the free rider problem

Lobster fishers monitored the resource and prevented free-riding by v-notching (Table 2). Some lobster fishers noted that they v-notch not only to protect the resource, but also because if they cannot catch it, they do not want to free ride and catch that lobster. Some lobster fishers believed they were not receiving any benefits from an egg-bearing lobster, and as a result, they did not want other lobster fishers to benefit from the same lobster by landing it. One lobster fisher described: “If I notch it, I know that guy next to me is not gonna keep it, so I don’t have to worry about it.” Some lobster fishers will create large pronounced notches, rather than small notches, so that v-notched lobsters cannot be caught by other lobster fishers for a longer period

of time. To prevent the free rider problem, some lobster fishers re-notched v-notched lobsters as well.

3.3.1.2. Compliance deterrent: Limited time/resources

Lobster fishers also described that they v-notched less because of limited time and resources (Table 2). Lobster fishers described that the catch of egg-bearing lobsters in recent years has been exceptionally high and that this had prevented them from v-notching. As one lobster fisher lamented, "I have to admit, we don't v-notch like we used to because there's so many. Like it gets to a point of ridiculousness. Like I couldn't have my guys v-notch all day long because we would never get done."

Indeed, the increase in the catch of egg-bearing lobsters makes it more difficult to v-notch given everything else done during the workday. For every trap haul, the lobster fishers need to haul the trap up to the boat, take the lobsters out of the trap, measure lobsters, release illegal lobsters (i.e. undersized, oversized, notched, or egg-bearing lobsters) back to sea, band the legal lobsters, place the legal lobsters in the holding tank, bait the trap, and release the trap back to sea. One lobster fisher described that when sea conditions are rough, v-notching the large amount of egg-bearing lobsters is even more difficult. V-notching may sometimes be the last priority when there are so many other things to attend to when lobster fishing.

3.3.1.3. Compliance deterrent: Threat of sanctions

Enforcement of the v-notch law also influences v-notching behavior. Because it is difficult to v-notch so many lobsters when there are already numerous lobsters on board, some lobster fishers expressed their fears of enforcement. Some lobster fishers set egg-bearing lobsters aside to v-notch later when handling a large catch. However, a couple of lobster fishers were

concerned about being caught with a v-notched or egg-bearing lobster on board. The Maine DMR [39] states “It is against the law to take, transport, sell or possess any lobster that is bearing eggs.” As a result, some fishers reported that they released egg-bearing lobsters immediately back into the ocean without v-notching them. These lobster fishers do not keep egg-bearing lobsters aside to v-notch later if they are busy. Lobster fishers describe how if they were caught with a v-notched lobster on board, they would be fined or lose their license. To be safe, one lobster fisher explained that he sometimes throws lobsters with eggs or old v-notches overboard without notching them first: “If you’re not sure, when in doubt, throw them over. It’s not worth losing the license or getting searched by any wardens and having any issues with them.”

Lobster fishers further explained how different enforcement officers have conflicting guidelines for what constitutes a v-notched lobster, and this creates additional uncertainty and fear among fishers. Some marine patrol officers consider any sort of mutilation a v-notch, but other marine patrol officers do not consider a small mutilation a v-notch. Interestingly, lobster fishers are not more likely to v-notch to avoid consequences of being caught not practicing v-notching because the practice is impossible to enforce without observers on board.

3.3.2. Ecological understanding

3.3.2.1. Compliance incentive: Sustainability benefit

Not surprisingly, most lobster fishers explained that they v-notch due to their ecological understanding that the conservation practice keeps the fishery sustainable (Table 2). Specifically, lobster fishers explained that by protecting the breeding stock, v-notching allows for more lobsters to enter the population. Lobster fishers attribute the current high landings and lobster

abundance to v-notching. Several lobster fishers believed that v-notching and other conservation measures would keep the lobster fishery sustainable in a changing environment.

3.3.2.2. Compliance deterrent: No benefit for sustainability

Lobster catches have been high in recent decades. As a result, some lobster fishers described that v-notching may not be as necessary as it was in the past because the lobster abundance is already high (Table 2). Many lobster fishers described that they believed, or knew of other lobster fishers who believed, that there were too many v-notched lobsters in the population. These lobster fishers describe how most egg-bearing lobsters that they catch have already been v-notched. Consequently, they report that some lobster fishers do not v-notch as much because they do not think it is necessary or beneficial. One lobster fisher explained: "Just because we're seeing so much, the mentality is, you know, there's so many more on bottom, why bother with it?"

3.3.2.3. Compliance deterrent: Risk to resource

Some lobster fishers expressed their ecological understanding that v-notching could cause disease or that disease could arise from the large density of lobsters caused by v-notching (Table 2). These lobster fishers described disease would spread or is already spreading quickly with the large amount of v-notched lobsters in the population. In this view, v-notching could hinder the sustainability of the lobster resource. These lobster fishers explained that increasing the density of lobsters was beneficial, but only until a certain point, at which the large density of lobsters would negatively interact with pathogens. One lobster fisher described:

> What I've been seeing in a lot of the bigger v-notched lobsters with eggs is shell disease. So,... me and [the warden] talked about it at length one day, and we kind of agreed that, to get rid of the shell disease, get rid of those egged lobsters.

Reardon et al. [40] found that shell disease prevalence has increased in the Gulf of Maine, although prevalence is still at low levels. High population densities can increase the prevalence of disease through a variety of factors [41].

3.4. Climate change

In addition to v-notching and other conservation measures, many fishers pointed to climate change as one factor mentioned that may have contributed to the large increase in lobster abundance, many fishers were uncertain about what effects this would have on the future of the fishery. Lobster fishers also described that climate change could increase the risk of shell disease. One lobster fisher explained:

> The global climate change concerns me. I think, personally that the reason why we've had some of these booms is because the temperatures make those kind of creatures more active. They breed more, they eat more, they grow more. And you have a boom. And I think if it goes too far the other way, we'll have a crash.

Interviews suggest that lobster fishers believed that climate change was a 'dread' risk, which invokes a feeling of lack of control, and also an 'unknown' risk, which is difficult to observe and quantify [42-44].

3.5. Variation in viewpoints on compliance factors across generations

Another theme in the interviews was a perception that there is a difference in v-notching compliance between the older and younger generations. Lobster fishers described how the younger generation of lobster fishers tended to fish harder and that there is less camaraderie in lobster fishing communities today than decades ago. Some lobster fishers described that the older generation tended to have a stronger conservation ethic. These lobster fishers believed the younger generation does not v-notch as much as the older generation. One lobster fisher, who was 60 years old, explained:

> The older generation was more worried about the resource. I think more careful, better stewards of the resource. The younger generation, I think, are more greedy. They're buying boats that are 600 to 800 thousand dollars right now, and to make that work, you've got to go fast, you've got to go hard, and you don't take the time to v-notch, you don't take the time to handle the lobster properly, and I don't think they see the overall big picture.

4. Discussion

For fisheries management to be effective, compliance of conservation measures needs to be high [45]. V-notching is perhaps the most important conservation measure in the Maine lobster fishery and fishers historically advocated for v-notching because they viewed it as beneficial to the population. Consistent with what other scholars have noted [21], our study found that Maine lobster fishers continue to view v-notching as important for sustainability of the fishery.

However, a decrease in compliance of v-notching was identified in this study. Our analysis further suggests a decline in v-notching compliance has occurred due to changes in the abundance of lobsters resulting in an increasingly high catch of lobsters (Fig. 1). We hypothesize that there is a relationship between conservation compliance and catch (Fig. 1). However, there are other factors that affect compliance. Catch is one factor that affected compliance in this case, but it was also the factor that seemed to change the most over time. This change in compliance has occurred even though the overall management structure and rules have stayed the same, highlighting the lack of adaptive capacity within the management structure. If compliance continues to decline, the effect of v-notching on future sustainability will change, which may further affect lobster fishers' perception of v-notching.

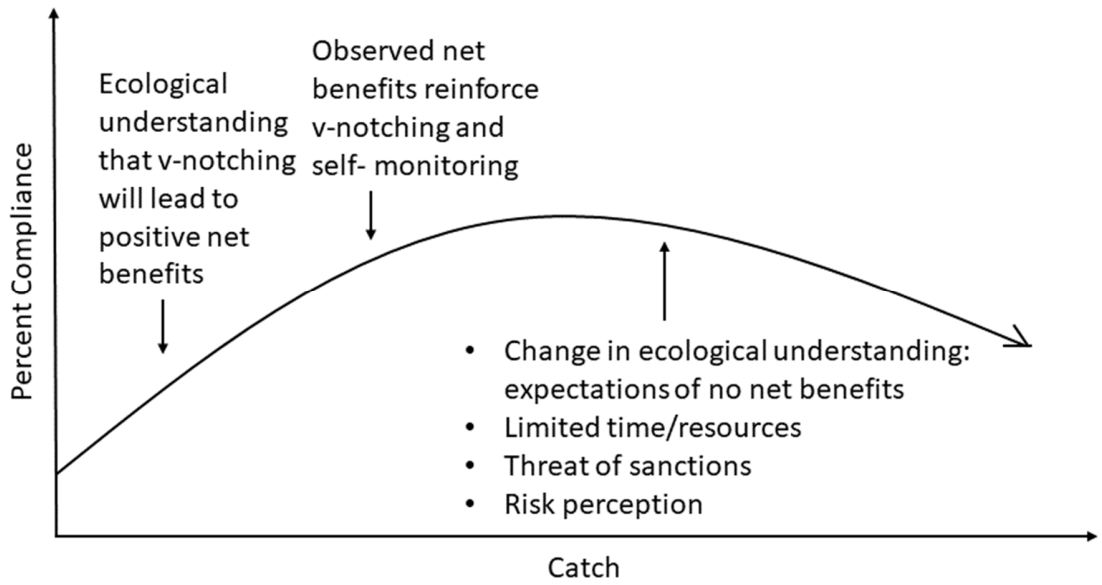

Figure 1. Theorized relationship between v-notching compliance and catch.

Although the lobster catch has increased partially due to v-notching [27], this increase has created unintended consequences that are challenging the norm such that for some lobster fishers, v-notching is no longer a priority (Fig. 1). Before resource abundance dramatically

increased, the cost of v-notching compliance was low and relatively easy to do [46]. Today, with a high amount of v-notched lobsters in the population, some lobster fishers question the continued benefit of the practice to the lobster population (Fig. 1). Because of the increasing catch, there are now some conflicting views: lobster fishers v-notch because it is important for sustainability, while other lobster fishers do not v-notch because they view it is no longer important for sustainability.

The perceptions of v-notching in this study suggest that lobster fishers' perceptions of the fishery and compliance are complex and related to the status of the lobster resource and various social and economic aspects. Compliance in this fishery with respect to v-notching can still be explained by the normative model of compliance that suggests fishers follow the rule because it is a norm [11]. At the same time, compliance for others is explained by the rationalist model that suggests fishers are not following the rule because it either does not provide a benefit or incurs a cost to them [11], which are due to the increasing resource abundance observed in recent years. A decline in v-notching non-compliance due to limited time and resources was related to the perceived costs or benefits, because v-notching would be an increased cost as lobster fishers would have less time to catch and handle legal lobsters. However, these constraints would differ with different fishing operations (i.e. number of crew, size of boat, number of traps, etc.).

Our findings (Fig. 1) are consistent with others who have shown that conservation can emerge as a result of either a depletion crisis or ecological understanding [12]. In the case of the Maine lobster fishery, a depletion crisis seemed to have created the conservation ethic, as v-notching was initiated after low catches of lobsters in the 1930s [21]. The ecological

understanding model explains how v-notching was maintained for some time. Lobster fishers had a shared understanding of the benefits of v-notching, such that everyone followed the rule. However, with changing resource abundance, the shared ecological understanding underlying conservation compliance may be changing for some lobster fishers. Additionally, in the Maine lobster fishery, depletion crisis and ecological understanding seem to be interrelated. Shared ecological understanding was facilitated by a depletion crisis, and ecological understanding may have eroded as the crisis dissipated and also as additional scientific uncertainty emerged, whether in the face of new information or new threats, such as climate change.

Given the compliance deterrents driven by high catches of lobsters (i.e., too many v-notched lobsters, limited time and resources, and fear of enforcement), we theorize a feedback loop where v-notching decreases with high catches of lobsters but increases with low catches of lobsters (Fig 1). These findings highlight the importance of adaptive management to adjust fishery regulations in response to changing incentive structures. Although a decline in compliance may seem to suggest a failure to adaptively manage the fishery, the feedback loop identified here can also be viewed as a de facto adaptive management strategy or harvest control rule implemented by lobster fishers. When the catch is high, some lobster fishers described the net benefits would be greater if less lobsters were v-notched. However, when catch is low, v-notching is a priority. Future research is needed to better understand the underlying dynamics and motivations of the feedback loop.

Additionally, we suggest that differences between the younger and older generations of lobster fishers may create differing perceptions of v-notching. Such division within communities can modify the behavior of fishers to favor short-term over long-term benefits [47]. When economic, social, and ecological conditions differ among resources users, there may be less

cooperation between users, resulting in less conservation [17]. Cooperation is reduced, because there is less solidarity due to increased inequality. For example, Maine lobster fishers from different regions prefered different trap limits due to differences in lobster abundance and distance to markets, resulting in disagreement on state-wide trap limit proposals [17]. However, we did not identify a significant difference in the perceptions of v-notching between younger and older generations due to the small sample size.

Sharing information and ongoing discussion among fishers, policy-makers, scientists, and enforcement agents about v-notching compliance and conservation is likely to benefit the management of this fishery by providing information to inform adaptive management. Interestingly, the threat of sanctions decreased v-notching compliance, because the management was not adapted to match the current circumstances. Marine patrol personnel and lobster fishers would benefit from an adaptive strategy that would allow lobster fishers to set aside egg-bearing lobsters to v-notch later, when there are high catches, without receiving penalties if stopped by marine patrol. Leeway for how long lobster fishers can hold egg-bearing lobsters could be considered in a formal adaptive management approach. With this leeway, lobster fishers may v-notch lobsters that they would not have v-notched due to fear of enforcement.

Education on the benefits of v-notching may also be important if biomass were to decline in the future; lobster fishers would be more likely to remember the benefits of v-notching. Additionally, with a precautionary approach to management and adaptive management, it is important that v-notching is still encouraged to preserve the breeding stock. The findings of this study may also have implications for other conservation regulations (i.e. prohibition of landing egg-bearing lobsters, minimum size), as compliance for these regulations may be changing in similar ways.

Furthermore, our study underscores the value of oral history interviews as a tool for documenting changes in behavior and motivations that can inform fisheries management discussions. Oral histories can also preserve social memory, which can have important implications for the future of the fishery. Social memory can remind lobster fishers of the benefits of v-notching in the past, and this may help sustain a norm that could potentially disappear and will be important should abundance and catch levels decline.

5. Conclusions

Understanding the effects of fishery resource abundance on conservation compliance in the Maine lobster fishery was necessary given the increases in resource abundance and the importance of compliance for effective fisheries management. The objective of this study was to examine how conservation compliance, specifically for v-notching in the Maine lobster fishery, can change with resource abundance. To do this, we conducted semi-structured interviews with managers, scientists, and lobster fishers, followed by oral history interviews with Maine lobster fishers. Maine lobster fishers believed that v-notching provided a sustainability benefit, and historically, this practice has been a norm among fishers. However, conservation compliance has declined for some fishers. This shows that conservation compliance can change even when the management system remains the same, indicating a lack of adaptive management. Changing resource abundance can change fishers' behavior through changes in their perceptions of the benefits and costs of the practice, which should be considered in adaptive management plans. Moreover, social memory is important for v-notching to continue into the future.

While fish abundance affects compliance, other factors, such as generational differences, fishing styles, and norms, also have effects on compliance. While this study has shed light on some factors influencing v-notching compliance in the Maine lobster fishery, more research is

needed to better understand the differences in compliance among different lobster fishers and fishing operations. In this study, the interviews were not structured, so not all lobster fishers discussed the same factors. This made it difficult to apply a quantitative analysis, but the semi-structured interviews were still useful in that they allowed lobster fishers to bring up topics of importance instead of having the topics predefined. Future studies should conduct structured interviews or surveys for a quantitative analysis to identify differences in compliance among different lobster fishers. For example, inshore and offshore lobster fishers have different fishing operations (i.e. offshore lobster fishers tend to have larger boats). Because inshore and offshore lobster fishers have different fishing operations and deal with different proportions of egg-bearing females and sizes of catches and lobsters, the inshore and offshore lobster fishers may have different v-notching compliances.

A previous study also hypothesized differences in compliances among different fishing styles and mindsets [48]. Compliance may increase if management considers the variety of fishing styles [48]. However, the sample size in our study on v-notching compliance was too small to determine significant differences across fishing operations. Additionally, future research should acquire a larger sample size to understand differences across generations. There is a need for more representative sampling to understand differences across operation sizes and geographical areas.

Another important topic for future studies is the impact of climate change on v-notching. In this study, lobster fishers described that aside from v-notching, climate change also influenced abundance, but it was unclear if this affected lobster fishers' v-notching compliance. Climate change may have been linked indirectly or directly to fishers' behavior, but from our interview data, this link could not be identified. However, lobster fishers thought shell disease could arise

from climate change and too many v-notched lobsters. Climate change may impact compliance by increasing the risk of shell disease and lobster abundance, but climate change also impacts many other dynamics of the lobster resource and the greater social-ecological system, so it is still unclear as to how climate change impacts compliance.

Future studies should incorporate these results into fishery simulations. Currently, Maine lobster fishery simulations lack fishing behavior information [49]. However, integrating qualitative and quantitative data requires a framework that can account for the different underlying assumptions associated with the two sources of data. This study also provides scenarios and hypotheses to be tested for the Maine lobster fishery. For example, lobster fishers expressed that v-notching, or protecting the spawning stock, may not be as important in the future as it was in the past. Using fishery simulations, this hypothesis can be tested. Compliance can be changing in other fisheries for regulations that are self-enforced and difficult to monitor. Scientists and managers in other fisheries should also consider changes in compliance caused by a change in resource status. Many other fisheries are facing changes in resource abundance due to high fishing pressure and a changing climate, so these fisheries may be facing changing conservation compliance as well.

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Data availability statement

Interview data are subject to IRB confidentiality restrictions, with some interviews and/or recordings available upon request from the second author.

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