

Are Greenland's inshore halibut fishers ready for individual transferable quotas?

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ABSTRACT

Fisheries policy that is comprehensible and agreeable to fishers is a cornerstone of democratic and inclusive governance of living marine resources. However, policy designers struggle to systematically include diverse perspectives and they may not understand the breadth and depth of fishers' knowledge about fisheries management and conservation. Failing to anticipate how reforms to management plans are received can spur policy rejection, distrust, and foster noncompliance. Knowing fishers' knowledge of, inclination toward, and vulnerability to proposed changes can help fishery managers design and implement inclusive and forward-thinking fishery management plans. In a representative survey of Greenland's inshore halibut fishers, we asked about current and proposed changes to the management of fisheries. From a response pool of experienced fishers, we found little to no knowledge about individual transferable quota programs, little to no inclination for or against these proposed changes, and a wide range of levels of vulnerability in the face of potentially curtailed access to fishery resources. Results suggest that fishers and fishery decision makers must increase the exchange of technical knowledge in understandable terms for Greenland's fisheries policy to achieve sustainability outcomes and to secure small-scale fisheries livelihoods. We recommend that policy makers increase outreach efforts to show fishers "under the hood", provide clear and accessible information, and seek suggestions and comments from fishers regarding proposed changes to the status quo. We further suggest that analysts conduct a transparent management strategy evaluation to model potential outcomes arising from any revised fishery management plan, fishing communities, and in turn, for Greenland's entire small-scale fishing segment.

1. Introduction

Fisheries policy that is comprehensible and agreeable to fishers is a cornerstone of democratic and inclusive governance of living marine resource [2,26,33,41]. However, policy designers struggle to systematically measure and include diverse perspectives [24,29]. Failing to anticipate how reforms to management plans are received can spur policy rejection, distrust, and foster noncompliance [28,31,35]. Knowing natural resource users' knowledge of, inclination toward, and vulnerability to proposed changes can help managers design and implement inclusive and forward-thinking natural management plans [13,25,40].

Greenland's inshore fishery for Greenland halibut (*Reinhardtius hippoglossoides*) is overcapitalized [46]. Historically, it has suffered from overharvesting in select areas, though length distributions of fish have stabilized or an stock status have improved [48]. To limit entrants and

reverse overcapitalization, The National Bank of Greenland [47], fishery economists advising the Government of Greenland [42], and the Fisheries Commission of Greenland [22] have proposed implementing individual transferable quotas (ITQs). ITQs convert resource access into a commodity that can be bought and sold, and ITQs are known to positively impact target species [8]. ITQ detractors argue that fishers and fishing communities are subject to disenfranchisement and expropriation of the resource under ITQ programs, and in particular, when quota is aggregated in the hands of a few [9,39,43]. They argue that fishers should be informed of the benefits and potential consequences [31,33]. Whether or not fishers or fishing communities are informed of the impacts, it has shown to be true empirically that ITQs can reverse overcapitalization and give rise to ecologically sustainable and profitable fisheries [7,15,19].

An ITQ is also thought to drive sustainable fisheries because one of its properties is as a contractual debt that can be collateralized [14]. One

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core recommendation from the Commission is to leverage the ITQ as a means of slowly harmonizing the biological advice with the total allowable catch. A total allowable catch that is locked to the biological advice by virtue of its use within an ITQ eliminates the possibility of the Government increasing the quota once it is fished up in a given season. A fishing quota becomes a monetary instrument when it becomes an ITQ. Because an ITQ can be collateralized, debt holders seek to ensure the value and integrity of that asset. Any party, including a government that manipulates the value of an ITQ is exposed to legal action by quota holders or third parties that hold ITQs as collateral, bonds, or other securities [5]. For these reasons, fisheries economists and fishery managers alike see the appeal of using the financial implications of an ITQ as a guarantor of a total allowable catch [18].

In 2022, we issued the Greenland Halibut Fishing Survey to all active inshore Greenland halibut fishers. The survey measured attitudes toward current and proposed changes to Greenland's management of Greenland halibut, resulting in a representative sample of responses from Greenland's halibut fishers ($n = 469$). These survey results were joined to each respondents' official catch landings records to evaluate fishers' knowledge, vulnerability and inclination toward those proposed changes.

1.1. Hypotheses

We hypothesized that fishers' knowledge, vulnerability, and inclination toward or against ITQs would explain their attitudes toward ITQs. Existing knowledge that informs our hypotheses are provided as footnotes. We hypothesized:

Knowledge¹:

- H₁ : The most ITQ-knowledgeable fishers are also the least vulnerable.
- H₂ : Fishers from towns are more ITQ-knowledgeable than fishers from settlements.
- H₃ : Fishers who earn the most are also the most ITQ-knowledgeable.

Preference or Inclination²:

- H₄ : Less vulnerable fishers are more inclined to support ITQs.
- H₅ : Higher earning fishers are more inclined to support ITQs.
- H₆ : High CPUE fishers are more inclined to support ITQs.

Vulnerability³:

- H₇ : Fishers in settlements are more vulnerable than fishers in towns.
- H₈ : ITQ skeptics are also the most vulnerable.

1.2. Survey design and distribution

The Greenland Halibut Fishing Survey was designed in autumn 2021 following the release of the Fisheries Commission's Report in July 2021. The Fisheries Commission was formed by the Government of Greenland to evaluate and recommend revision to Greenland's Fisheries Act of 1996, the legislation for Greenland's fishing activity [36]. The

Commission was tasked with drafting recommendations for Greenland's fisheries law with a view to ensuring the greatest possible long-term social benefit from fishing on a sustainable basis [22]. Following the recommendations and citing mixed opinions from Greenland's fisheries organizations and its members regarding those recommendations, then-Fisheries Minister Aqqaluk Egede declared that the Fisheries Commission Report was "not enough" to create a new fisheries law [34]. To clarify the Commission's recommendations and to elicit fishers' perspectives, the Fisheries Department hosted two in-person fisheries seminars in two locations in 2022, Nuuk and Ilulissat, Greenland, and live telecasted them on Facebook. Unlike the seminars, the survey was designed to systematically identify fishers' perspectives on current and proposed fishery management plans with a specific focus on Greenland's inshore Greenland halibut (*Reinhardtius hippoglossoides*) fishery. In addition, the survey served as an anonymous collection of perspectives among all halibut fishers without carrying the associations of politics or government in the collection of these perspectives, and to do so beyond the limited pool of seminar attendees.

In the design phase, we invited halibut fishery stakeholders⁴ to suggest questions and to offer input to the questions that would comprise the survey. The survey, drafted and issued using Qualtrics XM Online in 2022, was organized into sections, asking fishers to share information on their demography, their perspectives on the current halibut fishery, their perspectives on proposed changes to the halibut fishery based on the Fisheries Commission's recommendations [22], as well as an opportunity to provide feedback and to answer bonus questions.

The survey pool included all active (as of February 7 2022) inshore Greenland halibut fishing licensees who fish commercially within three nautical miles of Greenland's coast, resulting in a total sample of 1484 active licenses, of which 777 included contact information and 707 did not. The sample included dinghy, snow scooter, dog sledge, as well as larger inshore vessels targeting Greenland halibut. A contact list that included an anonymous numerical identifier was generated by Greenland Fisheries License Control Authority (GFLK). This anonymous numerical identifier allowed us later to anonymously join an individual survey response to an individual's fishing catch records. To protect human subjects and in accordance with definitions set forth by the Danish Data Protection Agency, the contact information as well as the catch records were anonymized by GFLK so that no natural person can be identified from the information or in combination with other information, in turn rendering this information not personal in nature [16, 17]. To further protect fishers, the anonymous numerical identifier was scrambled by the researcher and the key discarded, rendering the anonymization irrevocable.

The online survey was distributed using mobile phone numbers and emails assigned to each Greenland halibut license holder. We used an email inbox GHL@dartmouth.edu to distribute survey invitations that included a URL unique to each recipient. To ensure that email invitations were not overlooked and given that Greenlanders have on average more than one cell phone per person [52], the effective sample ($n = 777$) was also sent an invitation via SMS text with the same unique URL. An initial invitation, reminder, and final call notification were sent to the effective sample in Greenlandic, Danish, and English. Invitees were encouraged to participate with the prospects of winning gift cards to a country-wide general store (one of 18 DKK 500 and potentially one of 5 DKK 1800) in a raffle. The survey opened on 21st March 2022 and closed on 27th June 2022. Raffle prize winners were selected and notified on July 20th, 2022.

¹ Fishing populaces in settlements are known to be less educated and could be less knowledgeable. It is also known that Greenlanders with the largest incomes also tend to be the most educated, and could very well also be the most knowledgeable on ITQs [37,44,51].

² Fishers in other regions who are already effective, high earners and less vulnerable are more likely to espouse policies that would entitle them to greater revenues [11].

³ Labor markets in towns are known to be more diverse than in settlements, and household incomes tend to be smaller in settlements, so it is likely that fishers in these localities are more vulnerable when accounting for all vulnerability-related factors [38,51].

⁴ See appendix for full list of halibut fishery stakeholders whose opinions were solicited and who were given an opportunity to suggest questions and review researcher-drafted questions.

1.3. Landings Records

All commercial catch in Greenland must be landed and recorded with Greenland Fisheries License Control, resulting in the creation of comprehensive landings data of Greenland's inshore and offshore fishing activity. We received landings records from Greenland Fisheries License Control Authority with an anonymized numerical identifier for all inshore Greenland halibut fishing activity ($N = 892,508$). Greenland's landings records are organized in a normalized database, rendering them relational and appropriate to summarizing and in turn joining with an individual's response to the Halibut Fishing Survey. We constrained landings records to 2012–2022, and summarized for each license holder, including active and inactive licenses ($n = 2326$). Landings records were further constrained to the year 2021, allowing us to create summary statistics for a full year for all Greenland halibut inshore license holders.

2. Analytical Techniques

2.1. Nonresponse Bias Testing

Nonresponse bias is a possibility with every survey instrument, and if present, it may prevent researchers from suggesting that responses are representative of the overall sampled population. For example, if the fishers who responded to the Greenland Halibut Fishing Survey are different to those who did not respond, the survey responses cannot be considered representative. We did not receive survey responses from every fisher of the effective sample, and as a result, nonresponse bias was a possibility. We test for nonresponse bias by constraining the landings records (which were considered to contain the entire population of fishers) to observations to the year 2022 and comparing the survey population ($n = 346$) to the entire sample ($N = 816$) according to catch per unit of effort. Catch per unit of effort (CPUE) is a latent variable that serves as a proxy for a fishers' fishing performance. Catch per unit of effort is the quotient of landed catch and the time it took a fisher to harvest the catch, relative to how much gear was deployed to harvest said catch. Catch per unit of effort is an appropriate measure for evaluation because the current and proposed fishery regulations focus heavily on fishing performance and sustainability. We add precision to the estimate of CPUE by accounting the number of gears deployed. A CPUE for longlines is calculated as catch / 100 hooks / hour, and CPUE for gillnet fishing is calculated as catch / net / hour.

Fitting a generalized linear model (GLM) on a fisher's catch per unit of effort (kg landed fish/gear/hr) and a binary variable of whether the fisher completed the survey or not, we found that there was no significant difference between the performance of halibut fishers' who participated in the survey and those who did not ($p = .614$ for longlines and $p = .814$ for gillnets). However, a GLM fit to the postcode of fishers who did and did not complete the survey suggests a significant difference ($p = .001$). The response pool is skewed toward responses from Upernavik (3962, Uummannaq (3961), and Ilulissat (3952). These localities are also the all-time, top-three localities for numbers of halibut fishers. For these reasons, our data suggest that the survey responses are representative of the Greenland halibut fisher population in terms of fishing performance and come primarily from places known historically to be major inshore Greenland halibut fishing localities.

2.2. Knowledge, Vulnerability, Inclination Indices

To evaluate knowledge, vulnerability, and inclination, we create three indices. Each index draws upon variables from the Halibut Fishing Survey as well as official landings records. Indices allow us to provide a more holistic picture of factors that we argue are key to understanding changes to Greenland's halibut fishery policy. For each fisher, an index of their knowledge, vulnerability, and inclination toward ITQs is generated. We also aggregate fishers' indices at the locality-level to

facilitate locality-level analysis. We sum scores for each fisher, for each fishing locality, and across each index independently. Index scores for a fisher or fishing locality are fit together to test our hypotheses.

The goal of a knowledge index is not to ascertain a respondent's mastery of ITQs, but rather to estimate their grasp of the specific conditions, system properties, and related information that inform the design and execution of the ITQ management instrument recommended by the Fisheries Commission in their report. Taken together, ones' knowledge on these conditions, properties, and related information, such as the quota ceiling, quota allocation criteria, or familiarity with biological advice, estimate the level of familiarity or potential civil engagement a fisher could have within the policy design process. The Fisheries Commission report proposed a revised fisheries law with increased emphasis on biological sustainability, where a total allowable catch must not exceed amounts that can ensure long-term reproduction of the stock ([22]: p.7, p.11, p.17). The ITQ implemented in the Greenland halibut fishery will therefore reflect this sustainability requirement and biological advice is one cornerstone of this advice. Estimating a fishers' knowledge of biological advice helps us to understand their holistic appreciation of the proposed ITQ management instrument and how biological populations play a part of the ITQ.

Therefore, an index of *knowledge* is defined by the ability of fishers to correctly answer five questions about key conditions, system properties, and related information, on the proposed ITQ management plan and the information presented by the Fisheries Commission. The greater the quantity of questions the respondent answered correctly, the larger their score and in turn the estimate of their knowledge on the proposed ITQ management instrument. The smaller their score, the smaller the estimate of their knowledge of ITQs (see Table 1).

Vulnerability is defined as the risk of a fishers or a locality of fishers' inability to support themselves or their household if access to fishing were limited [4]. The risk of limited access is important to appreciate because exclusivity is one of the desired outcomes of ITQ programs [1, 20, 43]. The greater the vulnerability score, the more vulnerable the fisher, a fishing locality, or a municipality, is estimated to be, whereas the smaller the vulnerability score, the less vulnerable. The earnings with household income are used as a separate factor because we consider respondents with a low-income level as more vulnerable to economic change [3]. In addition, a high share of income from fishing makes a respondent more vulnerable independent of their absolute income level. We therefore include both factors separately. The vulnerability index is comprised of five characteristics: (Table 2).

We define *inclination* as an estimate of how inclined for or against ITQs and their characteristics a fisher or a fishing locality is. A fisher or fishing locality with a larger, positive inclination score is more inclined to support ITQs and the outcomes that arise from such programs. On the contrary, a fisher or fishing locality with a smaller, negative inclination score is comprised of fishers less inclined to support ITQs and expected outcomes. The inclination index consists of fishers' responses to several *Agree-Disagree* statements. Table 3 identifies how respondents are classified as either inclined or disinclined based upon their responses to the statements.

3. Results

3.1. Survey Results

The Halibut Fishing Survey received a response rate of 60%, or 469 recorded responses, 123 of which were opened but not filled out, resulting in 346 survey responses that were useful for analysis. Given that there was no significant difference between the survey pool and the entire population, what follows can be considered the representative perspectives of Greenland's active license holders for the inshore Greenland halibut fishery in 2021, including fishers that deployed net and longline gears upon dog sleds, snowmobiles, dinghies, and inshore vessels. The response pool was skewed right, having on average about 21

Table 1
Scoring criteria for the knowledge index.

Question Type	Question	Correct Answer	Score Assigned if Answered Correctly	Score Assigned if Answered Incorrectly
True/False	Inshore halibut fishing quota in area 47 has been more than 70% above biological advice in recent years	True	1	0
Agree/Disagree	A quota ceiling will prevent quota from leaving our town/settlement.	Disagree	1	0
Agree/Disagree	A quota ceiling will prevent a few persons/companies from owning all of the quota.	Agree	1	0
Fill in the blank (multiple choice)	A quota ceiling is ____.	the maximum percentage of the overall quota that a fisher is allowed to have the right to fish	1	0
Fill in the blank (multiple choice)	The Fisheries Commission recommended that quotas to halibut fishermen be allocated according to.	The best 3 years of fishing in the last 5 years.	1	0

Table 2
Scoring criteria for the vulnerability index.

Factor	Variable	Source	Score Range	Example	Justification
A fisher's mean catch per unit of effort (CPUE)	Catch (kg) / number of gears/ harvest time (hrs)	Landings Records	Bottom Quartile: 3 2nd Quartile: 2 3rd Quartile: 1 Top Quartile: 0	Fisher A, 5% percentile = score of 3 Fisher B, 95% percentile = score of 0	Fishers who are the least efficient are known to be more likely to exit ITQ fisheries
Mean price per kilo Earnings	DKK/kg Income (DKK)				Fishers who enjoy a higher kilo price or who earn more from fishing are more likely to sustain themselves in the face of decreased access to quota
Settlement or Town	Locality Type ^a	Landings Records	Settlement = 1 Town = 0	Fisher A (town) = 1 Fisher B (settlement) = 0	Labor markets in Greenland's settlements are thinner than in towns.
Fishing Income Share	% of household income from fishing	Survey	Bottom Quartile: 0 2nd Quartile: 1 3rd Quartile: 2 Top Quartile: 3	Fisher A (20% household income from fishing) = 0 Fisher B (95% household income from fishing) = 3	Fishers whose household incomes comprise more fishing are more vulnerable than those with diversified household incomes

^a In Greenland, a *town* has a population above 1000 inhabitants and a *settlement* has a population below 1000 inhabitants.

years of experience fishing commercially ($\bar{x} = 21.71$ years, $sd = 14.42$ years, $min = 1$ year, $max = 81$ years), stemming from generational experience fishing for 3.15 generations, on average. Most fishers have no crew, though 35% have at least one crew member ($n = 247$). On average, 68% of fishers' household income comes from fishing, which is conducted with very high levels of satisfaction with their jobs, their pay or compensation, job stability, standard of living, and their relationships with other fishers. Some fishers indicate an extremely bad (40%) or somewhat bad (23%) relationship with fishery biologists, and a somewhat good relationship (31%) or neither good nor bad relationship (38%) with the monitoring, control, and surveillance organization, Greenland Fisheries License Control Authority. Fishers indicate a mixed relationship with the Government of Greenland Fisheries Department, but they indicate somewhat good (49%) or extremely good (15%) relations with both local fishers associations and national fishers associations (32% and 14%, respectively).

73% of fishers do not trust the biological advice for Greenland's Greenland halibut fish stocks ($n = 225$), with 60% also disagreeing that the length of halibut are smaller than they were ten years ago. Despite disagreeing with recorded biological facts on Greenland halibut fish stocks, most accept the fact that the quota for Greenland's largest halibut fishing area, the Disko Bay, has been more than 70% over the biological advice [22]. Attitudes on current regulations are mixed, but responses to proposed regulations were counter to what we expected. Given public debates around ITQ, we presented fishers with two options of scenarios that they could encounter under the current or proposed fishery. Option A was a fishery with a total allowable catch, as it is currently managed, also known as an Olympic Fishery. Option B was a

fishery operating with a total allowable catch but under an ITQ management plan. Over 45% of fishers chose the Olympic Fishery, with 27.6% choosing neither option, and 27% choosing the ITQ. An ITQ offers stability, increased kilo prices of fish, a larger overall quota size, and other benefits, but fishers did not select the option with the properties most commonly associated with an ITQ. Recognizing the surprising minority preference for an ITQ, we sought to evaluate their knowledge and inclination more holistically.

3.2. Index of Vulnerability, Knowledge, and Inclination

We found that fishers have a wide range of vulnerability to changes to their access to fishing (See Fig. 1). Fishers in both East and West Greenland are amongst the most vulnerable. Despite settlements having thinner labor markets and more reliance upon fishing activity than fishers living in towns, we found that fishers in settlements were no more vulnerable in aggregate to fishers in towns. However, within both towns and settlements there reside Greenland halibut fishers with acute levels of vulnerability, and some localities are more vulnerable than others (See Table 4). We therefore reject the null hypothesis that fishers in settlements are more vulnerable than fishers in towns (H_7). Instead, fishers in both types of places are vulnerable. We found no systematic relationship between a fishers' inclination toward ITQs and their vulnerability ($p = .333$), thus rejecting the null hypothesis that ITQ skeptics are also the most vulnerable (H_8).

The index for inclination toward or against ITQs suggests that fishers are neither inclined nor disinclined to support ITQs. Specifically, results suggest that there is no relationship between vulnerability and

Table 3
Scoring criteria for the inclination index.

Statement	Classification	Scoring (ITQ Inclined)	Scoring (ITQ Disinclined)
"We need ITQs to encourage ineffective fishers to sell their quota and exit the fishery."	ITQ Inclined Statements	Somewhat agree = 1 Strongly agree = 2	Somewhat disagree = -1 Strongly disagree = -2
"Fishers who sell their quota and exit the fishery will find other ways to make an income."			
"I am not worried about having to sell my quota and exit the fishery."			
"If we implement ITQs, inshore halibut fishing will become like the shrimp fishery where a few companies own all of the quota."	ITQ Disinclined Statements	Somewhat disagree = 1 / Strongly disagree = 2	Somewhat agree = -1 / Strongly agree = -2
"Every Greenlandic person should have the opportunity to fish commercially, even if they cannot do so profitably."			
"Halibut fishermen from outside of my settlement/town will buy up the halibut quota in my town, resulting in very few in our town/settlement with quota to fish for halibut."			

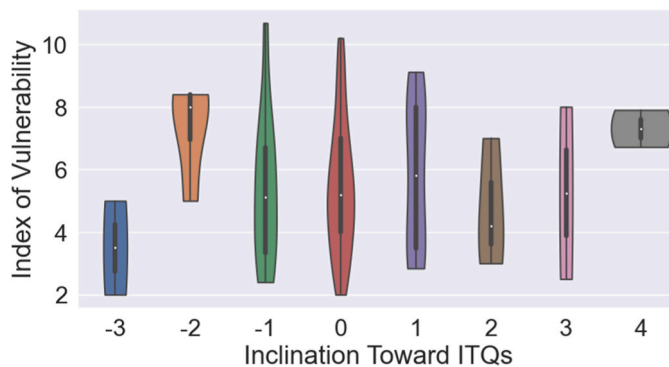


Fig. 1. Violin plot of vulnerability and inclination depicting no systematic differences between ITQ inclination and vulnerability.

Table 4
Abbreviated list of survey-participating individuals from localities identified as most and least vulnerable, with rank number.

Most Vulnerable	Least Vulnerable
1. Qaanaaq	32. Paamiut
2. Sermiligaaq	31. Ikerasak
3. Qeqertat	30. Kangerluk
4. Aasiaat	29. Nuuk
5. Upernavik Kujalleq	28. Uummannaq
6. Kangarsuatsiaq	27. Ukkusissat

inclination (H_4) ($p=.626$), and specifically, that less vulnerable fishers are no more inclined to support ITQs than more vulnerable fishers (H_5) ($p=.240$). When evaluating fishing performance and earnings, there is

no evidence that higher or lower earning fishers ($p=.13$) or higher or lower performing fishers are more or less inclined to support ITQs (H_6) ($p=.221$). Instead, inclination scores tend to be near to zero, suggesting that fishers have little to no inclination or preference on ITQs.

The index for knowledge suggests that fishers are not knowledgeable about proposed changes to how Greenland halibut would be managed. We reject the null hypothesis that the most knowledgeable are the least vulnerable (H_1), and that high CPUE fishers are more inclined to support ITQs (H_6). In contrast, there is no significant difference in knowledge levels between fishers from towns or settlements (H_2), between the largest and the smallest earnings (H_3), nor between the most and least vulnerable (H_7). Instead, knowledge, or lack thereof, is a prevalent feature amongst all these grouping variables. (Fig. 2).

4. Discussion

We rejected the null hypothesis for all eight of our hypotheses, suggesting that the fishing populace has a lack of knowledge on the topics. Our results also suggests that the knowledge deficit is not clustered within any segment of the fishing populace. In turn, the demonstrated lack of knowledge about proposed changes to Greenland's inshore halibut fishery raises a central question: why is it even important for Greenland's small-scale inshore Greenland halibut fishers to understand the technical minutiae of fishery management plans? Can these details not just be left to managers and analysts?

Whether it matters depends upon what civil society expects to be the level of involvement in the policy process, and if detailed knowledge is a prerequisite for democratic fisheries policy. For Greenland's fishers, unfortunately in this case of these results, but fortunately for an informed fishing populace, historically high levels of engagement between fishers and governors is a hallmark of Greenland's fishery management [27,29,30,49]. Globally, small-scale fishers participate in the management of their fisheries resources [2,12,50], and involvement is more common following calls from the UN and other major fishery organizations to support interactive governance [2,21]. Interactive governance refers to a type of control that considers social values, local knowledge, and ethical principles [32]. Importantly, interactive governance does exactly what it suggests: engaging civil society in the process of governing. For these reasons, revising Greenland's inshore halibut fishery with knowledge of the options and proposed changes also presents an opportunity for Greenland to set an example for world-class, progressive fisheries policy. Policy design that recognizes knowledge deficits and addresses these deficits through further analysis and information campaigns can enable democratic fisheries policy.

Results from the survey suggest that inshore Greenland halibut fishers have job stability, satisfactory work, and a cooperative work environment, which sets a high standard for all proposed actions to reform how the fisheries are managed in the segment. To enjoy broad

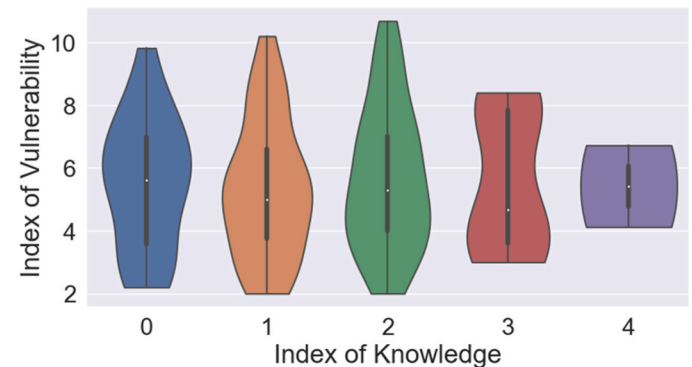


Fig. 2. Violin plot depicting no systematic difference between knowledge and vulnerability indices. The greater the vulnerability value, the more vulnerable. The greater the knowledge value, the more knowledgeable.

support for a proposed Fisheries Law will require concrete, defensible recommendations that are understood by the fishery managers, lawmakers, and the public alike. These recommendations must recognize that some localities are home to more vulnerable fisher households than others (See Table 4). These localities require policy conditions that recognize fishers' vulnerability to propose changes to their access to the fishery. Meeting these goals will be especially challenging, given that recent stock assessments have shown a modest improvement to the standing stock biomass, in turn increasing the total allowable catch, and in turn giving the impression that business as usual may suffice [23].

Our results suggest that decision makers will need to explain why business as usual is not sufficient and clarify that their proposed changes would not leave vulnerable fishers even worse off (See Table 4). It is therefore essential that proposed changes not only maintain these current standards while also delivering on sustainable and profitable fisheries, but that the changes themselves are understood and accepted by resource users. Despite having a comprehensive lived experience in the fishery as evinced in the years of experience of the survey respondents, fishery decisionmakers must increase the knowledge base on proposed changes. This technical knowledge specific to the proposed ITQ program is especially important for differentiating it from a controversial ITQ program implemented in Greenland's shrimp fishery in the late 1980's and early 1990's [29].

Survey results suggest that fishers have significant years of experience and in turn a steadfast commitment to the segment, but their knowledge of key technical measures appears to be lacking. Survey results suggest that no municipality is especially knowledgeable or not. Instead, the knowledge base on these specific management instruments is low across the response pool. One interpretation would be to say that fishers are not knowledgeable and that would be correct, but what are they lacking knowledge on? As it has been suggested in other natural resource management settings, there may be an epistemological mismatch between fishers and governors, with some espousing the introduction of traditional ecological knowledge (TEK), local ecological knowledge (LEK), or indigenous knowledge (IK), into the policy process [6,27,53]. Including TEK, IK, or LEK as such is not a panacea to this epistemological mismatch, especially in a country like Greenland where many fishery decision-makers are themselves indigenous, where "tradition" is predicated upon fisher engagement, and where local knowledge has historically been directly shared with fisheries ministers [29].

Instead, we suggest that fishery managers consider showing and explaining the decision process for the new Fisheries Law, and specific programs, such as the ITQ program for Greenland's inshore small-scale fishery for Greenland halibut. Doing so will instill trust and can identify fishery manager blindspots in the management plan design. That said, explaining a management plan in clear, easy-to-understand terms is an art and a skill. Managers who can tell stories about changes with visual aids, with numbers, and with widely accessible literary devices are poised to convey that information, bring more diverse minds into the discussion, and ultimately create the healthy debate that is necessary for democratic fisheries policy.

Secondly, and as a part of the knowledge sharing and knowledge co-production process, fishery managers should show and explain to fishers how exactly the proposed changes will affect them, their peers, and their fishing communities. The Fisheries Commission Report offered some scenario analysis, but it lacks transparency on methods and assumptions. Quantifying the uncertainty in each scenario, including all model assumptions, and running scenarios on management instruments beyond ITQs and IQs would fortify the trust that decision makers have in subsequent actions that they take on behalf of the fishing populace. Having a peer-review of these scenarios would increase confidence in the potential outcomes.

Conducting a management strategy evaluation of the Fisheries Commission's recommended framework for the ITQ program could provide more clarity and a more robust methodology for modeling

potential outcomes. A management strategy evaluation (MSE) is the process of modeling management plans or scenarios using empirical data to estimate the range of possible outcomes that would arise under any given management plan [10,45], with explicit mention of uncertainty and other model assumptions. MSE's can help fishery managers and the fishing populace alike understand and select which proposed strategies are appropriate for managing fisheries.

Using the recommended framework from the Fisheries Commission and the latest official catch records and responses from the Halibut Fishing Survey can identify how quota would be distributed differently under such a program. Catch records would allow researchers to scrutinize the proposed allocation framework for the ITQ program. It would allow researchers to estimate how much quota each individual could receive, how this quota would compare to their historic harvesting, and how their earnings would change. Importantly, catch records could also allow researchers to identify the minimum and maximum amounts of revenues that fishers, fishing communities, and municipalities can expect under this program. An MSE would serve as a pre-implementation audit, and it could not only show fishers how quota would be allocated and distributed, but it would also allow decision makers to estimate levels of future job satisfaction, job stability, and contributions to household incomes, among other factors. Crucially, a management strategy evaluation of the proposed ITQ program would allow decision-makers to identify individuals, localities, and municipalities that are unintentionally disadvantaged (if any) by an ITQ program and initial allocation.

In conclusion, our results suggest that there is no significant difference in knowledge, inclination toward ITQs, or of vulnerability between towns and settlements, nor between high and low earner quantiles, with a low level of knowledge in towns and in settlements. The high-level interpretation of this result is that all localities should be given the same level of attention communicating the current and proposed changes. However, there appear to be fishers both in towns and in settlements who are especially vulnerable if their access to fishing were to decrease under any revised fishery management plan. We encourage decision-makers to systematically identify these fishers and fishing communities and their associated socio-economic characteristics. Equipped with this information, managers can exercise foresight to support or protect them from household financial headwinds that may arise under a change to the current fishery management plan. A management strategy evaluation would identify unintentionally disadvantaged individuals or fishing communities, and together with fishers and fishery decision makers, managers could revise the management plan to build in protections for the vulnerable, ultimately creating a just, progressive, and inclusive small-scale fisheries policy.

The fishers' knowledge deficit sets a clear goal for improving and in turn achieving democratic and inclusive governance of living marine resources. However, knowledge itself is not the end goal; instead, fishers and fishery decision makers must leverage this knowledge to create a highly informed, transparent, and progressive fisheries policy. Greenland is already poised to deliver on this goal. The results of the survey suggest that fishers cannot at present make an informed decision on ITQs, and they should not have to without a baseline of knowledge on the proposed management instrument. Instead, fishery managers must take responsibility for the design of ITQs by exercising foresight for the social and economic outcomes that will arise from implementing an ITQ across Greenland's inshore small-scale fishery, and by sharing those projected outcomes with all fishers and considering the feedback before implementation of ITQs. Sharing in the process, Greenland can expect an efficient and interactive change of course to its inshore halibut fisheries, and in the near term, the design of a progressive fisheries policy.

Protection of human subjects and data protection and privacy

The authors declare that all study materials and procedures were reviewed and approved by Dartmouth College Committee for the

Protection of Human Subjects (CPHS). The authors hold a Study Agreement with Greenland Fisheries License Control Authority (GFLK) to anonymously extract and access official catch records and contact information of active fishing license holders. All actions set forth in the study comply with Datatilsynet Danmark (Danish Data Protection Authority) and Greenland's Personal Data Act. All data accessed and used are nonpersonal.

Software and reproducibility

We evaluated Halibut Fishing Survey responses and accompanying landings records in RStudio 2022.07.1 Build 554, "Spotted Wakerobin" Release (7872775e, 2022–07–22), Stata Version 17, and using Python version 3.10, Pandas Version 1.5.1, with Visual Studio Code for Mac. All analyses are reproducible, and data can be provided by the author upon reasonable request.

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Author statement

The authors have no competing interests to declare.

Declaration of competing Interest

The authors declare that they have no conflicts of interest.

Data availability

Data will be made available on request.

Appendix A

Name	Title and Organization	Reviewed Questions	Suggested Questions
Jens Paulsen	Chair, Fisheries Commission, CEO Arctic Law Greenland	✓	✗
Rasmus Hedeholm	Fishery Scientist / Project Manager, Sustainable Fisheries Greenland	✓	✗
Mads Nedergaard	Special Advisor, Former Chief, Greenland Fisheries License Control Authority (GFLK)	✓	✗
Martin Schiøtz	Special Advisor, Ministry of the Environment	✓	✗
Tønnes 'Kaka' Berthelsen	Operations Chief, Royal Greenland and Former CEO, KNAPK	✓	✗
Katrine Kærgaard	Head of Section, Fisheries Department	✓	✗
Sissel Fredsgaard	Academic Officer, Fisheries Department	✓	✗
Ole Ulloriaq Lønberg-Jensen	Academic Officer, Fisheries Department	✓	✗
Magnus Thun Hansen	Academic Officer, Greenland Fisheries License Control Authority	✓	✗
Iben Funch Døj	Academic Officer, Fisheries Department	✓	✗
Erik Lange	Director, (SQAPK) The Organization in Near Coast Greenland for Fishermen and Hunters	✓	✓
Bjarne 'Ababsi' Lyberth	Biologist, KNAPK	✓	✗
Akara Skifte	Consultant, KNAPK	✓	✓
Signe Bork Hansen	Academic Officer, Greenland Fisheries License Control Authority	✓	✓

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