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Original Article

Exploring diversity in expert knowledge: variation in local ecological knowledge of Alaskan recreational and subsistence fishers

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Local ecological knowledge (LEK) of resource users is a valuable source of information about environmental trends and conditions. However, many factors influence how people perceive their environment and it may be important to identify sources of variation in LEK when using it to understand ecological change. This study examined variation in LEK arising from differences in people's experience in the environment. From 2014 to 2016, we conducted 98 semi-structured interviews with subsistence fishers and recreational charter captains in four Alaskan coastal communities to document LEK of seven fish species. Fishers observed declines in fish abundance and body size, though the patterns varied among species, regions, and fishery sectors. Overall, subsistence harvesters provided a longer-term view of abundance changes compared with charter captains. Regression analyses indicated that the extent of people's fishing areas and their years of fishing experience were relatively important factors in explaining variation in fishers' perceptions of fish abundance. When taken together, perspectives from fishers in multiple regions and sectors can provide a more complete picture of changes in nearshore fish populations than any source alone. These findings underscore the importance of including people with different types of expertise in local knowledge studies designed to document environmental change.

Keywords: abundance change, Pacific halibut, perceptions, recreational fishing, rockfishes, subsistence, salmon

Introduction

For decades, scholars have emphasized the importance of local ecological knowledge (LEK) to the understanding of marine ecosystems (Johannes *et al.*, 2000; Hind, 2014) and many have called for incorporation of LEK of resource users into natural resource science and management (Neis *et al.*, 1999; Huntington, 2000; Ban *et al.*, 2017). A considerable body of research has focused on using LEK to understand historical trends and patterns in the environment (Neis *et al.*, 1999; Huntington, 2000; Raymond *et al.*, 2010; Thornton and Scheer, 2012). For example, LEK has been used for environmental monitoring (Moller *et al.*, 2004; Brook and McLachlan, 2008), understanding historical patterns of fish abundance (Anadón *et al.*, 2009; Hallwass *et al.*, 2013), identifying ecologically important areas (Bundy and Davis, 2013), and as an indicator of emerging environmental trends (Azzurro *et al.*, 2011).

Although there can be substantial differences between LEK and scientific knowledge, they are often complementary, together providing a more complete understanding of ecological change than either source alone (Huntington *et al.*, 2016; Thurstan *et al.*, 2016). LEK can offer both qualitative (e.g. resource "health", direction of change) and quantitative information about ecosystems. In this article, we focus on quantitative aspects of LEK specific to fisheries, where a growing body of research is aimed at developing tools to gather and analyse quantifiable information from fisher interviews for use with scientific data (Close and Brent Hall, 2006; Beaudreau and Levin, 2014; Léopold *et al.*, 2014; Tesfamichael *et al.*, 2014; Figus *et al.*, 2017). A key feature of these approaches has been to identify sources of variation in LEK that arise from differences in people's experience in the environment (e.g. Verweij *et al.*, 2010). Additionally, researchers have made varied and sometimes contradictory suggestions regarding how local experts ought to be identified (Davis and Wagner, 2003; Davis and Ruddle, 2010; Hitomi and Loring, 2018). For example, some authors suggest stratified sampling for participant characteristics such as age, fishing experience, and frequency of harvest prior to gathering LEK data (e.g. Bundy and Davis, 2013). Others note the importance of not allowing preconceptions about these characteristics to marginalize important voices and sources of knowledge (e.g. Hitomi and Loring, 2018).

Myriad factors can influence how local experts perceive their environment (Loring *et al.*, 2014). For example, fishers' perceptions of fish abundance changes can vary among individuals of different ages or durations of harvesting experience (Ainsworth *et al.*, 2008; Beaudreau and Levin, 2014). Beaudreau and Levin (2014) found that older fishers perceived greater declines in rockfishes over their lifetimes compared with younger individuals, consistent with the "shifting baseline syndrome" described by Pauly (1995). Therefore, characterizing potential sources of variation in LEK among groups of harvesters is important for interpreting ecological information derived from fishers' knowledge. Additionally, understanding how the temporal and spatial scales of LEK vary among groups of harvesters can aid in designing studies aimed at using fishers' knowledge to infer ecological change.

Here, we documented LEK of fish body size and abundance for seven harvested species in Alaska. Our objectives were to (1) quantify trends in body size and abundance since the 1980s for seven commonly fished species in Alaska with limited information on nearshore populations; and (2) evaluate variation in fisher perceptions of abundance changes related to attributes of their fishing experience. Using interview data from two geographic regions (Southeast and Southcentral Alaska) and two fishery sectors (recreational charter and subsistence), we evaluated the hypothesis that fishers' perceptions of fish populations may vary with attributes of their fishing experience, such as geographic region, sector, years of experience, and spatial extent of fishing. This hypothesis reflects an understanding of ecological knowledge based on information theory; for example, people's perceptions of environmental change may be influenced by characteristics of their information environments, such as the duration of their experience or spatial scale of observation (Verweij *et al.*, 2010). We acknowledge that this framing primarily considers experiential knowledge of resource users and does not consider other important dimensions of knowledge systems. For example, scholars have noted that knowledge systems, especially indigenous ones, are not limited to direct experience but also incorporate concepts and information that are imparted or revealed, as through oral histories, dreams, and intuition (Castellano, 2000).

Methods

Interviews with resource users

This study defines LEK following Huntington (2000), as "knowledge and insight acquired through extensive observation of an area or a species." From 2014 to 2016, we conducted 98 semi-structured in-person interviews to document LEK of subsistence harvesters and recreational charter fishing captains who target Pacific halibut (*Hippoglossus stenolepis*, hereafter 'halibut') in Alaska, under federal subsistence or charter regulations, respectively. These sectors were chosen because they fish in nearshore locations and target multiple species alongside halibut, yet they differ in how they are managed, their motivations, and their fishing practices. For example, charter captains target fish with customers and fish almost daily during the summer months using hook and line gear. In contrast, subsistence harvesters target fish for food or sharing with others. They typically fish less frequently than charter captains but do so throughout the entire year, and can use both rod and reel and setline gear. However, the two groups are not mutually exclusive and individuals who actively participated in both sectors were asked to respond to questions relevant to the sector with which they most strongly identified.

Since 2003, fishers participating in the federal subsistence halibut sector must qualify as a recognized rural resident or tribal member to register for a Subsistence Halibut Registration Certification (SHARC) through the National Oceanic and Atmospheric Administration (NOAA) (50 CFR 300). The communities of Gustavus, Hoonah, and Sitka in Southeast Alaska (Figure 1) were chosen as study communities because they have substantial participation in the subsistence halibut sector and have subsistence halibut participants with both tribal and rural subsistence halibut designations (Fall and Koster, 2014). Individuals who qualify for both tribal and rural designations (i.e. tribal member who live in a rural community) may choose which SHARC to apply for, thus, the two categories are not mutually exclusive. Due to the complexities of the tribal and rural designations, the published information on SHARCs (Fall and Koster, 2014) was used solely to identify that tribal and rural participants resided in the study communities. Our study did not verify SHARC status, rather the sampling frame for subsistence harvesters consisted of individuals who self-identified as harvesting halibut for subsistence uses and with primary residences in Gustavus, Hoonah, or Sitka in Southeast Alaska (Figure 1). Interviewees were recruited through community and government organizations, including the Sitka Tribe of Alaska and the Hoonah Indian Association.

The sampling frame for charter captains consisted of individuals who target halibut as part of their charter operation and whose boat operates out of Homer in Southcentral Alaska or Sitka in Southeast Alaska (Figure 1). These communities were chosen because there is a high concentration of charter fishing businesses in each location (Lew and Seung, 2010). Participants were recruited through newsletters from the Alaska Charter Association, Homer Charter Association, Southeast Alaska Guides Organization, and Sitka Charter Boat Operators Association. Project introduction letters were also mailed to the list of charter halibut permit holders in Homer or Sitka in 2014.

Additional participants from both sectors were identified using snowball sampling (Bernard, 2006), in which interviewees recommend knowledgeable individuals to participate. Prior to starting each interview, we reviewed the written consent form with the interviewee. The consent form identified the benefits and risks of the study, confidentiality, reporting requirements, and ways to contact the research team. Each participant was encouraged to ask questions and discuss any of their concerns. If they wished to proceed with the interview, the interviewee and researcher

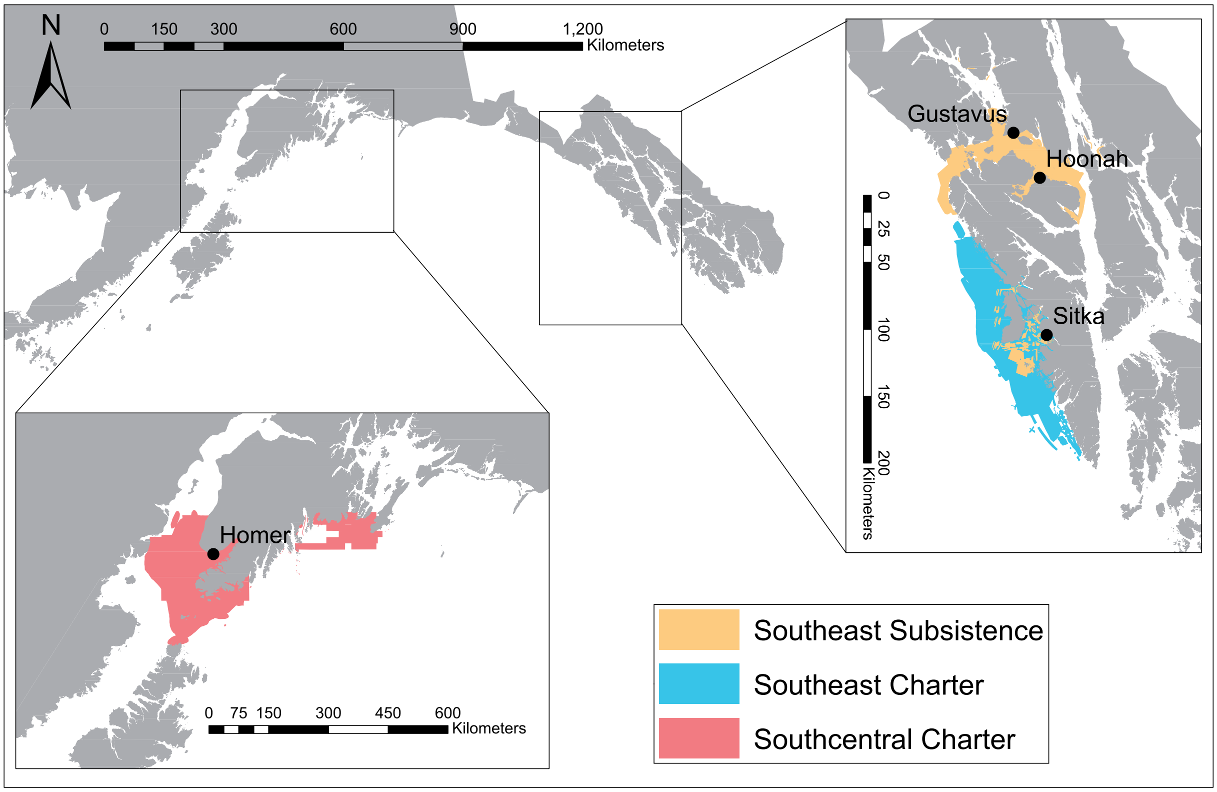

Figure 1. Map of study locations and the spatial extent for each sector's fishing locations for Pacific halibut, lingcod, and rockfishes.

signed two copies of the written consent form. One signed copy was given to the interviewee and the second signed copy was kept by the research team. The research was reviewed and approved by the University of Alaska Fairbanks Institutional Review Board (protocols 583323 and 601393).

During the interviews, interviewees were asked to report abundance levels and body size for halibut, Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), lingcod (*Ophiodon elongatus*), yelloweye rockfish (*Sebastes ruberrimus*), black rockfish (*S. melanops*), and Pacific cod (*Gadus microcephalus*, hereafter cod). Our methods for documenting fishers' perceptions of abundance and size patterns followed those of Ainsworth *et al.* (2008) and Beaudreau and Levin (2014). To summarize, participants were asked to classify the relative abundance and body size of each focal species for each decade in which they had fished, from the 1960s to the 2010s. For charter captains, the 2000s were split into 5-year periods instead of decades because some individuals wished to provide higher temporal resolution for recent years. Interviewees were asked to base these judgments of abundance and size on their observations and to skip species or periods for which they had insufficient knowledge.

Interview participants were asked to classify relative abundance in each decade (or 5-year period) according to seven categories: very high, high, medium-high, medium, medium-low, low, very low (Supplementary material). Relative body size of each focal species, defined as the average or typical range of sizes observed (retained and released), was classified according to three categories: large, medium, small (Supplementary material). For every species, respondents were asked to provide the approximate size range (length or weight) associated with each size category, e.g. 30–55 lb (13.6–24.9 kg) for a "medium halibut." Reported lengths were converted to weight using species- and region-specific length-weight regressions (S. Meyer, pers. comm.). Responses were collected in imperial units and were converted to metric units prior to analysis. Individuals may conceptualize fish abundance or size based on their own experiences and background (i.e. their information environment), so abundance and size categories reported by individuals are relative to their own baselines. Individuals may perceive and interpret absolute abundances differently (i.e. "medium" abundance to one person is "high" abundance to another; Beaudreau and Levin, 2014); thus, our statistical analyses (described below) were designed to assess the overall direction of ecological change observed among interviewees and potential sources of variance among individuals due to attributes of their fishing experience.

Fishers were also asked to provide basic demographic information and information on attributes of their fishing experience. These included gear types used, spatial locations of fishing, their age, total years of fishing experience, and average number of days fished per year. Fishers were also asked to draw areas on paper charts delineating their fishing areas for each target species or species group (Chan *et al.*, 2017). Maps were aggregated across individuals and displayed at a coarse resolution (1.5 km by 1.5 km grid cell) to protect the confidentiality of interviewees and respect the sensitive nature of fishing locations.

Analysis of body size and abundance changes

Distributions of sizes reported by interviewees were visualized with histograms showing the frequency of size observations in each of 30 bins of equal width. Fishers commonly reported a range of sizes, rather than one discrete size, for each species. When a size range was given, an observation was recorded for each bin covered by that range. For example, if an interviewee reported a typical halibut caught in the 1990s as 10–20 lb and the bin width for halibut was 5 lb, then the response would be assigned to the two bins spanning the reported range, i.e. 10–15 and 15–20 lb). Median size was calculated from the binned observations for each species, period, and sector after conversion to metric units. We used Kolmogorov–Smirnov (K-S) tests to statistically compare the size distributions between time periods for each species, region, and sector.

Categorical abundance levels were converted to integers from 1 to 7 (i.e. very low = 1, very high = 7). Abundance changes over time were visualized as boxplots showing the distribution of abundance scores across respondents, separately for each species, region, and sector. Abundance change per decade was estimated as the slope coefficient of the linear regression fit to each fishers' time series of abundance indices for a given species.

Analysis of variation in LEK of abundance

We used linear regression to evaluate whether variation in perceived abundance changes among individuals could be explained by where they fish, the extent of their fishing area, their fishing sector, and how long they have been fishing. A set of candidate models was determined a priori, representing alternative hypotheses about factors that might explain variation in fishers' perceptions of relative abundance changes. The response variable was abundance change per decade, as described above. The binary categorical variable *sector* was selected as a potential predictor because subsistence harvesters and charter captains differ in their fishing characteristics, such as gear type and frequency of harvest. The categorical variable *city* was selected to account for regulatory, socioeconomic, and environmental differences among communities that were not captured by other variables. The variable *total fishing area* was selected because spatial fishing patterns can differ between groups (Chan *et al.*, 2017). Total fishing area (km^2) was calculated for each interviewee as the total area used to target halibut, which encompasses areas used to target other species, based on digitized, georeferenced maps derived from participatory mapping (see Chan *et al.*, 2017). The variable *years of fishing experience* was selected to account for the potential framing bias, sometimes termed the "shifting baseline syndrome" (Pauly, 1995), in which an individual's perception of environmental change is relative to the state of the environment observed at the start of his or her own lifetime. All unique linear combinations of these four predictors, including the null model, were evaluated, resulting in 16 models for each of the seven species.

Akaike's Information Criterion, bias corrected for small sample size (AICc; Burnham and Anderson, 2002), was used for model selection. The ΔAICc was calculated for each model as the AICc minus the lowest AICc for that species' set of models. Models with lower ΔAICc were determined to be a stronger fit; however, models with ΔAICc within 2 of the lowest AICc were considered equivalent (Burnham and Anderson, 2002). The Akaike weight (w_i) was calculated for each model and is interpreted as the probability that a given model is the best fit to the data among the set of candidate models (Johnson and Omland, 2004). Akaike weights sum to 1 across all candidate models for a species and the closer w_i is to 1, the greater the weight of evidence in favour of that model (Burnham and Anderson, 2002). We calculated parameter weights for each of the predictor variables, in which w_i was summed across all models in the set that included the predictor variable for a given species. The closer the parameter weight is to 1, the greater the importance of that variable in predicting the response across the set of models (Burnham and Anderson, 2002). Statistical analyses were performed in R (R Core Team, 2016).

Table 1. Characteristics of interviewees in two fishery sectors (subsistence and charter) within two regions (Southeast and Southcentral Alaska).

	Charter Southcentral	Charter Southeast	Subsistence Southeast
Number of fishers			
	18	27	45
Years of fishing experience			
Mean (±SD)	22 (9)	13 (8)	26 (18)
Range (min − max)	2–34	3–34	1–72
Total fishing area for Pacific halibut (km^2)			
Mean (±SD)	3826 (3769)	485 (673)	145 (362)
Range (min − max)	559–12 222	37–2 909	1–2142
Age			
Mean (±SD)	55 (14)	40 (11)	52 (13)
Range (min − max)	31–76	24–62	28–75

Results

We interviewed 45 subsistence fishers in the communities of Gustavus ($n = 16$), Hoonah ($n = 17$), and Sitka ($n = 12$), and 45 charter captains in Homer ($n = 18$) and Sitka ($n = 27$). On average, subsistence fishers were older and had more years of fishing experience than charter captains (Table 1). These sample sizes are comparable to other studies of fishers' LEK and sufficient to characterize trends and variance in LEK among respondent groups (Beaudreau and Levin, 2014; Figus *et al.*, 2017). Although we asked participants to provide their gender, we did not explore gender in the analysis because only seven women were interviewed.

Temporal changes in body size

Charter captains observed declines in halibut size, with the median fish size in Southcentral decreasing from 30 kg in the 1990s to 10 kg in the 2010s and in Southeast decreasing from 40 kg in the 1990s to 20 kg in the 2010s (Figure 2). In the 1990s, histograms for both charter groups were right skewed and interviewees' observations of typical halibut sizes ranged from <0.5 to 136 kg. By the 2010s, tails of the histograms for both charter groups were truncated and respondents' observations of average halibut sizes ranged from <0.5 to 91 kg. Based on a K-S test, the size distributions differed significantly between the 1990s and 2010s for Southeast charter captains ($D = 0.32$, $p = 0.002$) and Southcentral captains ($D = 0.48$, $p < 0.001$; Figure 2). Median halibut size observed by subsistence harvesters remained relatively stable at 15–20 kg from the 1980s through the 2010s, as did the size distribution overall ($D = 0.07$, $p = 0.99$; Figure 2).

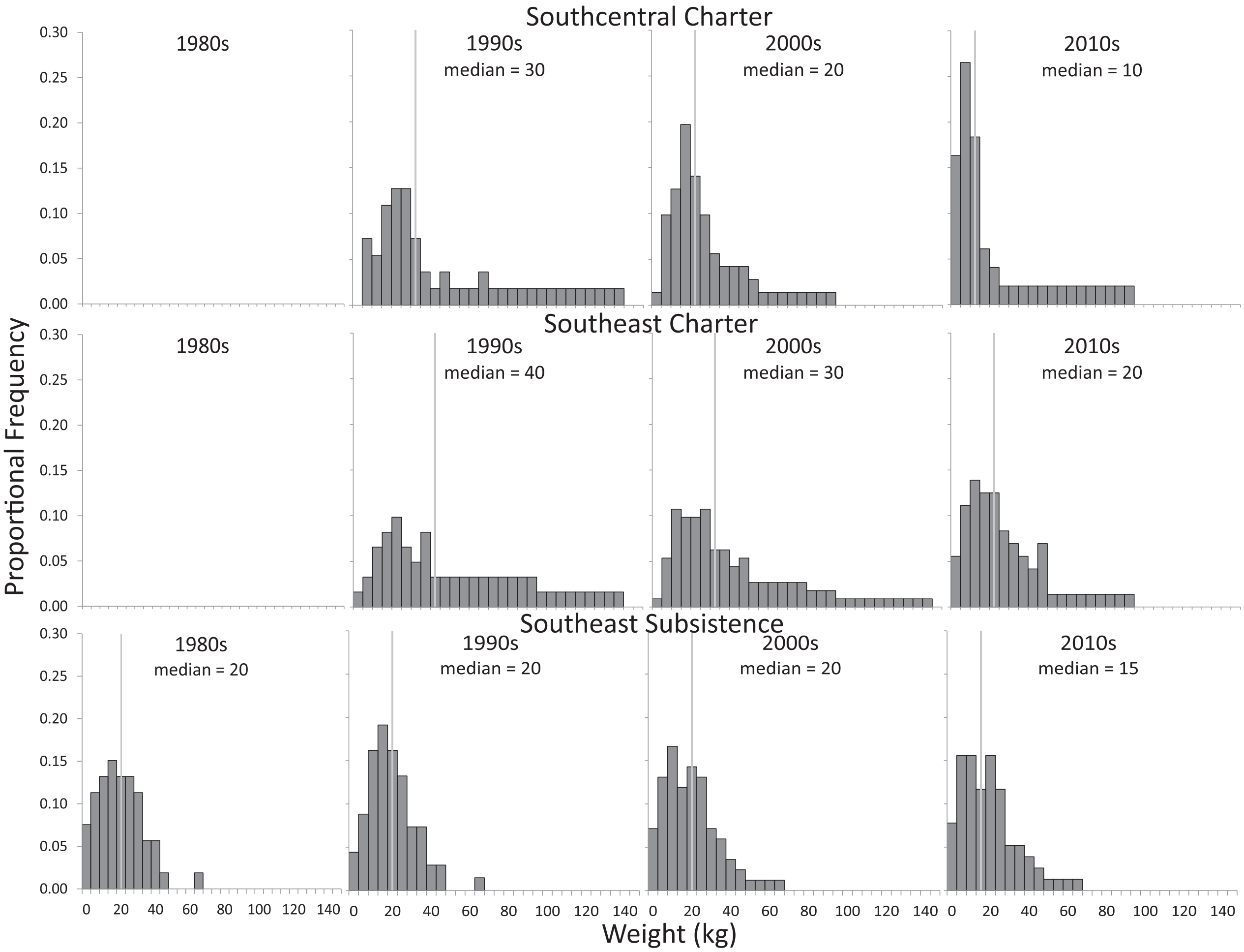

Figure 2. Reported average sizes (kg) for Pacific halibut by decade and sector group. *Y*-axis is in proportional frequency, which shows the percentage of responses in that size class for that decade and sector group. Vertical grey lines indicate median fish size. Decade and sector group combinations in which there were fewer than three responses are not shown.

For Chinook salmon, all three sectors observed a decline in median size from the 1990s to 2010s, with charter captains observing declines from 10.8 to 7.2 kg and subsistence fishers observing declines from 10.8 to 7.2 kg (Figure 3). Size distributions differed significantly over this period for all sectors (Southcentral charter captains: $D = 0.29$, $p = 0.02$; Southeast charter captains: $D = 0.41$, $p = 0.002$; subsistence harvesters: $D = 0.29$, $p = 0.04$; Figure 3). For coho salmon, median size was stable and size distributions did not differ significantly between the 1990s and the 2010s for any sector (Supplementary Figure S1).

Median lingcod size decreased over time for Southcentral charter captains, from 20 kg in the 1990s to 12 kg in the 2010s, but remained consistent for Southeast captains over this period at 11 kg (Figure 4). Lingcod size distributions differed significantly between the 1990s and 2010s for Southcentral ($D = 0.73$, $p < 0.001$) but not for Southeast ($D = 0.06$, $p = 0.99$) charter captains (Figure 4). Too few subsistence harvesters reported lingcod sizes to evaluate changes over time. For yelloweye rockfish, all three groups observed a decline in the median size between the 1990s and 2010s, from 6.3 to 5.4 kg for Southcentral charter captains, 5.0 to 3.6 kg for Southeast charter captains, and 3.6 to 0.9 kg for subsistence harvesters. Similarly, median size of black rockfish declined from 2.4 to 1.8 kg for Southcentral charter captains, 1.95 to 1.35 kg for Southeast charter captains, and 1.65 to 0.6 kg for subsistence harvesters from the 1990s to the 2010s. Shifts in size distributions of rockfishes across decades were not significant for any sector, except for black rockfish for Southcentral charter captains ($D = 0.38$, $p = 0.01$; Supplementary Figures S2 and S3). Median sizes of cod were relatively stable over time and distributions did not differ significantly between the 1990s and 2010s for any sector (Supplementary Figure S4).

Temporal changes in abundance

We used boxplots to visually assess temporal changes in the median and range of abundance indices reported by all fishers and linear regression to assess trends (i.e. estimated slope coefficient, β) reported by individual fishers for each species. Overall, subsistence harvesters provided a longer-term view of abundance changes (1960s–present) compared with charter captains (1990s–present). Charter captains in both regions perceived a decline in halibut abundance from the 1990s to the 2010s (mean estimated slope coefficient, $\overline{\beta} = -0.48$ in Southeast, -0.46 in Southcentral), while subsistence harvesters in Southeast observed a decline in halibut abundance from the 1960s to 1990s followed by a stable period ($\overline{\beta} = -0.14$; Figure 5).

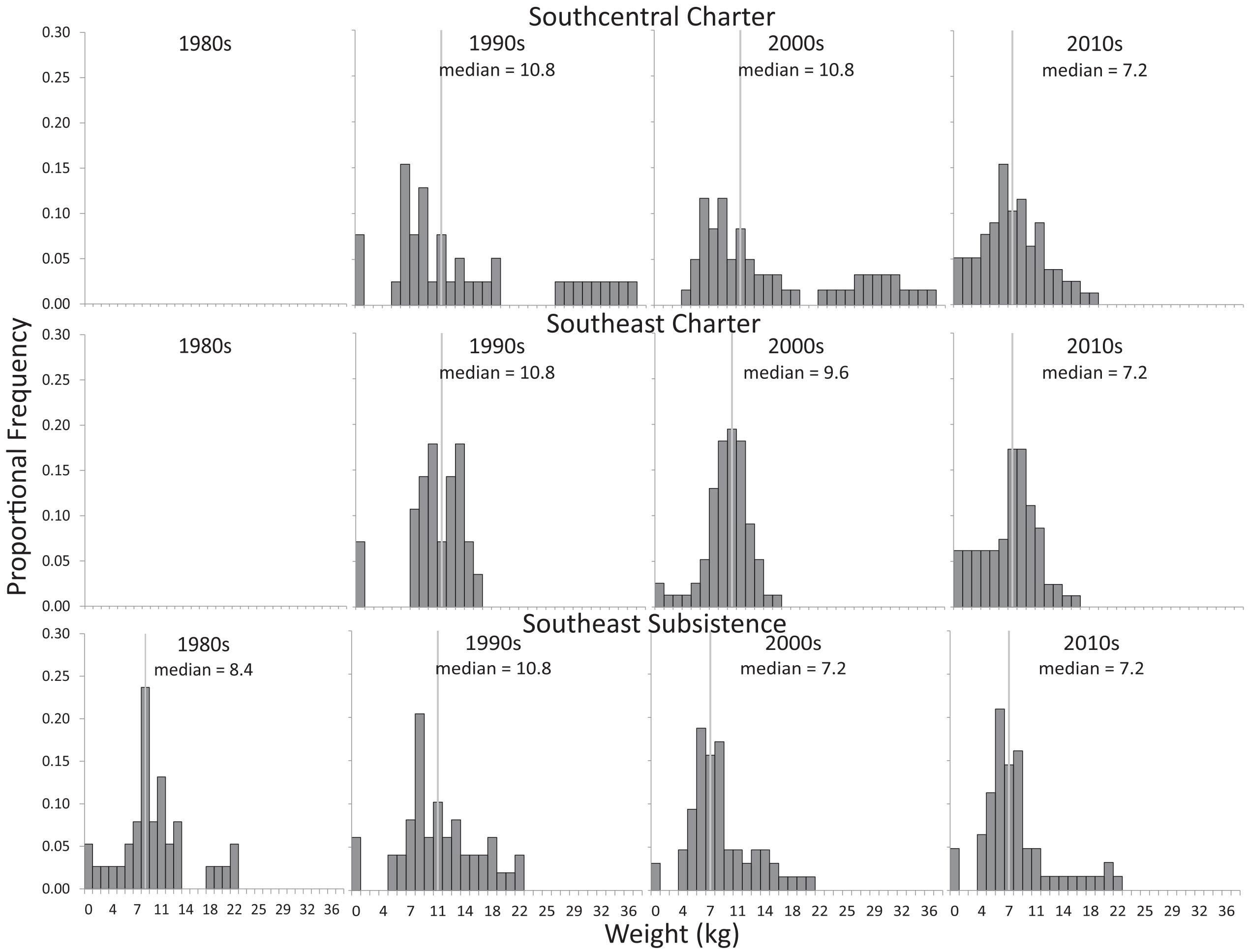

Figure 3. Reported average sizes (kg) for Chinook salmon by decade and sector group. *Y*-axis is in proportional frequency, which shows the percentage of responses in that size class for that decade and sector group. Vertical grey lines indicate median fish size. Decade and sector group combinations in which there were fewer than three responses are not shown.

For Chinook salmon, perceived abundance changes by charter captains were relatively flat overall, but varied among respondents (Southeast charter $\overline{\beta} = 0.50$, Southcentral charter $\overline{\beta} = -0.04$; Figure 6). Subsistence harvesters observed a decline in Chinook salmon from the 1970s to early 2000s followed by a relatively stable period ($\overline{\beta} = -0.31$; Figure 6). For coho salmon, both charter groups observed a decline in abundance from the 1990s to 2010s (Supplementary Figure S5), though this varied among respondents, particularly in Southeast where the average slope coefficient was positive (Southeast charter $\overline{\beta} = 0.33$, Southcentral charter $\overline{\beta} = -0.83$). Subsistence harvesters perceived relatively little change in coho salmon abundance since the 1970s ($\overline{\beta} = -0.07$; Supplementary Figure S5).

For lingcod, Southeast captains perceived little change ($\overline{\beta} = 0.07$) and Southcentral captains observed a decline ($\overline{\beta} = -1.20$) from the 1990s to present, while Southeast subsistence harvesters observed a decline from the 1980s to the early 2000s, followed by a period of relative stability ($\overline{\beta} = -0.27$; Figure 7). All three groups observed yelloweye rockfish abundance to have declined over time from the 1990s to 2010s, though the perceived decline was less pronounced among Southeast charter captains (Southeast charter $\overline{\beta} = -0.07$, Southcentral charter $\overline{\beta} = -0.50$, Southeast subsistence $\overline{\beta} = -0.67$; Supplementary Figure S6). For black rockfish, both charter groups observed a decline in abundance from the 1990s to 2010s (Southeast charter $\overline{\beta} = -0.78$, Southcentral charter $\overline{\beta} = -0.31$), while subsistence harvesters perceived a relatively stable trend over that period ($\overline{\beta} = -0.05$; Supplementary Figure S7). Pacific cod abundance was perceived by charter captains to be stable or increasing since the 1990s (Southeast charter $\overline{\beta} = 0.50$, Southcentral charter $\overline{\beta} = 0.08$), while subsistence harvesters observed a slight decline since the 1970s ($\overline{\beta} = -0.21$; Supplementary Figure S8).

Factors explaining variation in LEK of abundance

For halibut, five explanatory models were identified with AICc values within 2 of the minimum score (ΔAICc ≤ 2; Table 2), of which one was the null model. Each of the five explanatory models explained a low proportion of the total variance in observed abundance changes (adj. $r^2 = 0.003$–0.049; Table 2). The combined probability of these models being the best approximating models for the data was 0.74, although the weights of evidence were weak for any of the five models individually ($w_i = 0.096$–0.188; Table 2). The candidate model with the lowest AICc (adj. $r^2 = 0.049$) included the predictors sector and years of experience.

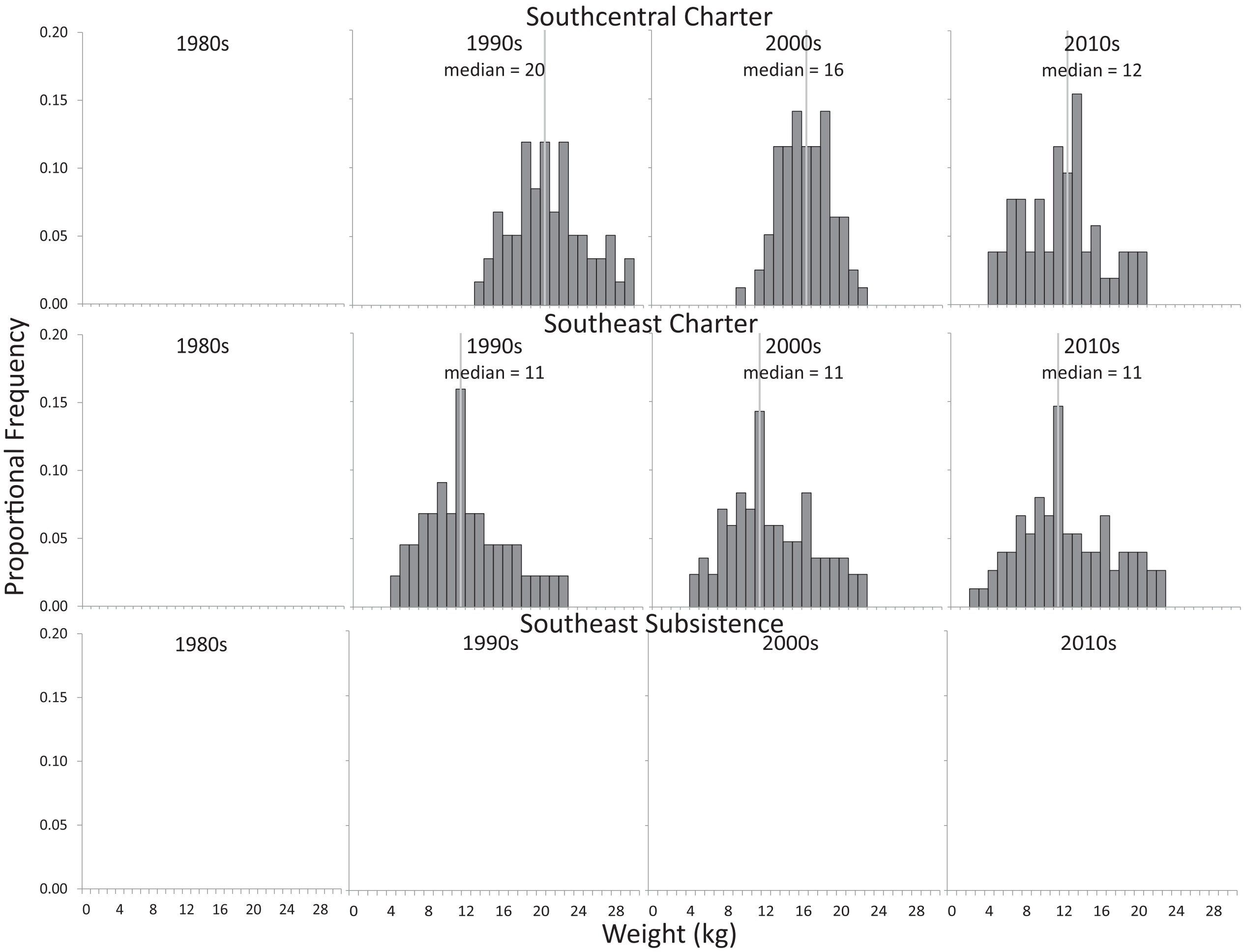

Figure 4. Reported average sizes (kg) for lingcod by decade and sector group. Y-axis is in proportional frequency, which shows the percentage of responses in that size class for that decade and sector group. Vertical grey lines indicate median fish size. Decade and sector group combinations in which there were fewer than three responses are not shown.

For Chinook salmon, the best model included city, years of experience, and fishing area (adj. $r^2 = 0.243$, $w_i = 0.456$; Table 2). Years of fishing experience was the most important factor in explaining variation in abundance trends of Chinook salmon among respondents (Table 3). For coho salmon, two explanatory models had AICc values within 2 of the minimum score (ΔAICc ≤ 2; Table 2). The candidate model with the best fit based on AICc (adj. $r^2 = 0.094$, $w_i = 0.194$) included one predictor, fishing area (Table 3).

The best model for lingcod (adj. $r^2 = 0.231$, $w_i = 0.514$; Table 2) included one predictor, fishing area (Table 3). For yelloweye rockfish, the best model included one predictor, city, and was a relatively good fit to the data (adj. $r^2 = 0.411$, $w_i = 0.562$; Tables 2 and 3). For black rockfish, two explanatory models were identified with AICc values within 2 of the minimum score (Table 2); among them was the null model. For cod, the best model (adj. $r^2 = 0.170$, $w_i = 0.452$) included one predictor, years of experience (Table 3).

Discussion

Drawing inferences about environmental change from LEK of harvesters requires an understanding about how people's experience in the environment may affect their perceptions of it. Our study suggests that, when taken together, perspectives from fishers in multiple regions and sectors can provide a more complete picture of abundance and size changes of nearshore fishes than any source alone. Some variation in fishers' perceptions of change was related to differences in age and duration of experience between groups. For example, halibut abundance trends began in the 1960s for subsistence fishers, 1980s for Southcentral charter captains, and 1990s for Southeast charter captains. Thus, the timing and extent of abundance declines for halibut differed among groups. Although subsistence and Southcentral charter respondents reported similar durations of fishing experience and fisher age, abundance trends from LEK covered a longer time period for subsistence respondents for all but two species (lingcod and black rockfish).

We used a primarily quantitative approach to describe LEK, but acknowledge that quantifying fishers' knowledge is not always possible or desirable. Broader ecosystem context may be lost if a focus is solely on quantitative indices derived from LEK; for example, many of the fishers we interviewed provided possible explanations for drivers of abundance changes (e.g. warming temperatures or overharvest) and shifting linkages among species and habitats. Additionally, understanding how people's values, beliefs, and positions of power or marginalization shape their

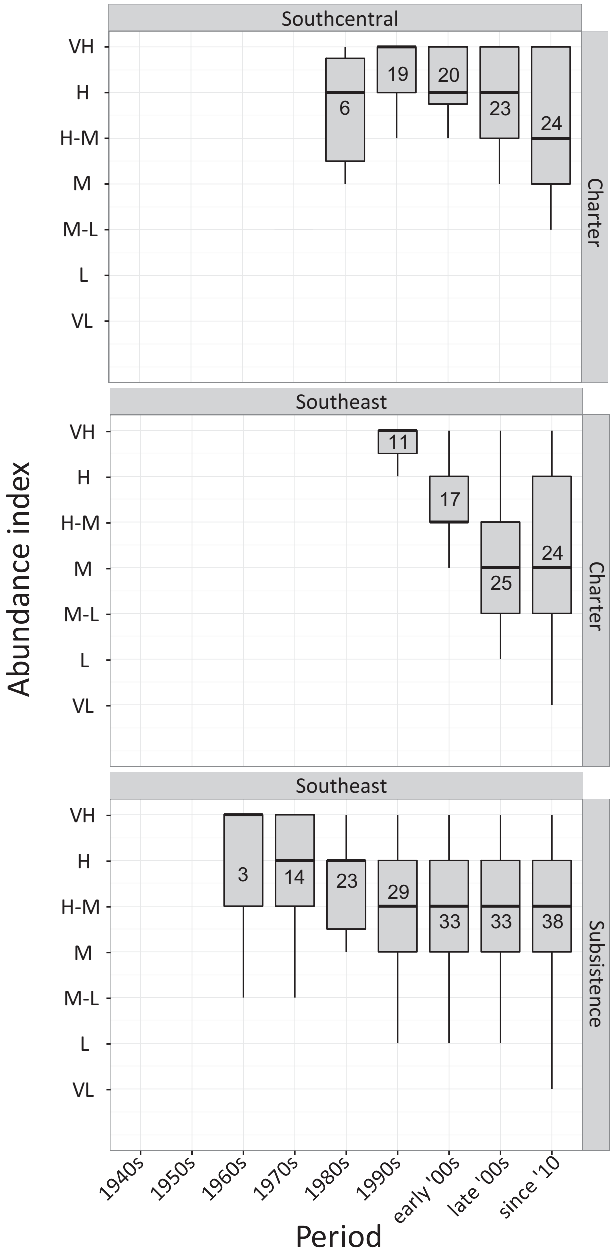

Figure 5. Reported abundance levels for Pacific halibut from interviews with subsistence and charter fishers in Southeast and Southcentral Alaska. Interviewees reported relative abundance on a seven-point scale: very high (VH), high (H), medium-high (M-H), medium (M), medium-low (M-L), low (L), and very low (VL). Decade and sector group combinations in which there were fewer than three responses are not shown. Shaded boxes delineate the interquartile range (IQR), with the median line in bold and number of interviewees shown for each period and sector. Whiskers extend to 1.5 * IQR and data beyond this range are shown as points.

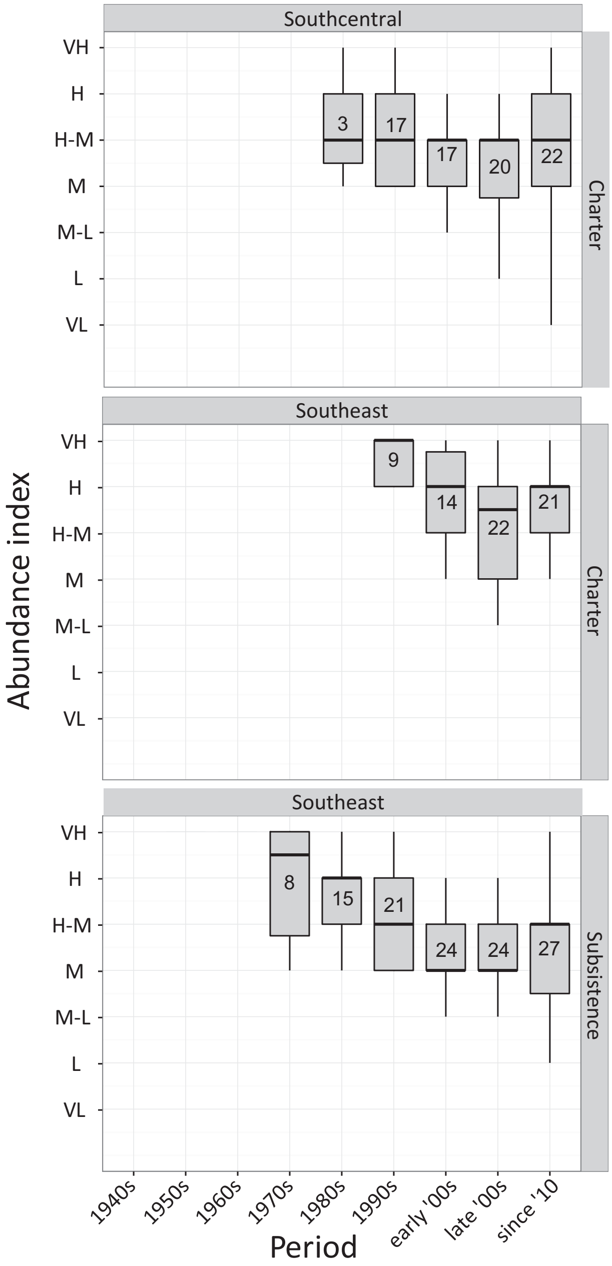

Figure 6. Reported abundance levels for Chinook salmon from interviews with subsistence and charter fishers in Southeast and Southcentral Alaska. Interviewees reported relative abundance on a seven-point scale: very high (VH), high (H), medium-high (M-H), medium (M), medium-low (M-L), low (L), and very low (VL). Decade and sector group combinations in which there were fewer than three responses are not shown. Shaded boxes delineate the interquartile range (IQR), with the median line in bold and number of interviewees shown for each period and sector. Whiskers extend to 1.5 * IQR.

experience in nature is essential for fully understanding all of the information encoded within their environmental observations. A combination of qualitative and quantitative methods in local knowledge research may ultimately help us gain a richer understanding of ecological change (e.g. Spoon, 2014), which to some extent cannot be fully understood outside of the societal context in which it occurs and is experienced. Most importantly, LEK does not have to be quantified nor integrated into a western science framework for inclusion in natural resource management (Raymond-Yakoubian *et al.*, 2017; Salomon *et al.*, 2018). Coproduction of knowledge, where knowledge holders are included as equal partners in research, is a step toward breaking

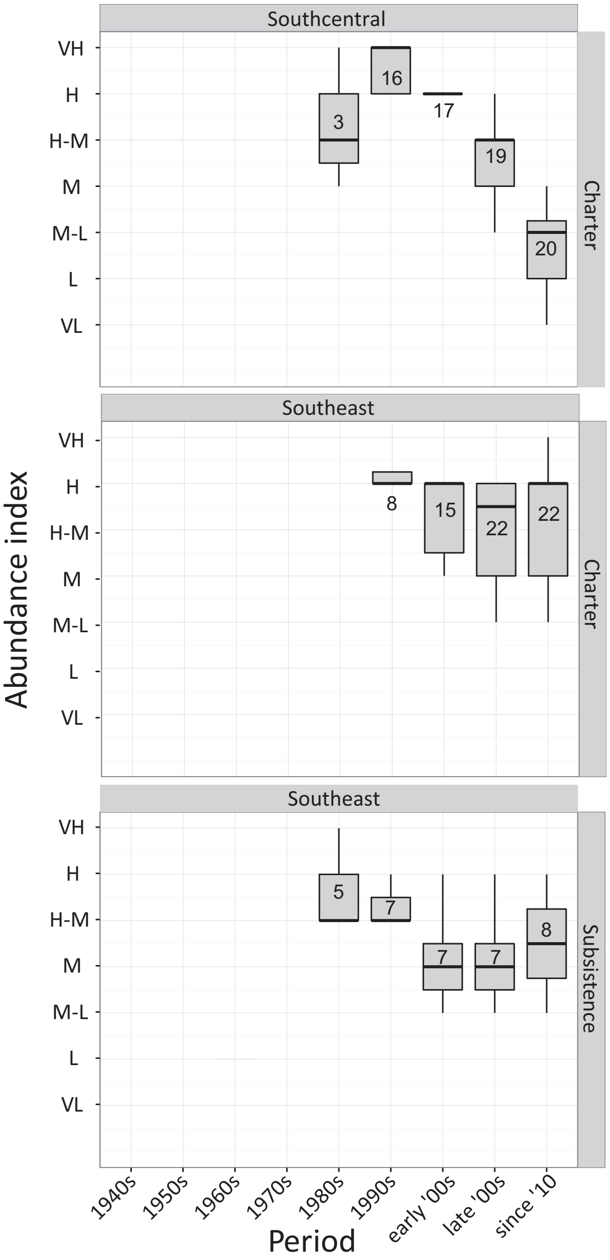

Figure 7. Reported abundance levels for lingcod from interviews with subsistence and charter fishers in Southeast and Southcentral Alaska. Interviewees reported relative abundance on a seven-point scale: very high (VH), high (H), medium-high (M-H), medium (M), medium-low (M-L), low (L), and very low (VL). Decade and sector group combinations in which there were fewer than three responses are not shown. Shaded boxes delineate the interquartile range (IQR), with the median line in bold and number of interviewees shown for each period and sector. Whiskers extend to 1.5 * IQR and data beyond this range are shown as points.

Table 2. Linear models of changes in abundance by species.

	Model	Adj. r^2	AIC_C	ΔAIC_C	w_i
Pacific halibut	Sector + years	0.049	210.0	0.0	0.19
	Sector + years + area	0.040	210.1	0.1	0.17
	Area	0.003	210.4	0.5	0.15
	Years + area	0.016	210.7	0.7	0.13
	Null model	NA	211.3	1.3	0.10
Chinook salmon	City + years + area	0.243	178.8	0.0	0.46
Coho salmon	Area	0.094	151.0	0.0	0.34
	Years + area	0.101	151.8	0.9	0.22
Lingcod	Area	0.231	118.9	0.0	0.51
Yelloweye rockfish	City	0.411	52.1	0.0	0.56
Black rockfish	Null model	NA	97.8	0.0	0.42
	Sector	0.006	99.3	1.6	0.19
Pacific cod	Years	0.170	42.7	0.0	0.45

Only the top models are shown (i.e. those with $\Delta AIC_C < 2$), along with their adjusted r^2 values (Adj. r^2), bias-corrected Akaike's information criteria (AICc), ΔAIC_C, and model weights (w_i). Sector describes the type of fishery (charter, subsistence); years is the total years of fishing experience reported by a fisher; area is the total area fished by each interviewee; and city is the primary fishing port reported by interviewees.

Table 3. Parameter weights for linear models of changes in abundance.

Species	Parameter	Weight
Chinook salmon	Years	0.94
	Area	0.85
	City	0.71
	Sector	0.64
Coho salmon	Area	0.82
	Years	0.37
	Sector	0.25
	City	0.21
Lingcod	Area	0.91
	Years	0.24
	Sector	0.23
	City	0.13
Yelloweye rockfish	City	0.95
	Area	0.18
	Sector	0.18
	Years	0.15
Pacific cod	Years	0.74
	Sector	0.31
	Area	0.20
	City	0.00

Only sets of models for species with adjusted $r^2 > 0.1$ are shown, therefore parameter weights are not shown for Pacific halibut and black rockfish. Sector describes the type of fishery (charter, subsistence); years is the total years of fishing experience reported by a fisher; area is the total area fished by each interviewee; and city is the primary fishing port reported by interviewees.

down barriers to meaningful engagement of resource users in conservation and management (Huntington *et al.*, 2004; Thornton and Scheer, 2012).

Alignment between fishers' LEK and western science has been explored extensively (e.g. Ainsworth *et al.*, 2008; Lauer and Aswani, 2010; Thurstan *et al.*, 2016); thus, we did not aim to assess the extent of agreement among LEK and scientific data. While some scientific survey data are available for halibut at comparable scales, the other focal species are data poor. Interview participants perceived declines in halibut abundance and body size, which is consistent with documented declines in halibut size at age and spawning stock biomass throughout the Gulf of Alaska (IPHC, 2014). Fishers also observed declines in relative abundance of black rockfish and yelloweye rockfish. While most nearshore rockfish in Alaska are not assessed, recreational harvest and targeting of rockfishes have increased substantially in some areas, including Sitka, over the past decade (ADF&G, 2017a; Beaudreau *et al.*, 2018) and an emergency closure was instituted in 2017 within a portion of southeastern Alaska waters that prohibited retention of demersal rockfishes (ADF&G, 2017b). For long-lived species, LEK can provide insight into long-term shifts in their abundance; for example, Beaudreau and Levin (2014) found strong agreement between LEK and scientific knowledge of lingcod declines in Puget Sound, Washington. In this study, fishers in all sectors perceived a decline in lingcod abundance from the 1990s to the early 2000s, especially in the Southcentral region. It is challenging to assess lingcod in Alaska due to their life history, variable movement patterns, and limited survey data (Green *et al.*, 2014). Consequently, fishers' knowledge addresses gaps in understanding of lingcod population change.

Fishers' observations of fish abundance or size may be influenced by attributes of their fishing experience, including locations, gear types, and how long they have been fishing (e.g. Verweij *et al.*, 2010; Beaudreau and Levin, 2014). Our model results suggested that years of fishing experience and area fished were among the most important factors in explaining variation in observations of relative abundance. Although sector was relatively unimportant in explaining variation in abundance changes, there were differences between charter and subsistence fishers in the duration of their fishing experience. An additional difference between charter and subsistence fishing that may affect observations of the environment is the type of allowable fishing gear. Customers on charter trips fish use rod and reel, while subsistence fishers target halibut using rod and reel and setline gear (Fall and Koster, 2014). Use of different gear types may lead to encounters with different sized fish (i.e. selectivity) or different catch rates, potentially affecting perceptions of halibut abundance and size.

Fishing regulations may also influence the species or sizes of fish that fishers have access to and, therefore, observe. From the 1990s to 2010s, charter captains in both regions observed declines in halibut median size; however, changes in the distribution of halibut size observed by charter captains may be related to the introduction of maximum size limits for charter halibut in 2007 and 2014 (Southeast and Southcentral Alaska, respectively; Gilroy *et al.*, 2011). Captains targeting only sizes below the limit would lead to increased encounters with smaller fish, reinforcing perceptions that fish sizes have decreased. In the subsistence sector, which does not have size limits (Fall and Koster, 2014), size distributions and median sizes remained consistent over time. Based on charter logbook data, halibut caught in the Southeast Alaska charter sector averaged between 4.3 and 12.0 kg in 2000–2015 (ADF&G, 2016). The median size of halibut observed by Southeast charter captains was ∼20 kg during this same period, suggesting that the sizes of halibut retained by charter captains was smaller than the sizes they observed on the fishing grounds (retained and released). People's perceptions of management should also be explored in future studies for its potential role in shaping the information that people report.

This study contributes to the growing body of research exploring how the identification of experts can shape LEK research (Davis and Wagner, 2003; Davis and Ruddle, 2010; Hitomi and Loring, 2018). Understanding the factors influencing fisher observations is important when eliciting ecological information, particularly if different groups of experts are drawing their knowledge from different components of the environment. Our study showed that LEK of Alaskan fishers may fill information gaps for data-poor species (e.g. lingcod). However, variation in LEK reflects both underlying patterns in animal populations and variation in fishers' perceptions of the environment, which must be understood in a system-specific context. We found differences in perceptions of fish abundance and size changes among respondent groups, underscoring the importance of including diverse groups when using LEK to document environmental changes. While it remains a challenge to differentiate the various factors influencing LEK, this study highlights the importance of explicitly accounting for spatial fishing information and duration of fishing experience when interpreting LEK. However, we acknowledge that the categories used to group respondents (e.g. demographics, location, distance travelled) reflect the assumptions and norms of the authors in this study and may differ from those chosen by the respondents and their communities, highlighting the complexity in the identification of experts and the subsequent implications in LEK research.

Supplementary data

Supplementary material is available at the ICESJMS online version of the manuscript.

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Author contribution

All authors contributed to conceptualization and design of the study. M.N.C. and A.H.B. collected data, performed analysis, and wrote and revised the manuscript. P.A.L. revised the manuscript for important intellectual content.

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