USING FISHERS' KNOWLEDGE TO EXPLORE SPATIAL FISHING PATTERNS, PERCEPTIONS OF REGULATIONS, AND ENVIRONMENTAL CHANGE IN ALASKA

By

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Abstract

In this dissertation, an interdisciplinary approach was used to examine fisher knowledge from recreational charter and subsistence fishers targeting Pacific halibut (*Hippoglossus stenolepis*) in Alaska. The first chapter identified biological, regulatory, social, and economic drivers of spatial fishing patterns by charter operators in two communities in Alaska. In Homer, the most frequently cited reasons for changes in the location and/or extent of fishing were changes in trip type and the price of fuel, while in Sitka, the most frequently cited reasons for spatial shifts were changes to Pacific halibut regulations and gaining experience or exploring new locations. The second chapter examined perceptions of charter operators to traditional and novel recreational fishery management tools. Results highlighted that controls on individual harvest can be perceived to have unintended consequences for charter businesses, such as effects on profitability and distance traveled. The third chapter explored variability in local ecological knowledge (LEK) of fish abundance and body size trends among charter operators and subsistence harvesters. Results suggested that people's perceptions of fish abundance and body size can be affected by attributes of their fishing experience and highlighted the importance of including people with different types of experience in the environment when using LEK to document environmental changes. Together, these chapters contribute to an improved understanding of the human dimensions of small-scale fisheries in Alaska, including perceptions of fishers regarding the management system and shifts in fishing behavior in response to environmental, socioeconomic, and regulatory change. Additionally, this project documented and evaluated variation in local ecological knowledge to contribute new information on data-limited marine fish species in Alaska.

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General Introduction

The long-term sustainability of Alaska's fisheries depends not only on the continued viability of fish populations, but also on the ability of individuals to maintain fishing lifestyles and livelihoods. Effects of fisheries policy on fishing patterns and fisher behaviors in small scale Alaskan fisheries are largely unexplored, even though the ways in which fishers adapt to policy changes have direct implications on key fishery variables, such as catch amounts, species targeted, and locations of harvest. In this dissertation, I used an interdisciplinary approach to examine fisher knowledge focusing on 1) motivations driving fishing behavior, 2) perceptions of regulations, and 3) environmental observations. This work is focused on recreational charter and subsistence fishers targeting Pacific halibut (*Hippoglossus stenolepis*) in Alaska.

The first chapter examines patterns and drivers of change in spatial behavior of charter operators in two Alaskan communities. Small-scale fishers may respond to a range of socioeconomic, cultural, regulatory, and environmental factors in determining their fishing locations. Adaptations to environmental or regulatory change can be seen through altered behaviors such as shifting fishing locations or targeting a secondary species. For example, recreational fishers are known to alter their fishing behavior when fish abundance is low; for example, recreational fishers may harvest alternative species that are similarly desirable (Sutton and Ditton 2005). Such adaptations may have the potential to affect other species or have localized effects on fish distribution (Cinti et al. 2010). Fishers may also shift their fishing behavior and spatial locations over time. Moreno-Báez et al. (2012) identified seasonal shifts in target species and areas by small-scale fishers in Mexico. From interviews with fishers in the Mediterranean, Coll et al. (2014) found that fishing activity expanded towards deeper and more distant areas over time. Changes in space use by fishers may be related to a suite of factors, each leading to different management implications. For example, a charter fishing business may travel towards deeper areas over time due to changes in customer preferences for deeper-dwelling species, distribution shifts of targeted species, or the motivation to combine fishing with eco-tourism. Therefore, appropriate management responses would vary based on the mechanisms driving spatial and temporal changes. Changed spatial distribution in a targeted species might indicate local depletions while changed customer preferences in target species might indicate market-driven shifts. Knowledge of high recreational use areas could be important in understanding the distribution of fishing activity and subsequent localized effects of fishing.

The second chapter examines perceptions of charter operators to traditional and novel recreational fishery management tools. The charter halibut sector has faced significant regulatory change over the past fifteen years, including limited entry, slot size limits, and day of week closure (50 CFR Parts 300). In the charter sector, changing size and bag limits may have the potential to affect customer expectations and subsequent fishing decisions by charter operators, such as target species and fishing locations. In 2011, the charter halibut sector in Southeast and South-central Alaska transitioned to a limited entry system, which set upper limits on the number of charter operators permitted in each management area. Starting in 2014, the charter sector has a combined yearly catch limit with the commercial sector in Southeast and South-central Alaska (50 CFR Parts 300). These regulations, combined with size and bag limit changes, may affect business decisions by charter operators. A study by Scrogin et al. (2004) found that fishing regulations have significant effects on recreational angler catch, harvest, and the site choice (Scrogin et al. 2004). Furthermore, perceptions of regulation change can affect anglers' degree of compliance or buy-in to the management process.

The third chapter explores variability in local ecological knowledge (LEK) of fish abundance and body size trends among charter operators and subsistence harvesters. In this study, LEK is defined as "the knowledge and insights acquired through extensive observation of an area or species" (Huntington 2000, Huntington et al. 2004). Because assessing animal abundance can be expensive and time-consuming, studies have examined how LEK can contribute to the estimation of abundance for aquatic and terrestrial species (e.g., Anadón et al. 2009, Hallwass et al. 2013, Taylor et al. 2011). Fisheries researchers have explored the use of LEK as a method for engaging with local stakeholders and documenting biological information on marine species, especially for data-poor species (Ainsworth et al. 2008; Beaudreau and Levin 2014). Fishers possess expert knowledge on many aspects of fish ecology, often in coastal areas where it is time- and resource-intensive to pursue western scientific methods of assessment (e.g., biomass surveys). Harvesters often develop informal methods of monitoring resources, including catch rates, assessments of body condition, and estimations of population sizes (Moller et al. 2004).

In the marine environment, accurately assessing abundance trends poses a substantial challenge. This is particularly evident in Alaska, the 4th least populous state in the U.S. (2010 U.S. Census; www.census.gov) with a longer coastline than the contiguous U.S. states combined (NOAA Office for Coastal Management; www.coast.noaa.gov). Although historical biomass and catch information are available for highly valued commercial species, such as Pacific halibut (Stewart and Martell 2016), data are limited for species that primarily support sport and subsistence fisheries, such as lingcod (*Ophiodon elongatus*; Green et al.

2014). However, there is a network of small-scale sport and subsistence fishers across the state with long-term and intimate knowledge of their local marine environments. These small-scale fishers cover widespread geographic regions and consist of diverse participants. However, fishers may perceive environmental observations differently based on frequency, duration, and seasonality of harvest. Therefore, understanding sources of variability in LEK between different user groups is a critical part of interpreting fisher observations of biological change.

Together, these chapters contribute to an improved understanding of the human dimensions of small-scale fisheries in Alaska, including perceptions of fishers regarding the management system and shifts in fishing behavior in response to environmental, socioeconomic, and regulatory change. Additionally, this project documented and evaluated variation in local ecological knowledge to contribute new information on data-limited marine fish species in Alaska.

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Chapter 1 Evaluating patterns and drivers of spatial change in the recreational guided fishing sector in Alaska[1]

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Abstract

Understanding the impacts of recreational fishing on habitats and species, as well as the social and ecological importance of place to anglers, requires information on the spatial distribution of fishing activities. This study documented long-term changes in core fishing areas of a major recreational fishery in Alaska and identified biological, regulatory, social, and economic drivers of spatial fishing patterns by charter operators. Using participatory mapping and in-person interviews, we characterized the spatial footprint of 46 charter operators in the communities of Sitka and Homer since the 1990s. The spatial footprint differed between Homer and Sitka respondents, with Homer operators consistently using larger areas for Pacific halibut than Sitka operators. Homer and Sitka showed opposite trends in core fishing location area over time, with an overall decrease in Homer and an overall increase in Sitka. For both Sitka and Homer respondents, the range of areas fished was greater for Pacific halibut than for rockfish/lingcod or Pacific salmon. Spatial patterns were qualitatively different between businesses specializing in single species trips and those that operated multispecies trips and between businesses with one vessel and those with multiple vessels. In Homer, the most frequently cited reasons for changes in the location and/or extent of fishing were changes in trip type and the price of fuel, while in Sitka, the most frequently cited reasons for spatial shifts were changes to Pacific halibut regulations and gaining experience or exploring new locations. The diversity of charter fishing strategies in Alaska may allow individual charter operators to respond differently to perturbations and thus maintain resilience of the industry as a whole to social, environmental, and regulatory change. This research also highlights the importance of understanding fishers' diverse portfolio of activities to effective ecosystem-based management.

Introduction

Recreational fishing contributes to food security, tourism, and other economic activities in coastal communities around the world. In the United States, a 2015 national saltwater recreational fisheries policy recognized the social, cultural, and economic importance of recreational fishing and the need for improved governance of this growing sector [1]. The principles of governance outlined in this policy place particular focus on maintaining environmental sustainability and access to fishing [1]. Therefore, the success of the policy relies on information about factors affecting anglers' access to and use of particular areas. While agencies often conduct angler surveys to document numbers, species, and sizes of harvested fish, there is rarely information on where harvest occurs. To understand the impacts of recreational fishing on habitats and species, as well as the importance of place to anglers, information is needed on the spatial distribution of fishing activities.

A wide range of biological, regulatory, economic, and cultural factors can influence where anglers choose to fish. Locations may be selected as a conservation measure [2], territoriality [3, 4], or to make political statements [5]. In addition, fish abundance has been shown to be positively correlated with angler catch rates [6] and this relationship has been explored as a driver of site selection in commercial fishing [7, 8]. However, fish abundance as a predictor of fishing location becomes problematic for small-scale fisheries because participants are not consistently motivated by high catch rates [9, 10]. In recreational fisheries, the drivers for selecting fishing locations result from the interaction of diverse factors, including economic variables, regulatory constraints, environmental conditions, and social interactions [11, 12]. In the U.S., a 2013 nationwide survey of over 9,000 recreational anglers reported that most important part of a fishing trip was spending time with family or friends (87% of responses), catching fish (83% of responses), and fishing in an uncongested area (79% of responses) [13]. In recreational charter fisheries, captains may modify aspects of the fishing experience to maintain the satisfaction of customers paying for guided fishing trips [14]. This includes providing sightseeing opportunities or offering different types of fishing trips (e.g., targeting different species, [15]), which may affect where charter vessels fish.

In this study, we examined the complex factors affecting the spatial distribution of fishing in a major United States recreational charter fishery. In Alaska, charter and sport fisheries are important both to local tourism sectors and as components of local food systems and security [16, 17]. A mail survey administered to residents and nonresidents who took sportfishing trips in Cook Inlet, Alaska, during 1997 found that for both residents and nonresidents, the primary purpose of their trip was to fish for Pacific halibut (*Hippoglossus stenolepis*) or Pacific salmon (*Oncorhynchus* spp.) [18], highlighting that access to highly-valued sportfish can be key drivers of tourism. Alaska alone harvested more sport-caught Pacific halibut (net weight) in 2015 than the combined sport fishery throughout the North American range [19]. An estimated 2,485 metric tons of Pacific halibut was harvested by Alaska's sport sector in 2015, with approximately 53% of that from charter fishing [19], making it the most targeted bottomfish in the Alaskan charter industry (47% by number in 2014) [20]. However, declines in Pacific halibut biomass [21] have led to increased restrictions on charter halibut fishing in Alaska in the past decade, including reductions in bag and size limits [22].

More than 90% of charter effort (angler days) for Pacific halibut within Alaska occurs in the Southeast and Southcentral regions (Figure 1-1) [20]. These two regions have different charter customer demographics and histories of halibut regulation. Participation by non-resident anglers is higher in Southeast Alaska (97% non-resident angler-days in 2014) compared to Southcentral

Alaska (74% non-resident angler-days in 2014) [20]. This is a substantial increase from twenty years prior, when in 1994, 52% and 33% of angler-days fished were by non-residents in Southeast Alaska and Southcentral Alaska, respectively [23]. The relative decline of resident participation may partially be attributed to residents being more sensitive to catch rates and trip costs [24]. In addition, Pacific halibut biomass estimates differ between the two regions [25], leading to greater restrictions in Southeast Alaska over the past decade compared to Southcentral Alaska (Table 1-1). In Homer, the community with the highest charter halibut landings in Southcentral Alaska [20], charter businesses operate both single species (i.e., Pacific halibut only) trips and multispecies trips. In contrast, Sitka, the highest charter halibut landings in Southeast Alaska, primarily operates multispecies trips [20].

Table 1-1 Pacific halibut charter fishing regulations for Sitka and Homer, Alaska from 1993-2016. Regulations displayed are for the height of the charter season (i.e., June through August). Table shows newly added regulations or adjustments to existing regulations [26, 27]

	Sitka (Southeast Alaska)	Homer (Southcentral Alaska)
1993[a]	• 2-fish daily bag limit per customer (no size limit)	
2003	• Guideline Harvest Level (GHL) program goes into effect	
2006	• No retention of Pacific halibut by crew	
2007	• 2-fish daily bag limit per customer (32 inches max size limit on one of the fish)	
2008	• June 1 – June 9: 1-fish daily bag limit per customer (no size limit) • June 10 – Dec. 31: 2-fish daily bag limit per customer (32 inches max size limit on one of the fish)	
2009	• 1-fish daily bag limit per	

	Sitka (Southeast Alaska)	Homer (Southcentral Alaska)
	customer (no size limit)	
2011	• Charter Halibut Limited Access Program (limited entry) goes into effect	
2011	• 1-fish daily bag limit per customer with 37 inches max size limit	
2012	• 1-fish daily bag limit per customer with a reverse slot limit. Allowable size is ≤ 45 inches or ≥ 68 inches	
2014	• 1-fish daily bag limit per customer with a reverse slot limit. Allowable size is ≤ 45 inches or ≥ 76 inches	• 2-fish daily bag limit per customer (29 inches max size limit on one of the fish) • A vessel limit of one trip per calendar day
2014	• Catch Sharing Plan (CSP) and Guided Angler Fish (GAF) go into effect	
2015	• 1-fish daily bag limit per customer with a reverse slot limit. Allowable size is ≤ 42 inches or ≥ 80 inches	• 2-fish daily bag limit per customer (29 inch max size limit on one of the fish) • A vessel limit of one trip per calendar day • 5-fish annual limit in a calendar year on charter vessel fishing trips (does not apply to GAF halibut) • Thursday closure: charter anglers may not catch and retain halibut (except GAF) on Thursday
2016	• 1-fish daily bag limit per customer with a reverse slot limit. Allowable size is ≤ 43 inches or ≥ 80 inches	• 2-fish daily bag limit per customer (28 inch max size limit on one of the fish) • A vessel limit of one trip per calendar day • 4-fish annual limit in a calendar year on charter vessel fishing trips (does not apply to GAF halibut) • Wednesday closure: charter anglers may not catch and retain halibut (except GAF) on Wednesday

[a]No restrictions back to 1974

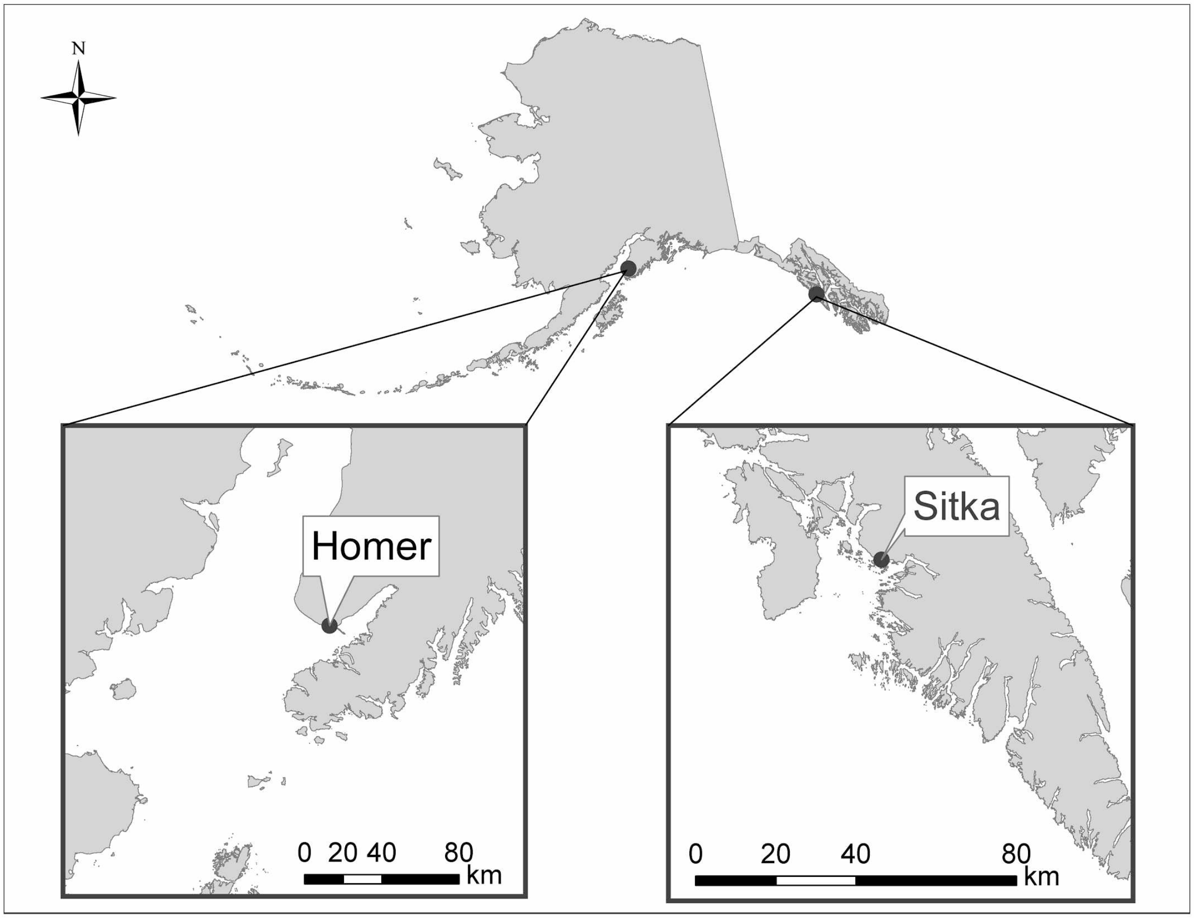

Figure 1-1 Map displaying the location of Homer and Sitka within the state of Alaska.

This study aimed to document changes to charter fishing locations over time and identified biological, regulatory, social, and economic drivers of spatial fishing patterns in Sitka and Homer. Using participatory mapping and in-person interviews, we characterized the spatial footprint of 46 charter operators since the 1990s. We hypothesized that patterns of spatial change have been different for charter captains based out of Sitka and Homer, driven by regional differences in: 1) percentage of non-resident clientele, 2) regulatory history, and 3) species availability. Additionally, multispecies trips may have a different spatial footprint than single species trips because fishing characteristics vary based on the type and number of targeted species (e.g., habitat, depth, trip duration etc.). Therefore, we also hypothesized that species diversification has affected the locations and geographic extent of fishing, specifically that core fishing locations differ between charter operators who conduct multispecies fishing trips and those who conduct single species fishing trips.

Materials and Methods

Participant selection and sampling frame

In 2014 and 2015, in-person interviews were conducted with 46 charter fishing operators working out of Sitka (n=27) or Homer (n=19). In this project, we defined a charter operator as a sport fishing guide registered with the Alaska Department of Fish & Game (ADF&G). We sought respondents who are charter operators based in Sitka or Homer during the main charter season (May – Sept), have five or more years of charter fishing experience in Alaska, target Pacific halibut on at least one charter trip per year, and/or hold a Charter Halibut Permit. Interview respondents were solicited through charter association newsletters (Alaska Charter Association, Sitka Charter Boat Operators Association, Southeast Alaska Guides Organization, and Homer Charter Association) and project information mailed to 2014 Charter Halibut Permit holders with addresses in Sitka or Homer (NOAA Fisheries Charter Halibut Permits List, https://alaskafisheries.noaa.gov/permits-licenses). Additional respondents were selected using snowball sampling [28], in which each study participant recommended other knowledgeable individuals to participate. The aim of this sampling method was to identify charter operators with diverse perspectives and experience levels; therefore, we did not aim to provide representative sampling of the charter fleet in either location. Rather, snowball sampling allowed us to identify people whose practices are indicative of broader patterns of change.

This project was approved by the University of Alaska Fairbanks Institutional Review Board (IRB project #583323-2). Written consent from each participant was obtained prior to each interview.

Participatory mapping

Mapping methods followed previous studies using local fishers to identify fishing locations [29-32]. Participants were asked to draw their primary fishing locations during charter trips on paper maps to document changes in spatial harvest patterns [31] for Pacific halibut, Pacific salmon, and rockfishes (*Sebastes* spp.). Additionally, respondents were asked to self-identify and draw locations for a fourth species that was important to charter fishing in their area. For the additional species, participants in Homer identified lingcod (*Ophiodon elongatus*), while participants in Sitka identified both lingcod and sablefish (*Anoplopoma fimbria*). We did not include fishing locations for sablefish because this species was not targeted by Homer participants and therefore, we are unable to compare between the two locations. Following identification of current fishing locations, we asked each participant if these locations had changed over time. If the current map did not cover the total years of charter fishing experience of the participant, the individual was asked to mark past fishing locations on additional maps. This process was repeated until paper maps represented the participant’s total years of charter fishing experience. Participants were asked to provide demographic information, number of years of participation in charter fishing, the type of trips they offer (e.g., half-day, full-day, multi-day) and the number of Charter Halibut Permits the operator or business possesses.

Paper maps were generated from a Geographic Information System (GIS) based index map that included local features, such as depth contours and delineation of local restricted fishing areas. All index maps were projected in the Alaska Albers coordinate system (NAD 1983-2011

Alaska Albers, WKID: 102966, Authority: ESRI). Based on pilot interviews with knowledgeable charter captains, the map scales of 1:490,000 and 1:475,000 were determined as appropriate for Sitka and Homer, respectively. An 8 km x 8 km grid was overlaid onto each paper map so that participants who did not wish to share specific fishing locations could mark grid cells. Four out of the total 46 participants (9%) chose to use the grid system instead of drawing individual fishing locations.

Map processing

All map processing and spatial analysis was completed in ArcMap 10.2 (ArcGIS 10.2, Environmental Systems Research Institute). Paper maps were scanned at 600 dpi and imported into ArcMap. Scanned maps were georeferenced against the index map using 3 or more ground control points per map [31]. Fishing locations were outlined and converted to vector-based polygons representing fishing locations for each respondent, species group, and time period. To standardize for individual drawing variations (e.g., dots vs. polygons), we used the 'aggregate polygons' tool on marked fishing locations for a respondent, species group, and time period to combine fishing locations that were within 1.5 km of each other. For analysis, lingcod and rockfishes were grouped because participants reported that these species were typically targeted using the same fishing locations. Fishing locations in the 1990s for lingcod/rockfish in Sitka were excluded because of low sample sizes of fewer than 5 respondents.

Analysis of fishing locations

The spatial distribution of fishing locations was visualized using heat maps showing fishing locations for all respondents by species group and time period. Heat maps were created by converting fishing location polygons into raster files of 1.5 km by 1.5 km grid cells. This grid cell size was used for all species groups and was approximately the mode of the distribution of polygon area size [31]. A raster sum calculator was used to identify and count overlapping fishing locations. Heat maps display the spatial distribution of fishing locations as the percentage of respondents using each 1.5 km x 1.5 km grid cell. Core fishing locations (CFL) are identified as sites with over 40% of respondents using that location, separated by species and time period. Maps are displayed by the percentage of respondents that fished in each time period and location. Pacific halibut maps additionally display polygons representing the three ADF&G sportfish statistical fishing areas with the highest charter bottomfish effort (by number of trips) for that time period. ADF&G polygons were summarized using unpublished data from the ADF&G charter logbook program [33], which records statistical fishing areas for every charter fishing trip in Alaska. We identified the three statistical fishing areas with the highest bottomfish effort for each time period relevant to our study (i.e., 1990-1999, 2000-2004, 2005-2009, and 2010-2015). Logbook data were only available for 1998-2001 and 2006-2015; therefore, ADF&G polygons for the 1990s and early 2000s were summarized using two years of logbook data.

The spatial footprint for individual respondents was evaluated using two metrics: total area fished and number of fishing locations. Total area (km^2) was calculated as the areal sum of fishing polygons per respondent for each species and decade. The number of fishing locations was assessed by counting the number of discrete fishing polygons per respondent for each species and decade. Boxplots were used to display the statistical distributions of fishing area and number of fishing locations across respondents. Using two-sample Kolmogorov-Smirnov tests in R (Rx64, version 2.15.2, http://www.R-project.org/), we assessed differences in the distribution of total area and number of fishing locations across decades, regions, and business types. The two-sample Kolmogorov-Smirnov test is a non-parametric test assessing if the distributions of two datasets differ significantly. Based on interviews, there is wide variation in how operators choose to fish, including those who prefer to stay close to port, travel further seasonally, tailor their travel distance to specific clients, and so forth. Therefore, assessing differences in distribution rather than using central tendency measures is a more robust way of examining differences between groups, while still accounting for the diversity in human behavior. Comparisons were made both between and within regions. In Sitka, we examined whether fishing behavior was related to the size of the fishing business by comparing attributes of fishing areas between single boat owner/operators (single-boat businesses) and lodge owners and multi-vessel owner/operators (multi-boat businesses). Individuals who self-identified as contractor or employee were grouped into the appropriate category, depending on the number of boats in the business for which they primarily worked. In Homer, we examined the relationship between fishing behavior and trip type by comparing attributes of fishing areas between respondents who operated single species trips and those who operated multispecies trips. While the majority of respondents indicated some participation in both trip types, respondents typically self-identified their business with a primary specialization in single or multispecies. Therefore, each respondent in Homer was categorized as operating multispecies or single trips based on the majority of trip types over the duration of his or her charter fishing experience.

Characterizing drivers of spatial change

During the interviews, participants were asked to explain why their charter fishing locations or area fished had changed over time (if any). For each participant, reasons for spatial change were coded using ATLAS.ti 7 (2002-2017, ATLAS.ti Scientific Software Development GmbH). Similar drivers were grouped into categories [28] and the percentage of respondents identifying each category as a driver of spatial change was calculated. Respondents were able to self-identify more than one driver of change (i.e., percentages do not add up to 100).

Results

Comparing Homer and Sitka, there were opposite temporal trends in the spatial footprint of core fishing locations (CFL), locations where >40% of respondents target Pacific halibut. In Homer, there was an overall decrease in CFL area over time from 1,946 km^2 in the 1990s to 1,402 km^2 in the 2010s (Table 1-2). In Homer, CFL area expanded to the south in the early 2000s and subsequently retracted starting in the late 2000s (Figure 1-2). In contrast, for Sitka, there was an increase in CFL area over time from 43 km^2 in the 1990s to 246 km^2 in the 2010s (Table 1-2). CFL area in the 1990s was close to the port of Sitka, with just a few locations along the outer coast (Figure 1-3). From the early 2000s onwards, the extent of fishing expanded towards the outer coast and further north and south (Figure 1-3).

Table 1-2 Areas of core fishing locations for Pacific halibut by time period and town.

Town	Year	Area (km^2)
Homer	1990-1999	1946
Homer	2000-2004	2320
Homer	2005-2009	1860
Homer	2010-2015	1402
Sitka	1990-1999	43
Sitka	2000-2004	115
Sitka	2005-2009	193
Sitka	2010-2015	246

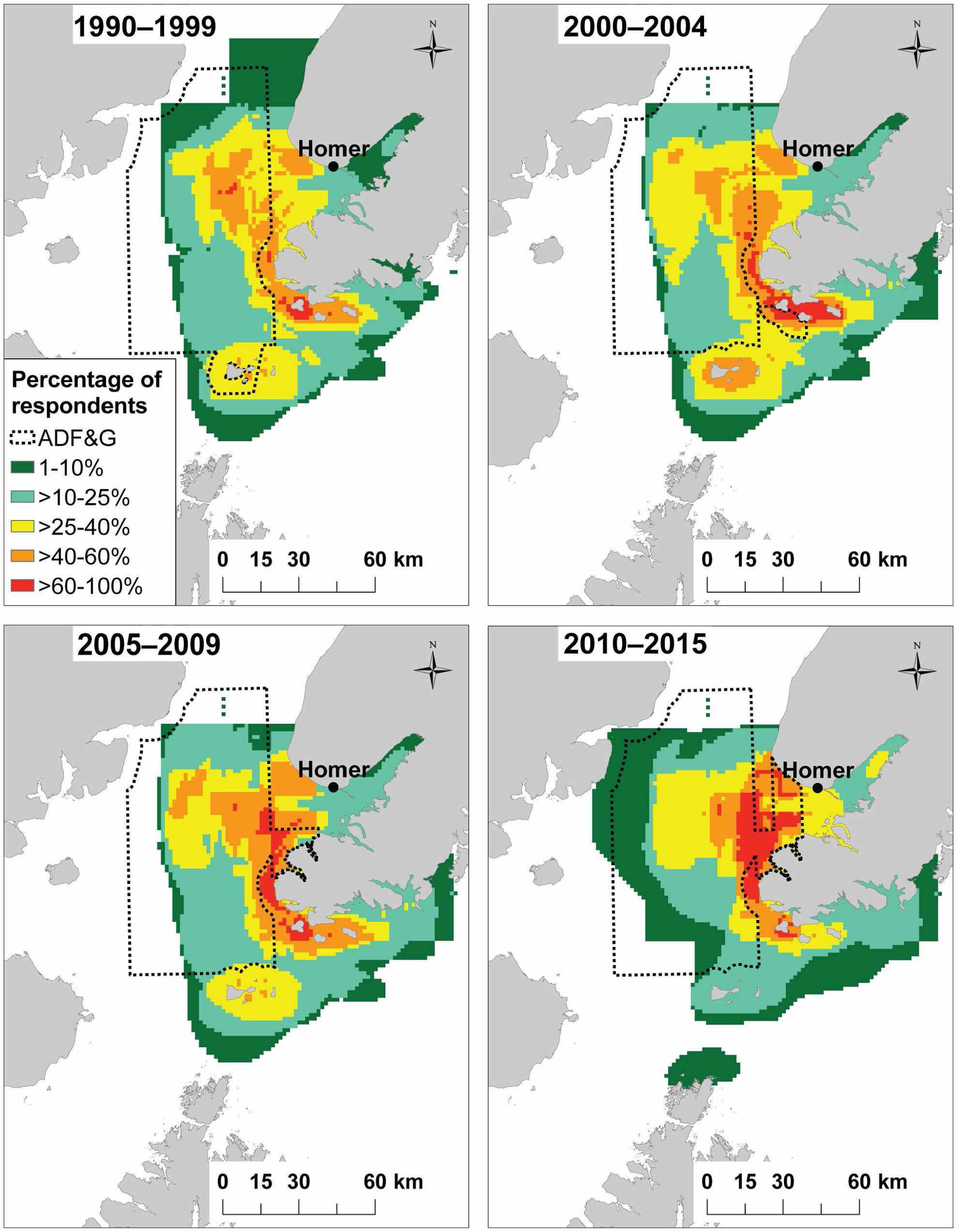

Figure 1-2 Pacific halibut fishing locations in Homer for 1990-1999, 2000-2004, 2005-2009, and 2010-2015. Locations are displayed by the percentage of respondents who fished during that time period. The dashed line represents the three ADF&G statistical fishing areas with the highest charter bottomfish effort (by number of trips), based on ADF&G charter logbook data [33].

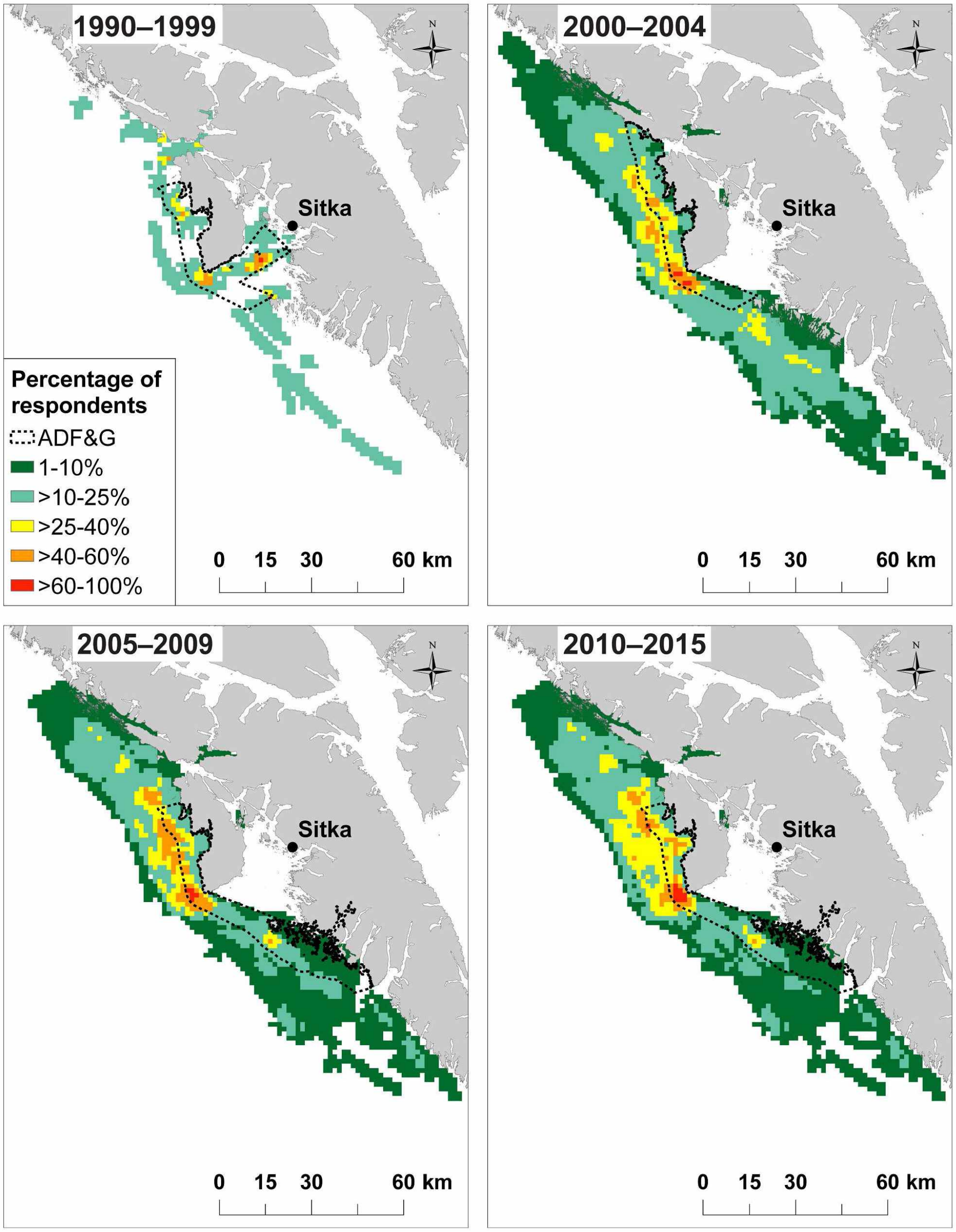

Figure 1-3 Pacific halibut fishing locations in Sitka for 1990-1999, 2000-2004, 2005-2009, and 2010-2015. Locations are displayed by the percentage of respondents who fished during that time period. The dashed line represents the three ADF&G statistical fishing areas with the highest charter bottomfish effort (by number of trips), based on ADF&G charter logbook data [33].

In both study communities, the median and range of areas fished (km^2) for Pacific halibut across respondents were greater than those for rockfish/lingcod or Pacific salmon (Figure 1-4). Median area fished for Pacific halibut was higher for charter operators in Homer compared to operators in Sitka (17 times higher in the 1990s, 10 times higher in the 2000s, and 13 times higher in the 2010s; Figure 1-4). The distributions of area fished for Pacific halibut differed significantly between the two communities based on a two-sample Kolmogorov-Smirnov test (Table 1-3). The distribution of areas fished for Pacific halibut did not differ among decades in either community, except for Sitka between the 1990s and 2000s, based on a two-sample Kolmogorov-Smirnov test (Table 1-4). Homer operators used fewer discrete locations for all three species groups compared to Sitka operators (Figure 1-5). The distribution of the number of fishing locations across respondents that were used to target Pacific halibut differed significantly between Homer and Sitka for the 2010s only (Table 1-3).

Table 1-3 Test statistics and p-values for two-sample Kolmogorov-Smirnov tests evaluating differences between Homer and Sitka in the distributions of total area fished and number of fishing locations across respondents.

	All time periods, all species	All time periods, halibut	1990s, halibut	2000s, halibut	2010s, halibut
Total area fished	D = 0.492, p-value = <0.01	D = 0.697, p-value = <0.01	D = 0.867, p-value = <0.01	D = 0.805, p-value = <0.01	D = 0.642, p-value = <0.01
Number of locations	D = 0.333, p-value = <0.01	D = 0.4, p-value = <0.01	D = 0.422, p-value = 0.27	D = 0.192, p-value = 0.84	D = 0.618, p-value = <0.01

Table 1-4 Test statistics and p-values for two-sample Kolmogorov-Smirnov tests evaluating differences in the distributions of total area fished and number of fishing locations across respondents for Pacific halibut.

	1990s vs. 2000s	2000s vs. 2010s	1990s vs. 2010s
Homer			
Total area fished	D = 0.216, p-value = 0.85	D = 0.212, p-value = 0.83	D = 0.144, p-value = 1
Number of locations	D = 0.212, p-value = 0.87	D = 0.190, p-value = 0.91	D = 0.1, p-value = 1
Sitka			
Total area fished	D = 0.504, p-value = 0.05	D = 0.114, p-value = 1	D = 0.489, p-value = 0.06
Number of locations	D = 0.231, p-value = 0.87	D = 0.303, p-value = 0.19	D = 0.213, p-value = 0.92

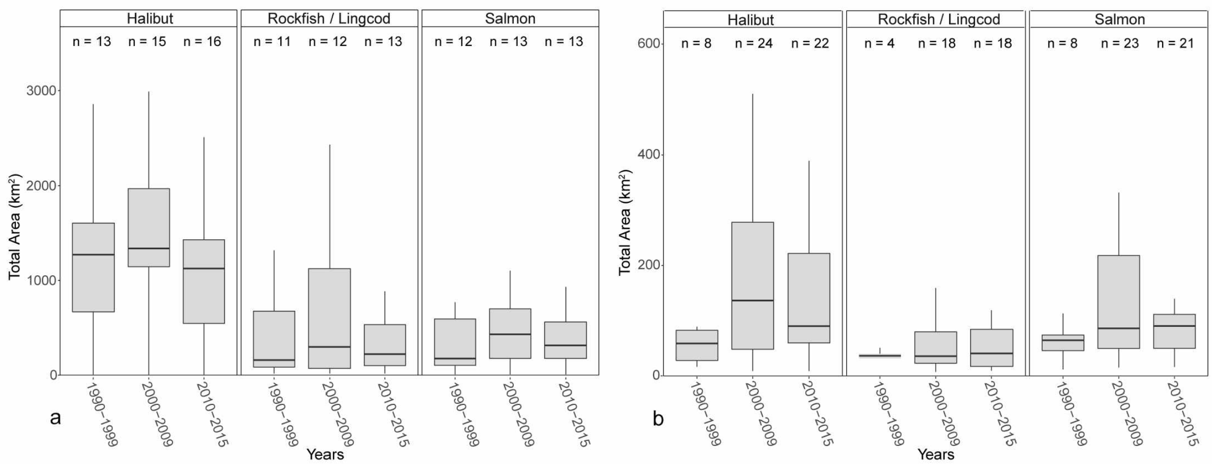

Figure 1-4 Box and whisker plot of total fishing area (km^2) for Pacific halibut, rockfish/lingcod, and salmon for the 1990s, 2000s, and 2010s in Homer (a) and Sitka (b). The lower whisker extends from the first quartile to the lowest value within 1.5*IQR of the first quartile. The upper whisker extends from the third quartile to the highest value within 1.5*IQR of the third quartile. Outliers ranging above and below 1.5*IQR have been removed. Note that the scale for the y-axis is different between plots.

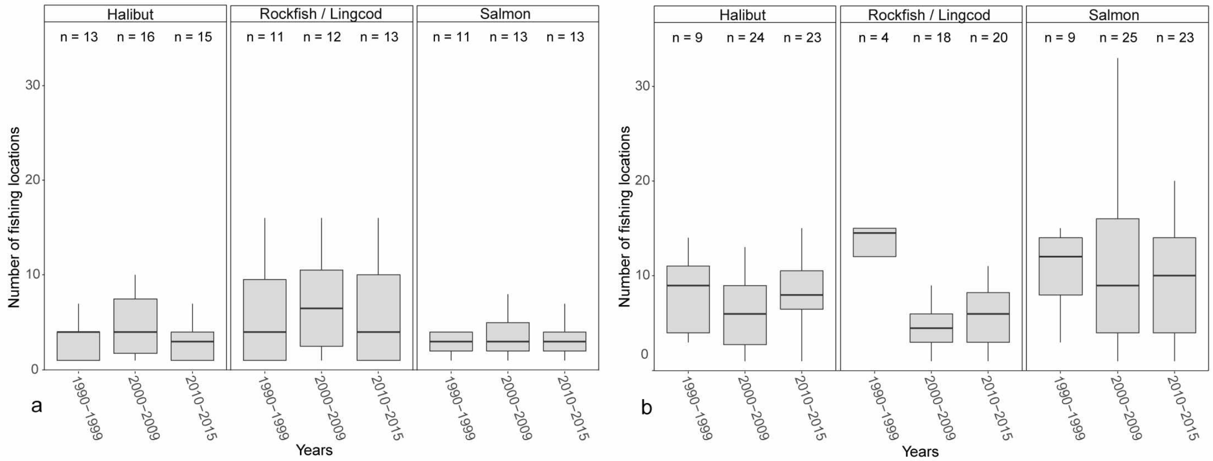

Figure 1-5 Box and whisker plot displaying the number of fishing locations for Pacific halibut, rockfish/lingcod, and salmon for the 1990s, 2000s, and 2010s in Homer (a) and Sitka (b). The lower whisker extends from the first quartile to the lowest value within 1.5*IQR of the first quartile. The upper whisker extends from the third quartile to the highest value within 1.5*IQR of the third quartile. Outliers ranging above and below 1.5*IQR have been removed.

Due to low sample sizes, we were unable to statistically compare the distributions of area fished and number of fishing locations among charter trip types. Qualitatively, the median area fished for single species trips in Homer was greater than for multispecies trips; however, the distribution of areas fished among respondents was wider for multispecies trips compared to single-species trips (Figure 1-6). The median area fished for rockfish/lingcod and Pacific salmon in Sitka was higher and the distribution of areas fished wider for multiple vessel businesses compared to single vessel businesses (Figure 1-7). For Pacific halibut, median area fished was similar between single vessel and multiple vessel businesses, with single vessel businesses showing a wider distribution of areas (Figure 1-7).

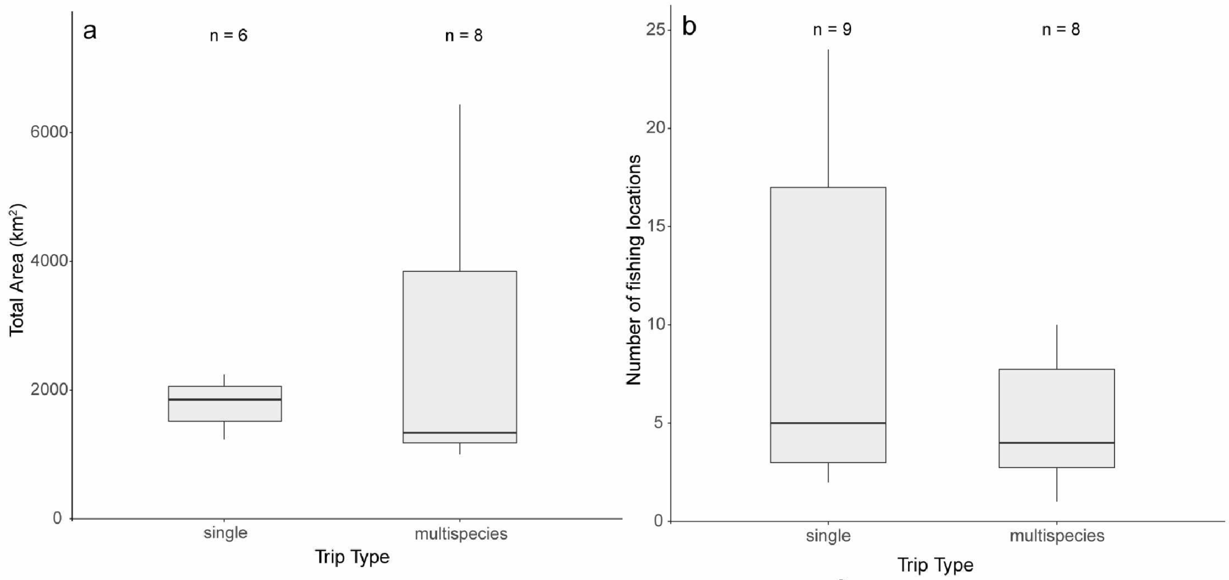

Figure 1-6 Box and whisker plot displaying total fishing area (km^2) (a) and the number of fishing locations (b) for Pacific halibut in Homer, categorized by whether the respondent targets single or multispecies trips for the majority of their charter fishing experience. For both plots, the lower whisker extends from the first quartile to the lowest value within 1.5*IQR of the first quartile. The upper whisker extends from the third quartile to the highest value within 1.5*IQR of the third quartile. Outliers ranging above and below 1.5*IQR have been removed.

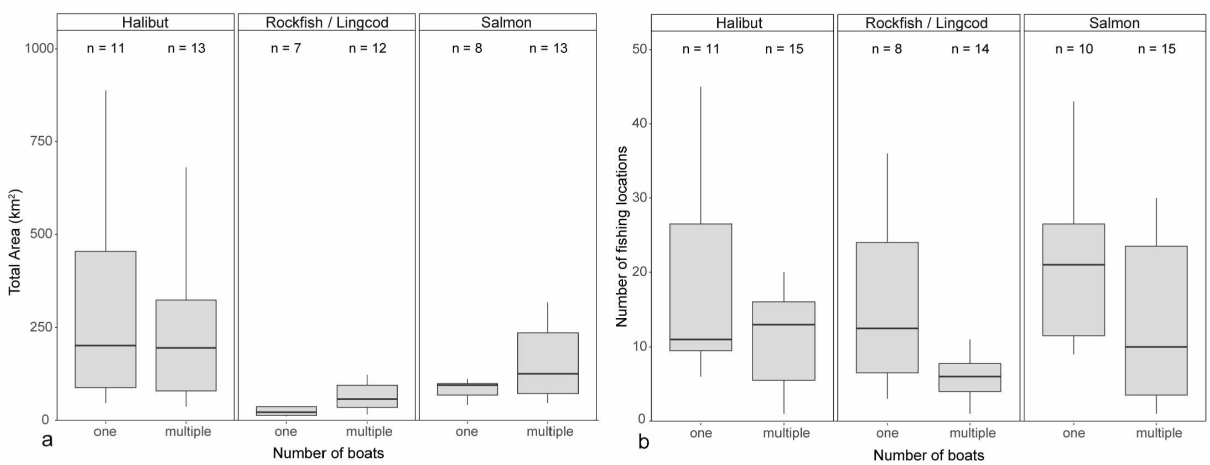

Figure 1-7 Box and whisker plot displaying total fishing area (km^2) (a) and the number of fishing locations (b) for Pacific halibut, lingcod/rockfish, and salmon fishing locations in Sitka, categorized by whether the respondent's business had one or multiple charter boats. For both plots, the lower whisker extends from the first quartile to the lowest value within 1.5*IQR of the first quartile. The upper whisker extends from the third quartile to the highest value within 1.5*IQR of the third quartile. Outliers ranging above and below 1.5*IQR have been removed.

Reasons reported for spatial changes in fishing for Pacific halibut varied between Homer and Sitka. In Homer, the most frequently cited reasons for changes in the location and/or extent of fishing were changes in trip type (45%) and the price of fuel (45%; Table 1-5). In contrast, for Sitka, the most frequently cited reasons for spatial shifts were changes to Pacific halibut regulations (57%), and gaining experience or exploring new locations (38%; Table 1-5). For both locations, changes to Pacific halibut abundance or distribution were the third most frequently cited reason for spatial change (36% in Homer, 24% in Sitka; Table 1-5).

Table 1-5 Summary of the drivers of change to charter fishing locations targeting Pacific halibut.

Driver of change	Homer	Sitka
Change in trip type	45%	0%
Price of fuel	45%	0%
Changes to Pacific halibut abundance or distribution	36%	24%
Gaining experience/exploring new locations	27%	38%
Technological changes (e.g., fishing gear, boat, GPS)	18%	19%
Competitive pressure to target bigger/better halibut	18%	0%
Changes to Pacific halibut regulations	9%	57%
Change in captain's fishing preferences	9%	0%
Changes to Pacific salmon regulations	0%	5%

Discussion

Overall, the spatial footprint of charter fishing differed between Homer and Sitka respondents, with Homer operators consistently using larger areas for Pacific halibut than Sitka operators. For both Sitka and Homer respondents, the range of areas fished was greater for Pacific halibut than for rockfish/lingcod or Pacific salmon. Spatial patterns were qualitatively different between businesses specializing in single species trips and those that operated multispecies trips in Homer. Similarly, spatial patterns were qualitatively different between businesses with one vessel than those with multiple vessels in Sitka. Homer and Sitka showed opposite trends in core fishing location (CFL) area over time, with an overall decrease in Homer and an overall increase in Sitka.

Over the past twenty years, angler effort for charter bottomfish has changed from being focused primarily in Southcentral to a more even distribution between Southeast and Southcentral regions. In 1998, there were 96,158 angler-days of effort for charter bottomfish in Southcentral Alaska and 65,390 angler-days in Southeast [34]. By 2014, Southcentral saltwater charter bottomfish angler effort had increased to 109,981 angler-days, with a similar level of effort in Southeast at 100,940 angler-days [20]. Our results show that even as charter bottomfish effort has equalized between Southeast and Southcentral regions, median area fished for Pacific halibut has been consistently higher for charter operators in Homer compared to those in Sitka over the past twenty years (Figure 1-4).

Collectively, respondents' fishing maps suggest that over the past twenty years, space use has been consistently different between Homer and Sitka charter boats, with Homer operators using larger fishing areas than Sitka operators to target all three species groups (Figure 1-4). The distributions of total area fished and the number of fishing locations for Pacific halibut were statistically different between Homer and Sitka respondents (Table 1-3). Space use between the two communities may differ, in part, due to the habitat and distribution of targeted charter species. During interviews, respondents in Homer explained that charter fishing locations for Pacific halibut and Pacific salmon can be found within several kilometers of town (Figure 1-2, S1 Fig), but lingcod locations are limited to sites greater than 20 km from Homer (S2 Fig). While charter fishing locations in Homer are naturally spatially segregated by target species, Sitka captains noted that there is suitable habitat for all three species groups within several kilometers of town (Figure 1-3, S3 Fig, S4 Fig).

In explaining why spatial changes occurred, Homer respondents identified the price of fuel as a major factor in changes to their spatial footprint (Table 1-5). From 2000-2005, the average price of #2 marine diesel in the port of Homer, Alaska, was $1.47 per gallon and by 2011-2015, it had increased to $3.39 per gallon (Fisheries Economics Data Program, Pacific States Marine Fisheries Commission, http://www.psmfc.org/efin/data/fuel.html). In the 2000s, Homer respondents had a median total fishing area for Pacific halibut that was 10 times greater than Sitka respondents (Figure 1-4); therefore, it is likely that the increase in fuel prices had a greater effect on Homer respondents than on Sitka respondents. In the 2010s, the majority of Homer respondents retracted the area they used to target Pacific halibut to reduce fuel consumption and, therefore, cost (Table 1-3 and Figure 1-7). Two Homer charter operators explained the role that fuel costs played in their decision to stop fishing further south:

> "*Back in the 80s, I probably fished there 30, 40% of the time. I used to take my big boat down there. One day I went down there and it cost $700. I didn't go there for a while after that. There was a time when you'd see 20 or 30 boats down there and now very few boats go down there*." – Anonymous #1

> "*We used to fish around the Barren Islands a lot, the fleet did, when I was first here in the 90s. We used to go down there on a regular basis. The fuel prices affected that because if fuel prices get outrageously high, your rates will be outrageously high for a lot of people* [customers] *too. That created a disincentive to go down there*." – Anonymous #2

The importance of fuel costs in determining charter fishing behavior has been found in other studies as well. Research on the Ohio Lake Erie charter industry showed that in 2006, for boat-owning captains, boat fuel was the largest (29%) annual operating expense [35]. Additionally, the cost of fuel was the most cited concern facing the charter industry in Lake Erie (64% of 232 respondents) [35]. In an analysis of Cook Inlet saltwater sportfishing charter operations near Homer, Alaska, fuel was the second greatest expenditure, after proprietor income [36], highlighting the potential impact of fuel costs on charter businesses in Homer.

In Sitka, the price of fuel was not cited by any respondent as affecting fishing locations or area fished. Rather, Sitka respondents most frequently cited Pacific halibut regulations as the driver of spatial change (57%; Table 1-5). A Local Area Management Plan (LAMP) was implemented in 1999 in which Pacific halibut charter fishing was no longer permitted inside Sitka Sound in the summer months [27]. In addition to LAMP, which pushed charter Pacific halibut fishing to locations greater than 30 km from town (Figure 1-3), starting in the late 2000s, the Sitka charter fleet faced almost yearly regulatory changes regarding Pacific halibut, especially to bag and size limits (Table 1-1). In Homer, where regulations have been more stable and less restrictive, just 9% of respondents indicated that regulations had affected their fishing locations. Similarly, in a recreational fishery in Washington State, only 5% of respondents cited the role of regulations in affecting their fishing locations [31]. These differences in major drivers of spatial change highlight that Homer respondents may be more vulnerable to economic variables such as fuel prices, while Sitka respondents have been more affected by fisheries regulations.

The charter industry operates under different business models in Homer and Sitka, which may explain some of the differences in spatial attributes of fishing among respondents in those communities. Homer has charter businesses that specialize in targeting Pacific halibut and those that target multiple species. Respondents who mainly operated multispecies trips had a wider distribution, but smaller median area for Pacific halibut than those operating primarily single species trips, highlighting that the type of trips offered at a charter business likely affects fishing patterns; however, the spatial attributes could not be statistically compared between these respondent groups due to low sample sizes (Figure 1-5). In Homer, trip type was among the most frequently cited reasons for spatial change (Table 1-5), showing that trip characteristics, such as the targeted species and trip duration, can be indicators of where fishing occurs. Because of reliable Pacific salmon fishing, Sitka charter businesses operate primarily multispecies trips, most often consisting of Pacific halibut and Pacific salmon [20]. In Sitka, both the total area used and the number of discrete locations differed among respondents based on the size of their charter business (Figure 1-7). For Pacific halibut, multiple-boat businesses used a greater number of individual locations than single boat businesses (Figure 1-7). For rockfish/lingcod and Pacific salmon, single boat operators had greater median number of individual locations, but used smaller total areas. Again, while they could not be evaluated statistically, these qualitative differences between single- and multiple-boat businesses highlight that fishing behavior of charter operators may differ based on the size of the business (Figure 1-7).

People operate a diversity of business sizes in the saltwater sportfishing charter industry in Alaska, from owner-operator vessels to fishing lodges with multiple boats. Additionally, charter operators can specialize in single species trips or pursue multiple species based on their skills, customer base, and marketing strategy. The diversity of charter fishing strategies in Alaska allows these groups to respond differently to social, environmental, and regulatory perturbations. Response diversity has traditionally been defined as the range of responses of species within a functional group to environmental change, particularly in the context of maintaining ecosystem function [37]. In recent years, response diversity has expanded to research on social-ecological systems and can be defined as the range of human reactions to the same challenges, opportunities, or risks [38]. Social-ecological resilience has been attributed to response diversity, which may be a crucial part of the adaptive capacity of a system [37, 38]. In Alaska, variation in business sizes and trip types may allow charter fishing to persist as a viable industry long term. For example, in 2014, a regulation was implemented in Southcentral Alaska that prohibited charter operators from fishing for Pacific halibut on Thursdays (Table 1-1). For businesses that only targeted Pacific halibut, the Thursday closure forced them to either reduce business operations or quickly find an alternative target species; however, for businesses that specialized in multiple species, the Thursday closure removed Pacific halibut from the repertoire on that day, but operators were still able to pursue other species (e.g., lingcod and Pacific salmon). Undoubtedly, the day closure reduced the flexibility of charter businesses by placing additional constraints on them, but it affected various actors differently. We argue that the resilience of the charter industry in part depends on the diversity of business strategies within the industry and variation in how different individuals respond to change.

In Alaska, diversity in charter fishing originates from endogenous factors within charter businesses (e.g., variation in business models), but also from exogenous drivers such as differences in regulatory restrictions between regions. In Sitka, with the bag limit already at one fish, there have been yearly changes to Pacific halibut size limits for the past five years (Table 1-1). In Homer, few limits were placed on charter fishing until 2014, but the community has faced a faster pace of change since then, with three new regulations simultaneously added in 2015 (Table 1-1). The constancy of incremental regulatory changes may give Sitka businesses the outlook stability needed pursue long-term business goals, such as marketing reliable trips to customers or expanding the business, rather than having to quickly adapt to sudden large changes. Barring major future changes, we might expect stability in the spatial footprint of charter fishing in Sitka. However, the uncertain climate of future regulatory change in Homer makes it difficult to predict how charter operators will shift their behavior, including target species and locations, to accommodate new regulations. These differences between Homer and Sitka illustrate the importance of recognizing the place-based context in which policies for bag limits, spatial closures, or other management changes are made so that the impacts on local people, and associated ecological impacts, can be appropriately assessed.

Acknowledgements

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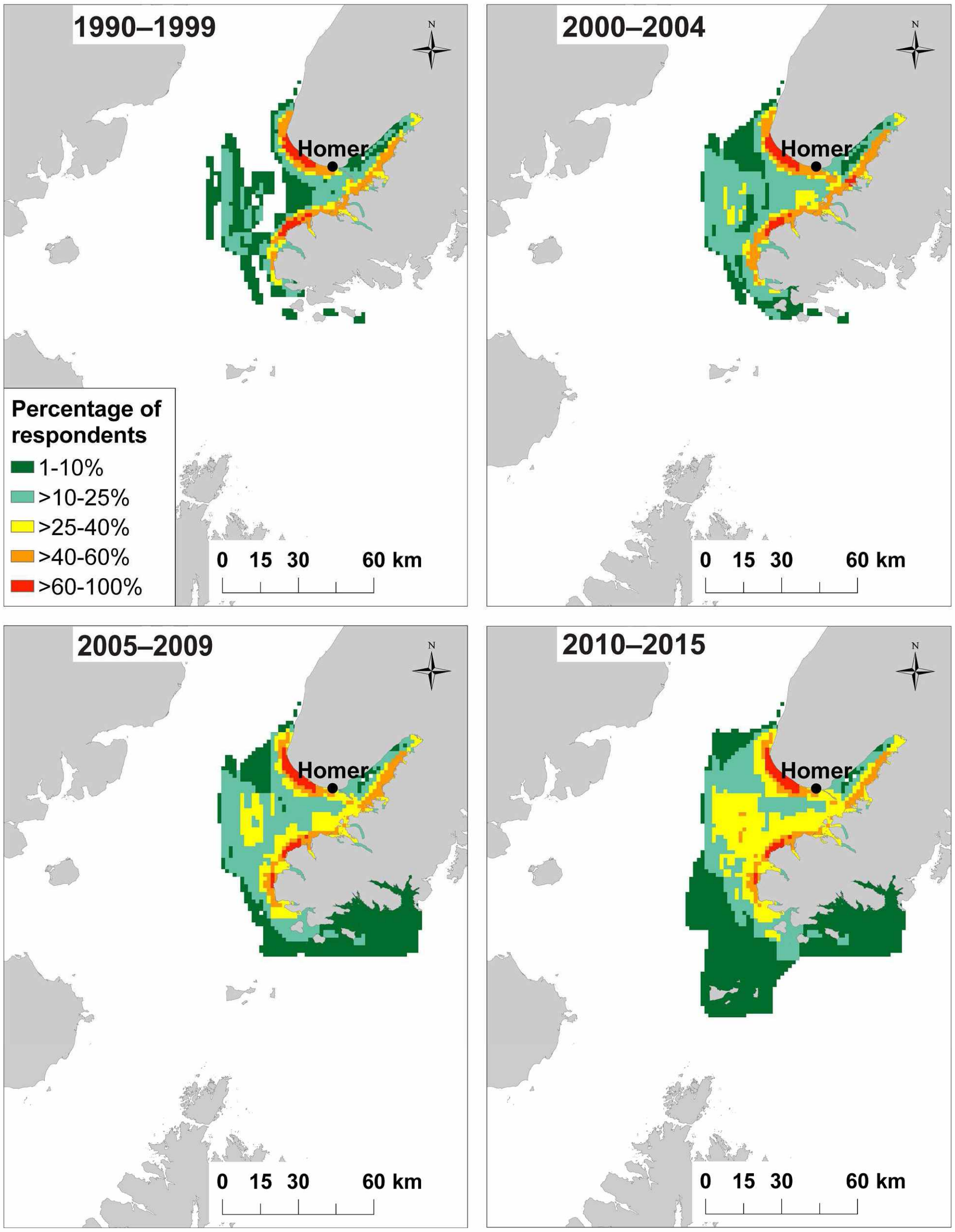
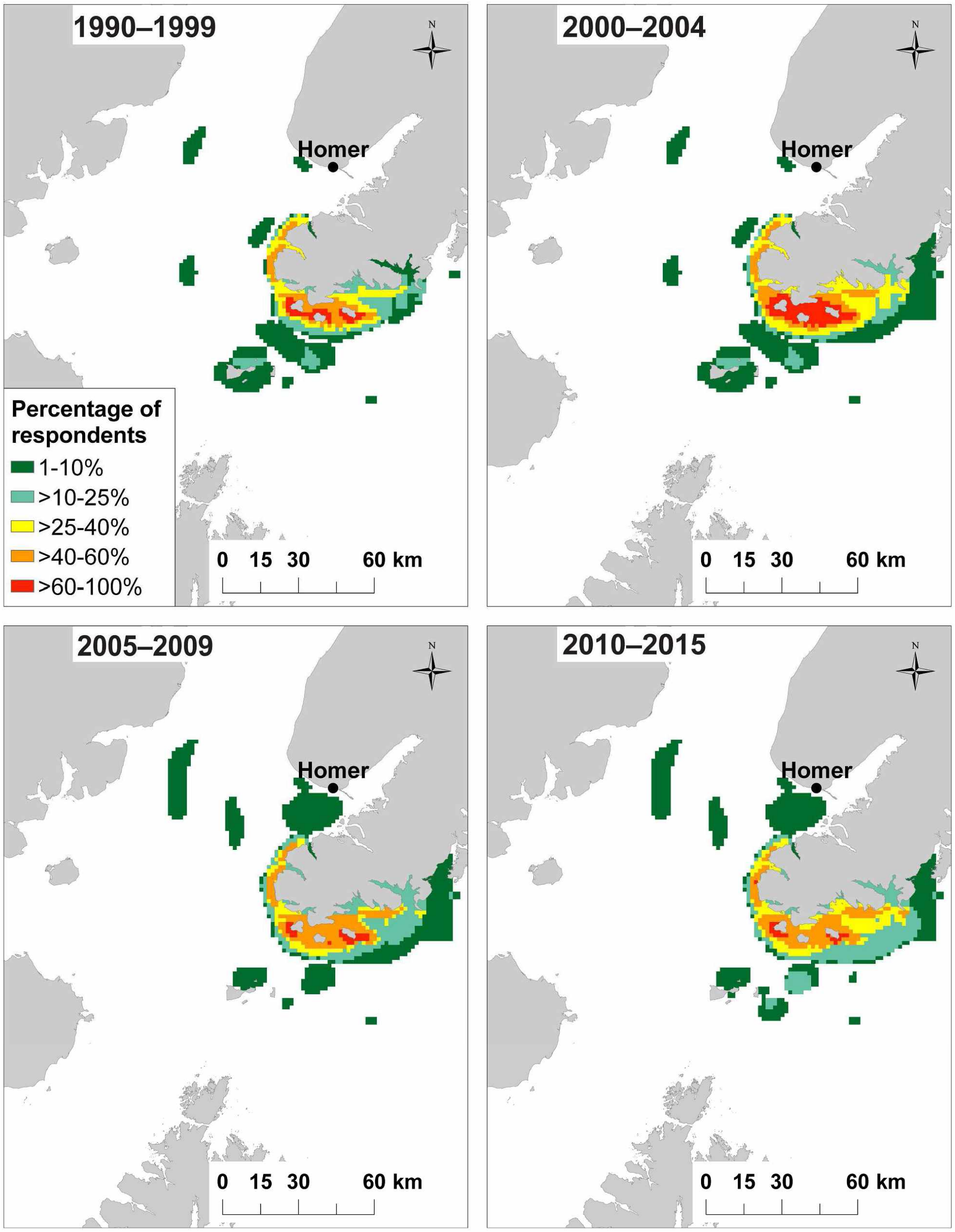
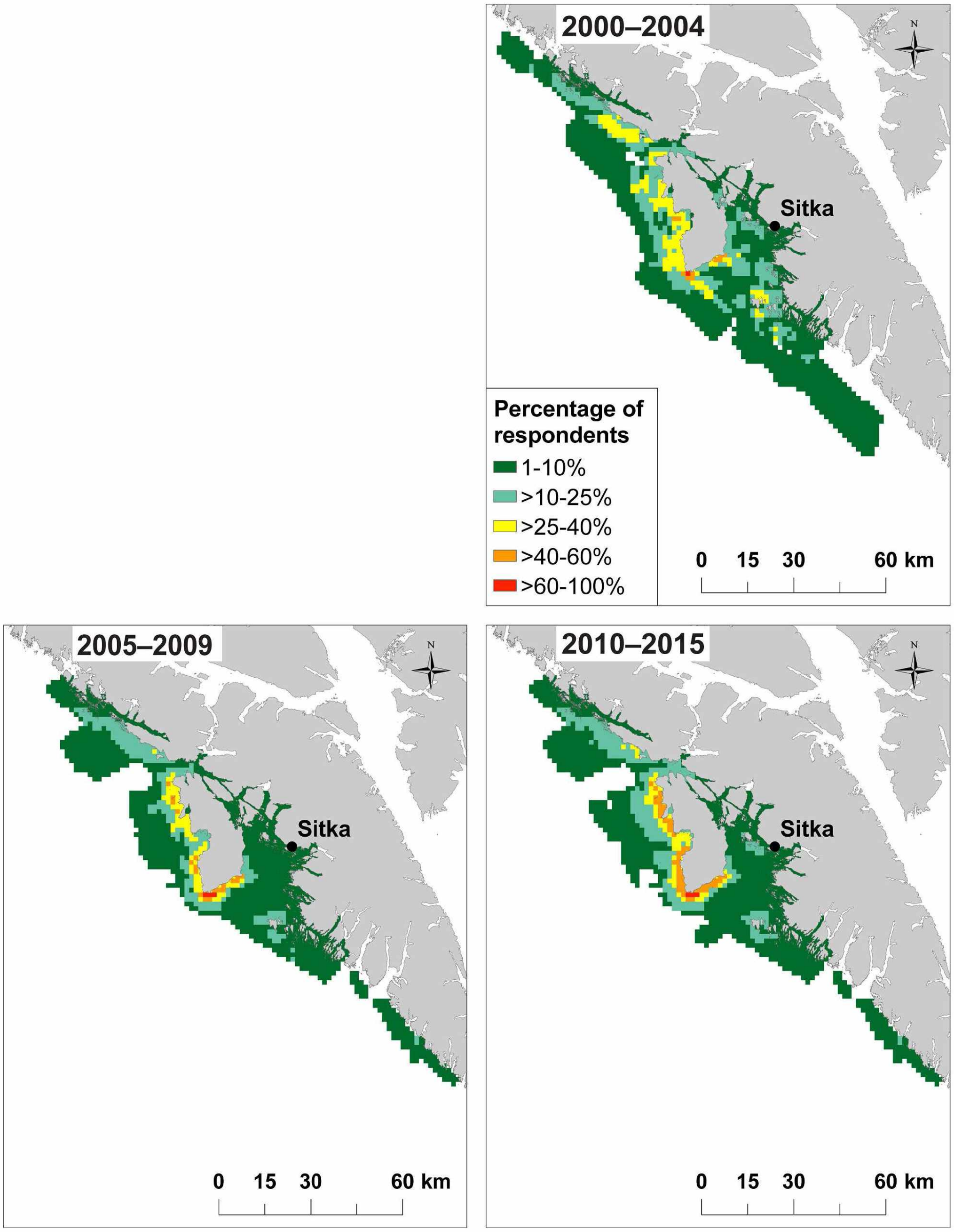
Supporting information



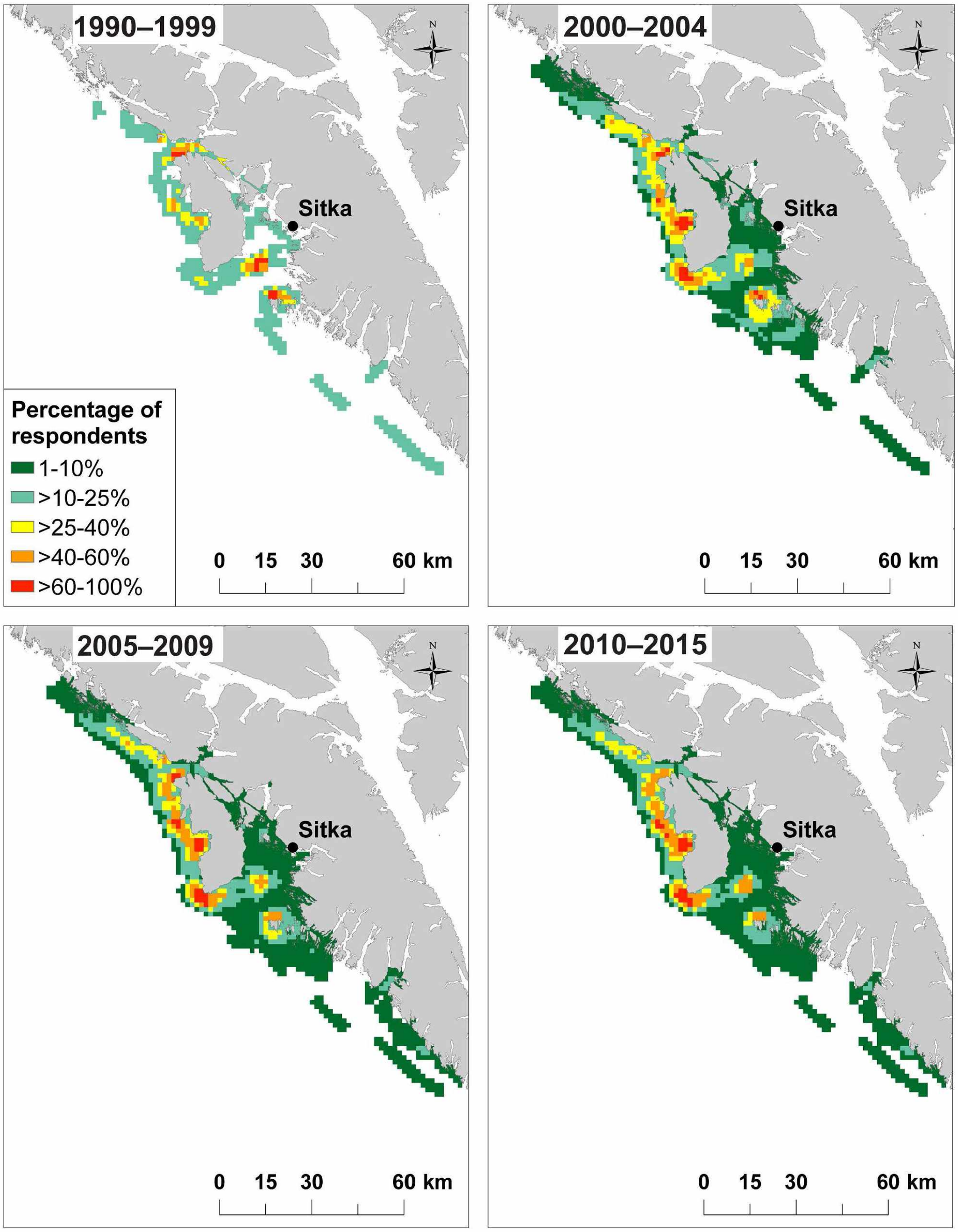
S1 Fig. Salmon fishing locations in Homer for 1990-1999, 2000-2004, 2005-2009, and 2010-2015. Locations are displayed by the percentage of respondents who fished during that time period.



S2 Fig. Lingcod and rockfish fishing locations in Homer for 1990-1999, 2000-2004, 2005-2009, and 2010-2015. Locations are displayed by the percentage of respondents who fished during that time period.



S3 Fig. Lingcod and rockfish fishing locations in Sitka for 2000-2004, 2005-2009, and 2010-2015. Locations for 1990s are not shown due to low sample size (<5 respondents). Locations are displayed by the percentage of respondents who fished during that time period.



S4 Fig. Salmon fishing locations in Sitka for 1990-1999, 2000-2004, 2005-2009, and 2010-2015. Locations are displayed by the percentage of respondents who fished during that time period.

S1 Text. Questions administered to interview respondents. After acquiring informed consent, the interview team asked a series of questions to the participant on charter fishing experience, charter business information, and fishing locations.

1. In Alaska, what fisheries have you participated in? Mark more than one if applicable.

□ Commercial fishing
  Which years: ____
  Target species: ____
  Methods / gear type(s) used: ____
  Approx. days per year and changes over time:

□ Recreational fishing - Unguided
  Which years: ____
  Target species: ____
  Methods / gear type(s) used: ____
  Approx. days per year and changes over time:

□ Subsistence fishing
  Which years: ____
  Target species: ____
  Methods / gear type(s) used: ____
  Approx. days per year and changes over time:

□ Other, please specify: ____
  Which years: ____
  Target species: ____
  Method(s) used: ____
  Approx. days per year and changes over time:

□ Recreational fishing – Charter fishing (as an operator only)
  Which years: ____
  Target species: ____
  Methods / gear type(s) used: ____
  Approx. days per year and changes over time:

Background information on charter business [Respondent fills out]

1. How would you characterize your involvement in the charter fishery? (Circle all that apply)
   a) Charter owner/operator, single vessel
   b) Charter owner/operator, multi-vessel owner
   c) Charter business / lodge owner
   d) Employee (hired as captain)
   e) Independent contractor (hired for services as captain and boat)
2. What best describes the majority of your business activity? (Circle all that apply)
   a) Fishing only
      i. "Half day" trip
      ii. "Three-quarter day" trip
      iii. "Full day" trip
      iv. "Overnight" trip
      v. "Multi day" trip
   b) Combination fishing and dedicated eco-tour/wildlife-viewing

c) Combination fishing and hunting

3. How many and what type of boats does this operation have?
4. How many Charter Halibut Permits does this operation have?
5. What is your position within this operation? (examples: lead skipper, owner-operator)
6. What months do you participate in this charter operation?

Spatial changes [Respondents fill out]

1. On the maps provided, mark the areas that you target halibut and each of the other species for each decade you have participated in the charter sector. [Respondents will be given a different color for each species.]

Currently, what are the areas you target the following species:
Halibut - green
Salmon - orange
Lingcod - yellow
Rockfish - pink
Other -
Have your fishing areas changed since you first started charter fishing? Why?
Can you recommend anyone else to interview?

Chapter 2 Evaluating the recreational fishery management toolbox: Charter captains' perceptions of harvest controls, limited access, and quota leasing in the guided halibut fishing sector in Alaska[1]

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Abstract

Examining the reasons why individuals choose to participate or comply with certain fishing regulations is a key part of successful fisheries management. This paper presents a case study that evaluates fisher perceptions of multiple recreational fishery regulations, including traditionally used methods of bag and size limits and a novel regulation involving quota leasing, in the for-hire (i.e., charter) recreational fishing sector for Pacific halibut (*Hippoglossus stenolepis*) in Alaska. This study examined responses from open-ended and Likert-scale questions from semi-structured interviews with 45 charter operators in Homer and Sitka. Our results highlight that controls on individual harvest can be perceived to have unintended consequences for charter businesses, such as effects on profitability and distance traveled. In response to open-ended questions on a voluntary quota leasing program, participants discussed themes of inequity reflecting broader perceptions of conflicts with the commercial sector and the management system. Perceived inequities that have not been fully addressed can shape how stakeholders feel about current management institutions and affect compliance. Therefore, it is important to understand the historical and political contexts of fishery systems to better anticipate participation in future management approaches.

Introduction

As harvests in marine recreational fishing have increased in magnitude in the U.S. over the last few decades [1], scholars have explored ways to reduce the environmental impact of recreational fishing [2, 3]. Currently, the tools available for managing recreational fisheries focus primarily on the angler. Some place restrictions on individual anglers, such as daily catch limits, possession limits, and size limits, and others focus on the entire sector, such as where, when, and how fish can be caught. However, as the effectiveness of these methods to restrict recreational catch have been increasingly scrutinized, it has become evident that while individual harvest controls limit individual catch, they do not effectively limit total recreational harvest because there are no limits on licenses or effort (i.e., number of participants) [4]. To control total recreational harvests, tools affecting sector-wide effort and catch have emerged, such as quota allocation, and limits on the total number of licenses issued.

While traditional harvest control tools have been at the core of managing recreational fishing, research shows that success of fishing regulations largely depends on fisher compliance [5-7]. The lack of compliance can affect the efficacy and outcomes of fisheries regulations [8-10]. Examining the reasons why individuals choose to participate in recreational fisheries or comply with certain fishing regulations, including social dynamics and perceptions of management is a key part of successful fisheries management [11-14]. Understanding the human dimensions of recreational fisheries, such as fisher behavior, motivations, and attitudes, allows managers to better anticipate responses to regulations and to design regulations that are more likely receive support from stakeholders [15].

For guided fishing businesses, perceptions of regulations by captains can play an important role in how regulations and fishing advisories are transmitted to recreational anglers

[16]. Therefore, captains of fishing businesses have the potential to affect angler compliance on a large scale. This paper presents a case study that evaluates charter captains' perceptions of multiple recreational fishery regulations, including traditionally used methods of harvest controls and a novel regulation involving quota leasing, in the for-hire (i.e., charter) sector for Pacific halibut (*Hippoglossus stenolepis*) in Alaska. Charter fishing is a popular activity in Alaska and an important source of revenue for businesses in tourism-focused coastal communities. Pacific halibut (hereafter referred to as halibut) is the most harvested bottomfish in the charter sector, comprising 47% of bottomfish harvest in 2014 [17]. Controls on the charter sector were established in 1975 (two-fish bag limit with no size limit) [18], which remained unchanged for over 30 years until 2007 in Southeast Alaska and 2014 in Southcentral Alaska [19, 20]. Concerns over the growth of the charter sector have led to the implementation of additional restraints on charter fishing effort, including a limited entry program in 2011 (75 Federal Register 554) and an assortment of measures starting in 2014 in the form of trip limits, a closure of one or more days per week, and voluntary quota leasing [21]. However, with the exception of an analysis of the voluntary leasing program [22], there has been little research on the perceptions and support of these recent management measures by the charter industry.

The objective of this study was to examine charter operators' perceptions of traditional and novel recreational fishery management tools in two communities: Homer, Alaska, and Sitka, Alaska. We hypothesized that perceived impacts of regulations on charter captains and their businesses would differ between Homer and Sitka, due to differences in their social, economic, regulatory, and ecological characteristics. Homer is located in the Southcentral region of Alaska and is on the Alaska road system. It is accessible to much of the state, including the Anchorage metropolitan area, the largest population center in Alaska (2016 U.S. census population estimates; www.census.gov). Sitka, by comparison, is located on Baranof Island, in the Southeast region of Alaska, and is accessible only by plane or boat. The Southcentral region attracts more Alaska resident angler effort (26% of charter angler-days fished by residents in 2014) compared to the Southeast region (3% charter angler-days fished by residents in 2014; Powers and Sigurdsson 2016). In addition to differences in their customer base, Sitka and Homer also differ in the variety of species available, the types of trips offered to customers (e.g., Pacific halibut-only vs. multispecies), and their histories of regulation [23]. Below, we discuss how these differences set the context for understanding charter operators' perceptions of recent regulation changes. Ultimately, the research we report here highlights the importance of understanding the political and historical context of local fishery systems and provides a deeper examination of the possible impacts of regulation on charter businesses.

<u>Management of the charter halibut sector in Alaska</u>

Management of Pacific halibut (halibut, hereafter) occurs at the international, federal, and state levels. At the international level, halibut is jointly governed between the United States and Canada through the International Pacific Halibut Commission (IPHC), which conducts annual stock assessments and sets an overall catch limit and apportions it among ten regulatory areas, one in the U.S. Pacific Northwest, one encompassing the coast of British Columbia, and eight in waters off Alaska. In addition, the IPHC establishes seasons, minimum size limits for commercial fisheries, and other annual management measures [24]. Each nation is responsible for ensuring that the sum of directed catches (commercial, sport, and subsistence), incidental catch, and discard mortality is no greater than the limit set by the IPHC. Under the Magnuson-Stevens Fishery Conservation and Management Act (U.S. Public Law 94-265), authority to allocate catch among fishing sectors devolves to the North Pacific Fishery Management Council (NPFMC) subject to consistency with national standards and other applicable federal law. Responsibility for reviewing NPFMC decisions, implementing management measures, monitoring catches, and enforcing regulations falls to the National Marine Fisheries Service (NMFS). At the state level, the Alaska Department of Fish and Game (ADF&G) administers license programs for sport fishers and sportfishing guides, oversees a logbook program that is required for charter vessels, conducts creel surveys, and manages an annual statewide harvest survey of sport anglers in Alaska.

Halibut catch in the Alaskan charter fishery is influenced, primarily, through size limits, gear restrictions, and bag and possession limits. Even though catch restrictions are common recreational fishing management tools, they alone cannot restrict sector-wide harvests without accompanying constraints on participation [25]. This challenge has been observed in Alaska's charter sector; as charter halibut harvest increased in Alaska throughout the early 2000s [21], there was also a 14% increase in the number of saltwater-guide businesses in Alaska, from 847 in 1999 to 917 in 2006 [26, 27]. In an attempt to control charter sector growth, NPFMC established the Charter Halibut Limited Access Program in 2011 to limit the number of charter vessels permitted to offer charter trips for halibut in Southeast and Southcentral Alaska [28]. This program issued a fixed number of federal Charter Halibut Permits (CHP) to charter operators and/or businesses based on historical participation as a charter operator during a set of qualifying years. In 2014, the Guided Angler Fish (GAF) program was introduced, which allows for temporary one-way leasing of commercial individual fishery quota (IFQ) for use by charter businesses, including self-transfers for charter operators who also own IFQ (78 Federal Register 75843). The GAF program is dependent on willing participation from the commercial sector, which has been managed under IFQs since 1995 [29]. A charter operator participating in the GAF program leases IFQ from a commercial fisher and during that charter season, can designate a customer who can harvest halibut up to non-charter sport bag and size limits (i.e., two fish daily bag limit with no size restrictions) (50 CFR 300.65, Lew et. al 2016). While the charter operator pays an up-front cost to the commercial fisher to lease IFQ, this cost is typically passed on to the charter customer who harvests under the more liberal GAF guidelines. In 2014, the first year of the program, approximately 18.6 metric tons of IFQ were leased equating to around 2,000 fish [30], but only 1,069 fish were actually harvested [31].

Participation in the GAF program has been relatively limited by charter businesses since its inception in 2014 (7% of the unique 564 CHP holders participated in 2016; Scheurer 2016, Charter Halibut Permits List https://alaskafisheries.noaa.gov/permits-licenses). A 2015 mail survey conducted by NOAA and sent to all CHP holders (response rate of 48%) found that the most frequently cited reasons for not participating in the GAF program during 2014 were that "leasing GAF was too expensive" (46% of participants), followed by "did not support the GAF program" (45% of participants) and "did not want to conduct business with commercial fishing businesses" (22% of the participants) [22]. In 2016, the average cost per GAF halibut was $197 and $353 in Southcentral and Southeast (Scheurer 2016). In Southcentral Alaska, "did not support the GAF program" was the most frequently cited reason (52% of participants) for not participating [22]. These survey results, combined with consistent low participation, suggest that there is substantial charter opposition to the GAF program. While the NOAA survey showed a general lack of support amongst charter businesses and captains, it was not designed to identify why they did not support the GAF program. Our research fills this gap by identifying the key reasons for low charter participation and resistance to the GAF program.

Materials and Methods

Semi-structured, in-person interviews [32] were conducted with charter operators in Homer (May and June of 2015) and Sitka (May and June of 2014 and 2015). Participants were initially solicited through newsletter announcements distributed by four charter associations (Alaska Charter Association, Homer Charter Association, Southeast Alaska Guides Organization, and Sitka Charter Boat Operators Association). Additionally, introduction letters were mailed in spring 2014 to 2014 CHP holders with their CHP address listed in Sitka, AK. Introduction letters included a one-page summary of the research project, anticipated travel dates to Sitka or Homer, and researcher contact information. In spring 2015, introduction letters were mailed to 2015 CHP holders with their CHP address listed in Homer, AK.

Additional participants were identified using snowball sampling, in which participants are invited to suggest individuals to participate [32]. All participants were active charter operators at the time of the interview (i.e., captain of a charter vessel and/or a charter business owner). Interviews attempted to capture a broad diversity of views that could shed light on the varied ways that people are experiencing regulation changes [33], but did not attempt to assess the extent to which these views are represented among charter operators as a whole. Participants were asked to volunteer for interviews and were not provided incentives for participating. The project received approval from the Institutional Review Board through the University of Alaska Fairbanks (#583323).

Charter operators' views of how regulations have affected their fishing businesses were examined through two types of questions. Close-ended questions using a Likert-scale were used to assess perceptions of individual harvest controls directly targeting charter-fishing behavior (e.g., changes to bag limits, restrictions on number of charter trips per day). Open-ended questions were used to assess perceptions of sector-wide controls with broad ranging effects on charter businesses. These are described in detail below.

To examine individual harvest controls, two regulations in each region implemented in the last five years were selected. These regulations were selected based on conversations with charter operators, charter organizations, and managers during the project development phases and were identified as having substantial impacts on charter businesses in each local region. In Sitka, participants were asked about the effects of 1) a decrease in bag limit in 2009, and 2) a change from a maximum size limit to a reverse slot limit in 2012. In the Homer, participants were asked about 1) the implementation of a vessel trip limit in 2014, and 2) the establishment of a size limit in 2014. Participants were asked to answer closed-ended questions on the effects of a particular regulation on their charter business (Appendix 2-1). For example, a participant was asked whether that regulation decreased, had no effect, or increased the distance he or she traveled on an average trip. Likert-scale responses were summarized using the package 'likert' [34] in R (Rx64, version 2.15.2, http://www.R-project.org/).

To evaluate effects of sector-wide regulations, open-ended questions were used to ask about charter operators' perceptions of the effects of the CHP and GAF programs on their businesses (Appendix 2-2). Open-ended responses to each question were transcribed and analyzed for themes in ATLAS.ti 8.0 (2002–2017, ATLAS.ti Scientific Software Development GmbH) [35]. The analysis was inductive, meaning that concepts were coded as they were encountered, and no *a priori* coding dictionary was used. Quotes from interview participants are presented throughout the paper to provide context for the coded themes. In some cases, spelling, spacing, and punctuation were standardized for ease of reading. Every effort was made to maintain the meaning conveyed by participants.

Results

Eighteen charter operators were interviewed in Homer and 27 charter operators in Sitka. Participants from Sitka and Homer differed in their years of experience as a charter operator, age, and residency (Table 2-1). On average, Homer participants were older with more years of charter experience compared to Sitka participants (Table 2-1). Most of the Homer participants (94%) reside in Alaska, while 62% of the Sitka participants reside full time in the state. Over 85% of participants in each study location responded to Likert-scale questions (Table 2-2).

Table 2-1 Characteristics of interviewees in this study.

Interviewee characteristics	**Sitka**	**Homer**
Number of participants	27	18
Age (average)	40	55
Age (range)	24 - 62	31 - 76
Years of charter operating experience (average)	13	22
Years of charter operating experience (range)	3 - 25	2 – 34
Percent of participants who reside in Alaska	62%	94%

Table 2-2 The number of interviewees who responded to Likert-scale questions on the effects of regulation changes on the distance traveled to fishing grounds, profitability, and the number of unguided recreational anglers.

Number of responses to Likert-scale questions			
	Distance traveled	Profitability	Unguided recreational anglers
Sitka 2009 bag limit	24	23	24
Sitka 2012 size limit	25	23	25
Homer 2014 trip limit	16	16	17
Homer 2014 trip limit	16	17	16

Perceptions of individual harvest controls

In Southeast Alaska, a 2009 rule shifted charter halibut regulations from a two-fish bag limit with one less than 32 inches, to a one-fish bag limit with no size restrictions [19]. A majority of Sitka participants (58%) reported that this regulation increased the distance they traveled on an average charter trip, while 42% indicated no effect; no participants reported a decrease in the distance traveled following the change (Figure 2-1). This reduction in bag limit in Southeast Alaska was also perceived by 48% of Sitka participants to decrease the profitability of their fishing business, with 52% reporting no effect and no participants reporting an increase (Figure 2-2). Sitka participants largely viewed the bag limit reduction as having no effect on the number of unguided recreational anglers fishing in their areas (Figure 2-3).

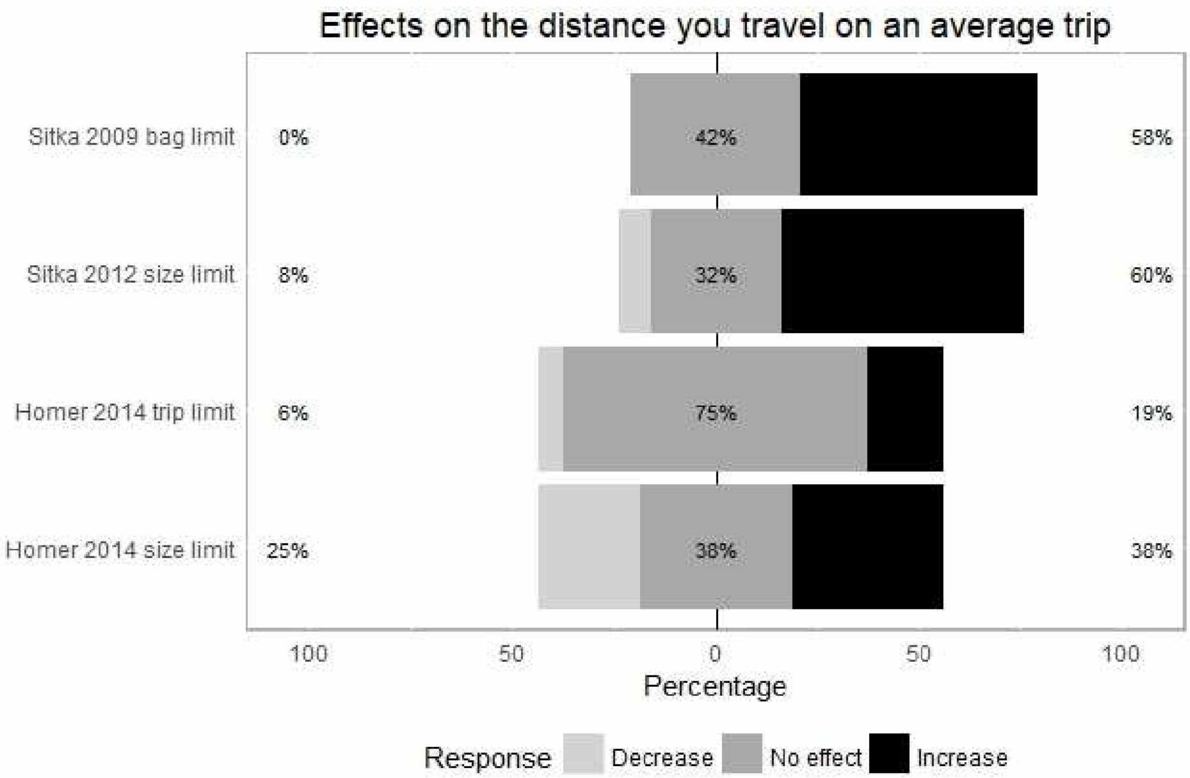

Figure 2-1 Interviewee responses to a Likert-scale question on the impact of a regulation on the distance traveled. Interviewees were asked to choose whether a regulation decreased, had no effect, or increased their distance traveled on an average charter trip. Interviewees were asked to respond only for regulations specific to their region.

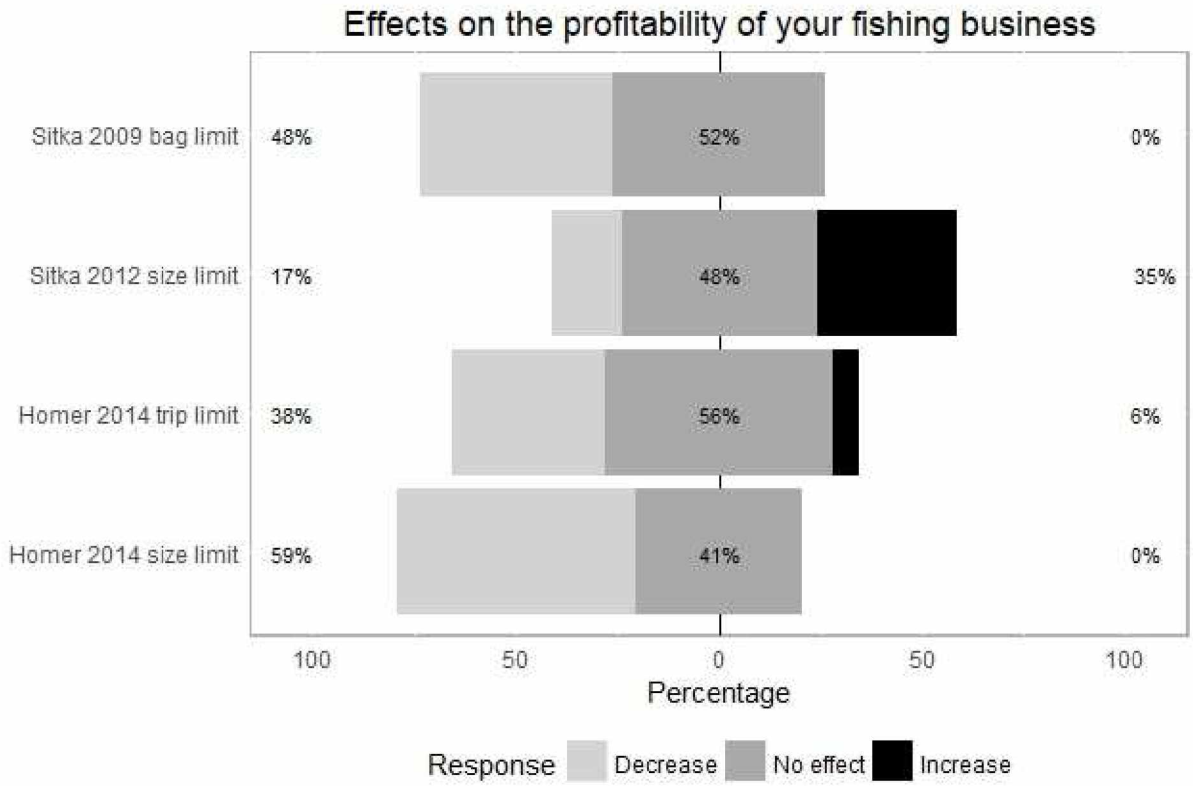

Figure 2-2 Interviewee responses to a Likert-scale question on the impact of a regulation on profitability. Interviewees were asked to choose whether a regulation decreased, had no effect, or increased the profitability of their fishing business. Interviewees were asked to respond only for regulations specific to their region.

The second regulation assessed was a 2012 regulation, which changed halibut limits in Southeast Alaska from one-fish less than 37 inches to a reverse slot limit of one-fish that could either be ≤45 inches or ≥68 inches. This regulation liberalized the maximum size limit of halibut from 37 to 45 inches and added a larger size class of halibut that could be retained. In other words, this regulation created a size class of halibut that cannot be retained (46 to 67 inches). The majority of Sitka participants (60%) reported that this regulation increased the distance they traveled on an average trip, while 8% reported a decrease and 32% perceived no effect (Figure 2-1). This change in the size limit was also perceived by 35% of Sitka participants to increase the profitability of their fishing business, with 48% reporting no effect and 17% participants reporting a decrease (Figure 2-2). As with the bag limit reduction, most Sitka participants indicated that the change in size limit had no effect on the number of unguided recreational anglers fishing in their areas (Figure 2-3).

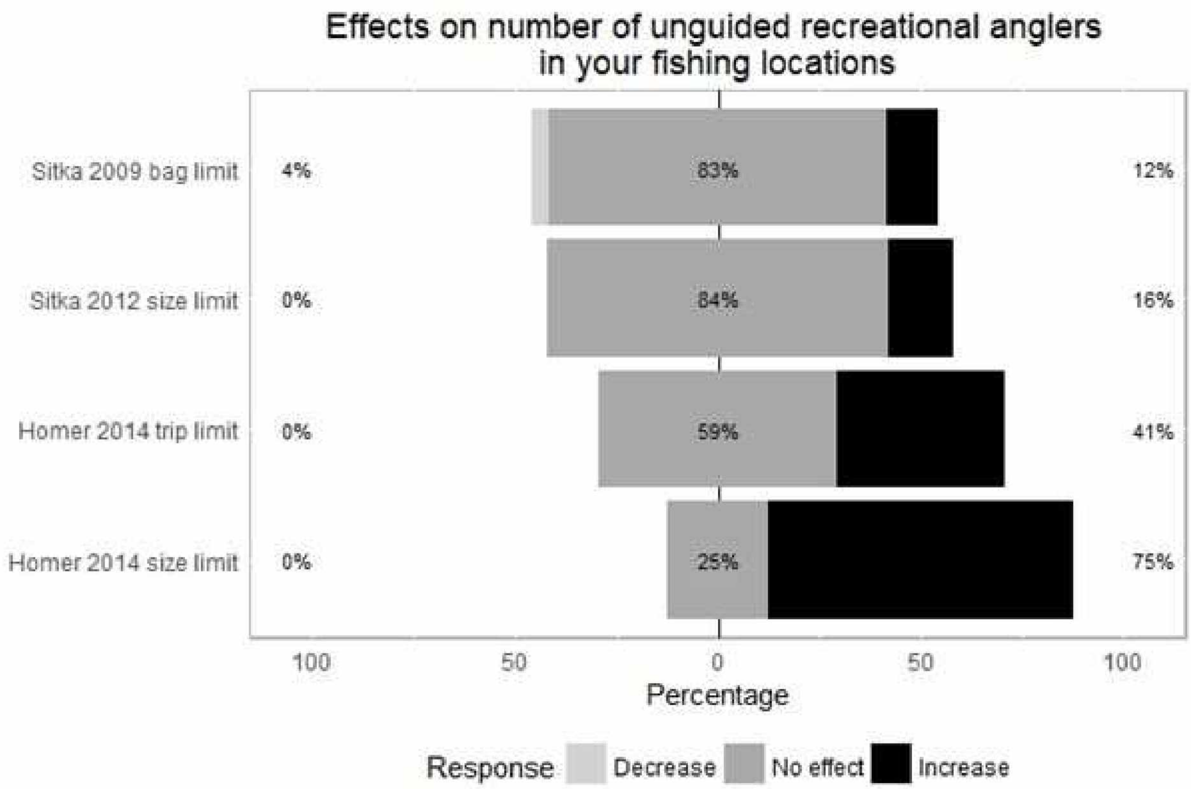

Figure 2-3 Interviewee responses to a Likert-scale question on the impact of a regulation on unguided recreational anglers. Interviewees were asked to choose whether a regulation decreased, had no effect, or increased the number of unguided recreational anglers in their charter fishing locations. Interviewees were asked to respond only for regulations specific to their region.

The first regulation assessed for Homer was a 2014 regulation that limited a charter vessel to one charter halibut trip per calendar day. Previously, the number of charter trips per day had not been restricted and Homer-area businesses primarily offered a choice of half-day and full-day trips [23]. At the height of the season, businesses operating half-day trips were able to schedule two trips per day (e.g., morning and afternoon). For businesses that were operating two half-day trips per day, this regulation was perceived to reduce their business substantially. This regulation specifically affected businesses operating half-day trips, with little effect on those who operated full-day trips. Of the Homer interviewees, five out of 18 currently still operate half-day trips (i.e., one half-day trip per day). The majority of Homer participants viewed this regulation as having no effect on the distance they travel to fish (75%, Figure 2-1), the profitability of their business (56%, Figure 2-2), or the number of unguided anglers fishing in their areas (59%, Figure 2-3). However, 38% reported that their profitability had decreased (Figure 2-2) and 41% indicated that the number of unguided anglers had increased (Figure 2-3) because of the trip limit.

In Southcentral Alaska, a 2014 regulation was implemented that established a size limit for the second allowable fish. Specifically, the regulations changed from a two-fish bag limit with no size restrictions to a two-fish bag limit with a maximum size of 29 inches for one of the retained fish. Homer interviewees were divided on the effects of this regulation on the distance they travel on an average trip, with 25% reporting a decrease, 38% reporting an increase, and 38% reporting no effect (Figure 2-1). A slight majority (59%) indicated that the regulation had a negative effect on the profitability of their businesses, while 41% reported no effect (Figure 2-2). Most Homer participants perceived that the introduction of a size limit on the second fish increased the number of unguided recreational anglers who fish in the same areas (75%; Figure 2-3).

<u>The Charter Halibut Permit (CHP) program</u>

The CHP program limited the number of charter boats in the charter halibut sector in both study locations. From the analysis of open-ended questions, the most common theme regarding the effects of the CHP program was that it had “no effect on me or my business” (41%). Other effects reported included “decreased the number of charter operators” (22% of interviewees), “overall negative effect on me or my business” (14%), and “the limited entry program was inequitable” (14%). The sampling frame in this study consisted of charter operators active in the charter business in 2014 or 2015 and did not include charter operators who did not qualify for a permit, were unable to purchase a permit, or who do not target halibut; therefore, perceptions of the limited access program documented here are biased towards operators who qualified for a permit or had the ability to purchase a permit.

Although the majority of interviewees commented that the limited access program had no effect, some interviewees shared their frustration with the CHP program, namely, that the qualifying process did not properly address extenuating circumstances and that the cost of entry into the sector increased after the CHP program was implemented. As a charter operator said,

> I think they are [CHPs] going for like, $20,000 now. That’s a huge deterrent…there are so many expenses…The cost for entry in this business is a barrier in itself especially when the economy’s down. Even if the young guys like me who are all about conservation and we want to help save the fishery, we can’t even get in the business…because it just costs too much.

Guided Angler Fish (GAF)

The GAF program allows charter operators to lease commercial halibut IFQ for use by charter clients, up to unguided sport halibut limits. Half of the interviewees discussed concerns of inequity related to the GAF program. Other predominant themes that were identified from open-ended responses included: “the program favors the commercial sector” (31% of interviewees), “no effect on me or my business” (25%), and “overall negative effect on me or my business” (22%). Perceptions of inequity centered on several perceived themes including lack of consultation with the charter sector and unfair distribution of benefits and costs. Specifically, 31% of interviewees commented that the GAF program favors the commercial sector, in particular because of the perception that benefits of the program were accrued more towards commercial sector. As a charter operator said,

> I refuse to participate in it [GAF]. There's no way I'm going to commingle sport fishing with commercial fishing…I would be aiding and abetting commercial fisherman to sit home and do nothing and make a lot of money off it and I refuse.

Some interviewees in the current study indicated a lack of support for the GAF program because they do not believe that commercial fishing for halibut should have transitioned to catch shares in the first place. For example, one charter operator said,

> I just disagree with it [commercial halibut IFQs] on general principle and I won't have anything to do with it. I won't buy a GAF fish… I think it's an insult to the charter sector.

A quarter of interviewees reported that the GAF program has no effect, and 22% reported an overall negative effect. Interviewees who perceived no effect from GAF were simply not planning to participate in the program and did not see how the program could be beneficial or detrimental to their charter business. Interviewees who noted an overall negative effect from GAF were primarily concerned that the charter businesses who participate in GAF would be more competitive than businesses without GAF. Specifically, interviewees mentioned that charter operators who already possessed commercial fishing quota would benefit from the GAF program because of the ability to self-lease (i.e., lease from your commercial halibut quota to your charter business). A charter operator said,

> It won't allow me to grow my business if I wanted to, it puts me at a decided disadvantage with sport fishing charter companies that already own commercial fishing quota. I think that's the biggest complaint with a lot of charter boat

owners, we're not fortunate enough to have quota, so we can't GAF, because it's pretty cost prohibitive.

Discussion

Charter captains perceived the effects of fishing restrictions in different ways. A majority of respondents in Sitka perceived specific bag and size limit changes to increase their distance traveled on an average trip (58% and 60%, respectively). This aligns with our previous findings that Sitka captains expanded their fishing areas over time due to changes in halibut regulations (Chan et al. 2017). One possible explanation for this result is that tighter limits may lead anglers to seek fish of the allowable sizes in new areas, particularly if there is spatial heterogeneity in the size structure of the target species. Most Homer interviewees perceived that the 2014 size limit increased the number of unguided recreational anglers in their fishing locations and decreased the profitability of their businesses (75% and 59%, respectively). Previous research found that restricting the size of the second fish in a two-fish bag limit could still maintain economic value for charter trips in Alaska [36]. However, our results suggest that there could be indirect effects of the charter size limit on the number of unguided recreational anglers when no size limits are placed on non-charter halibut. As a charter operator explained,

> We go out and put the anchor down and there could be 50 boats parked around us. The increase in the number of small boats in Alaska, especially on the Kenai Peninsula and Anchorage…has tremendously increased.

Charter captains suggested this had resulted, in part, from resident anglers shifting from charter fishing to fishing on private boats (e.g., "bare-boat charters," or vessels offered for daily lease to anglers). While our study did not seek to corroborate charter operators' perceptions with independent data, these results show that charter operators consider regulations targeted at their fishing behavior to have broader impacts on the profitability of their businesses and potential competition for space with unguided anglers.

Understanding the governance structure and representation within governing bodies is important for interpreting charter perceptions of the GAF program and other regulations. The decision-making body at NPFMC consists of 11 voting members, the NMFS regional administrator and ten members nominated by the governors of Alaska (6), Washington (3), and Oregon (1); non-voting members include representatives of various federal departments and agencies (U.S. Coast Guard, U.S. Department of State, U.S. Fish and Wildlife Service, and Pacific States Marine Fisheries Commission) [37]. As specified in regulation, the NPFMC includes four voting members who represent federal or state government: the NMFS Alaska Region Administrator (or designee), the Alaska Department of Fish and Game Commissioner (or designee), the Washington Department of Fish and Wildlife (or designee), and the Oregon Department of Fish and Wildlife Commissioner (or designee). While often perceived as being focused on commercial fisheries, these government officials oversee commercial, sport, subsistence, and treaty fisheries within their respective jurisdictions. For the last decade, one of the seven appointed NPFMC members self-identified as representing recreational fisheries [38-42] with the six remaining appointees self-identifying as representing commercial interests or "other" interests. In a 2016 report to Congress, the U.S. Department of Commerce specifically encouraged governors to nominate to the NPFMC representatives from the recreational sector and the "other" sector (e.g., academics, scientists) [39]. Approximately one third of the interviewees commented that the GAF program favors the commercial sector. As one operator said,

> I would absolutely never, ever, ever, ever buy any GAF fish…The reason that thing all went through is because the [NPFMC] is all made up of commercial

> fishing interest people. There's nobody on our side there. No matter how much you say to them, how many letters you write. That's not catch sharing.

Thus, the composition of NPFMC membership plays a substantial role in how charter operators view governing bodies such as the NPFMC and IPHC. NPFMC voting members are all either direct political appointees or are nominated by governors of the relevant states and appointed by the Secretary of Commerce. Therefore, the lack of recreational sector representation on the NPFMC is a function of appointments to the NPFMC. Sector representations in Regional Fishery Management Councils in some other parts of the U.S. include more recreational representation than the NPFMC [39]. For example, the 2016 representation in the Gulf of Mexico Fishery Management Council consisted of four members representing recreational fishing sector, four members representing commercial fishing sector, and three other members [39]. While the NPFMC has made considerable efforts to more fully include stakeholder input, such as establishment of the Charter Halibut Management Committee [43], members of the NPFMC are still heavily skewed towards commercial sector interests [39].

In addition to increasing recreational fishing sector representation on management bodies, management could be made more inclusive by explicitly recognizing the diverse nature of recreational fisheries [15, 44]. Novel approaches designed to manage recreational fisheries include quota programs for charter fishing [45], increased stakeholder participation through angling organizations [46], and a policy approach in Australia that explicitly includes all sectors in the management process [47]. In 2015, the U.S. Gulf of Mexico red snapper (*Lutjanus campechanus*) recreational sector was formally split between the private angling component and the Federal for-hire component, resulting in separate quotas and seasons between the two components (80 Federal Register 22422). Additionally, the Gulf of Mexico Fishery Management

Council is currently exploring alternative management measures for the Federal for-hire component including establishment of an IFQ program [48]. Catch share programs specific to recreational sectors have been explored in the U.S. [49] and Australia [50]. For Pacific halibut, programs aimed at reallocating quota between commercial and recreational sectors have been implemented in Canada [51] and through the GAF program in the U.S. [31].

Since its inception, the GAF program has seen low participation and a lack of support from the charter industry. Lew et al. (2016) found that the high cost of participation was the most frequently cited reason that charter operators did not use GAF in 2014 and 45% of respondents "did not support the GAF program." The lack of support for GAF could be related to perceptions that the program is disadvantageous to the charter sector relative to the commercial sector. In the current study, half of the interviewees perceived that the GAF program was inequitable (Table 2-4). For example, a charter operator said,

> It's crazy to lease from a commercial guy what was given to him. It's immoral. Why should I have to lease some of it when it was given to you? It's not yours to own, it's our resource.

The GAF program symbolizes decades of conflicts between the commercial and charter fishing sector in Alaska stemming, in part, from the implementation of catch shares in the commercial halibut sector [29], which allocated IFQ based on historical participation in the commercial halibut fishery.

Conflicts between different fishing sectors have been documented worldwide [52-55]. For example, Harrison and Loring [56] found that in conflicts surrounding Alaska's Upper Cook Inlet salmon fisheries, participants felt their rights were not being sufficiently protected and that existing laws are not being fully enforced. However, the conflicting sectors actually shared a majority of values [56]. In 2016, the North Pacific Fishery Management Council approved the creation of a non-profit charter halibut recreational quota entity (RQE) that would be eligible to purchase commercial halibut quota to use in the charter sector [57]. The RQE program is similar to the GAF program in that it would allow transfer of commercial halibut quota to the charter sector, though RQE transfers would add to the entire charter sector allocation, rather than be for the benefit of individual charter anglers. However, not only does the GAF program currently have low charter participation but also, according to our findings, the GAF program evoked strong sentiments about inequities. In the context of the GAF and RQE programs, these programs can only function when there are willing sellers and buyers; therefore, understanding perspectives in both sectors is equally important.

To achieve coexistence between sectors, it is important that stakeholder groups perceive management agencies as unbiased and independent [58]. For example, the Western Australia Integrated Fisheries Management policy, adopted in 2004, addresses how fishery resources can be equitably allocated through setting harvest levels for each resource, using an independent allocation committee process [50]. Crowe et al. (2013) noted that the Australian model has created a policy framework in which management has shifted from a blame game with high levels of conflict between sectors to one where all sectors are focused on sustainability of the resource first and then identifying sectoral allocation. Although the Australian example is not perfect, it does specifically address the need to structure a management framework to reduce conflict between user groups. Perceived inequities that have not been fully addressed can shape how stakeholders feel about current management institutions and affect compliance. Therefore, it is important to understand the historical and political contexts of fishery systems to better anticipate participation in future management approaches.

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Appendix 2-1

1. The **Charter Halibut Permit Program** (Limited Entry) which started in 2011 was the limited entry program for charter operators, what was the effect of that on you?

    - any effects on your business, in particular?

"The Charter Halibut Limited Access Program established new federal Charter Halibut Permits (CHPs) for operators in the charter halibut fishery in regulatory Areas 2C (Southeast Alaska) and 3A (Central Gulf of Alaska). Since February 1, 2011, all charter halibut vessel operators in Areas 2C and 3A with clients onboard must have a valid CHP onboard during every charter vessel fishing trip."
http://alaskafisheries.noaa.gov/sustainablefisheries/halibut/sport.htm

2. The **Guideline Harvest Level program** were benchmark halibut levels for the charter sector from 2003 – 2013, what was the effect of that on you?

    - any effects on your business, in particular?

Guideline harvest levels were benchmark harvest levels for participants in the charter halibut fishery in effect from 2003 – 2013 http://alaskafisheries.noaa.gov/sustainablefisheries/halibut/sport.htm

3. The Catch Sharing Plan started in 2014, and it links the halibut quota of the charter sector as a certain percentage of the commercial halibut quota and it creates the GAF program, where charter operators can buy commercial halibut quota. What was the effect of that on you?

    - any effects on your business, in particular?

"The Catch Sharing Plan (CSP) defines an annual process for allocating halibut between the charter and commercial halibut fisheries in Areas 2C and 3A. It establishes sector allocations that vary in proportion with changing levels of annual halibut abundance and that balance the differing needs of the charter and commercial halibut fisheries over a wide range of halibut abundance in each area. The CSP also authorizes limited annual leases of commercial individual fishing quota (IFQ) for use in the charter fishery as guided angler fish (GAF)."
http://alaskafisheries.noaa.gov/sustainablefisheries/halibut/csp/cspoverview0214.pdf

Appendix 2-2

Sitka operators only (Southeast):

1. In 2009, when the regulations changed from a 2 fish bag limit (one is less than 32 inches) to a one fish bag limit (no size restrictions), what were the effects on the following?

	Decrease	No effect	Increase
Your access to productive fishing areas			
The number of halibut your customers retain on charter trips			
The size of halibut your customers retain on charter trips			
The percentage of time you target halibut on charter trips			
The number of customers making charter trips			
The profitability of your fishing business			
The number of guided recreational anglers (i.e., other charter boats) who fish in the areas that you fish			
The number of unguided recreational anglers who fish in the areas that you fish			
The distance you travel on an average trip			

Sitka operators only (Southeast)

2. In 2012, when the regulations changed from a one fish bag limit (less than 37 inches) to a reverse slot limit (U45, O68), what were the effects on the following?

	Decrease	No effect	Increase
Your access to productive fishing areas			
The number of halibut your customers retain on charter trips			
The size of halibut your customers retain on charter trips			
The percentage of time you target halibut on charter trips			
The number of customers making charter trips			
The profitability of your fishing business			
The number of guided recreational anglers (i.e., other charter boats) who fish in the areas that you fish			
The number of unguided recreational anglers who fish in the areas that you fish			
The distance you travel on an average trip			

Homer-area operators only (South-central):

4. In 2014, when the regulations changed to allow one trip per calendar day per vessel, what were the effects on the following?

	Decrease	No effect	Increase
Your access to productive fishing areas			
The number of halibut your customers retain on charter trips			
The size of halibut your customers retain on charter trips			
The percentage of time you target halibut on charter trips			
The number of customers making charter trips			
The profitability of your fishing business			
The number of guided recreational anglers (i.e., other charter boats) who fish in the areas that you fish			
The number of unguided recreational anglers who fish in the areas that you fish			
The distance you travel on an average trip			

Homer-area operators only (South-central):

5. In 2014, when the regulations changed from a 2 fish bag limit (no size restrictions) to a 2 fish bag limit (max size for second fish is 29 inches), what were the effects on the following?

	Decrease	No effect	Increase
Your access to productive fishing areas			
The number of halibut your customers retain on charter trips			
The size of halibut your customers retain on charter trips			
The percentage of time you target halibut on charter trips			
The number of customers making charter trips			
The profitability of your fishing business			
The number of guided recreational anglers (i.e., other charter boats) who fish in the areas that you fish			
The number of unguided recreational anglers who fish in the areas that you fish			
The distance you travel on an average trip			

Chapter 3 Exploring diversity in expert knowledge: characterizing variation in local ecological knowledge of fishers in Alaska[1]

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Abstract

There is a considerable body of research focused on using local ecological knowledge (LEK) to understand historical trends and patterns in the environment. However, a wide range of factors can influence how local experts perceive their environment and it may be important to account for 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 to document LEK of seven harvested fish species by subsistence fishers and recreational charter captains in four Alaskan coastal communities. Fishers observed declines in abundance and body size for most species, though the patterns varied among species, regions, and fishery sectors (subsistence, charter). Overall, subsistence harvesters provided a longer-term view of abundance changes (1960s to present) compared to charter captains (1990s to present). Regression analysis was used to evaluate the hypothesis that variation in perceptions of fish abundance and body size among individual fishers is related to their fishing practices, years of fishing experience, and spatial extent and location of fishing. Although linear models showed poor fits to the data, the total fishing area and years of fishing experience were relatively important factors in explaining variation in LEK of fish abundance. Our results suggest that people's perceptions of fish abundance and body size can be affected by attributes of their fishing experience and highlights the importance of including people with different types of experience in the environment when using LEK to document environmental changes.

Introduction

For decades, scholars have emphasized the importance of local ecological knowledge (LEK) to the understanding of marine ecosystems (Berkes et al. 2000; Johannes et al. 2000; Olsson and Folke 2001) and some have called for incorporation of LEK of resource users into natural resource science and management (Huntington 2000; Neis et al. 1999). A considerable body of research has focused on using LEK to understand historical trends and patterns in the environment (Hind 2015; Huntington 2000; Mackinson 2001; Neis et al. 1999; Raymond et al. 2010; Thornton and Scheer 2012). For example, LEK has been used for environmental monitoring (Brook and McLachlan 2008; Moller et al. 2004), 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 data, including their spatial and temporal scales (Gagnon and Berteaux 2009), the two sources of information can provide complementary knowledge that together provide a more complete understanding of ecological change than either one alone (Thurstan et al. 2016, Huntington et al. 2004). In fisheries, a growing body of research is aimed at developing tools to gather and analyze quantifiable information from fisher interviews for complementary use with scientific information (Close and Brent Hall 2006; Léopold et al. 2014; Tesfamichael et al. 2014; Beaudreau and Levin 2014; Figus et al. 2017). A key feature of these quantitative 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). In addition, researchers have suggested the use of systematic approaches in the gathering and analyses of LEK, particularly in the identification of local experts (Davis and Ruddle 2010; Davis and Wagner 2003). For example, Bundy and Davis (2013) stratified sampling for participant characteristics such as age, fishing experience, and frequency of harvest prior to gathering LEK data.

A wide range of 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 to 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 abundance and body size for seven harvested species in Alaska. Our specific objectives were to (1) quantify trends in abundance and body size of seven commonly fished species in Alaska, for which limited information on nearshore populations is known, since the 1980s; and (2) evaluate variation in fisher perceptions of abundance and body size in relation to fisher characteristics, specifically geographic region, sector, years of experience, and spatial extent of fishing. Using interview data from two geographic regions and two fishery sectors, we evaluated the hypotheses that fisher characteristics such as age, duration of fishing experience, spatial extent of fishing, and harvesting frequency may affect perceptions of trends in fish abundance and body size.

Methods

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*) in Alaska, under federal subsistence or charter regulations, respectively. These two groups were chosen because they fish in nearshore locations and target multiple species alongside Pacific halibut, yet they differ in their motivations, time spent fishing, and fishing methods. For example, charter captains target fish with customers as part of their jobs, operate charter vessels almost daily during the summer months, and use hook and line gear. In contrast, subsistence harvesters target fish for food for household consumption or for 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.

Interviews with subsistence harvesters were conducted in Southeast Alaska (Figure 3-1), in the communities of Gustavus, Hoonah, and Sitka. Interviewees were initially solicited through recommendations by community organizations, such as local non-profits, the mayor's office, and the Sitka Tribe of Alaska. Additional respondents were solicited using snowball sampling (Bernard 2006) in which previous respondents recommend knowledgeable individuals to participate. The sampling frame for subsistence harvesters consisted of individuals who self-identified as harvesting Pacific halibut for subsistence uses and with primary residences in Gustavus, Hoonah, or Sitka. These communities were chosen because they reflect a diverse range of subsistence halibut participants with tribal/rural subsistence halibut designations (Fall and Koster 2014) and demographic variables such as population size and income. Additionally, all three communities have substantial participation in the subsistence halibut sector (Fall and Koster 2014).

Interviews with charter fishing captains were conducted in Homer in Southcentral Alaska and Sitka in Southeast Alaska (Figure 3-1). Respondents from the charter-fishing sector were solicited through newsletter announcements from the Alaska Charter Association, Homer Charter Association, Southeast Alaska Guides Organization, and Sitka Charter Boat Operators Association. In addition, respondents were solicited from project introduction letters, which were mailed to the list of charter captains who owned a permit to target Pacific halibut on their charter boats in Homer or Sitka in 2014. Additional project respondents were identified using snowball sampling (Bernard 2006). The sampling frame for charter fishing captains consisted of individuals who are currently active in the charter industry, who target Pacific halibut as part of their charter operation, and whose charter boat operates out of Homer or Sitka. These communities were chosen because there is a high concentration of charter fishing businesses in each location (Lew and Seung 2010).

During the interviews, respondents were asked to report abundance levels and body size for the following species: Pacific halibut, Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), lingcod (*Ophiodon elongatus*), yelloweye rockfish (*Sebastes ruberrimus*), black rockfish (*S. melonops*), and Pacific cod (*Gadus microcephalus*). 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, respondents 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 (i.e., 2010 to the date of the interview). For charter captains, the 2000s were split into 5-year periods instead of decades because some respondents wished to provide higher temporal resolution for recent years. Respondents were asked to base these judgments of abundance and size on their observations and were permitted to skip species or periods for which they had insufficient knowledge.

Relative abundance was classified according to seven qualitative categories: very high, high, medium-high, medium, medium-low, low, very low (Appendix 3-1). 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 qualitative categories: large, medium, small (Appendix 3-1). For every species, respondents were asked to provide the approximate size range (length or weight) associated with each size category (e.g., 30-55 lbs. for a "medium halibut"). Reported lengths for Pacific halibut, lingcod, Pacific cod, yelloweye rockfish, and black rockfish were converted to weight (lbs.) using species- and region-specific length-weight regressions (ADF&G unpublished). Sizes for Chinook salmon and coho salmon were not reported in lengths and conversion was not needed.

In addition to information related to body size and abundance, respondents were asked to provide basic demographic data and information on attributes of their fishing experience. These included gear types used, spatial locations of fishing, fisher age, total years of fishing experience, and average number of days fished per year. If these attributes changed over time, respondents were asked to describe those changes in detail. Fishers were also asked to draw areas on paper charts delineating their fishing areas for each target species or species group (i.e., rockfishes, halibut, lingcod, cod, salmon; Chan et al. 2017).

Analysis

Relative Abundance

Categorical abundance levels were converted to integers from 1 to 7 (i.e., very low = 1, very high = 7). Charter captains reported relative abundance and size separately for early 2000s and late 2000s, whereas subsistence harvesters reported values for the entire 2000 decade. Abundance changes over time were visualized as boxplots showing the distribution of abundance scores among respondents, separately for each species, region (Southeast, Southcentral), and sector (charter, subsistence).

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 (charter or subsistence), and how long they have been fishing. 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. We fit linear models to abundance change estimates, individually for each species. 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 binary categorical variable, *sector*, was selected as a potential predictor because subsistence harvesters and charter captains vary 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 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 sum total area used to target halibut, which encompasses areas used to target other species, based on a digitized, georeferenced maps derived from participatory mapping (see Chan et al. 2017 for detailed methods). 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 additively-separable combinations of these four predictors, including the null model, models with single variables, and models with multiple variables, 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. Linear regression was conducted using the 'lm' function in R (R Core Team 2016), while AICc was calculated using the 'MuMIn' package in R (Bartoń 2017). The ΔAICc was calculated for each model and consisted of 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 amongst the set of candidate models (Johnson and Omland 2004). Akaike weights sum to one across all candidate models for a species and the closer w_i is to one, the greater the weight of evidence in favor of that model (Burnham and Anderson 2002). We also 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).

Relative Size

For each species, the size range (max size – min size) across all respondents was divided by thirty to create size bins of equal width that captured the observed size range for that species.

Distributions of typical size for each species and period were visualized using histograms showing the frequency of size observations (as reported by respondents) in each of thirty size bins of equal width. Respondents 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 a respondent reported a typical halibut in the 1990s as 10 - 20 lbs and the bin width for halibut was 5 lbs, then the response would be assigned to the two bins spanning the reported range, i.e., 10-15 lbs and 15-20 lbs). Using the histograms, median size for each species, period, and group were estimated by identifying the point on the x-axis with equal observations on either side. Estimates of median size were used for visualization.

Results

Respondent summary

We interviewed a total of 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 3-1).

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 to present) compared to charter captains (1990s to present). Charter captains in both regions perceived a decline in

Pacific halibut abundance from the 1990s to the 2010s (mean estimated slope coefficient, $\bar{\beta}$ = -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 ($\bar{\beta}$ = -0.14; Figure 3-2).

For lingcod, Southeast captains perceived little change ($\bar{\beta}$ = 0.07) and Southcentral captains observed a decline ($\bar{\beta}$ = -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 ($\bar{\beta}$ = -0.27; Figure 3-3). 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 $\bar{\beta}$ = -0.07, Southcentral charter $\bar{\beta}$ = -0.50, Southeast subsistence $\bar{\beta}$ = -0.67; Figure 3-4). For black rockfish, both charter groups observed a decline in abundance from the 1990s to 2010s (Southeast charter $\bar{\beta}$ = -0.78, Southcentral charter $\bar{\beta}$ = -0.31), while subsistence harvesters perceived a relatively stable trend over that period (Southeast subsistence $\bar{\beta}$ = -0.05; Figure 3-5).

For Chinook salmon, perceived abundance change by Southeast and Southcentral charter captains were relatively flat overall, but varied among respondents (Southeast charter $\bar{\beta}$ = 0.50, Southcentral charter $\bar{\beta}$ = -0.04; Figure 3-6). Subsistence harvesters observed a decline in Chinook salmon from the 1970s to early 2000s followed by a relatively stable period ($\bar{\beta}$ = -0.31; Figure 3-6). For coho salmon, both charter groups observed a decline in abundance from the 1990s to 2010s (Figure 3-7), though this varied among respondents, particularly in Southeast where the average slope coefficient was positive (Southeast charter $\bar{\beta}$ = 0.33, Southcentral charter $\bar{\beta}$ = -0.83). Subsistence harvesters perceived relatively little change in coho salmon abundance since the 1970s ($\bar{\beta}$ = -0.07; Figure 3-7). Pacific cod abundance was perceived by charter captains to be stable or increasing since the 1990s (Southeast charter $\bar{\beta}$ = 0.50, Southcentral charter $\bar{\beta}$ = 0.08), while subsistence harvesters observed a slight decline since the 1970s (Southeast subsistence $\bar{\beta}$ = -0.21; Figure 3-8).

Temporal changes in body size

Southeast and Southcentral charter respondents observed declines in Pacific halibut size, with the median fish size in Southeast decreasing from 88 lbs. in the 1990s to 41 lbs. in the 2010s and in Southcentral decreasing from 62 lbs. in the 1990s to 21 lbs. in the 2010s (Figure 3-9). In the 1990s, histograms for both charter groups were right skewed and respondents' observations of typical Pacific halibut sizes ranged from <1 to 300 lbs. By the 2010s, tails of the histograms for both charter groups were truncated and respondents' observations of average Pacific halibut sizes ranged from <1 to 200 lbs. Median Pacific halibut size observed by Southeast subsistence harvesters remained stable at 41 lbs. from the 1980s through the 2010s (Figure 3-9).

Median lingcod size decreased over time for Southcentral charter respondents from 44 lbs. in the 1990s to 27 lbs. in the 2010s, but remained consistent for Southeast charter respondents over this period at 25 lbs. (Figure 3-10). Median lingcod size reported by subsistence harvesters decreased from 17 lbs. in the 1990s to 7 lbs. in the 2010s (Figure 3-10). For yelloweye rockfish, all three groups observed a decline the median size from the 1990s to 2010s, with size decreasing from 14 to 12 lbs. for Southcentral charter captains, 11 to 8 lbs. for Southeast charter captains, and 8 to 2 lbs. for Southeast subsistence fishers (Figure 3-11). For black rockfish, all three groups observed a decline the median size from the 1990s to 2010s with observed decreases of 5 to 4 lbs. for Southcentral charter captains, 4 to 3 lbs. for Southeast charter captains, and 4 lbs. to 1 lb. for subsistence fishers (Figure 3-12).

For Chinook salmon, all three groups observed a decline in the median size from the 1990s to 2010s, with Southcentral and Southeast charter captains observing declines from 24 to 19 lbs. and subsistence fishers observing declines from 24 to 16 lbs. (Figure 3-13). For coho salmon, changes in median size from the 1990s to 2010s varied among respondent groups, with Southcentral charter captains observing no change in median size (11 lbs.), Southeast charter captains observing a decline from 11 to 9 lbs., and subsistence fishers observing an increase from 10 to 11 lbs. (Figure 3-14). Distributions of Pacific cod were relatively stable over time, with a decrease in median size from 9 to 8 lbs. observed by Southcentral charter captains, a decrease from 6 to 5 lbs. observed by Southeast charter captains, and no change observed by Southeast subsistence fishers (6 lbs.; Figure 3-15).

Model results

For Pacific halibut, five explanatory models were identified with AICc values within 2 of the minimum score (ΔAICc $\leq$ 2; Table 3-2), 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 3-2). 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 3-2). The candidate model with the lowest AICc (adj. r^2 = 0.049) included the predictors sector and years of experience.

For black rockfish, two explanatory models were identified with AICc values within 2 of the minimum score (ΔAICc $\leq$ 2; Table 3-2). The candidate model with the best fit based on AICc was the null model. The best model for lingcod (adj. r^2 = 0.231, w_i = 0.514; Table 3-2) included one parameter, fishing area (Table 3-3). For yelloweye rockfish, the best model included one parameter, city, and was a relatively good fit to the data (adj. $r^2 = 0.411$, $w_i = 0.562$; Table 3-2, Table 3-3).

For Chinook salmon, the best model included city, years of experience, and fishing area (adj. $r^2 = 0.243$, $w_i = 0.456$ (Table 3-2). Years of fishing experience was the most important factor in explaining variation in abundance trends of Chinook salmon among respondents (Table 3-3). For coho salmon, two explanatory models were identified with AICc values within 2 of the minimum score (ΔAICc ≤ 2; Table 3-2). 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 3-3). For Pacific cod, the best model (adj. $r^2 = 0.170$, $w_i = 0.452$) included one predictor, years of experience (Table 3-3).

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 understanding abundance and size changes of nearshore fish species requires perspectives from fishers in multiple sectors and regions, whose knowledge together provides a more complete picture than any one source alone. Some variation in fishers' perceptions of change was related to differences in age and duration of experience between groups. In this study, for example, Pacific halibut abundance trends reported by at least three respondents 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. Similarly, Chinook salmon abundance trends reported by at least three respondents began in the 1970s for subsistence fishers, 1980s for Southcentral charter captains, and 1990s for Southeast charter captains. Although subsistence and Southcentral charter respondents reported similar durations of fishing experience and fisher age overall, abundance trends from LEK covered a longer time period for subsistence respondents for all species in this study except for lingcod and black rockfish (Figures 3-2 to 3-8). Subsistence respondents spanned a wider range in years of fishing experience, allowing us to capture LEK over a broader time scale.

In general, variation in LEK of fish abundance changes from this study was poorly explained by linear models, as evidenced by low adjusted r^2 values (Table 3-2); however, models for lingcod, yelloweye rockfish, and Chinook salmon showed relatively better fits to the data than those for other species (adj. $r^2 > 0.2$). The generally poor model fits to the data suggest that there are other factors, not included as potential predictors, which may be important in explaining variation in fishers' perceptions of abundance change. Across species, the explanatory variables of total fishing area and years of fishing experience were relatively more important than other factors in explaining variance in abundance changes (Tables 3-2 and 3-3). This suggests that attributes of people's spatial fishing experience (e.g., the size of their fishing footprint) and how long they have been fishing may affect their ecological observations. A similar effect has been observed in other studies of fishers' LEK (e.g., Beaudreau and Levin 2014, Verweij et al. 2010).

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, this study did not aim to assess the extent of agreement among LEK and scientific data (e.g., surveys). In addition, while some scientific survey data are available for Pacific halibut at comparable spatial-temporal scales, the other species we focused on are relatively data-poor. For long-lived species like lingcod, LEK can provide valuable 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, all three respondent groups perceived a decline in lingcod abundance from the 1990s to the early 2000s, with Southcentral charter respondents observing more severe decline over that period (Figure 3-3). LEK of lingcod abundance indicated the greatest decline among species, especially in the Southcentral region, according to charter captains we interviewed. It is challenging to assess fishery effects on lingcod in Alaska due to their complex life history, variable movement patterns, and lack of a stock assessment for the species (Green et al. 2014). Consequently, fishers' knowledge may address important gaps in scientific understanding of lingcod population change.

In interpreting changes in fish abundance or size from LEK, it may be important to evaluate LEK in the context of how fishers experience and observe their environment. From the 1990s to 2010s, charter captains in both regions observed declines in halibut median size, while subsistence harvesters observed no change (Figure 3-9). However, changes in the distribution of halibut size observed by charter captains (e.g., truncated histograms over time, Figure 3-9) may be related to the introduction of maximum size limits for charter halibut in 2007 in Southeast and 2014 in Southcentral (Gilroy et al. 2011). Captains targeting only sizes below the maximum limit would lead to increased encounters with smaller fish and, therefore, reinforce 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 from this research remained consistent over time (Table 3-2, Figure 3-9). The Alaska Department of Fish and Game mail survey identified the average halibut caught in the non-charter sport sector in Southeast Alaska, which do not have size limits (Gilroy et al. 2011), to range from 14.04 lbs to 20.59 lbs between 2000 and 2015

(ADF&G 2016). Charter logbook data identified the average halibut caught in the charter sport sector in Southeast Alaska during the same time period to range from 9.40 lbs to 26.36 lbs (ADF&G 2016).

An additional difference between charter and subsistence fishing that may affect observations of the environment is the type of allowable fishing gear. For example, customers on charter trips fish using rod and reel. In addition to rod and reel, subsistence fishers can target halibut using 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. Fisher observations may also be influenced by where fishing occurs and the spatial extent of fishing. Specifically, differences in observed halibut size may reflect spatial characteristics of fishing effort, including the physical locations (Figure 3-1) and the total area in which fishing occurs (Table 3-3). Characteristics of charter fishing locations can differ between business types (i.e., half-day vs. full-day trips) and the species targeted (i.e., single species vs. multi-species trips) (Chan et al. 2017).

Understanding the factors influencing fisher observations is important when eliciting ecological information, particularly if different groups of experts are gathering their knowledge from different components of the environment. Our study showed that LEK of Alaska sport and subsistence fishers may fill information gaps for data-poor species (e.g., lingcod). However, variation in LEK may reflect 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, which highlights the importance of including diverse groups when using LEK to document environmental changes. While it remains a challenge to tease apart the range of factors explaining variation in LEK, this study highlights the importance of explicitly accounting for spatial fishing information and duration of fishing experience when interpreting LEK.

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Figures

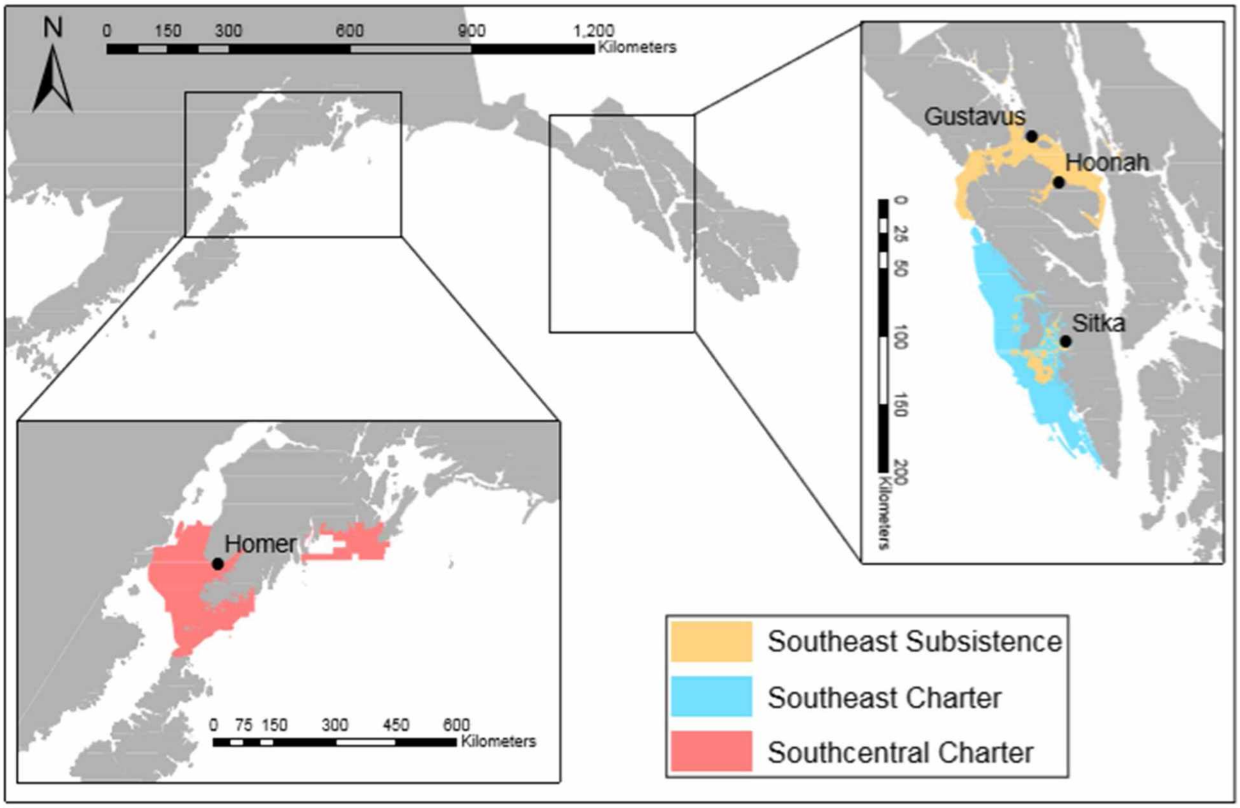

Figure 3-1 Map of study locations and the spatial extent for each sector's fishing locations for Pacific halibut, lingcod, and rockfish.

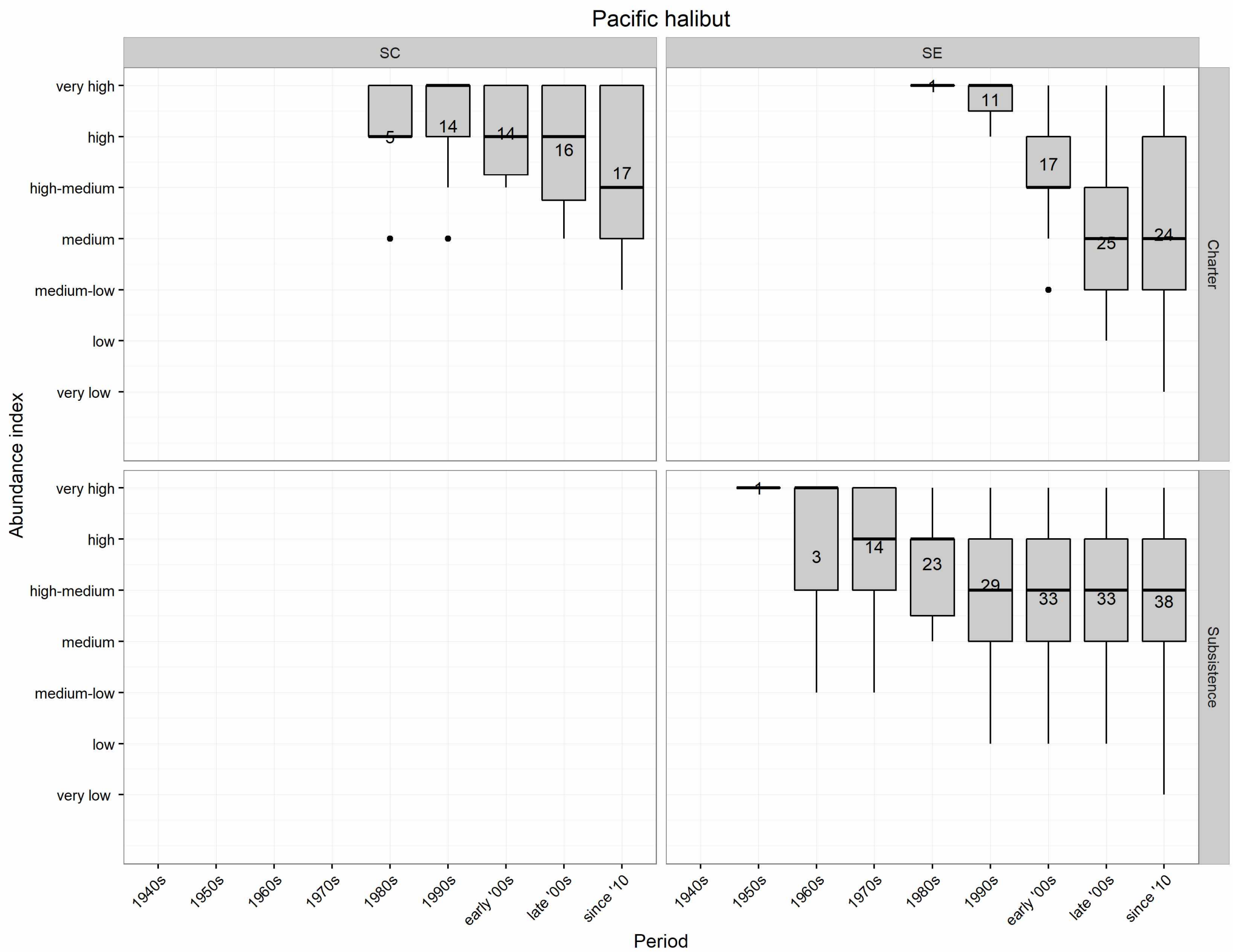

Figure 3-2 Reported abundance levels for Pacific halibut from interviews with subsistence and charter fishers in Southeast and Southcentral Alaska.

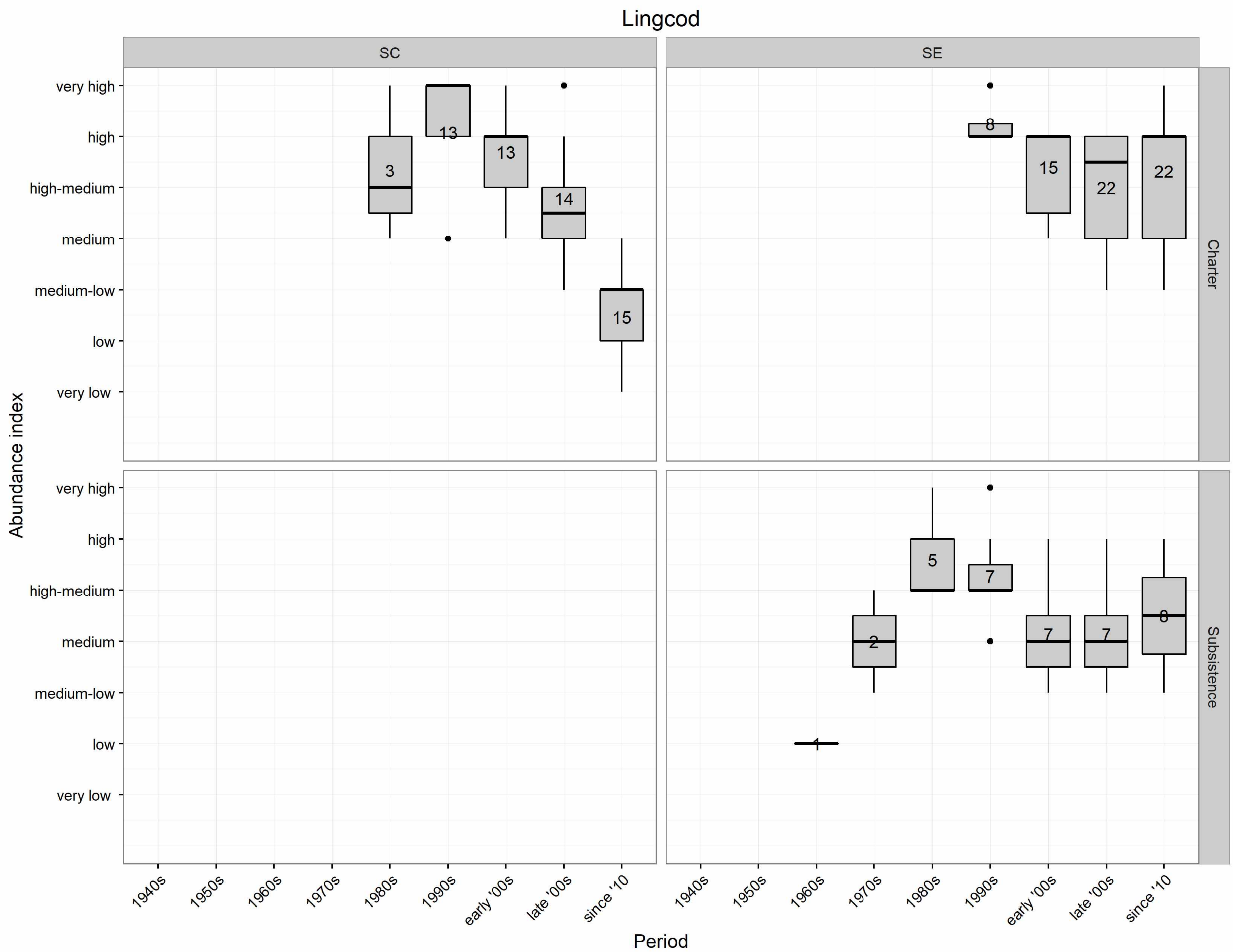

Figure 3-3 Reported abundance levels for lingcod from interviews with subsistence and charter fishers in Southeast and Southcentral Alaska.

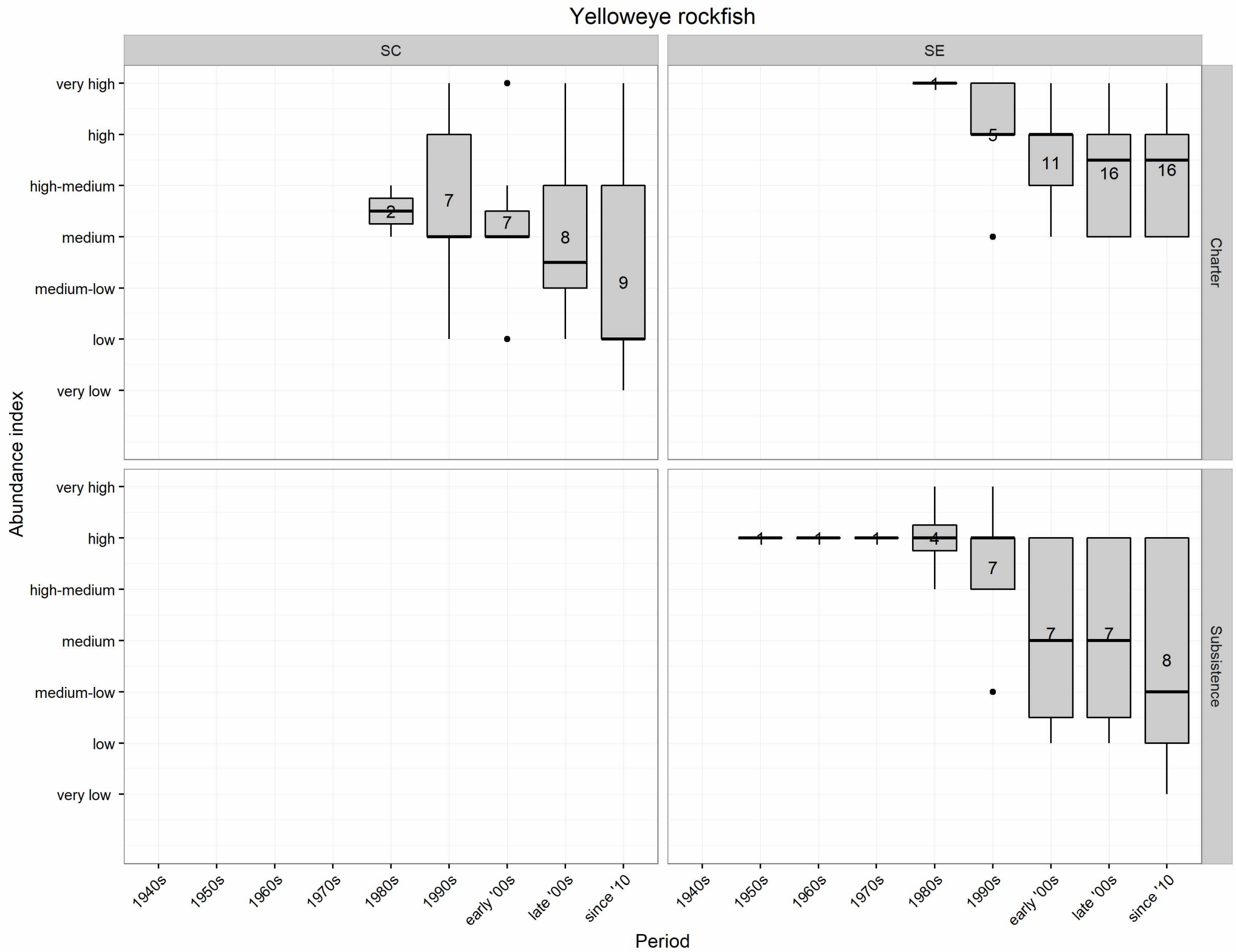

Figure 3-4 Reported abundance levels for yelloweye rockfish from interviews with subsistence and charter fishers in Southeast and Southcentral Alaska.

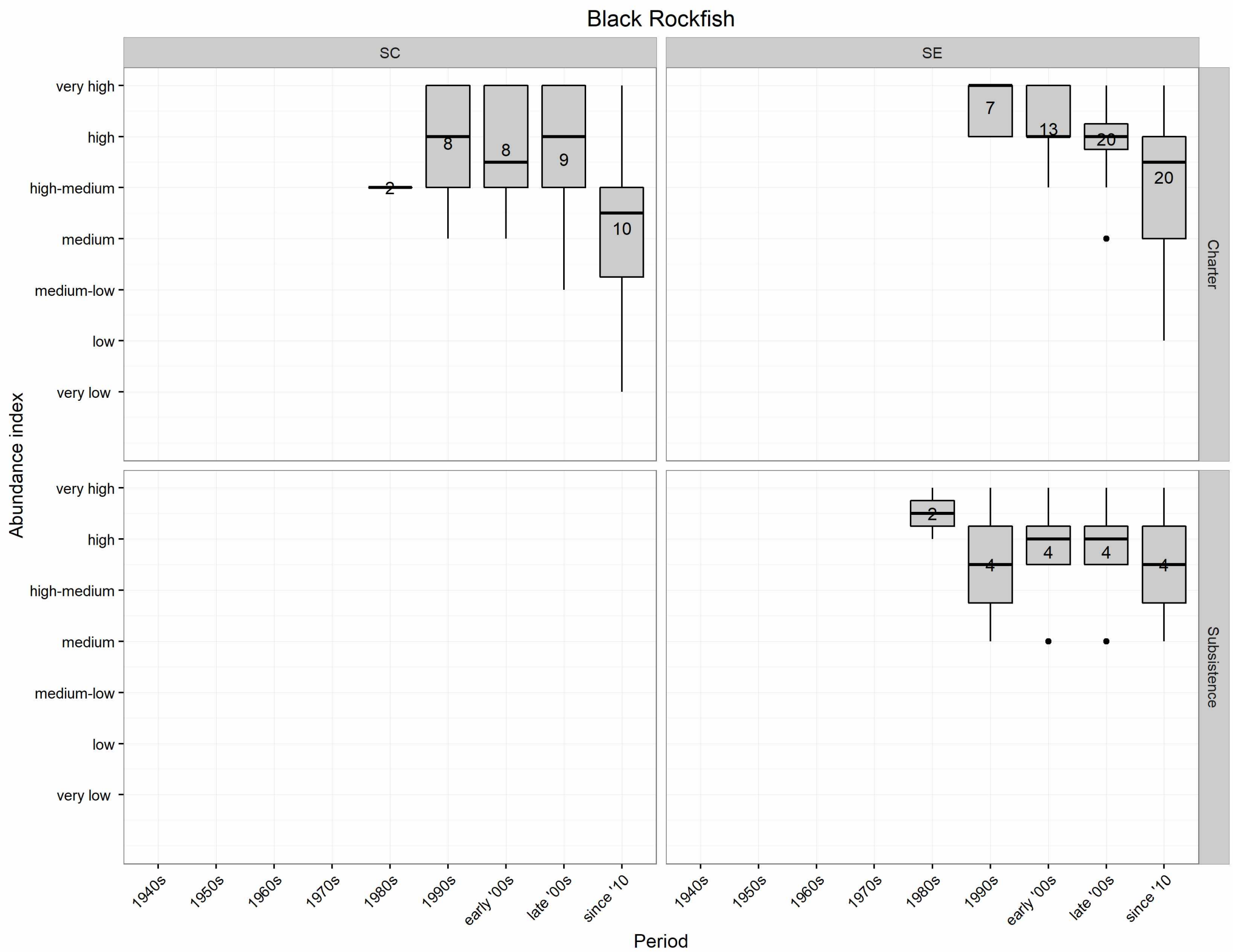

Figure 3-5 Reported abundance levels for black rockfish from interviews with subsistence and charter fishers in Southeast and Southcentral Alaska.

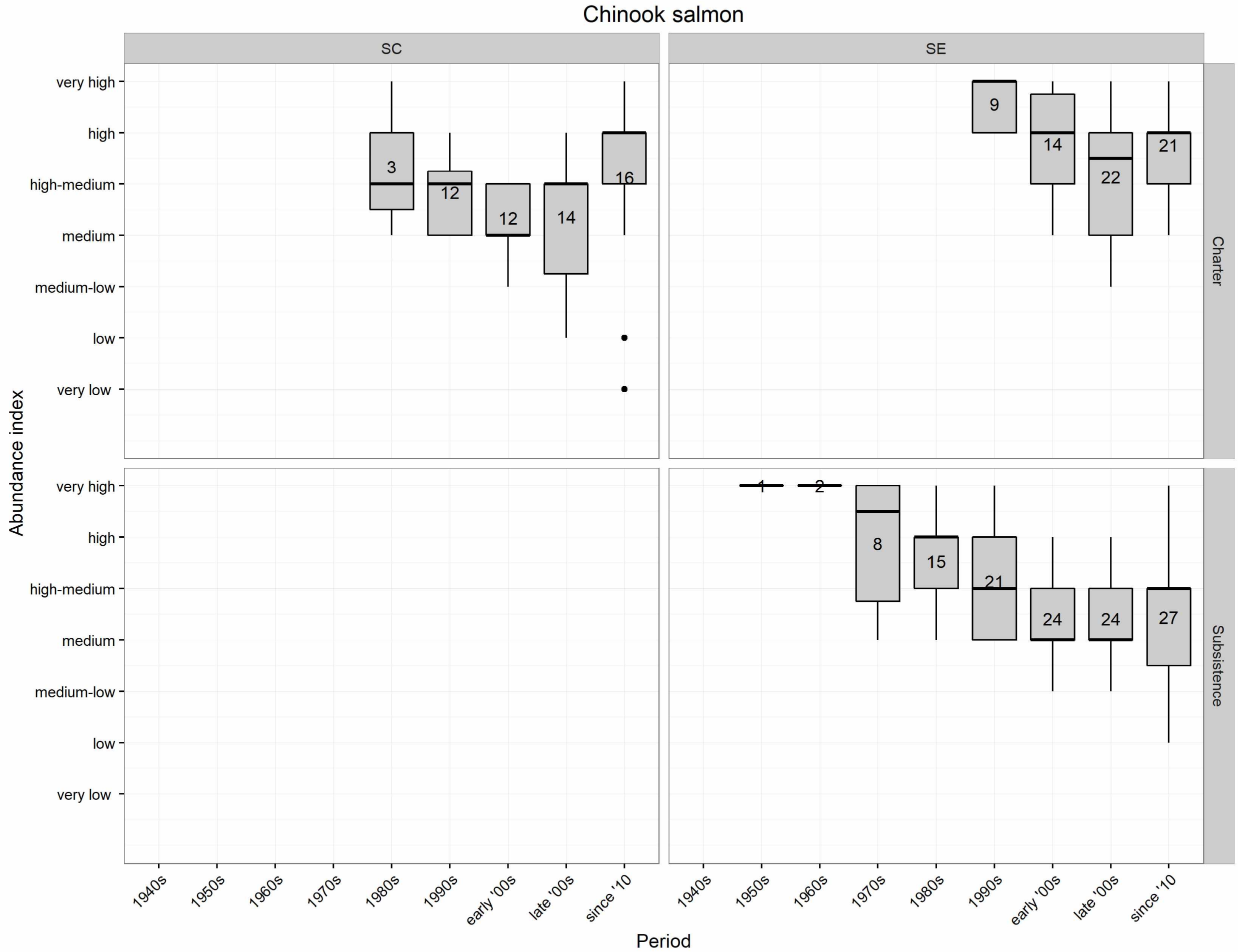

Figure 3-6 Reported abundance levels for Chinook salmon from interviews with subsistence and charter fishers in Southeast and Southcentral Alaska.

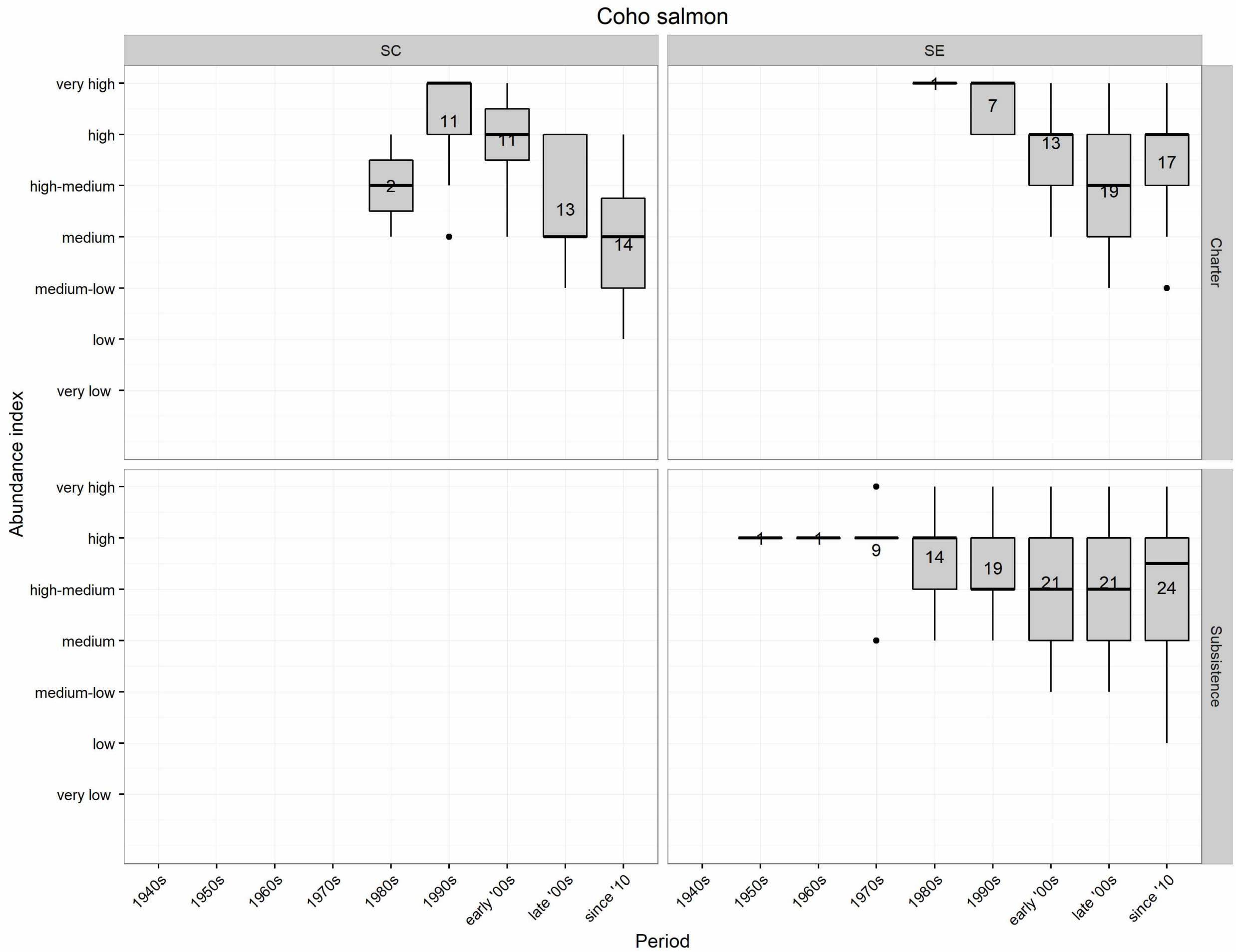

Figure 3-7 Reported abundance levels for coho salmon from interviews with subsistence and charter fishers in Southeast and Southcentral Alaska.

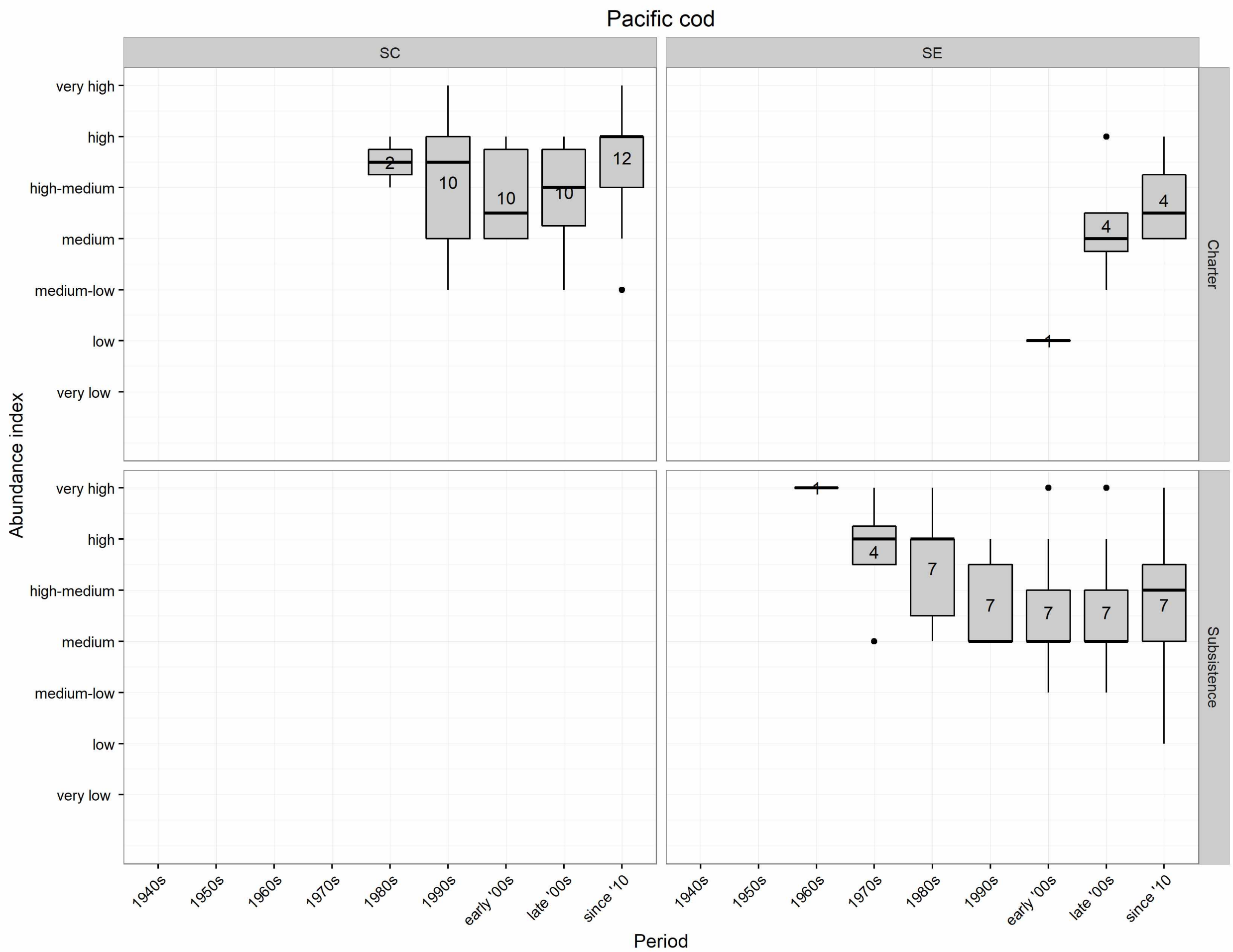

Figure 3-8 Reported abundance levels for Pacific cod from interviews with subsistence and charter fishers in Southeast and Southcentral Alaska.

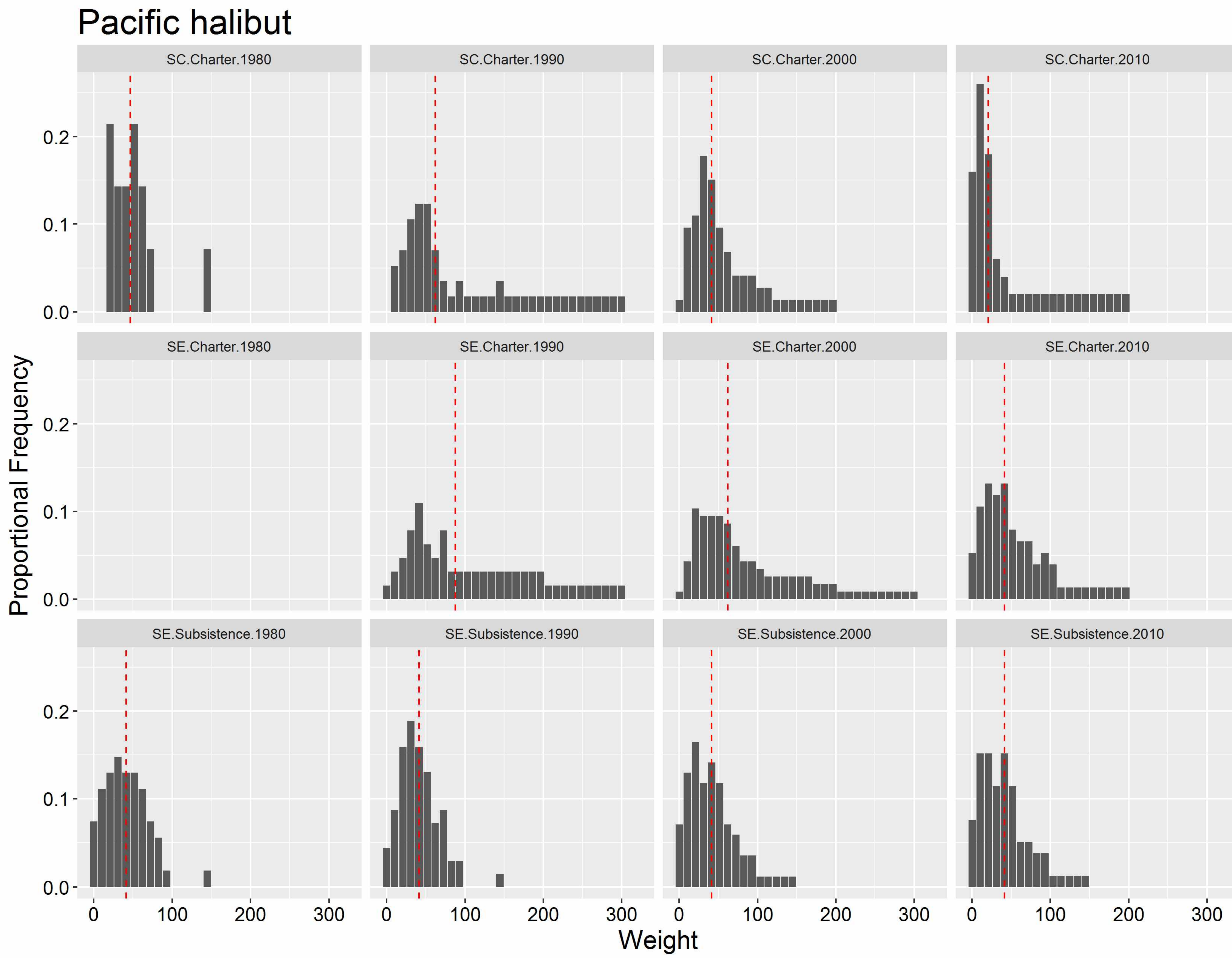

Figure 3-9 Reported average sizes (lbs) for Pacific halibut by decade and sector group. Y-axis is in proportional frequency, which shows the percentage of responses in that size class for that decade and sector group. Decade and sector group combinations in which there were fewer than three responses are not shown.

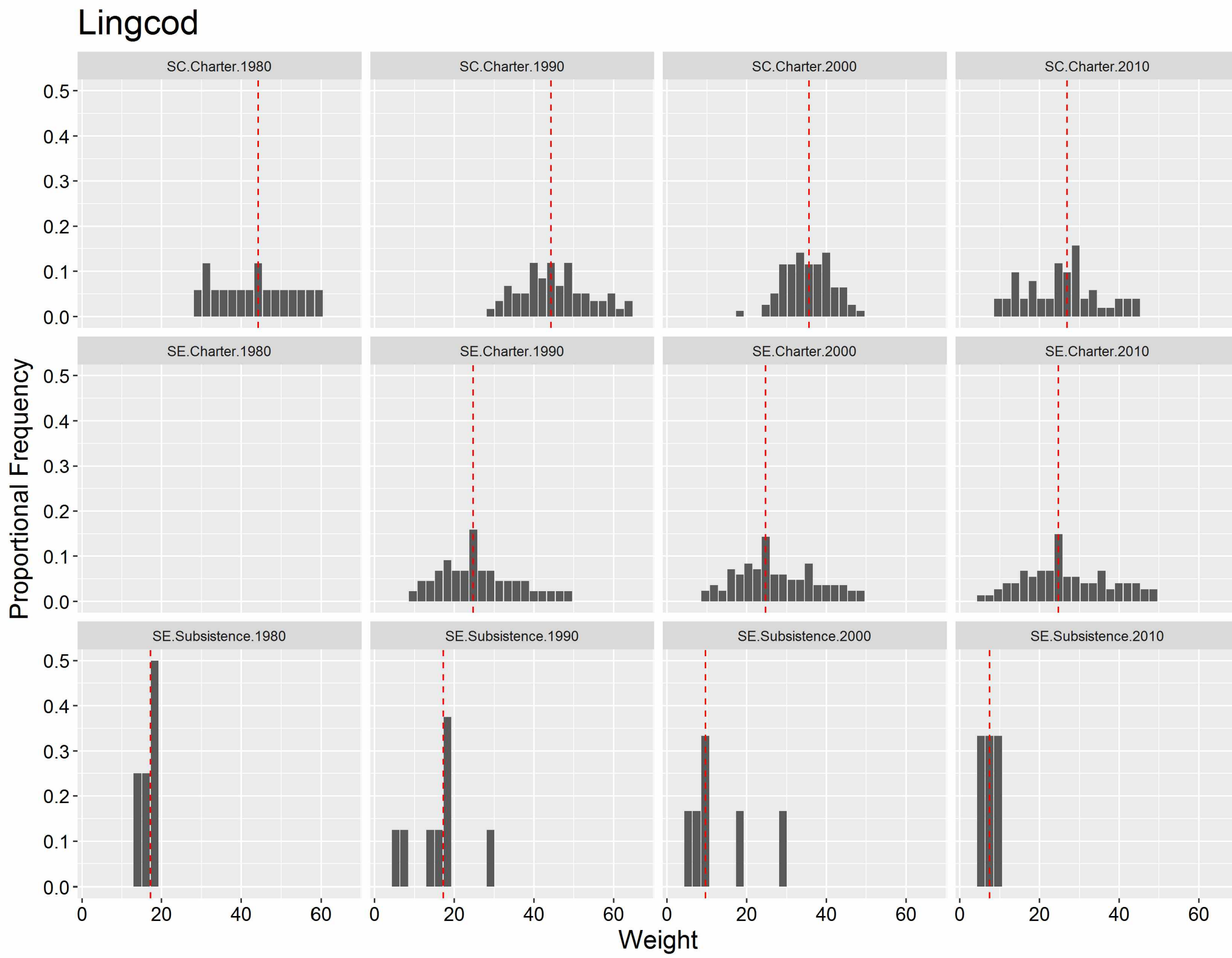

Figure 3-10 Reported average sizes (lbs) for lingcod by decade and sector group. Y-axis is in proportional frequency, which shows the percentage of responses in that size class for that decade and sector group. Decade and sector group combinations in which there were fewer than three responses are not shown.

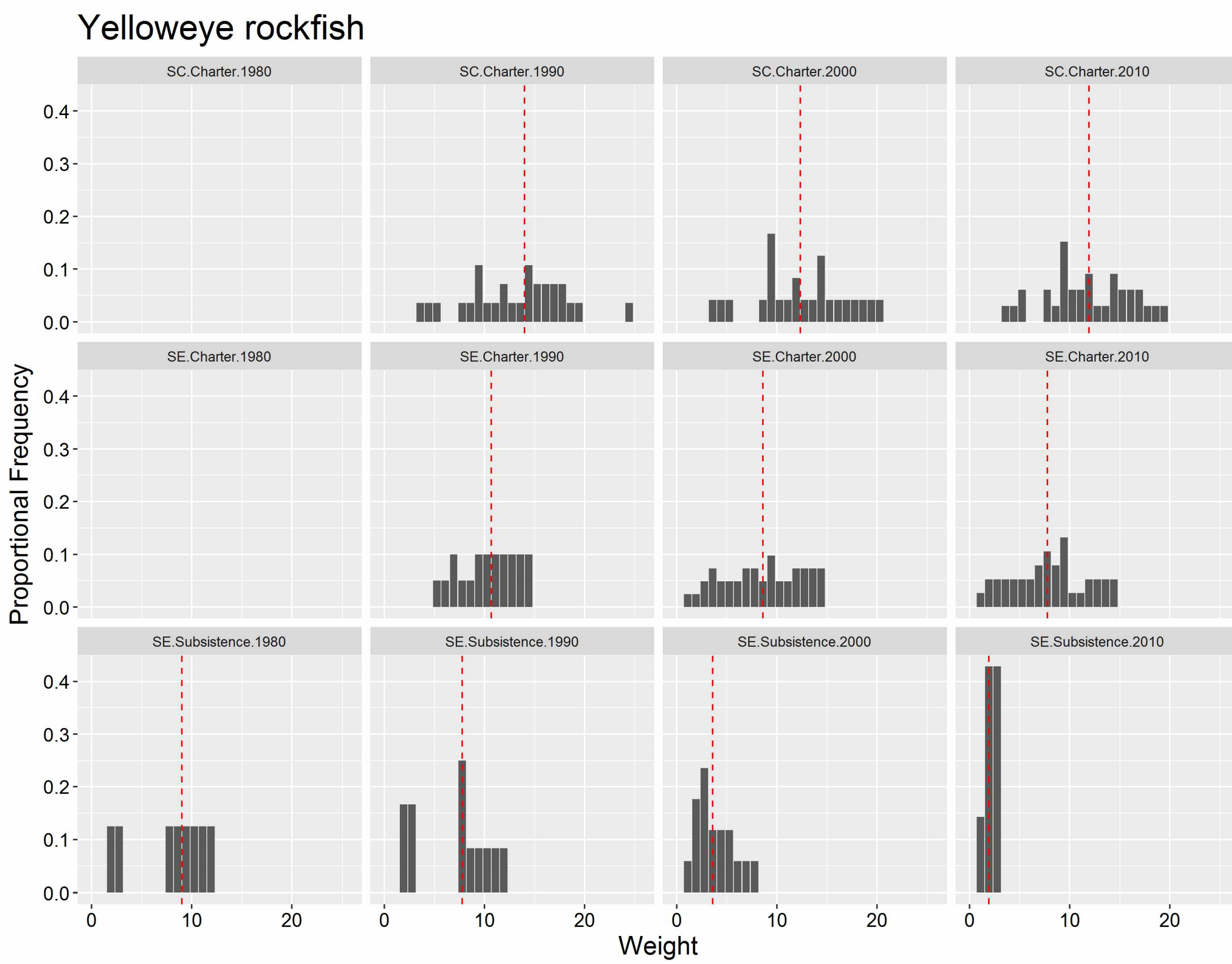

Figure 3-11 Reported average sizes (lbs) for yelloweye rockfish by decade and sector group. Y-axis is in proportional frequency, which shows the percentage of responses in that size class for that decade and sector group. Decade and sector group combinations in which there were fewer than three responses are not shown.

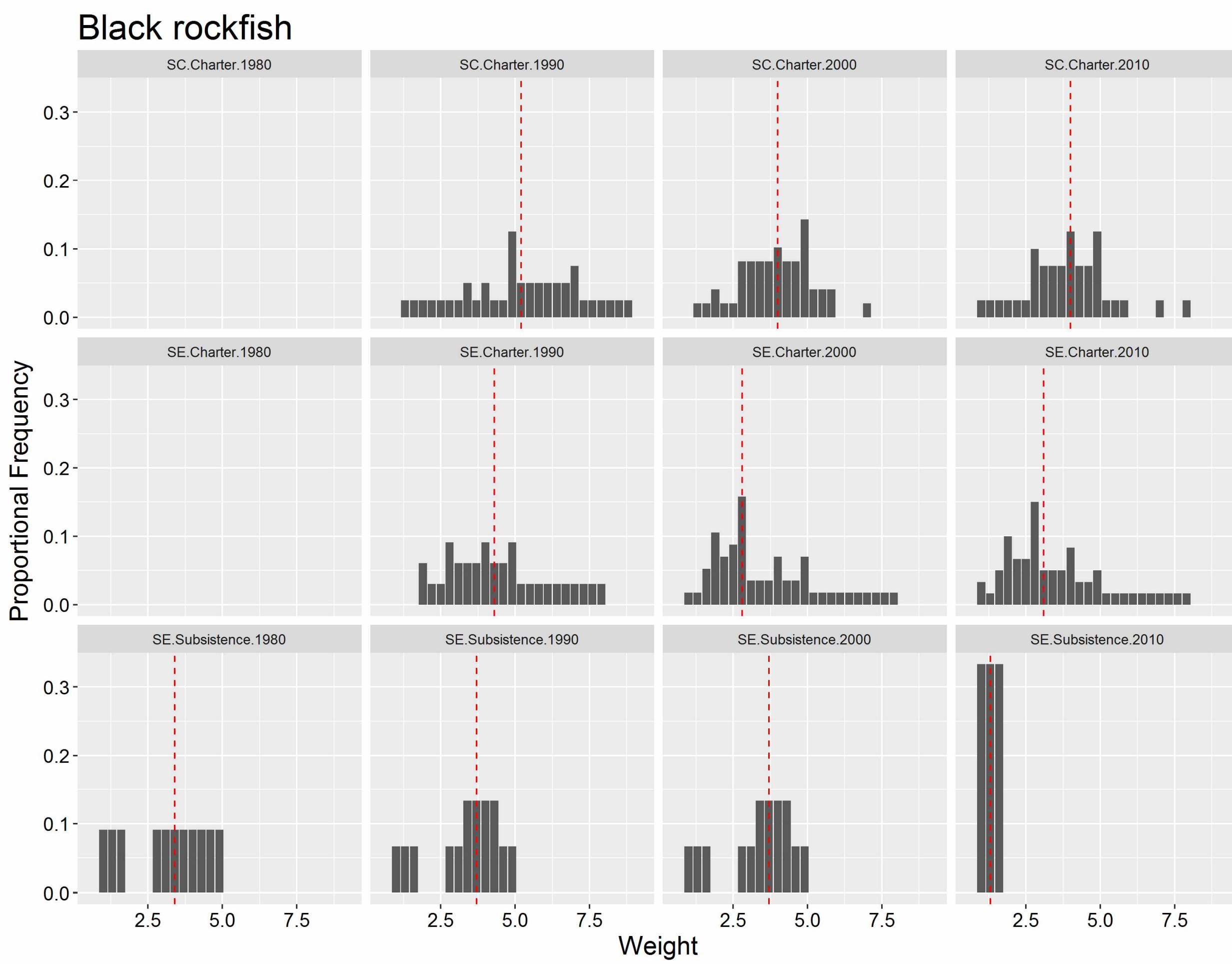

Figure 3-12 Reported average sizes (lbs) for black rockfish by decade and sector group. Y-axis is in proportional frequency, which shows the percentage of responses in that size class for that decade and sector group. Decade and sector group combinations in which there were fewer than three responses are not shown.

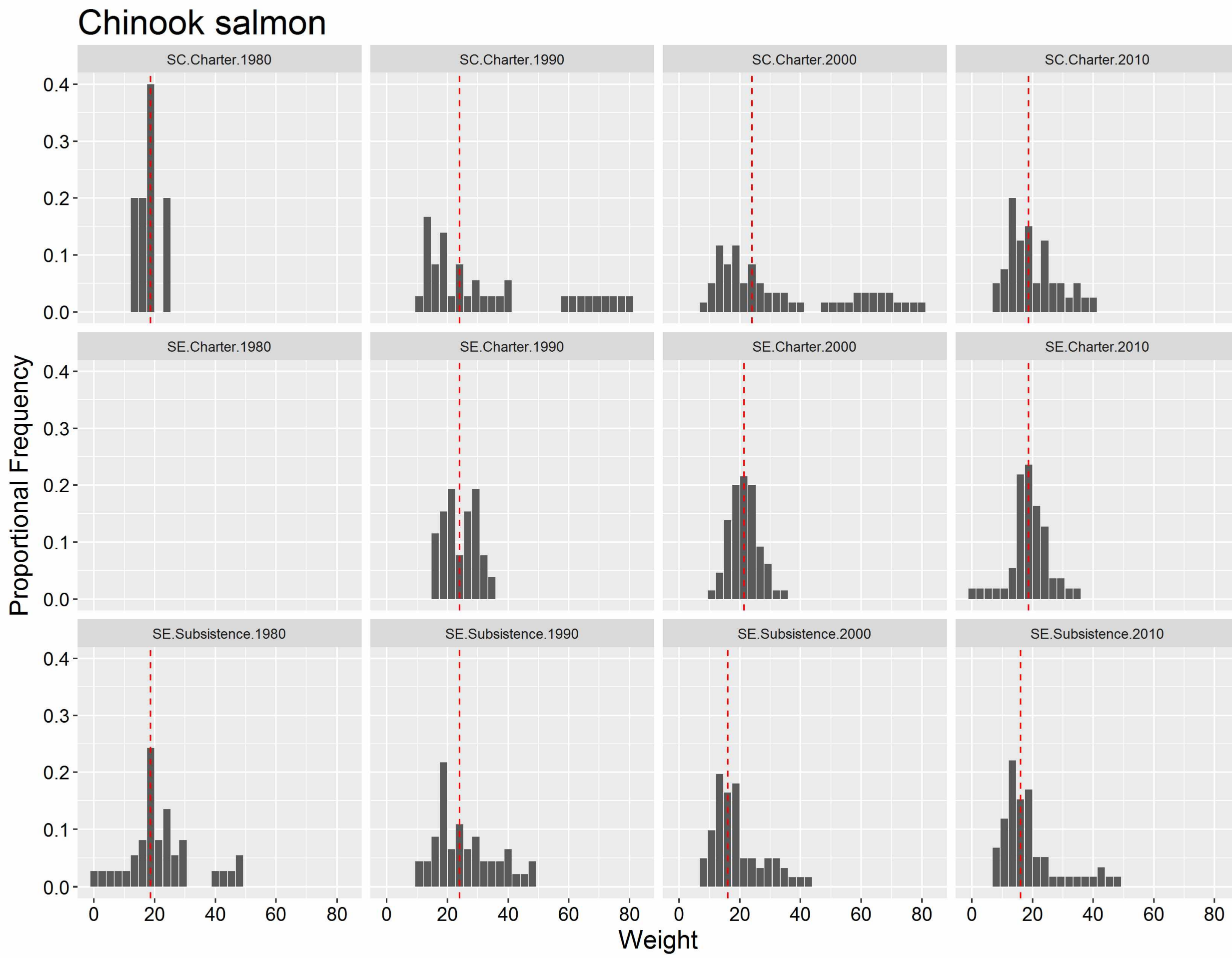

Figure 3-13 Reported average sizes (lbs) for Chinook salmon by decade and sector group. Y-axis is in proportional frequency, which shows the percentage of responses in that size class for that decade and sector group. Decade and sector group combinations in which there were fewer than three responses are not shown.

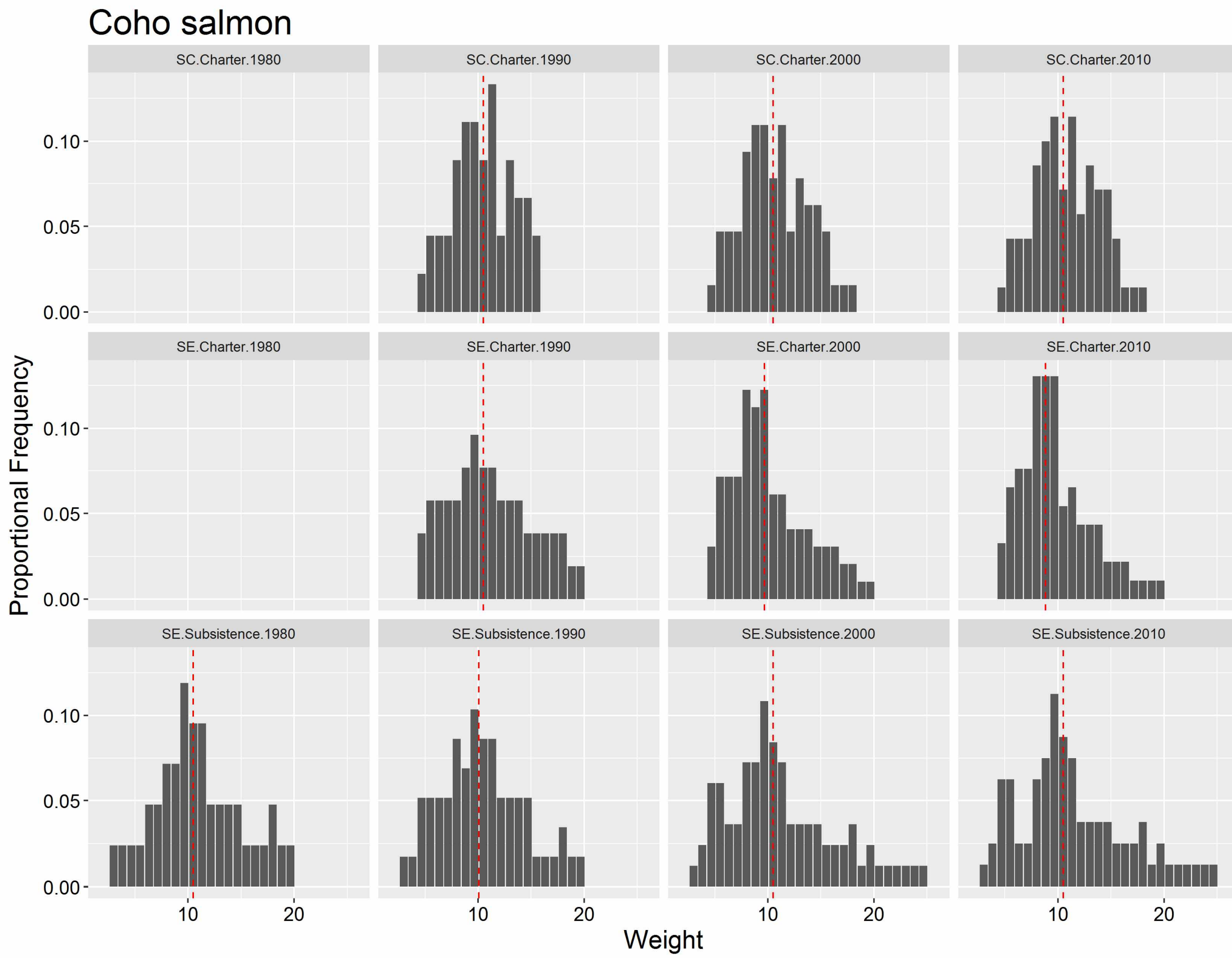

Figure 3-14 Reported average sizes (lbs) for coho salmon by decade and sector group. Y-axis is in proportional frequency, which shows the percentage of responses in that size class for that decade and sector group. Decade and sector group combinations in which there were fewer than three responses are not shown.

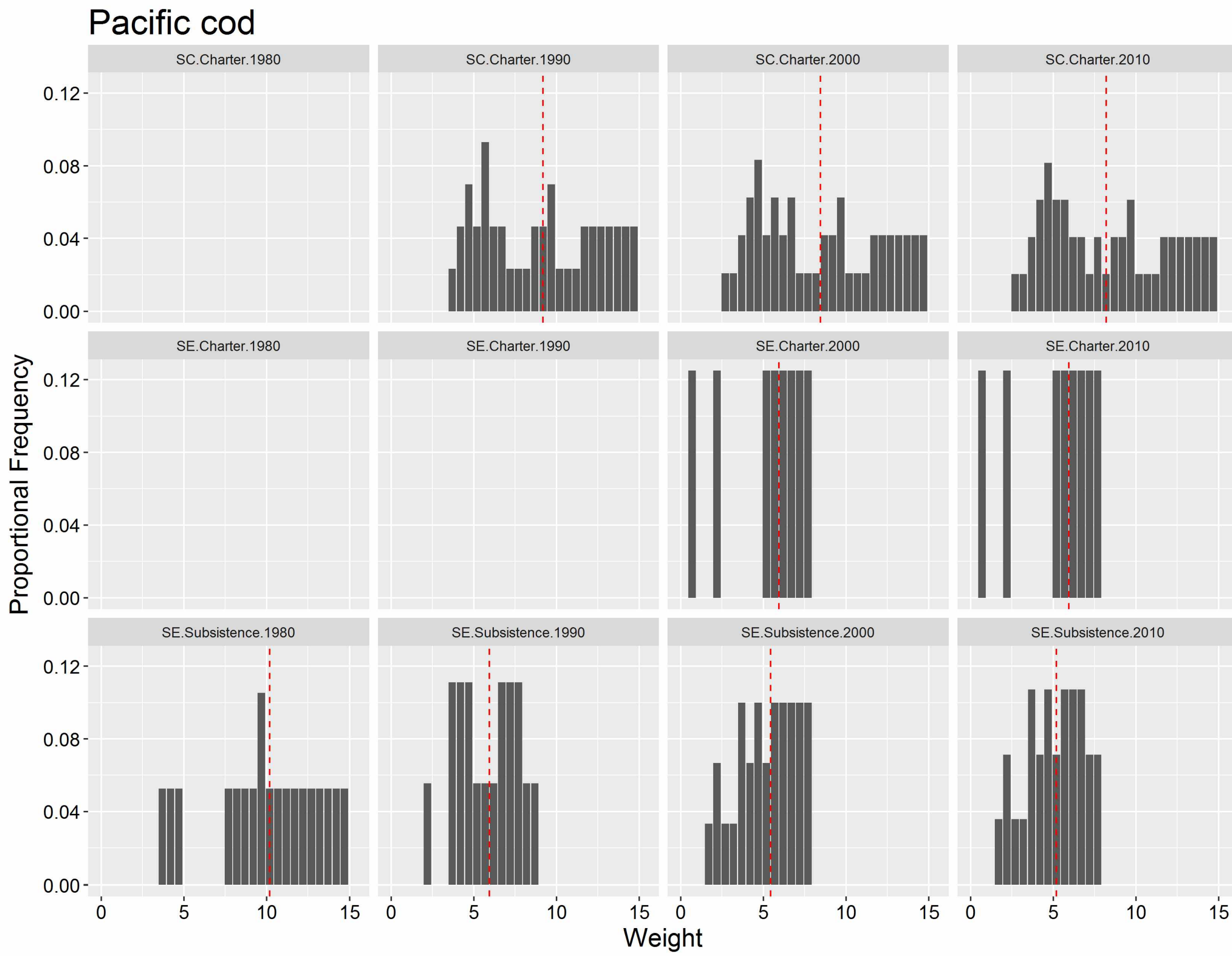

Figure 3-15 Reported average sizes (lbs) for Pacific cod by decade and sector group. Y-axis is in proportional frequency, which shows the percentage of responses in that size class for that decade and sector group. Decade and sector group combinations in which there were fewer than three responses are not shown.

Tables

Table 3-1 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 respondents			
	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)	3,826 (3,769)	485 (673)	145 (362)
Range (min - max)	559 – 12,222	37 – 2,909	1 – 2,142
Age			
Mean (± SD)	55 (14)	40 (11)	52 (13)
Range (min - max)	31 – 76	24 – 62	28 – 75

Table 3-2 Linear models of changes in abundance by species. Only models with Δ AIC_C <2 are displayed.

	Model Parameters	Adj. r^2	K	AIC_C	Δ AIC_C	w_i
Pacific halibut	*Sector + Years Experience*	0.049	3	210.0	0.0	0.188
	Sector + Years Experience + Area	0.040	2	210.1	0.1	0.174
	Area	0.003	1	210.4	0.5	0.149
	Years Experience + Area	0.016	2	210.7	0.7	0.133
	Null Model	NA	NA	211.3	1.3	0.096
Black rockfish	*Null Model*	NA	NA	97.8	0.0	0.416
	Sector	-0.006	1	99.3	1.6	0.188
Lingcod	*Area*	0.231	13	118.9	0.0	0.514
Yelloweye rockfish	*City*	0.411	5	52.1	0.0	0.562
Pacific cod	*Years Experience*	0.170	6	42.7	0.0	0.452
Chinook salmon	*City + Years Experience + Area*	0.243	4	178.8	0.0	0.456
Coho salmon	*Area*	0.094	6	151.0	0.0	0.339
	Years Experience + Area	0.101	4	151.8	0.9	0.222

Table 3-3 Parameter weights for linear models of changes in abundance. Only sets of models for species with Adj. $r^2 > 0.1$ are shown, therefore parameter weights are not shown for Pacific halibut and black rockfish. For each set of models, the parameter closest to 1 is bolded.

	Species	Parameter	Weight
Abundance	Chinook salmon	***Years Experience***	**0.935**
		Area	0.853
		City	0.705
		Sector	0.636
	Yelloweye rockfish	***City***	**0.953**
		Area	0.177
		Sector	0.175
		Years Experience	0.149
	Pacific cod	***Years Experience***	**0.735**
		Sector	0.305
		Area	0.196
		City	0.000
	Coho salmon	***Area***	**0.820**
		Years Experience	0.369
		Sector	0.249
		City	0.212
	Lingcod	***Area***	**0.909**
		Years Experience	0.242
		Sector	0.230
		City	0.133

Appendix 3-1

Please specify the **abundance** level you have observed for each species over the span of time you have been fishing. Use categories in abundance table (below): very low, low, low medium, medium, medium high, high, very high.

	1960s	1970s	1980s	1990s	early 2000s	late 2000s	since 2010
halibut							
Chinook/king salmon							
coho/silver salmon							
________rockfish ________rockfish							
lingcod							
Pacific cod							

1960s	1970s	1980s	1990s	early 2000s	late 2000s	since 2010
Very High	Very High	Very High	Very High	Very High	Very High	Very High
High	High	High	High	High	High	High
Med-High	Med-High	Med-High	Med-High	Med-High	Med-High	Med-High
Medium	Medium	Medium	Medium	Medium	Medium	Medium
Med-Low	Med-Low	Med-Low	Med-Low	Med-Low	Med-Low	Med-Low
Low	Low	Low	Low	Low	Low	Low
Very Low	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low

Please specify the **average body size** of each species you have observed since you have been involved in charter fishing. Use *categories* small, medium, and large for each period.

Average body size	1960s	1970s	1980s	1990s	early 2000s	late 2000s	since 2010
halibut							
Chinook/king salmon							
coho/silver salmon							
________rockfish ________rockfish							
lingcod							
Pacific cod							

For each species, what is the approximate size range for small, medium, and large categories?

Approx. Length Range	Small	Medium	Large
halibut			
Chinook/king salmon			
coho/silver salmon			
________rockfish ________rockfish			
lingcod			
Pacific cod			

General Conclusion

The importance of expert knowledge in environmental decision-making is being increasingly recognized, yet the application of such knowledge in fisheries management has had a complicated journey (see Hind 2015). Local experts possess knowledge about fish populations, species distributions, and emerging environmental phenomena, yet the use of this knowledge to inform resource management has been variable. Local knowledge may not fully align with western science, but the two can complement each other to inform more robust and informed management decisions. Local knowledge often captures a localized understanding of species and habitats, information on anomalous events, and trends in the environment over long time horizons (i.e., years to decades; Huntington et al. 2004). In contrast, scientific knowledge may include a larger geographic extent or more detailed information on seasonal and interannual patterns, but may take place over a short timeframe (i.e., months to years). Together, local knowledge of resource users and scientific knowledge can provide an improved understanding of the environment than either source alone.

In this dissertation, I presented multiple types of local knowledge that inform the science and management of small-scale fisheries in Alaska. My colleagues and I examined the use of fisheries local knowledge to document shifts in spatial fishing patterns (Chapter 1) and fish abundance and size (Chapter 3), and discussed ways in which this information complements current scientific data collection programs or fills gaps in current understanding of fishing distribution and fish populations. We also explored the perceptions of recent policy decisions on fishers and the ways in which they are adapting to ever-changing regulatory and ecological environments (Chapter 2).

This study took an inclusive approach to defining experts, as individuals self-identified as fishers with knowledge of their sector and specific attributes of the environment (e.g., Pacific halibut biology and ecology). Other studies may identify experts as key stakeholders (e.g., individuals with knowledge of the management system) or community-identified experts (e.g., Elders holding multiple generations of indigenous knowledge). Using the concept of information theory may be a useful way to better understand expert knowledge (Bateson 1972). Loring et al. (2014) examined Alaska's salmon fisheries and identified that user groups have different types of fishing they practice including gear type, season, and geographic range, which collectively informs the ecological information that users observe. These observations led to different perceptions of sustainability, particularly the perception that some user groups are more sustainable than others (Loring et al. 2014). Variability in how experts are defined can lead to differences in LEK and disparities in perceptions of the management system. Therefore, researchers and managers who wish to better understand a fishery using LEK should understand the implications of different ways of defining expertise and eliciting expert knowledge, and be explicit in their methodology.

Finally, it is important to recognize that there are other valuable approaches in addition to the ones used in this dissertation, ranging from ethnographic studies (see Wheeler and Thornton 2005, Johannes et al. 2000) to systematic surveys (Lew and Larson 2012, Davis and Ruddle 2010). In addition, the exact approach to including local knowledge in resource management is one of scholarly debate (see Holm 2003, Agrawal 1995), and continued work will require adaptive management systems that incorporate multiple knowledge sources. Resource users both drive and respond to changes in ecological systems, thus their knowledge is crucial for understanding how social-ecological systems will adapt to future change. It is within this context that this body of work was pursued, with the intention that expert knowledge can improve management of our natural resources, resulting in positive outcomes for stakeholders, local economies, and the ecological system as a whole.

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Appendix A. Research approval letters from the University of Alaska Fairbanks Institutional Research Board

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Institutional Review Board

909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

April 1, 2014

To: Anne Beaudreau
Principal Investigator

From: University of Alaska Fairbanks IRB

Re: [583323-1] Fishing behaviors and responses to regulations in the charter halibut sector of Alaska

Thank you for submitting the New Project referenced below. The submission was handled by Exempt Review. The Office of Research Integrity has determined that the proposed research qualifies for exemption from the requirements of 45 CFR 46. This exemption does not waive the researchers' responsibility to adhere to basic ethical principles for the responsible conduct of research and discipline specific professional standards.

Title:	Fishing behaviors and responses to regulations in the charter halibut sector of Alaska
Received:	March 26, 2014
Exemption Category:	*2*
Effective Date:	April 1, 2014

This action is included on the April 2, 2014 IRB Agenda.

Prior to making substantive changes to the scope of research, research tools, or personnel involved on the project, please contact the Office of Research Integrity to determine whether or not additional review is required. Additional review is not required for small editorial changes to improve the clarity or readability of the research tools or other documents.

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909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

May 2, 2014

To: Anne Beaudreau
Principal Investigator

From: University of Alaska Fairbanks IRB

Re: [601393-1] Subsistence halibut fishing practices in Southeast Alaska

Thank you for submitting the New Project referenced below. The submission was handled by . The Office of Research Integrity has determined that the proposed research qualifies for exemption from the requirements of 45 CFR 46. This exemption does not waive the researchers' responsibility to adhere to basic ethical principles for the responsible conduct of research and discipline specific professional standards.

Title:	Subsistence halibut fishing practices in Southeast Alaska
Received:	May 1, 2014
Exemption Category:	*2*
Effective Date:	May 2, 2015

This action is included on the May 7, 2014 IRB Agenda.

Prior to making substantive changes to the scope of research, research tools, or personnel involved on the project, please contact the Office of Research Integrity to determine whether or not additional review is required. Additional review is not required for small editorial changes to improve the clarity or readability of the research tools or other documents.