USING LOCAL KNOWLEDGE TO INFORM COMMERCIAL FISHERIES SCIENCE AND MANAGEMENT IN POLAND AND ALASKA

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Abstract

Science and decision making in commercial fisheries management take place in the context of uncertainty. This research demonstrates ways that local knowledge held by fishermen can be used to mitigate that uncertainty. This dissertation documents local knowledge of fishermen in Poland and Alaska, and contributes to the development of methods for utilizing that local knowledge in commercial fisheries management. Specific case study examples were developed through exploratory interviews with fishermen in the two study regions. Interviews were conducted with Baltic cod (*Gadus morhua*) fishermen in Poland and Pacific halibut (*Hippoglossus stenolepis*) fishermen in Alaska. Qualitative and quantitative methods were used to analyze local knowledge about ecosystems, as well as preferences held by fishermen about regulations. Cultural consensus analysis was used to quantify agreement among fishermen in Poland about the abundance and condition of cod, and generalized additive modeling was used to show how fishermen and scientists attributed different causes to similar observed phenomena. Multiple factor analysis and logistic regression were used to demonstrate how fishing characteristics influence encounters with incidental catch in the commercial fishery for halibut in Southeast Alaska. Finally, an analytic hierarchy process model was used to shed light on preferences halibut fishermen have about data collection methods on their vessels. All findings show how the inclusion of fishermen's local knowledge in fisheries management need not be limited to informal conversations or public testimony at meetings in order to be meaningfully interpretable by managers.

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List of Abbreviations

ADFG: Alaska Department of Fish & Game

AHP: Analytic Hierarchy Process

AIC: Akaike Information Criterion

ALFA: Alaska Longline Fishermen's Association

ANOVA: Analysis of Variance

CCA: Cultural Consensus Analysis

CI: Consistency Index

Council: North Pacific Fishery Management Council

C*r*: Consistency Ratio

df: degrees of freedom

EAF: Ecosystem Approach to Fisheries

EBFM: Ecosystem-Based Fisheries Management

EM: Electronic Monitoring

EU: European Union

EU CFP: European Union Common Fisheries Policy

GAM: Generalized Additive Modelling

IBSFC: International Baltic Sea Fisheries Commission

ICES: International Council for the Exploration of the Sea

IFQ: Individual Fishing Quota

IPHC: International Pacific Halibut Commission

IRB: Institutional Review Board

KMO: Kaiser-Meyer Olkin Test

LEK: Local Ecological Knowledge

LFK: Local Fisheries Knowledge

MCDA: Multiple Criteria Decision Analysis

MFA: Multiple Factor Analysis

MSC: Marine Stewardship Council

MSE: Management Strategy Evaluation

NAFC: North Atlantic Fisheries College

NMFS: National Marine Fisheries Service

NMFRI: National Marine Fisheries Research Institute

NPFMC: North Pacific Fishery Management Council

NOAA: National Oceanic and Atmospheric Administration

NRC: National Research Council

Obs: Human Observers

OR: Odds Ratio

PCA: Principle Components Analysis

PFRCC: Pacific Fisheries Resource Conservation Council

POLR: Proportional Odds Cumulative Ordered Logistic Regression

RI: Random Index

SQ: Status Quo

SSC: Scientific and Statistical Committee

TAC: Total Allowable Catch

UAF: University of Alaska Fairbanks

UN FAO: United Nations Food and Agriculture Organization

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General Introduction

Science and decision making in commercial fisheries management take place in the context of uncertainty. Scientists and managers attempt to mitigate that uncertainty by gathering biological data on fish populations and by using systematic methods for making decisions. Furthermore, they often attempt to incorporate fishermen's views into the development of policy options. However, integration of fishermen's local ecological knowledge into biological assessments remains uncommon. It also remains uncommon for managers to analyze fishermen's preferences or incorporate their knowledge into policy decisions in a systematic way. Using two case studies, this research documents how fishermen in two commercial fisheries—targeting Baltic cod (*Gadus morhua callarias*) in Poland and Pacific halibut (*Hippoglossus stenolepis*) in Alaska— perceive ecological and policy change. This work contributes to development of methods for integrating local knowledge more broadly in fisheries management.

Contemporary commercial fisheries management in the United States and the European Union is conceptually embedded within Ecosystem-Based Fisheries Management (EBFM) and the Ecosystem Approach to Fisheries (EAF). While the US fisheries management system tends to focus on EBFM (see: Phinney & Tromble 2010; Osgood 2011) and the European Union Common Fisheries Policy (EU CFP) system tends to reference EAF (see: Europa 2008), in practice, the two concepts are synonymous. Both are guided by the idea that fishery management plans should function in ways that create inclusive rather than exclusive understandings of the environment. In addition, both demand a holistic understanding of the marine environment, one that includes commercial fishermen as a part of the marine ecosystem. The US Commission on Ocean Policy (2004) defines EBFM:

> Ecosystem-based management looks at all the links among living and nonliving resources, rather than considering single issues in isolation. This system of

> management considers human activities, their benefits, and their potential impacts within the context of the broader biological and physical environment (page 63).

The European Commission describes EAF (Eur-lex 2008) using the definition from the United Nations Food and Agriculture Organization (UN FAO) Fisheries and Aquaculture Department Glossary of Fisheries Terms:

> An approach to fisheries management and development that strives to balance diverse societal objectives, by taking into account the knowledge and uncertainties about biotic, abiotic and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries. The purpose of EAF is to plan, develop and manage fisheries in a manner that addresses the multiple needs and desires of societies, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by marine ecosystems (UN FAO 2013).

EBFM and EAF identify the importance of a focus on the human/social aspects of fishery ecosystems, and have been influential in the US and Europe since the early 2000s (TheFishSite 2008; also see: Brodziak & Link 2002; Garcia et al. 2003).

Failures of single-species fisheries management schemes have been widespread, and policy-makers are now more open to alternative methods for measuring fish stock abundance, estimating catch-per-unit-effort, selecting management measures, and increasing fishermen compliance with regulations (Moller et al., 2004; Suarez de Vivero et al., 2008). These include dynamic and adaptive strategies for implementing sustainable practices such as the community approach, co-management, and the concept of ecosystem services (Luck et al., 2012). The driving force behind all of these ideas is to improve human-environment exchanges for mutual benefit.

EBFM and EAF are both rooted in management systems that have traditionally relied on natural science-based approaches, to the exclusion of considering human dimensions of the ecosystem or using social science as a form of best available scientific information. Link et al. (2017) note that even now, "Inclusion of human dimensions into integrated ecosystem assessments has been lagging, but is fundamental." To date, management agencies have invested very little in human dimensions data collection programs. This information gap can be addressed, in part, through more effective engagement with commercial fishermen who hold important knowledge of local fisheries and ecosystems and unique understanding of the likely efficacy and impacts of alternative management actions. By broadening the management focus to include human dimensions and social science, commercial fishermen may be approached as experts who hold important *local fisheries knowledge* for informing scientists and policymakers:

> [Local fisheries knowledge] LFK is knowledge concerning many aspects of commercial, subsistence, and recreational marine fishing/harvest, including the marine environment and species; fishing culture and society; fishing technology and practices; and business and economic aspects of fishing. LFK is acquired and possessed by those involved on a day-to-day basis in marine fishing/harvesting and related activities (e.g., fish processing, boat building, and fishing gear construction). LFK is derived from personal and collective observations and experiences over a single lifetime or many generations. LFK is transmitted orally and through observation. LFK can be possessed personally and communally. LFK is connected to place and is locally specific (NMFS, 2013).

Local knowledge is the product of knowledge formation and dissemination based on personal, shared and inherited experience (Martin et al., 2007). It is a way of knowing, a worldview, that is connected to a specific place, and emerges from a compendium of life experiences and observations. Bearers of local knowledge are often relatively small groups of people, who may or may not be indigenous to the area or base their understandings on knowledge that evolves over many generations (PFRCC, 2011).

Local knowledge is often (mis)understood as contradictory to natural science, but natural science and local knowledge are complimentary. Local knowledge may be summarized or analyzed using both qualitative and quantitative social science methods. Qualitative social science "does not seek a single or generalizable truth, but rather uncover[s] multiple perspectives and interpretations" of the world (Charnley et al., 2017). Recent academic work has identified evaluative criteria for how local knowledge as social science data—especially qualitative social science—might be incorporated into fisheries management processes alongside other forms of best available science (Huntington, 2000; Charnley et al., 2017; Raymond-Yakoubian et al., 2017).

Community involvement—including that of fishermen—in management has a tendency to be misunderstood and marginalized (Olson, 2005). The increasingly holistic ecosystem views encouraged by EBFM and EAF have allowed the local knowledge of fishermen to gain ground as a legitimate source of expert information in scientific and management arenas (Marshall, 2007). However, debates and difficulties continue to arise concerning the efficacy and ethics of incorporating fishermen knowledge into management schemes (Maurstad, 2002; Neis & Felt, 2000; Witt, 2007; Suarez de Vivero et al., 2008). Carr and Heyman (2012) have found that fishermen possess valuable knowledge, especially in smaller-scale and artisanal environments, and they can provide valuable input during regulatory negotiations. Yet they worry about the potential for local knowledge to be biased and self-interested. Nevertheless, examples of successful scientific research focusing on local knowledge abound (see: Bergmann et al., 2004; Grant & Berkes, 2007). This has had positive impacts on the efficacy of fisheries management.

Incorporating local knowledge into research and policymaking has been found to increase fishermen compliance with new regulations (Martin et al., 2007). Local knowledge is also compatible with multiple existing management methods, and can provide information that is otherwise unattainable. Some researchers have long argued that local knowledge can be used to construct large-scale pictures of regional fisheries extending back several decades (Neis & Felt, 2000). Examples include Beaudreau and Levin (2014), Beaudreau and Whitney (2016), Figus et al. (2017), and Chan et al. (2017).

A growing influence of integrated approaches to fisheries management (e.g., EBFM; EAF) demands that relationships between ecological, social, and economic costs and benefits of fisheries management actions be further researched (Leslie and McLeod, 2007; Levin et al., 2009; Marshall et al., 2017). Integrated approaches to management further call for the knowledge and perceptions of fishermen—as experts—be incorporated into science and decision making in a systematic way (Charnley et al., 2017).

This dissertation documents how Polish and Alaskan fishermen perceive ecological and policy shifts in their fisheries, and contributes to the development of methods for incorporating that expert local knowledge into management. Specific case study examples for this research were developed through exploratory interviews with fishermen in both study regions. Data collection for this work took the form of in-person surveys and semistructured interviews (Bernard, 2011) that occurred between 2013 and 2015. In Poland, fishermen were concerned about changes in the condition and abundance of the cod in coastal waters, potentially resulting from an upswing in harvests of sprat (*Sprattus sprattus*) throughout the Baltic Sea. In Alaska, there was discontent among fishermen with recent changes to expand the federal fisheries observer program to monitor incidental catch and discards aboard halibut longline vessels.

Study Region: Poland

Poland's Baltic cod fishery has been managed under season limits, as well as restrictions on vessel size and fishing power, minimum mesh and landing size, and Total Allowable Catch (TAC). Individual fishermen are allotted a portion of the TAC each year; they can fish their allotment or transfer it to others through non-market transfers. During the 1990s, apportionment of Baltic cod to national quotas was negotiated through the International Baltic Sea Fisheries Commission (IBSFC). When Poland was admitted to the EU in 2004, Polish catches of Baltic cod came under jurisdiction of the EU Common Fisheries Policy (EU CFP). On January 1, 2006, the IBSFC was disbanded, resulting in all Baltic Sea cod management taking place through EU CFP legislation and a bilateral agreement between the EU and Russia. The International Council for Exploration of the Sea (ICES) provides most of the accepted scientific advice for determining a similar system of TAC quotas for commercial fish species in the Baltic Sea. Beginning in 2008, all vessels longer than 8 meters have been subject to a Multi-Annual Plan for cod that applies throughout the Baltic Sea. In 2016, the Polish TAC for Baltic cod in the region studied for this research (subdivisions 25-32) was roughly 24 million pounds.

For this case study (Chapter 1), a short written survey of 130 Polish fishermen during fall 2013 provided key design information for 31 in-depth interviews recorded with Polish cod fishermen during fall 2014. A mixed methods approach to analyzing these interview data included cultural consensus analysis and generalized additive modeling.

Study Region: Southeast Alaska

The Pacific halibut fishery is one of the most lucrative commercial fisheries in the Alaska (McDowell Group, 2017). For most of the 20th century, the halibut fishery in Alaska was managed as an open access fishery, with a fleetwide TAC. Since 1995, this fishery has been managed under an individual fishing quota (IFQ) program. In the halibut IFQ program, landings of the target species (halibut) and landed incidental catch species (e.g., rockfish) are carefully monitored, and are largely transparent (McIlwain, 2013). However, until 2013, discarded incidental catch in this fleet was not subject to independent monitoring. In 2013, the North Pacific Fishery Management Council extended the federal fisheries observer program to include vessels targeting halibut.

The commercial fishery for Pacific halibut involves over 1,000 vessels, most of which are less than 60 feet (18 meters) in length overall (Witherell et al., 2012). For this study, we focused on the Southeast Alaska regional halibut fishery. Focusing our study in one region allowed us to analyze preferences while controlling for factors that vary across the regulatory areas (e.g., incidental catch/discard regulations). Southeast Alaska 28 different communities that land a combined 250-300 million lbs. of fish each year with an ex-vessel value of about $250 million. In 2016, the TAC for Pacific halibut in Southeast Alaska was roughly 4 million pounds.

Exploratory visits to Hoonah (spring 2014) and Petersburg (fall 2014) and test interviewing in Haines during January 2015 provided key design information for 78 in-depth interviews recorded with commercial halibut fishermen in the Southeast Alaska region (Area 2C) during spring 2015. A mixed methods approach to analyzing these data included multiple factor analysis and proportional odds logistic regression (Chapter 2), text analysis and the analytic hierarchy process (Chapter 3).

Contributions of this Research

This dissertation uses case studies from Polish and Alaskan commercial fisheries to contribute to the development of practical mechanisms for integrating local knowledge into existing fisheries management structures.

Chapter 1 documents local ecological knowledge about Baltic cod. In 2012 and 2013, local media reported that fishermen were observing increased occurrences of cod with poor body condition ('skinny' cod) in their catches from waters off Poland. Polish cod fishermen were interviewed to assess the strength of their agreement about the abundance and body condition of cod. Agreement among fishermen was assessed about trends in abundance and occurrence of 'skinny' cod, as well as the mechanisms explaining those patterns. Cultural consensus analysis showed strong agreement among Polish fishermen that 'skinny' cod may be attributed to overfishing on sprat, a key prey species. Generalized additive models were used to show that trends in fishermen's observations of abundance and 'skinny' cod occurrence may be partially explained by variation in temperature, salinity, and sprat abundance.

Chapter 2 illustrates how data from interviews with commercial fishermen can be used to document incidental catch in the Pacific halibut fishery off Southeast Alaska. Patterns of incidental catch in the halibut fishery generally paralleled patterns of incidental catch in a fishery-independent stock assessment survey that used similar gear. Additionally, results from a proportional odds logistic regression model indicated the presence of a strong unavoidable component of incidental catch in the halibut fishery. This suggested that increased onboard monitoring of this fleet would be unlikely to reveal broad trends in incidental catch that were not already apparent in fishery-independent surveys. Smaller, but statistically significant, relationships in the regression model and a multiple factor analysis indicated that incidental catch can also be influenced by observable and controllable characteristics of fishing operations (e.g., fishing grounds, season, vessel length, gear configuration).

Chapter 3 presents results of a study measuring the degree of support halibut fishermen in Alaska have for different types of data collection methods on their vessels. Halibut fishermen were interviewed in four communities across Southeast Alaska, to document their preferences about data collection on their fishing vessel. Interviews included pairwise comparisons of four types of data collection methods, which were analyzed using the analytic hierarchy process. Results indicated that it is possible to gather reliable preference data for conducting decision analysis from a relatively small group of fishermen using one event of semistructured one-on-one interviewing. Findings shed light on how incorporating fishermen's preferences might alter potential solutions to a management problem—in this case, which data collection methods to use in the halibut fleet. Results also highlight potential ways to improve upon the existing data collection program in the commercial halibut fleet.

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Chapter 1 Using local ecological knowledge to inform fisheries assessment: Measuring agreement among Polish fishermen about the abundance and condition of Baltic cod (*Gadus morhua*)[1]

Abstract

While fisheries managers often attempt to incorporate stakeholders' views into development of policy options, integration of fishermen's local ecological knowledge into biological assessments remains uncommon. Using the case of the eastern Baltic cod (*Gadus morhua*) resource, this paper documented local ecological knowledge about a managed fishery stock. In 2012 and 2013, local media reported that fishermen were observing increased occurrences of cod with poor body condition ('skinny' cod) in their catches from waters off Poland. Polish cod fishermen were interviewed (n = 31) to quantify the strength of their agreement about the abundance and body condition of cod. Agreement among fishermen was assessed about trends in abundance and occurrence of 'skinny' cod, as well as the mechanisms explaining those patterns. Cultural consensus analysis showed strong agreement among Polish fishermen that 'skinny' cod may be attributed to overfishing on sprat, a key prey species. Fishermen and scientists observed similar declines in the abundance and condition of cod along the Polish coastline; however, they may perceive causes of those changes differently. Generalised additive models were used to show that trends in fishermen's observations of abundance and 'skinny' cod occurrence may be partially explained by variation in temperature, salinity, and sprat abundance.

[1] Figus, E., Carothers, C., and Beaudreau, A. H. (2017). Using local ecological knowledge to inform fisheries assessment: measuring agreement among Polish fishermen about the abundance and condition of Baltic cod (*Gadus morhua*). *ICES Journal of Marine Science* 71(8): 2213-2222. doi: https://doi.org/10.1093/icesjms/fsx061

Introduction

The European Union Common Fisheries Policy (EU CFP) calls for the “broad involvement of stakeholders at all stages of the [Common Fisheries] policy from conception to implementation” (EU, 2002). Including stakeholders early in the governance process broadens the knowledge base for fisheries management (Linke et al., 2011), leading to adoption of better policies as well as broader support for those policies (e.g., EU, 2002; Marciniak, 2010). Fishermen’s local ecological knowledge (LEK) can provide a foundation for developing fisheries policies that stakeholders accept as legitimate (Marciniak, 2010) and incorporating LEK into research and policymaking has been found to increase fishermen’s compliance with new regulations (Martin et al., 2007). Nevertheless, interpreting and integrating LEK of resource users into assessment and management remains a challenge because information gathered from stakeholders may be difficult for agencies to incorporate into decisions (Steelman, 1999) and agency personnel are often unfamiliar with social science methods (Huntington, 2000).

LEK is the product of complex processes of knowledge formation and dissemination based on personal, shared and inherited experience (Martin et al., 2007). It is knowledge that is connected to a specific social group or place. Failing to show consideration for perceptions and observations of fishermen may lead to information gaps, lack of support for management measures, or reduced efficacy of management measures (McCay and Finlayson, 1995). LEK can inform management by providing information to support stock assessment that may be available more quickly than formal stock assessment data, that complements scientific information, or that is otherwise unattainable (Johannes, 1998; Johannes et al., 2000; Johannes and Hviding, 2000;

Saenz-Arroyo et al., 2005). LEK has been used to construct historical patterns in regional fisheries extending back several decades (Neis and Felt, 2000; Beaudreau and Levin, 2014).

LEK may also be valuable to management of Atlantic cod (*Gadus morhua*) in Baltic Sea fisheries off Poland, which are currently managed as part of the European Union Common Fisheries Policy (EU, 2013). Since Poland joined the European Union in 2004, Polish cod fishermen have been subject to various direct and indirect EU regulations, including: fleet reductions; seasonal and area closures; 100% transparency (observation) of landings; increased fines for non-compliance; a three-year stock rebuilding plan called 'Trójpolówka'; and, a Multi-Annual Plan for managing the eastern Baltic cod stock. In addition, joining the European Union and the Common Fisheries Policy introduced Polish fishermen to new forums for stakeholder participation, including: the Baltic Sea Advisory Council; Producer Organizations; World Wildlife Fund Round Table Meetings; and, Fisheries Local Action Groups to promote investment in fisheries-dependent communities (Figus, 2015). However, Polish coastal fishermen generally do not tend to be active participants in the current management process (Figus, 2015). It has been found that participation in those forums tends to include the same limited group of fishermen as those who participated in management discussions before EU accession (Figus, 2015). Fishermen often garner the attention of local media in Poland, but their LEK is rarely documented or analysed in a way that would facilitate its incorporation in regular assessment or management processes.

In 2012 and 2013, local media reported that fishermen were observing increased occurrences of cod with poor body condition ('skinny' cod) in their catches from waters off Poland (Bierndgarski, 2013) as well as declines in cod abundance. Fishermen attributed these changes in cod abundance and condition to increased exploitation of sprat (*Sprattus sprattus*) (Pelczarski et al., 2006), an important prey species for cod (Eero et al., 2012). Cod fishermen called for reductions in the sprat fishery to mitigate adverse impacts on cod stocks. In light of media attention on the issue, the National Marine Fisheries Research Institute in Poland (NMFRI) released a document on the 'skinny' cod phenomenon in 2013: "Skinny Cod: Facts and Myths" (NMFRI, 2013). Scientists saw changes in the cod resource as an example of localized depletion resulting from a spatial mismatch of cod and cod prey and as a consequence of size-dependent predation rather than as evidence of an overall decline in the cod stock (NMFRI, 2013, page 5). Scientists believed that fishermen's concerns for the cod resource were premature. A lack of structured documentation of Polish fishermen's observations about 'skinny' cod made it difficult to make meaningful comparisons between fisheries-independent science and what fishermen observed on the fishing grounds (LEK).

This paper illustrates how social science methods can be used to document LEK about a fishery resource (in this case, eastern Baltic cod), to quantify the strength of agreement among fishermen about that knowledge, and to use that information to explore mechanisms that might drive the observed phenomena. Specific objectives were to: (1) determine the degree of agreement among fishermen in their understanding of trends in cod abundance and condition; (2) evaluate differences and similarities between fishermen's knowledge and scientific information on cod ecology and body condition provided by NMFRI; (3) explore relationships between fishermen's consensus observations and variation in environmental state variables; and (4) determine whether NMFRI scientists and Polish fishermen observed the same patterns in cod abundance and body condition but attributed them to different causal factors.

Methods

Study region

Poland is one of nine countries bordering the Baltic Sea (Figure 1.1). The Polish Baltic Sea coastline is 528 kilometres long, and has 74 recognized docking areas for loading, unloading and harbouring of vessels (Ministry, 2008).

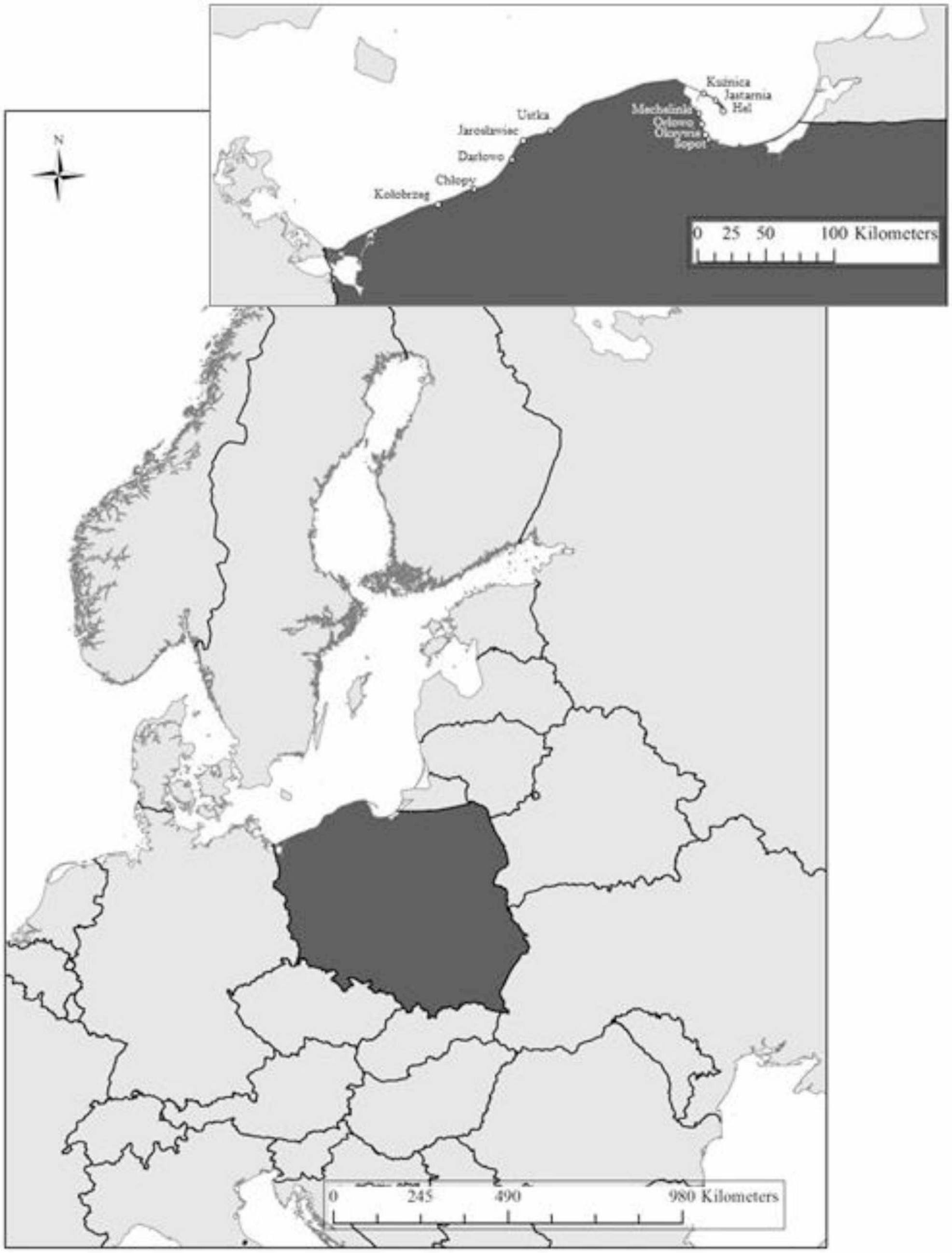

Figure 1.1 Map of the Polish coastline showing study communities. Inset of the Baltic Sea region with political boundaries.

Since the 1990s, Polish commercial fishing efforts have shifted from a focus on large-scale factory trawling in distant waters to smaller scale operations on the Baltic Sea. The majority of Polish national fishing effort is now composed of two sectors: coastal fisheries operating in inshore territorial waters and a cutter fishery operating exclusively on the Baltic Sea (FAO, 2012). Cutters are 15 metres or longer and may target sprat as well as cod. A majority of Polish fishermen operate in small scale coastal fisheries composed of vessels less than 15 metres in overall length, generally not involved in sprat fishing (Figus, 2014).

Interviews

To assess fishermen's knowledge and determine agreement among fishermen regarding cod ecology and body condition, we combined semi-structured interviews (Bernard, 2011) with a cultural consensus analysis (CCA) survey instrument (Romney et al., 1986). Thirty-one Polish cod fishermen were interviewed and surveyed in twelve coastal communities (Table 1.1) during November and December 2014. The interview group composed roughly eight percent (7.87%) of total registered fishing vessels in the twelve study communities. Interviewees were chosen using a snowball sampling approach (Babbie, 2007) in which experienced cod fishermen known from previous research (Figus, 2015) were asked to recommend other suitable fishermen to participate. Recorded interviews were conducted one-on-one with fishermen who had at least twenty years of fishing experience, had a current connection to the Baltic cod fishery, and were recommended as knowledgeable by other fishermen. Interviews ranged from 30 to 90 minutes in length and were conducted in the Polish language. Test interviews of the interview protocol and survey instrument took place at the beginning of fieldwork. Interview responses were translated to English by the lead author.

Table 1.1 Interviewee characteristics, including: community of residence; vessel size class; and, interviewee age.

Community	Number of Interviewees
Kołobrzeg	2
Chłopy	2
Darłowo	1
Jarosławiec	6
Ustka	2
Mechelinki	1
Orłowo	2
Oksywie	1
Sopot	2
Kuźnica	4
Jastarnia	7
Hel	1
Vessel Length	**Number of Interviewees**
< 8 m	12
8.1-11.9 m	9
≥ 12 m	10
Age	**Number of Interviewees**
30-40	2
41-50	8
51-60	15
61-70	6

Research design was informed by previous studies using LEK to assess historical abundance trends (Beaudreau and Levin, 2014) and CCA to measure agreement among participants (Carothers et al., 2014). A formal CCA model (Romney et al., 1986) was used to measure agreement across responses to 28 yes/no statements. Semi-structured interviews (Bernard, 2011) were used to elicit personal narratives of fishing experiences related to Baltic cod, which provided context for interpreting responses to the CCA statements (Appendix 1.A). Development of the interview protocol was informed by previous work in the Polish cod fleet during 2011 (Figus, 2015) as well as a pilot study completed during 2013 (E. Figus, unpublished). The pilot study (E. Figus, unpublished) consisted of a 33-question written survey identifying concerns and perceptions of Polish fishermen about Baltic Sea fisheries management and reforms to the EU CFP. The pilot survey was completed by 131 fishermen in Poland, of which 105 were vessel owners who together comprised 17.4% of all Polish vessels fishing on the Baltic Sea.

During interviews, participating fishermen were asked to score cod abundance and the percentage of 'skinny' cod in their catches on a Likert scale (6-point scale, from 'very low' to 'very high') for each decade in which they had fishing experience starting with the 1960s. Interviews documented: 1) duration of cod fishing experience; 2) observations of shifting abundance of adult cod and perceived causes; 3) observations of shifting condition of adult cod and perceived causes; and, 4) demographic information about the interviewees (Appendix 1.A). The CCA survey instrument was administered between portions 3 and 4 of each recorded interview.

Formal CCA models gauge the similarity of responses between all pairs of interviewees (in this case, fishermen) to produce 'competence' scores that measure how well each fisherman's responses aligns with the rest of the interview group (Weller, 2007). The CCA survey instrument for this research contained 28 yes/no proposition statements (Table 1.1). Statements in the CCA survey instrument were based on responses to open-ended questions about challenges identified by fishermen in the 2013 pilot survey (E. Figus, unpublished) as well as statements drawn from the NMFRI 'Facts and Myths' document (NMFRI, 2013; bolded statements in Table 1.2). Participants were interviewed individually and were not exposed to the CCA statements prior to their interview. Interview questions allowed participants to describe observations and perceptions of cod in detail, while the completed CCA survey instrument yielded yes/no responses that could be quantitatively analysed.

Table 1.2 Original consensus survey instrument with 28 yes/no statements. * indicates that a given statement was used in the formal analysis. **Bolded** statements were taken from NMFRI documents (2013; 2014)

Consensus Statements	YES	NO
1. Cod move seasonally*	97%	3%
2. Cod prefer colder water	94%	6%
3. Cod prefer warmer water*	6%	94%
4. It is normal for cod to eat sprat*	100%	0%
5. It is normal for cod to eat other cod*	42%	58%
6. Cod populations are in a good state*	13%	87%
7. Cod populations are in a bad state	87%	13%
8. Today there are a lot of cod*	6%	94%
9. The cod population is getting smaller	94%	6%
10. Prey found in the stomachs of cod is changing*	94%	6%
11. Cod have enough to eat*	13%	87%
12. Cod do not have enough to eat	84%	16%
13. Today cod eat other cod*	58%	42%
14. Today cod eat different things than they used to*	81%	19%
15. Joining the EU caused an increase in the cod population in Poland*	3%	97%
16. Joining the EU caused a decrease in the cod population in Poland	71%	29%
17. 'Skinny' cod is a normal thing*	29%	71%
18. The number of 'skinny' cod changes from season to season*	94%	6%
19. 'Skinny' cod are occurring more frequently*	87%	13%
20. 'Skinny' cod are occurring more rarely	10%	90%
21. The number of sprat impacts the number of 'skinny' cod*	97%	3%
22. Fishmeal catches in Polish waters are increasing	81%	19%
23. Fishmeal catches in Polish waters are decreasing*	19%	81%
24. Fishmeal catches are overfishing sprat*	100%	0%
25. If there were more sprat in the Sea, there would be more cod*	100%	0%
26. If there were more sprat in the Sea, there would be fewer cod	0%	100%
27. Fishmeal catches cause more occurrences of 'skinny' cod*	97%	3%
28. Fishmeal catches cause fewer occurrences of 'skinny' cod	3%	97%

Analysis

CCA (Romney et al., 1986) was carried out to determine the degree of agreement among fishermen in their understanding of cod abundance and condition. Interview responses were used to shed light on characteristics of the shared or divergent knowledge identified through CCA. Interview results from semi-structured interviews were analysed using inductive text analysis (Bernard, 2011), and completed CCA surveys were analysed in the UCINET software package

(Borgatti et al., 2002). Tables reflecting decadal time series perceptions of cod abundance and ‘skinny’ cod prevalence were analysed using generalised additive modelling, or GAM, (Wood, 2011) in the R software program (R Core Team, 2016).

CCA is a form of exploratory factor analysis that treats participants, rather than items, as variables of interest and identifies clusters of similar answer patterns (Fielding-Miller et al., 2016). CCA makes it possible to measure the level of agreement between participants in a study (Romney et al., 1986) and to determine whether or not variance of responses is part of a shared overall body of knowledge in the study group (Borgatti and Halgin, 2011). Eigenvalues output by the model characterise the amount of variance explained by each factor. A high eigenratio (ratio of the largest eigenvalue to the second largest eigenvalue) is considered to indicate good model fit and allows the first factor loadings to be interpreted as competence (knowledge) scores for each interviewee (Borgatti and Halgin, 2011). CCA models are based on three assumptions: (1) participant responses are independent, (2) questions address related topics and are of comparable difficulty, and (3) there is a single set of answers to the CCA statements that interviewees will agree upon as correct statements (Weller, 2007). An important strength of CCA is that it does not require large samples to ensure confidence in results (Romney et al., 1986). This, coupled with the speed of analysis offered by formal CCA, makes it a suitable tool for informing environmental policy. In studies of environmental knowledge, CCA has been used to compare consensus estimates within (Carothers et al., 2014) and across multiple cultural groups (Miller et al., 2004; Naves et al., 2015).

The CCA model assumes that if an informant does not know the answer to a statement, their response is random (Weller, 2007). To control for this, statements may be organized to elicit a mixture of positive and negative responses with inverses of some statements included (Weller, 2007). Inverse statements were included in the interview protocol for this project to control for guessing bias in responses (example: statements 2 and 3 in Table 1.2). For most pairs of statements, if a respondent answered, ‘yes,’ to the first, they would answer, ‘no,’ to the second, or vice versa. To avoid pseudo replication, only one of each pair of statements was chosen (randomly) to be included in the analysis (starred statements in Table 1.2). A mixture of both positive and negative statements was removed to maximize yes/no response variation in the reduced model. A formal CCA was then run in UCINET on 19 of the 28 statements using the multiple choice model setting (Table 1.2).

Decadal trends in abundance indices and proportions of ‘skinny’ cod reported by respondents were visualized using GAM. GAM is a nonparametric regression method that is useful for characterizing patterns in data without assuming a particular form of parametric relationship (Wood, 2006). GAM was used to explore the relationships between environmental drivers and fishermen’s observations of abundance and ‘skinny’ cod occurrence. Cod abundance indices and proportions of ‘skinny’ cod in the catch were modelled separately as a function of year, seawater temperature, seawater salinity, and, sprat commercial catch data as covariates. Baltic Sea temperature, salinity, and sprat catch data were retrieved from the International Council for the Exploration of the Sea (ICES) database (ICES, 2016) and condensed into decadal averages for the Polish coastal region (Subdivisions 25 and 26) in the Baltic Sea. A full model and nine reduced models (including all possible combinations of predictors) were fit to the abundance and ‘skinny’ cod data. The ten alternative models were then compared with one another using the Akaike Information Criterion (AIC), where models with a $\Delta AIC \leq 2$ were considered to perform equivalently (Burnham and Anderson, 2002). Analyses were performed in RStudio, version 0.99.902 (R Core Team, 2016), using default settings in the ‘mgcv’ package (Wood, 2011).

Results from interviews, CCA, and GAMs were then compared with scientific views from NMFRI press releases during 2013 and 2014.

Results

Most of the 31 participants were between 40 and 60 years old (Table 1.1) and representative of the three vessel length classes in the Polish fishery (Table 1.1). This loosely reflected composition of the Polish fishing fleet, as most participants operated exclusively in the small scale coastal fishery, while six participants had cutter vessels greater than 15 metres in length. All respondents were current fishermen, with the exception of one who had recently retired. Even though interviewees came from twelve different communities and three vessel classes (Figure 1.1; Table 1.1), CCA model results indicated that a shared set of beliefs was present in the interview group regarding the ecology and condition of Atlantic cod. For most of the 28 yes/no statements there was over 80 or 90% agreement among project participants (Table 1.2).

The CCA model yielded an eigenratio greater than three (Table 1.3). A high eigenratio and a lack of negative competence scores indicate a good fit to the model. There was a large range of competence scores (Table 1.3), but only three interviewees had competence scores below 0.5. The mean first factor loading, or the average competence score, was between .5 and .9, an acceptable level for confirming the existence of a shared set of beliefs (Gatewood and Cameron, 2009).

Table 1.3 Consensus analysis results.

Model Output	
Mean 1st Factor Loading	0.792
No. of Negative Competencies	0.000
Largest Eigenvalue	20.588
2nd Largest Eigenvalue	2.779
Ratio of Largest to Next	7.407
Lowest Competence Score	0.153
Highest Competence Score	0.958

CCA results indicating a good fit to the model allow the modeller to ascertain which answers to each statement in the survey instrument are 'correct' for the given respondent group (Borgatti and Halgin, 2011). In this case, the consensus responses for experienced Polish cod fishermen are those answers chosen by more than 50 percent of the respondents (Table 1.2).

Fishermen were generally in agreement in their understandings of cod abundance and condition in the Baltic Sea near Poland. They largely agreed with the statement that cod move seasonally (see percentages of agreement in Table 1.2), but disagreed with the statement that cod prefer warm water. They agreed with statements that it is normal for cod to eat sprat, that the number of sprat influences the number of cod, and that if there were more sprat there would be more cod. Fishermen were also in strong agreement that cod eat different things now than they used to. Fishermen largely disagreed with statements that Baltic cod populations are in a good state, that cod have enough to eat, and that there are a lot of cod in the Baltic Sea. Fishermen generally did not agree with the statement that 'skinny' cod is a normal condition, but largely agreed with the statement that 'skinny' cod are occurring more frequently. They agreed that numbers of 'skinny' cod change from season to season, that industrial fishmeal catches of sprat cause more occurrences of 'skinny' cod and that fishmeal fleets are overfishing sprat near Poland. They generally did not agree with the statement that fishmeal catches in Polish waters are decreasing.

Some CCA statements generated mixed feedback or required additional explanation. Two statements about cannibalism—whether it is normal for cod to eat other cod and whether this phenomenon has been occurring in recent years—generated the least agreement in the consensus survey. Responses to open-ended questions during interviews suggested that disagreement about cannibalism may arise from different perceptions fishermen had about normal, healthy behaviour, as opposed to the behaviour of cod under stress or decreased body condition. Furthermore, some interviewees had observed cod inside the stomachs of cod in their catches, while others had not. In another pair of statements (statements 15 and 16 in Table 1.2), fishermen were asked whether joining the European Union influenced the health of Baltic cod stocks off Poland. The statement used in the final CCA (statement 15 in Table 1.2) returned strong agreement that joining the EU did not lead to an increase in the cod population. However, it is worth noting that multiple interviewees felt that governance within the EU, and the EU CFP, had no influence on Baltic cod stocks at all. In sum, cod fishermen were largely in agreement in their understandings of cod abundance and condition in the Baltic Sea waters off the coast of Poland.

To evaluate differences and similarities between fishermen's knowledge and scientific information on cod ecology and body condition provided by NMFRI, interview results were compared with NMFRI documentation (2013). Like fishermen, scientists from NMFRI acknowledged that the condition of cod off Poland had declined:

> Yes, cod are in a worse condition.... In 2012 cod were on average 30% 'thinner' than six years earlier.... The NMFRI has observed deterioration in the condition of cod since 2007. At that time—after a period of stagnation—the number of fish at age 2 began to increase (NMFRI, 2013; translated by Elizabeth Figus).

Scientists from NMFRI also found that smaller scale fishermen, who made up a majority of the participants in this research, were likely to be disproportionately impacted by shifts in the abundance and condition of cod near the Polish coastline:

> There is more cod in the eastern stock than a few years ago. The problem of lower availability and fishing yield for cod may be related to their distribution. Fishermen who fish on smaller vessels, with limited days at sea are restricted with respect to the fishing grounds and are not able to follow the cod when the adverse thermal or feeding conditions make the fish move to the areas further from the regional coast (NMFRI, 2013; translated by Elizabeth Figus).

Overall, fisherman and scientists generally agreed that the abundance and condition of cod had declined in nearshore waters off Poland.

To explore relationships between fishermen's consensus observations and variation in environmental state variables, the decadal abundance and body condition tables completed during interviews were analysed using GAM (Figure 1.2). Although not all interviewees were able to provide observations about abundance levels for the earliest decades, there was general agreement that the abundance of legal-sized cod (38cm) in Polish waters has declined over time. Similarly, there was general agreement that the prevalence of 'skinny' cod in catches has increased since the 1960s. Four GAMs performed equivalently (ΔAIC < 2) to describe variance in cod abundance (year only; year + sprat + temp + salinity; year + sprat + salinity; sprat + temp) and four models performed equivalently to explain variance in 'skinny' cod in catches (year only; sprat only; sprat + salinity; year + salinity) (Table 1.4). Excluding year, sprat was among the most important variable in explaining both abundance and percent 'skinny' cod in catch. Sprat catches explained over 30% of the variation in fishermen's observations about cod abundance and the percent of 'skinny' cod in their catches (Table 1.4). The relationship between sprat catch and cod abundance was variable and the percentage of ‘skinny’ cod observed generally increased with increasing sprat catch (Figure 1.3).

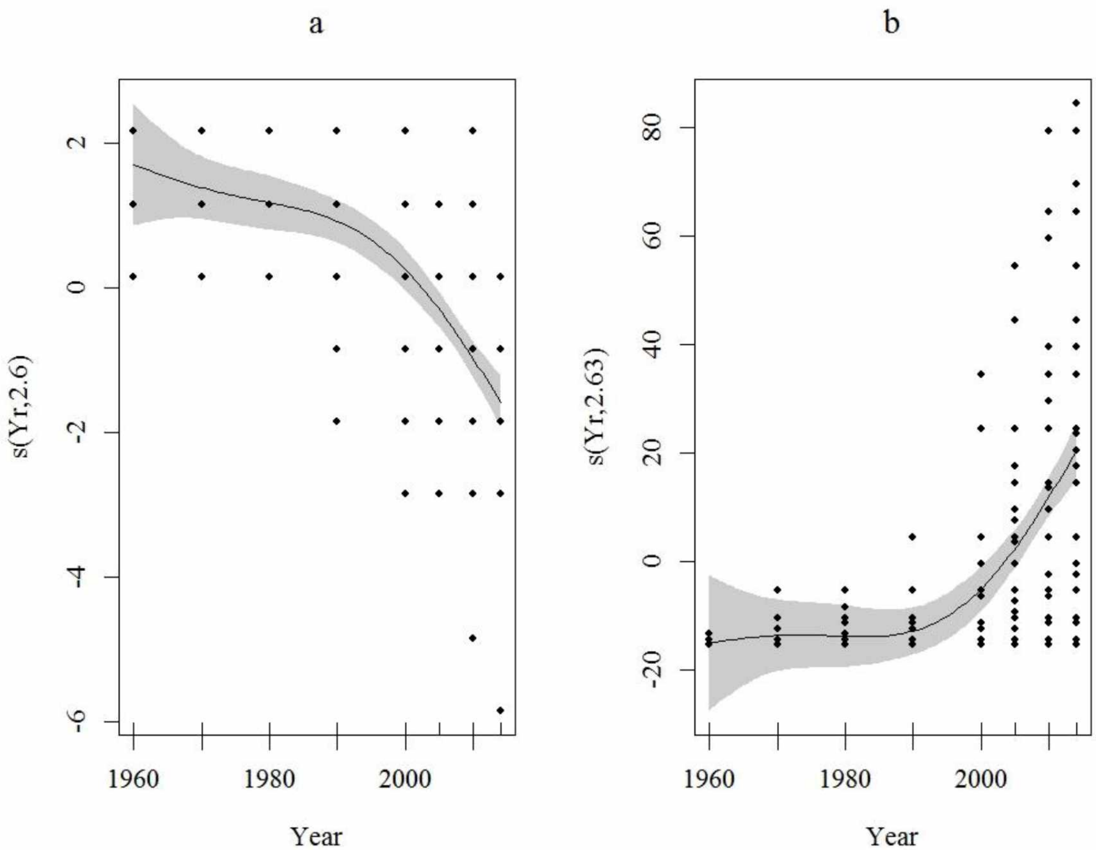

Figure 1.2 GAM fits for candidate model 1, showing partial effect of year on observed cod abundance (a) and percent of ‘skinny’ cod in commercial catches (b). Partial effect of year on the response variables is shown on the y-axis.

Table 1.4 GAM outputs.

Abundance Candidate Model	Variable(s)	Deviance Explained	Df	AIC	ΔAIC
1	Yr	41.80%	4.604	646.443	0.632
2	Sprat	39.00%	4.961	656.512	10.702
3	Temp	33.00%	4.581	673.841	28.030
4	Sal	6.48%	4.491	738.826	93.015
5	Yr, Sprat, Temp, Sal	43.20%	7.042	646.799	0.988
6	Yr, Sprat, Sal	43.00%	6.094	645.419	0.000
7	Yr, Sal	42.00%	5.494	647.560	2.141
8	Sprat, Temp	43.40%	6.901	645.811	0.000
9	Sprat, Sal	39.80%	5.960	655.970	10.160
10	Temp, Sal	33.80%	5.434	673.380	27.569

Skinny Cod Candidate Model	Variable(s)	Deviance Explained	df	AIC	ΔAIC
1	Yr	33.70%	4.629	1665.928	0.000
2	Sprat	33.90%	4.969	1665.981	0.053
3	Temp	22.50%	4.658	1696.100	30.172
4	Sal	4.95%	4.229	1734.357	68.429
5	Yr, Sprat, Temp, Sal	34.10%	7.055	1669.809	3.881
6	Yr, Sprat, Sal	38.00%	6.454	1669.483	3.555
7	Yr, Sal	38.00%	5.657	1667.704	1.776
8	Sprat, Temp	33.90%	5.962	1667.952	2.024
9	Sprat, Sal	34.00%	5.967	1667.864	1.936
10	Temp, Sal	27.80%	6.612	1686.275	20.347

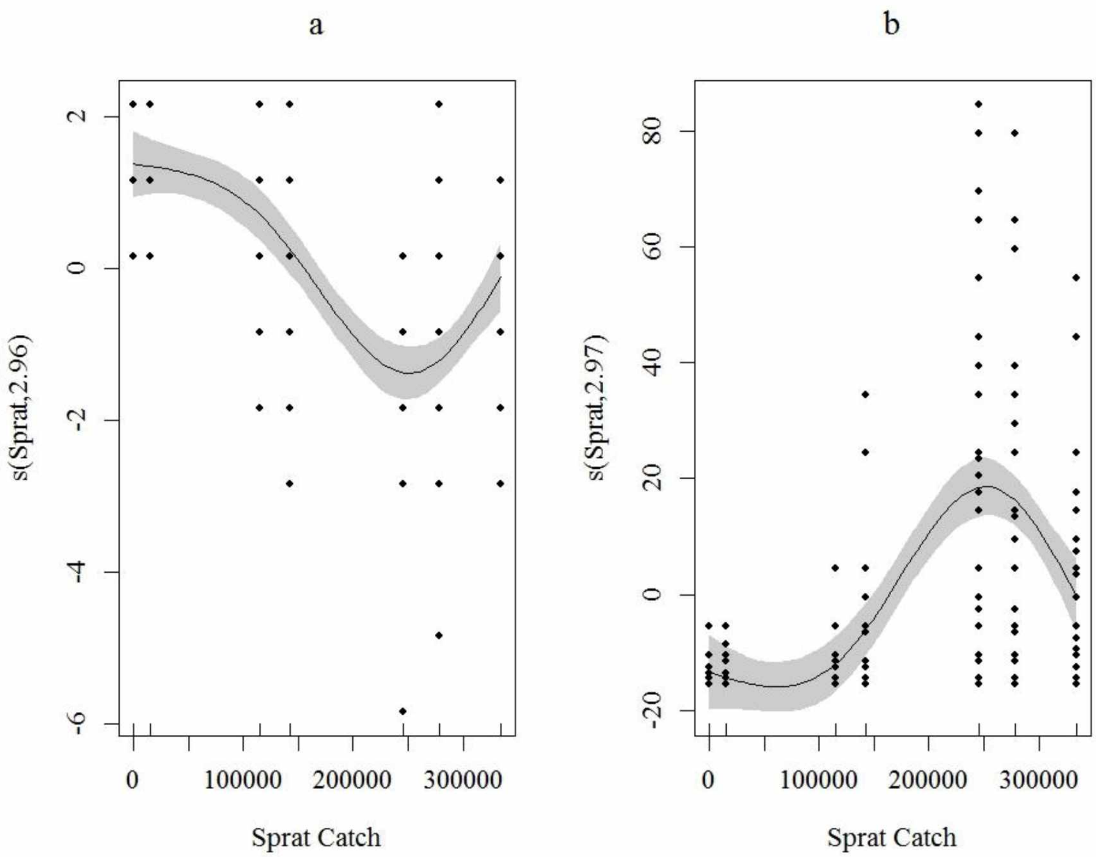

Figure 1.3 GAM fits for candidate model 2, showing partial effect of commercial sprat catch on cod abundance (a) and percent 'skinny' cod in catches (b). Partial effect of commercial sprat catch on the response variable is shown on the y-axis.

Results from the CCA and inductive text analysis (Bernard, 2011) of the recorded interviews were compared with documents from NMFRI (2013; 2014) to determine whether NMFRI scientists and Polish fishermen attributed the patterns in cod abundance and body condition to different causal factors. Results suggest that conflicts between fishermen and scientists about 'skinny' cod highlighted in the media may be attributed to differing contexts in which the observations are interpreted, rather than disagreement about the observations themselves.

Interviewees strongly agreed with one another that fishmeal catches of sprat caused more occurrences of 'skinny' cod (Table 1.2). Fishermen also agreed with one another that fishmeal catches were not decreasing, even though 100% of interviewees asserted that fishmeal fleets were overfishing sprat off Poland (Table 1.2). In contrast, statements from NMFRI (2013) asserted that the sprat fishmeal fishery had not caused declines in cod stocks:

> There is enough sprat in the Baltic to meet the nutritional requirements of cod. In the 1980s, during the period when the biomass of cod was the highest, despite a lower biomass of sprat stocks than now, the condition of cod was better. The problem is not an overexploited sprat stock, but rather their migration and the lack of corresponding migration of the cod which do not follow the sprat…This was not related to overexploitation, but rather to hydrological changes (NMFRI, 2013; translated by Elizabeth Figus).

In 2014, NMFRI released another opinion piece on the issue of ‘skinny’ cod and sprat in the Baltic Sea:

> ‘Thinning’ of cod may be an effect of many changes, for example: low salinity and oxygen levels in former spawning grounds, changes in the location of sprat, changes in their access to other prey species, increasing parasitism…. (NMFRI, 2014; translated by Elizabeth Figus).

NMFRI did not consider overfishing of sprat to have occurred or to be a factor affecting the current abundance or condition of cod.

In response to open-ended interview questions, fishermen placed blame for observed decreases in the abundance and condition of cod in Polish waters on the fishing industry and fisheries managers:

> Interviewer: “And in your opinion, why has the amount of cod changed?”
> Respondent: “Fallen? Yeah. Yeah it is also overfishing. That is one thing. Mmmmm, above all overfishing [of cod]….”

Fishermen noticed increasing numbers of juvenile cod in their catches, and they voiced concern about the impacts of the industrial trawl fisheries targeting sprat, whom they referred to as 'fishmeal' fishermen:

> Respondent: "In my opinion, it is overfished. The large cod are overfished. I catch a lot of little juveniles as well. There was, there were times … and … in my opinion, yea, those guys who fish for fishmeal do a lot."

During interviews, some fishermen explained that cod living closest to shore were able to feed on shallow water species, especially in estuarine environments. Others noted an apparent increase in the benthic isopod *Saduria entomon* as a part of the diet of cod in their nearshore catches. However, in the eyes of many fishermen, the big picture for the cod fishery was simple; there were fewer sprats off the Polish coastline available for cod to eat because they were being overfished, so cod were starving:

> Respondent: "You can see 'skinny' cod. It doesn't have anything to eat. They catch sprats, everything, herring, for fishmeal. Cod is simply losing weight, because it has nothing to eat."

NMFRI described the big picture differently; fluctuations occurred as part of the natural state of things:

> Nature has in one way or another always managed to cope with an excess of predators in the absence of food. In the marine ecosystem, 'carcasses' are quickly consumed, so the threat of a natural disaster due to the massive mass death of cod is premature (NMFRI, 2013; translated by Elizabeth Figus).

According to NMFRI, in 2013 it was too early to raise an alarm about cod stocks off Poland (NMFRI, 2013).

Discussion

This paper presents an application of CCA and GAM that captures LEK from Polish cod fishermen representing a cross-section of communities, age groups and vessel classes. Overall, CCA identified strong and consistent agreement among Polish fishermen regarding cod ecology, with more than 80% of respondents agreeing on their response to yes/no statements about cod, with the exception of whether cannibalism is normal in cod. All fishermen interviewed in this study agreed that 'skinny' cod could be attributed, in part, to overfishing on a key prey species (sprat). Fishermen and NMFRI observed similar declines in the abundance and condition of cod along the Polish coastline. However, fishermen and NMFRI perceived different causes behind those changes. GAM confirmed that the observed changes may be partially explained by variations in environmental variables, including temperature.

Sprat catch was among the explanatory factors included in the set of best models for cod abundance and prevalence of 'skinny' cod, which resonates with other scientific literature showing a link between cod and sprat dynamics (Harvey et al., 2003; Van Leeuwen et al., 2008; Eero et al., 2012). Ecosystem-based management approaches that consider the linked dynamics of cod and their prey may be needed for cod recovery (Harvey et al., 2003; Pelczarski et al., 2006; Eero et al., 2012). Recent harvesting patterns have shown an imbalance of high fishing pressure on sprat in the southwestern Baltic and high abundance of sprat in the northern regions (Eero et al., 2012). At the same time, cod abundances have been high in the southwestern Baltic (Eero et al., 2012). This has resulted in a general spatial mismatch in food availability for cod (NMFRI, 2013, page 5), possibly leading to further declines in cod abundance as well as decreased body condition. Results of the GAM corroborate fishermen's perspectives about causes of the observed decline in cod abundance, while suggesting that other factors play a role in the variation of cod abundance and condition in the Baltic Sea as well.

Despite overall agreement in their observation of ecological change in the Baltic, there is general mistrust between fishermen and NMFRI. Fishermen express concern that managers and scientists don't care about their well-being, while managers and scientists worry that fishermen are trying to game the system for personal financial gain (NMFRI, 2013). There is strong and consistent agreement among the fishermen who participated in this study, but differences in how fishermen, scientists, and policymakers gather and process information can lead to disparate views about the ecological system and condition of managed stocks (Verweij et al., 2010). Shared ecological observations may not be enough to mitigate potential conflicts between fishermen and the views put forth by fisheries scientists. Different values, incentives, political views, and social/cultural backgrounds all affect how that knowledge is interpreted and used.

At the same time, when it comes to addressing management challenges, fishermen and NMFRI might have more in common with one another than they think. When asked what they would change about Polish fisheries, many fishermen interviewed for this project stated a need for regulations that discourage industrial fishing and promote artisanal operations in the Baltic Sea:

> Interviewer: "[...]. what would you change?"
> Respondent: "Simply, I would not allow trawl vessels over 30 metres. And, and, and you can write a ban on fishmeal fishing, that it should be fisheries for human consumption. Those two things."

In the 'Facts and Myths' document, NMFRI (2013) also states an interest in discouraging the largest vessels:

> There have never been any formal regulations prohibiting vessels above a certain length to fish in the Baltic. NMFRI is of the opinion that such regulations should be put into force (translated by Elizabeth Figus).

Disparate views between fishermen and NMFRI in Poland have led to a challenge of how to effectively engage stakeholders in assessing and managing the cod fishery; however, there are more shared observations, perceptions and goals than originally apparent.

The idea of fishermen's LEK as a leading indicator of abundance changes is not new (Saenz-Arroyo et al., 2005; Hind, 2015; NAFC, 2016), but it remains underutilised in fisheries management. While there is widespread agreement that inclusion of stakeholders in the development of fisheries policies leads to adoption of better policies and to broader support for those policies (e.g., EU, 2002; Marciniak, 2010), interpreting and integrating LEK of resource users into assessment and management remains a challenge for various reasons (e.g., concern about validity (Carr and Heyman, 2012); difficulty of inclusion into management decisions (Steelman, 1999); unfamiliarity with social science methods (Huntington, 2000). One reason for this may be that fisheries scientists tend to understand the environment based on theory and quantitative analyses, while fishermen tend to base their understanding on personal experiences on the water (Miller et al., 2004).

Utilising LEK has been shown to have the capacity to prevent further fish stock declines where mainstream fisheries science has failed (Hind, 2015). In certain cases it has been shown that fishermen have the ability to contribute key information about marine habitat use across fish species (Garcia-Quijano, 2007), and to observe fluctuations in fish abundance earlier than managers and scientists (Beaudreau and Levin, 2014). McCay and Finlayson (1995) recommend a 'de-centring of science' to allow fishermen and community members to play direct roles in management. Prevailing power dynamics in the Newfoundland cod fishery during the 1980s, which lacked meaningful exchanges between scientists, managers, and fishermen, likely hindered any real opportunity to slow or change the collapse of cod stocks in the region (McCay and Finlayson, 1995). In the Baltic, LEK of fishermen has the potential to be a means of identifying, responding, and adapting to changing ecological and social conditions, despite data uncertainty or time mismatch between industry observations and scientific reporting.

In 2008, scientists were applauding recovery programs for eastern Baltic cod as a success (Doring and Egelkraut, 2008). In January of 2015, the Marine Stewardship Council (MSC) awarded Polish eastern Baltic cod fisheries certification as a well-managed and sustainable fishery (MSC, 2017). Yet in 2016 eastern Baltic cod appeared to be in crisis again. Cod quota in Poland was reduced by 33% between 2013 and 2016. That was a decline of 33% since the end of the 'Trójpolówka' recovery program that paid two thirds of the cod fleet to stay ashore for three years. ICES advised a cut in eastern Baltic cod quotas for both 2015 and 2016, and management of eastern Baltic cod was carried out using the data limited approach in 2016:

> Due to changes in the biology of the eastern cod stock, the International Council for the Exploration of the Sea ('ICES') has not been able to establish the biological reference points for cod stocks in ICES subdivisions 25-32, and instead advised that the TAC for that cod stock be based on the data limited approach (EU, 2015).

In response to the decision to use the data limited approach in managing the fishery, MSC suspended certification of eastern Baltic cod as a sustainable fishery in late 2015 (MSC, 2015). The LEK of Polish cod fishermen documented in this study identified recent and continuing declines of eastern Baltic cod. NMFRI in Poland may benefit from considering LEK as a leading indicator of ecological changes.

Conclusions

This research highlights the potential value of fishermen's LEK for marine science and commercial fisheries management. Fishermen's LEK is often high quality and complementary to information routinely sought by fisheries scientists (Hind, 2015; Stephenson et al., 2016). LEK that is un-representative or un-systematic has been considered to be ill-suited for comparisons with other knowledge sources (Davis and Ruddle, 2010). The research presented in this paper highlights an example of how LEK can be rigorously collected to provide structured, reliable information that represents prevailing perceptions of a Polish fishing fleet and may be compared with scientific information to potentially inform policy.

This research confirms that LEK can be summarized and compared with scientific information. Nearshore cod fishermen interviewed for this project placed a high value on small scale fisheries. Their belief that sustainable small scale fisheries are important structured their interpretations of cause and effect concerning shifts in cod abundance and condition. Fishermen and scientists use different sources of information, and may attribute different causes to the same observed phenomena. Characterizing agreement and disagreement among stakeholders, scientists, and managers about changes in the ecosystem is an important step towards identifying sources of conflict in fisheries. Building trust and respect among all participants in the management process may be imperative for the continued existence of the commercial cod fishery off Poland.

The results of this research suggest that NMFRI and Polish fishermen would benefit from working together to understand how the Baltic Sea ecosystem is changing, and to design effective management strategies for cod. Methods outlined in this paper could be used broadly by fisheries managers to catalogue the strength of agreement among fishermen and allow scientists to learn about the marine ecosystem in new ways. North Sea surveys conducted by the NAFC Marine Centre (NAFC, 2016) could serve as additional templates for greater incorporation of fishermen's LEK into scientific analyses of the Baltic Sea marine ecosystem.

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Appendices

Appendix 1.A. Interview Protocol.

All of the information in this interview refers to the eastern cod stock in the Baltic. Furthermore, all information in the interview refers to legal-sized cod within 12 nm of shore. Today this refers to cod longer than 38cm. Before 2003, this referred to cod longer than 35cm

Wszystkie informacje w tym wywiadzie odnoszą się do Bałtyckiego stada dorsza wschodniedo. Co więcej, wszystkie informacje w tym wywiadzie odnoszą się do wymiarowego dorsza, w odległości do 12 mil morskich od brzegu. Dziś oznacza to dorsza powyżej 38cm długości. Przed 2003 rokiem, oznaczało to dorsza powyżej 35cm długości.

Part 1: Fishing Experience (filled in by Elizabeth)

Część 1: Doświadczenie zawodowe (jako rybak) [wypełnia Elizabeth]

1. In what year did you start fishing commercially?

   W którym roku zaczął/zaczęła Pan/Pani pracę rybaka ?

1a. How many years have you fished for cod?

   Ile lat poławia Pan/Pani dorsza ?

2. Which gear type(s) have you used to fish cod commercially?

   Które typy sprzętu wykorzystywał(a) Pan/Pani do połowu dorsza ?

   1 Stawne kotwiczne sieci skrzelowe
   2 Takle stawne
   3 Pułapki
   4 Tuka denna
   5 Takle dryfujące
   6 Włok denny
   7 Włok pelagiczny
   8 __________________
   9 __________________

3. Have you always used this gear type [asked in regards to each type of gear they say they use]?

   Czy zawsze wykorzystywał(a) Pan/Pani ten sprzęt/te sprzęty-- zaznaczonych sprzętów?

4. When was the last time you changed gear types?

   Kiedy ostatni raz zmienił(a) Pan/Pani rodzaj (wykorzystywanego) sprzętu ?

Rok	Sprzęt – Sprzęt	Powód

5. Which months do you fish for cod?

   W których miesiącach roku poławia Pan/Pani dorsza ?

Sty	Lut	Mar	Kwi	Maj	Cze	Lip	Sie	Wrze	Paź	List	Gru

6. Have you always fished those months?

   Czy zawsze łowił(a) Pan/Pani w tych miesiącach ?

7. Approximately how many days do you currently spend fishing cod each year)?

   W przybliżeniu, ile dni każdego roku spędza Pan/Pani na połowie dorsza ?

   Currently: ____________ days [will accept months]

   Obecnie: ____________ dni [może być w miesiącach]

8. On the map provided, mark the areas that you have ever targeted legal-sized cod:

   Na dołączonych mapach, proszę zaznaczyć obszary na których kiedykolwiek poławiał(a)

   Pan/Pani wymiarowego dorsza:

[I will show fishermen maps of the Polish coastline, with lines marking different distances from shore, and ask them to circle large areas indicating their general fishing habits. This map will represent lifetime fishing areas for each fisherman.]

[Pokażę rybakom mapy polskiego Wybrzeża, z liniami znaczącymi różne odległości od brzegu, prosząc ich o zakreślenie okręgiem dużych obszarów, wskazujących na ich nawyki połowowe. Każda mapa będzie pokazywać wszystkie obszary na których rybak kiedykolwiek w swoim życiu poławiał.]

Part 2: Changing number of legal-sized [filled out by Elizabeth]

Część 2: Zmiana ilości wymiarowego dorsza [wypełnia Elizabeth]

Again: All information in this section refers to the eastern cod stock, and legal-sized cod within 12nm of shore. Today, this means cod over 38 cm in length. Before 2003, this meant 35 cm in length.

Jeszcze raz: Wszystkie informacje w tym wywiadzie odnoszą się do Bałtyckiego stada dorsza wschodniedo, i wymiarowego dorsza, w odległości do 12 mil morskich od brzegu. Dziś oznacza to dorsza powyżej 38cm długości. Przed 2003 rokiem, oznaczało to dorsza powyżej 35cm długości.

The goal of this section is to document your observations about the amount of legal-sized cod along the Polish coastline, over time.

1. Please specify the number of legal-sized cod you have observed over the span of time you have been fishing.

   Proszę określić ilość wymiarowych dorsza zaobserwowaną w czasie Pana/Pani pracy jako rybaka.

      [Filled in by interviewee, in Appendix 1]
      [Wypełniane przez ankietowanego w dodatku 1]

2. Please explain why you think that abundance levels have/have not changed over time:

      Dlaczego Pana/Pani zdaniem, rozmiar populacji (ilość) dorsza się zmienił(a) (lub nie)?

Part 3: Changing size of cod [filled out by Elizabeth]

Część 3: Zmiany rozmiaru dorsza [wypełnia Elizabeth]

Again: All information in this section refers to the eastern cod stock, and legal-sized cod within 12nm of shore. Today, this means cod over 38 cm in length. Before 2003, this meant 35 cm in length.

Jeszcze raz: Wszystkie informacje w tym wywiadzie odnoszą się do Bałtyckiego stada dorsza wschodniedo, i wymiarowego dorsza, w odległości do 12 mil morskich od brzegu. Dziś oznacza to dorsza powyżej 38cm długości. Przed 2003 rokiem, oznaczało to dorsza powyżej 35cm długości.

1. Have you heard the term, ‘skinny’ cod?

   Czy słyszał(a) Pan/Pani określenie ‘chudy dorsz’?

2. What is a ‘skinny’ cod? Please describe a ‘skinny’ cod?

   Czym jest ‘chudy dorsz’? Proszę go opisać.

3. Please indicate which of the photos denotes the best example of a ‘skinny’ cod.

   Która fotografia najlepiej przedstawia przykład ‘chudego dorsza’?

4. Using the photos provided, please specify the average amount of ‘skinny’ cod you have landed as a percentage of total cod catch since you started fishing. [Interviewee is asked to use Appendix 2]

   Przy użyciu fotografii, proszę określić jaki procent całkowitego wyładunki (od czasu kiedy zaczął/zaczęła Pan/Pani pracę rybaka) stanowi ‘chudy dorsz’.

   [Ankietowany będzie proszony o użycie dodatku 2]

5. Why is the amount of skinny cod changing/not changing?

   Dlaczego Pana/Pani zdaniem liczba ‘chudych dorszy’ się zmienia (lub nie)?

Filled out by Interviewee: Please indicate whether you agree or disagree with each statement. There will be some repetition from earlier questions, but please bear with me

Uzupełniane przez ankietowanego/ankietowaną: Proszę wskazać czy zgadza się Pan/Pani (lub nie) z każdym z poniższych zdań. Proszę o wskazanie nawet, jeśli wcześniej pojawiło się podobne pytanie.

[It will be explained that repetition is intentional, and that it is important for them to answer every statement—even if they feel “it depends,” they should please choose whether they generally agree or disagree. Interviewee will also be handed a straight edge to help keep on the correct line for each response].

[Wyjaśnię, że powtórzenia są intencjonalne oraz że bardzo ważne jest odpowiedzenie na każde ze zdań. Nawet jeśli odpowiedź brzmi “to zależy”, będą proszeni o wybranie czy się zgadzają, czy nie. W celu uniknięcia pomyłek, ankietowani wyposażeni zostaną w jakieś narzędzie z prostą krawędzią.]

In Polish coastal waters where you fish (<12nm from shore):

W polskich wodach przybrzeżnych (<12nm od brzegu), gdzie Pan/Pani poławia:

	TAK	NIE
1. Cod move seasonally Dorsz przemieszcza się sezonowo		
2. Cod prefer colder water Dorsz woli ***zimniejsze*** wody		
3. Cod prefer warmer water Dorsz woli ***cieplejsze*** wody		
4. It is normal for cod to eat sprat Normalnym jest zjadanie szprota przez dorsza		
5. It is normal for cod to eat other cod Normalnym zjawiskiem jest zjadanie się dorsza przez dorsza		
6. Cod populations are in a good state Populacje dorsza są w dobrym stanie		
7. Cod populations are in a bad state Populacje dorsza są w złym stanie		
8. Today there is a lot of cod Dziś jest sporo dorszy		
9. The cod population is getting smaller Populacja dorsza maleje		
10. Prey found in the stomachs of cod is changing Zmienia się pokarm znajdowany w żołądkach dorsza		
11. Cod have enough to eat Dorsza ma wystarczająco dużo pożywienia		
12. Cod do not have enough to eat Dorsz nie ma wystarczającej ilości pożywienia		
13. Today cod eat other cod Dorsz zjada dziś dorsza		
14. Today cod eat different things than they used to Dziś dorsz zjada inne rzeczy niż dawniej		
15. Joining the EU CFP caused an increase in the cod population in Poland Dołączenie do Wspólnej Polityki Rybołówstwa UE spowodowało wzrost populacji dorsza w Polsce		
16. Joining the EU CFP caused an decrease in the cod population in Poland Dołączenie do Wspólnej Polityki Rybołówstwa UE powoduje spadek ilości dorsza w Polsce		
17. 'Skinny' cod is a normal thing Normalnym zjawiskiem jest 'chudy dorsz'		
18. The number of 'skinny' cod changes from season to season Liczba 'chudych dorszy' zmienia się z sezonu na sezon		

	TAK	NIE
19. ‘Skinny’ cod are occurring more frequently ‘Chudy dorsz’ staje się coraz częstszy		
20. ‘Skinny’ cod are occurring more rarely ‘Chudy dorsz’ staje się coraz rzadszy		
21. The number of sprat impacts the number of ‘skinny’ cod Liczba szprota wpływa na liczbę ‘chudego dorsza’		
22. Fishmeal catches in Polish waters are increasing Połów paszowy w Polskich wodach zwiększy się		
23. Fishmeal catches in Polish waters are decreasing Połów paszowy w Polskich wodach zmniejsza się		
24. Fishmeal catches are overfishing sprat Połowy paszowe wykorzystują szprota		
25. If there were more sprat in the Sea, there would be more cod Więcej szprota wpłynęłoby na większą ilość dorsza		
26. If there were more sprat in the Sea, there would be fewer cod Więcej szprota wpłynęłoby na mniejszą ilość dorsza		
27. Fishmeal catches cause more occurrences of ‘skinny’ cod Połów paszowy powoduje częstsze występowanie chudego dorsza		
28. Fishmeal catches cause fewer occurrences of ‘skinny’ cod Połów paszowy powoduje rzadsze występowanie chudego dorsza		

Part 4: Demographic information [filled out by Interviewee]

Część 4: Informacje demograficzne [wypełniane przez ankietowanych]

[This will be prefaced by explanation that I would like to record these demographic data about interviewee to help with analysis. They are sterile questions that the interviewee should fill in as they see fit—they do not have to fill in any information that they do not want to].

[Ta część będzie poprzedzona wyjaśnieniem, że dane te zbieram od ankietowanych w celach pomocniczych. Na te pytania ankietowany może odpowiedzieć (lub nie), wedle woli.]

1. In what year were you born?

   W którym roku się Pan/Pani urodził(a) ?

2. In which town do you live?

   W której miejscowości Pan/Pani mieszka ?

3. Including yourself, how many people are in your household?

   Ilu ludzi (wliczając Pana/Panią) liczy Pana/Pani gospodarstwo domowe ?

4. What's your economic situation?

   Jaka jest Pana/Pani sytuacja ekonomiczna ?

   a. Zła
   b. Średnia
   c. Dobra
   d. Bardzo dobra

5. What percentage of your total annual household income is earned from commercial fishing? Household includes family members and others who share your residence.

   Jaki procent dochodu Pana/Pani gospodarstwa domowego stanowi dochód z pracy rybackiej ? Gospodarstwo domowe to członkowie rodziny oraz wszyscy inni ludzie zamieszkujący ten sam dom/mieszkanie.

   a. 1 – 15%
   b. 16 – 50%
   c. 51 – 75%
   d. 75 – 99%
   e. 100%

6. How many vessels do you currently own? _____________

   Ile łodzi Pan/Pani obecnie posiada ?

7. Vessel length(s):

   Długości łodzi:

Last Questions [filled in by Elizabeth]:

Ostatnie pytania [wypełnia Elizabeth]:

1. Do you have any questions for me?

   Czy ma Pan/Pani jakieś pytania do mnie ?

Thank you for your time ☺
Dziękuję za poświęcony czas ☺

Appendix 1/Dodatek 1

Again: All information in this section refers to the eastern cod stock, and legal-sized cod within 12nm of shore. Today, this means cod over 38 cm in length. Before 2003, this meant 35 cm in length. *Jeszcze raz: Wszystkie informacje w tym wywiadzie odnoszą się do Bałtyckiego stada dorsza wschodniedo, i wymiarowego dorsza, w odległości do 12 mil morskich od brzegu. Dziś oznacza to dorsza powyżej 38cm długości. Przed 2003 rokiem, oznaczało to dorsza powyżej 35cm długości.* Please specify the number of legal-sized cod you have observed (or other people have told you about) over the span of time you have been fishing [put an 'X' in the corresponding box for each time period]: *Proszę określić ilość wymiarowych dorsza zaobserwowaną przez Pana/Panią (lub kogoś innego, np. znajomych) w czasie Pana/Pani pracy jako rybaka. [Proszę proszę wstawić 'X' w odpowiednim polu dla każdego okresu]:*

	Lata 60-te	Lata 70-te	Lata 80-te	Lata 90-te	Wczesne lata około 2000	Późne lata po roku 2000	Od roku 2010-tego	2014
Bardzo wysoka								
Wysoka								
Średnio wysoka								
Średnio niska								
Niska								
Bardzo niska								

Appendix 2/Dodatek 2

Again: All information in this section refers to the eastern cod stock, and legal-sized cod within 12nm of shore. Today, this means cod over 38 cm in length. Before 2003, this meant 35 cm in length.

Jeszcze raz: Wszystkie informacje w tym wywiadzie odnoszą się do Bałtyckiego stada dorsza wschodniedo, i wymiarowego dorsza, w odległości do 12 mil morskich od brzegu. Dziś oznacza to dorsza powyżej 38cm długości. Przed 2003 rokiem, oznaczało to dorsza powyżej 35cm długości.

Using the photos provided, please specify the average amount of 'skinny' cod you have landed as a percentage of total landed catch of cod since you started fishing. *Przy użyciu zdjęć, proszę określić procentowy udział złowionego 'chudego dorsza' w całkowitym połowie, w okresie od początku Pana/Pani pracy jako rybaka.*

Rok	1960s	Lata 70-te	Lata 80-te	Lata 90-te	Wczesne lata około 2000 roku	Późne lata po 2000 roku	Od 2010 roku	2014
% połowu								

Chapter 2 Comparing self-reported incidental catch among fishermen targeting Pacific halibut and a fishery independent survey[1]

Abstract

This paper illustrates how interview data can be used to document incidental catch, to compare fishermen's ecological knowledge with fishery-independent data, and to explore putative relationships between characteristics of fishing operations and incidental catch in the Pacific halibut fishery. Results from a multiple factor analysis demonstrate statistically significant relationships between fishing characteristics and the incidental catch of various species. Results from a proportional odds logistic regression model indicate the presence of a strong unavoidable component of incidental catch in the halibut fishery. Consequently, patterns of incidental catch in this fishery generally parallel patterns of incidental catch in fishery-independent stock assessment surveys that use similar gear. This suggests that increased onboard monitoring of this fleet is unlikely to reveal broad trends in incidental catch that are not already apparent in the fishery-independent stock assessment surveys. Nevertheless, smaller but statistically significant relationships in the model indicate that incidental catch can be influenced by observable and controllable characteristics of fishing operations (e.g., fishing grounds, season, vessel length, gear configuration). This suggests that the proportional odds model presented in this paper can be used to generate operation-specific estimates of incidental catch by species from incidental catches observed in fishery-independent surveys based on known characteristics of fishing operations.

[1] Figus, E. C., Criddle, K. R. Comparing self-reported incidental catch among fishermen targeting Pacific halibut and a fishery independent survey. In review at *Marine Policy*.

Introduction

Fishing results in catches of non-target, or incidental, species as well as catches of the target species because fishing gear is not perfectly selective and because there are markets for some incidental catch species. Incidental catches may be landed because of their market value or as a regulatory requirement, used as bait, or discarded at sea. Accurate data on catch and discard mortality of target and incidental species is considered crucial for accurate stock assessments, and for the sustainable management of commercial fisheries (NRC, 1998; Cahalan et al., 2010). Catch accounting is especially challenging when fishing is dispersed in space and time and catch is distributed across large numbers of small vessels, as it is in the commercial fishery for Pacific halibut (*Hippoglossus stenolepis*) in Southeast Alaska.

A diverse array of species (e.g., rockfishes, lingcod, and sharks) is commonly caught incidentally in the commercial halibut fishery in Southeast Alaska. Data on commercial halibut landings are considered highly accurate, largely as a result of regulations related to an individual fishing quota (IFQ) system put in place in 1995 (Pautzke and Oliver, 1997). However, accounting for incidental catch species and for the discard mortality of under-sized halibut continues to pose a challenge (Cahalan et al., 2010). The bottom longline gear used in the halibut fishery is relatively non-selective, thus fishermen may encounter numerous incidental catch species. Some incidental catch species are focal species for other commercial or sport fisheries or have life-history characteristics that render them vulnerable to overfishing, even with modest levels of fishing mortality (e.g., rockfishes, lingcod; Leaman, 1991; Palof et al., 2010).

Pacific halibut is a demersal righteye flounder species that inhabits coastal waters across the North Pacific from California to Japan but with highest densities in the Gulf of Alaska and eastern Bering Sea regions off Alaska. It is a large, slow-growing, long-lived species that reaches maturity between 8 and 12 years of age, with some individuals recorded at more than 50 years of age (ADFG, 2017). Pacific halibut support important subsistence, sport, and commercial fisheries in Alaska (McDowell Group, 2015). In 2010, there were 1,646 unique vessels fishing commercially in the federal fisheries off Alaska. Vessels targeting halibut made up a vast majority of those by number (n = 1,060), with most of those measuring less than 60 feet (18 meters) in length overall (Witherell et al., 2012).

The International Pacific Halibut Commission (IPHC) is responsible for stock assessment and setting overall limits for catch of halibut. The stock assessments are based on an ensemble of age-structured models of coastwide population dynamics that rely on data from standardized annual fisheries-independent surveys and catch accounting (Stewart et al., 2014). Model results are used to set overall catch limits which are apportioned among ten regulatory areas, Areas 2A-4E (Figure 2.1), based on estimates of the regional distribution of biomass evidenced by differing catch rates in the IPHC survey (IPHC, 2017; Stewart et al., 2014). For this study, we focused on a single regulatory area, Southeast Alaska (Area 2C), in order to tease out specific associations between fishing characteristics and incidental catches at the regional level.

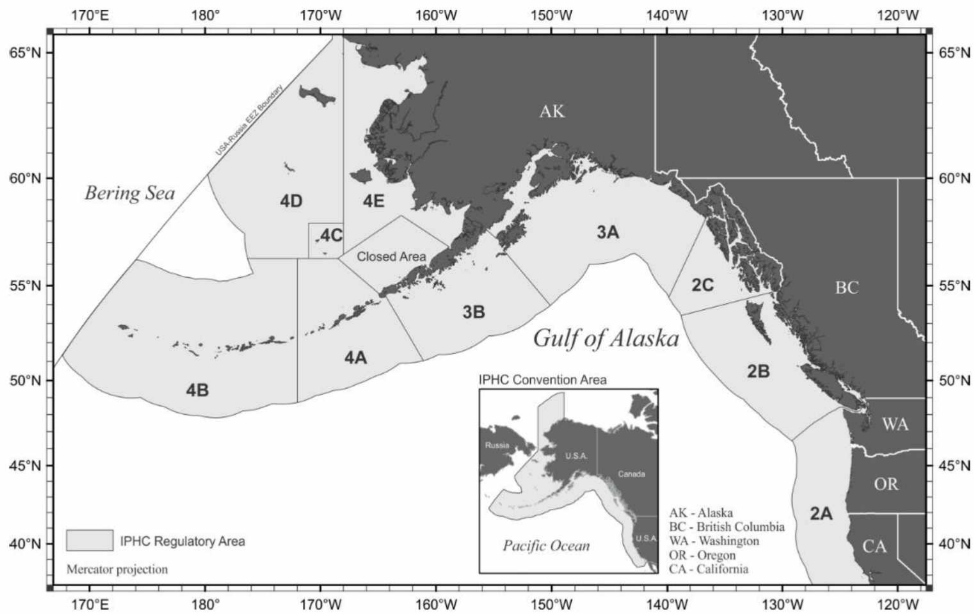

Figure 2.1 IPHC Regulatory Areas (courtesy of the IPHC).

Although fishery-independent longline surveys conducted annually by the IPHC use gear similar to that used in the commercial fishery, fisheries managers are uncertain whether patterns of incidental catch observed in IPHC surveys are characteristic of patterns of incidental catch in the commercial fishery across seasons and areas (Brylinsky et al., 2010). Fishery managers often mistrust self-reported data because fishermen may benefit from under reporting their catches of incidental species (Lordan et al., 2011) and because data that are self-reported by a subset of fishermen may not be representative of the fishery as a whole (Davis and Ruddle, 2010). They have, consequently, begun to implement on-board monitoring programs to account more fully for catch and discard mortality of incidental catch and undersized halibut in the halibut fishery (NPFMC, 2010).

This study contributes to a growing body of work showing that self-reported observations of even small groups of fishermen can provide reliable, structured accounts of prevailing experiences throughout a fishing fleet (Carruthers and Neis, 2011; Figus et al., 2017; Macdonald et al., 2014; Neis, 1992; Neis et al., 1999; Saenz-Arroyo and Revollo-Fernandez, 2016). This paper evaluated the use of interview data to document trends in incidental catch—in this case, incidental catches of non-target species while targeting Pacific halibut—in comparison with fisheries-independent data, and explored putative relationships between characteristics of fishing operations and incidental catch. The study objectives were to: (1) test for coherence in self-reported incidental catch among fishermen in Southeast Alaska; (2) test for coherence in self-reported incidental catch between fishermen and IPHC survey observations in Southeast Alaska; and, (3) explore putative relationships between fishing characteristics and prevalence of encounters with incidental catch species. Our results shed light on the potential to incorporate self-reported incidental catch data with fishery-independent survey data to inform stock assessment and fisheries management decisions.

Methods

This research combined qualitative and categorical data provided by fishermen during semistructured interviews with quantitative data derived from fishery-independent surveys conducted by the IPHC. During the winter of 2014, we sent a letter to every halibut IFQ holder in four communities in Southeast Alaska informing them of our project and inviting them to participate in an interview. Over 100 IFQ holders responded to those letters. We set up interviews with respondents that were available to meet during the spring of 2015, and further used snowball sampling to recruit fishermen from the study communities to participate in one-on-one, recorded, semistructured interviews (Bernard, 2011; Appendix 2.A). Between February and May 2015, we conducted interviews with 72 halibut fishermen residing in Juneau, Petersburg, Sitka, and Hoonah (Figure 2.2; Appendix 2.B).

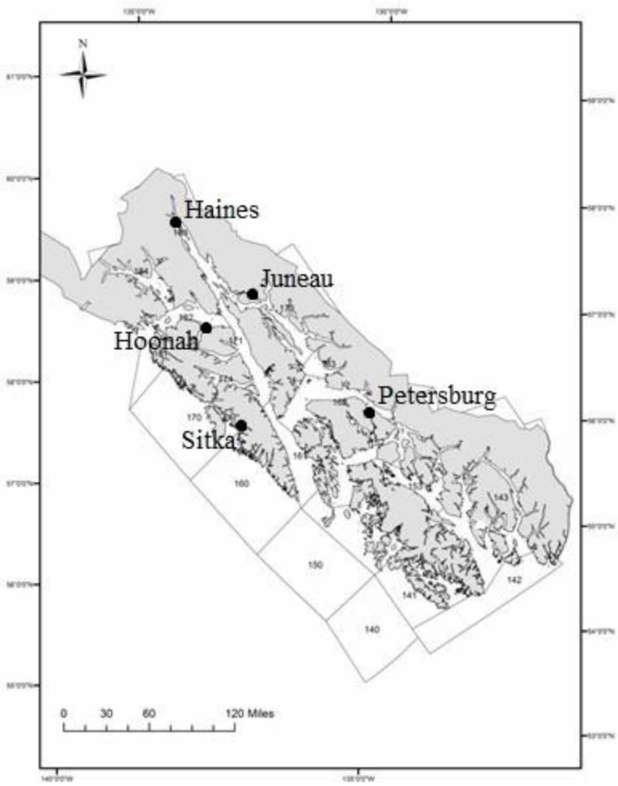

Figure 2.2 Map of Regulatory Area 2C, Southeast Alaska, with study communities labeled (created by corresponding author).

Southeast Alaska is home to 28 communities with a combined population of about 72,000 scattered over a 91,010 km^2 landscape. Fisheries based in Southeast Alaska land 114-136 thousand metric tons of fish each year with an ex-vessel value of about $250 million. Juneau, Petersburg, and Sitka are major ports for IFQ halibut in Southeast Alaska (Witherell et al., 2012). Hoonah is typical of the many small coastal communities in the region, with only a small number of residents that participate in commercial halibut fishing. Although demographic information was collected during interviews (including age, years of fishing experience, gender, ethnicity, and fisheries income information), interview sampling was not stratified for demographic characteristics. There were not enough responses from underrepresented groups in the interview group to be able to explore subgroup differences beyond age and years of fishing experience in any quantitatively or qualitatively meaningful way. There was, however, ample representation across vessel seize categories and fishing operation characteristics to allow for testing of differences across these variables. Interviewees composed an average of 20% of total IFQ shares in their corresponding communities of residence, and were almost exactly reflective of quota classes, or types of quota, in their communities (see Appendix 2.B).

During interviews, fishermen described characteristics of their fishing operations, as well as how often they observed different incidental catch species. Interviewees were asked to reflect on the mix and prevalence of species hooked by their gear and to sort pictures of 51 incidental catch species into categories of occurrence to reflect how often they encountered each species while fishing for halibut (Figure 2.3; Appendix 2.C). Species included in the sorting exercise were determined based on responses from nine test interviews with fishermen in Haines, Alaska, during January 2015, as well as their occurrence in the IPHC survey. All interviewees completed the sorting exercise. Answers to additional interview questions provided information on individual attributes (age, years of experience), areas fished (Appendix 2.D), community of residence; vessel length; gear used; whether or not they target sablefish and halibut on the same trip (combo fish); and, fishing season (Appendix 2.B).

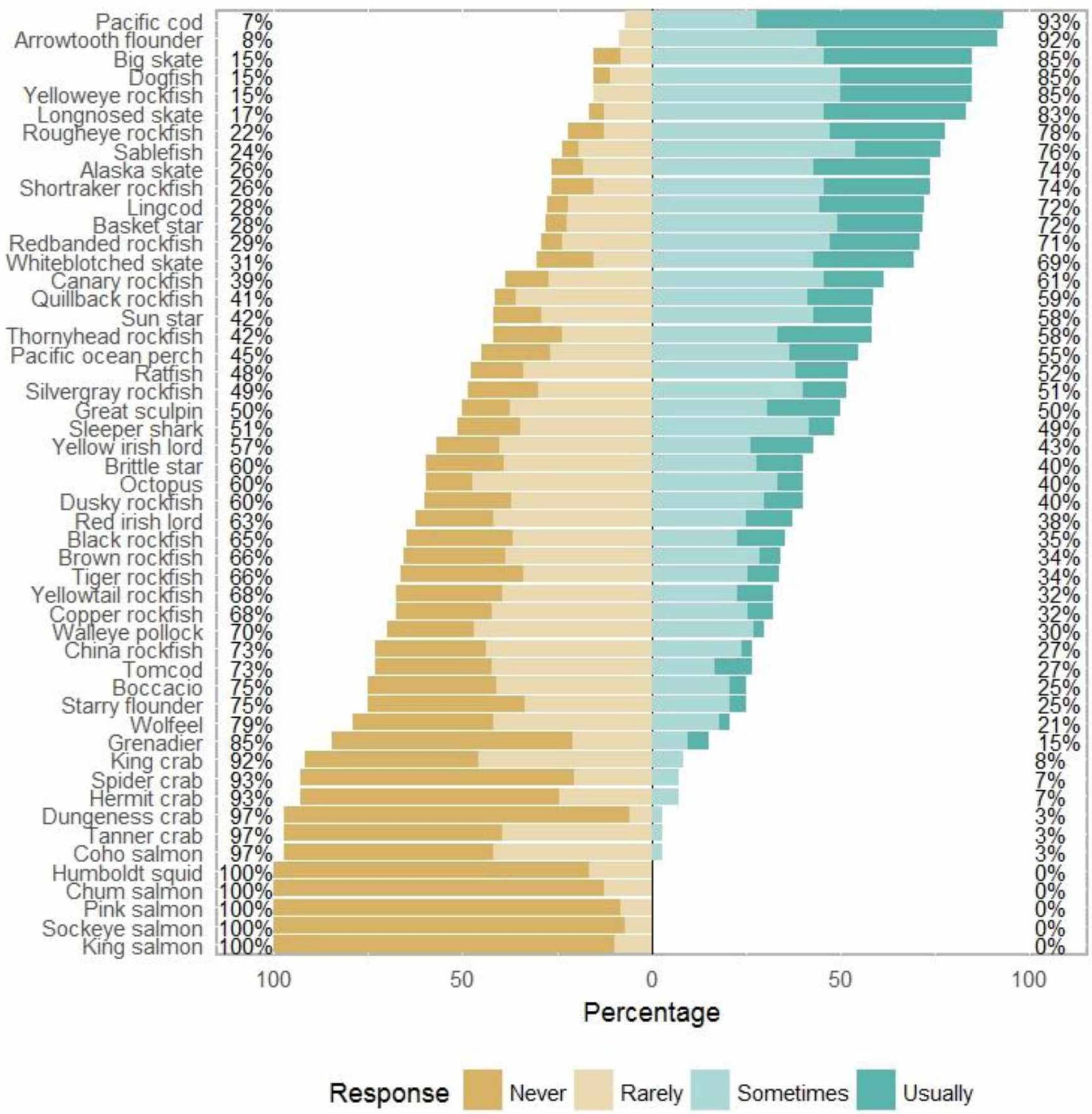

Figure 2.3 Frequency of interviewee responses for encounters with incidental catch species, created using the 'likert' package (Bryer and Speerschneider, 2016) in the R software program (R Core Team, 2016).

The IPHC collects information about incidental catch occurrence on the first 20 hooks of every 100-hook skate of longline gear that they fish. They use these 20 hook counts to extrapolate estimates of incidental catch at each survey station overall. Incidental catch observations from the IPHC survey were analyzed for the years 1998 to 2015 across 93 fishing stations located in Area 2C. Although the IPHC fishes a total of 124 stations in Area 2C, only 93 stations coincide with areas fished by interviewees (Appendix 2.E). Incidental catch values from IPHC surveys over 18 years of survey data were summarized by taking median values across stations and years. Median values were chosen because the distribution of observations was skewed, in which case a median is a better descriptor of the center point than the mean.

Pearson's correlations, chi-square tests, and ANOVA were used to inform development of two families of multivariate statistical models that were used to explore putative relationships between fishing characteristics (e.g., vessel, gear, season fished) and incidental catch. The first of these, multiple factor analysis (MFA), is an approach that generalizes the principal components analysis (PCA) methods (Pages, 2015). The second inferential model was a proportional odds cumulative ordered logistic regression model (POLR) (McCullagh, 1980). MFA and POLR modeling were carried out in the R software program (R Core Team, 2016), using the 'mfa' command in the 'FactoMineR' package (Lê et al., 2008) and the 'polr' command in the 'MASS' package (Venables and Ripley, 2002).

Pearson's correlation coefficients were used to test for coherence in self-reported incidental catch among fishermen (Objective 1) as well as between fishermen and IPHC survey observations (Objective 2). In order to estimate the Pearson's correlation coefficients, prevalence data from the sorting exercise during interviews were mapped into ordered categories 0 through 3, with 0 corresponding to 'Never' encounter and 3 corresponding to 'Usually' encounter, for each of the 51 incidental catch species. Chi-square statistics were used to test for independence across fishing characteristics reported by interviewees. ANOVA was used to test for relationships between IPHC stations fished across fishing characteristics (Appendix 2.B). Results from Pearson's correlations, chi-square and ANOVA tests suggested that multivariate analyses might be necessary to tease out relationships among incidental catch and characteristics of fishing operations, and provided indications of which variables to include in multivariate analyses.

MFA was used to identify latent associations (eigenvalues) among halibut fishing characteristics and frequency of encounters with incidental catch species. MFA has the advantage over PCA of being able to consider qualitative and quantitative variables simultaneously. MFA also provides a framework for explaining the components, not just reducing the data to simpler linear functions (Pages, 2015). MFA projects observed variables and their covariance structure onto a smaller number of dimensions represented as latent factors. In this case, an MFA run on a covariance matrix of incidental catch species prevalence using varimax rotation was used to assess which species and fishing characteristics seem to be related to one another. The MFA did this by indicating how species and characteristics grouped across dimensions of the data. Following Budaev (2010) recommendations for best practice in factor analysis, we ran a Keyser-Meyer-Olkin (KMO) test of sampling adequacy, a Bartlett's test of homogeneity of variances, and a Horn's parallel analysis for factor retention.

POLR models are predictive models that characterize the odds of observing an ordered outcome as a function of one or more explanatory variables (Agresti, 2013; Agresti and Kateri, 2011; McCullagh, 1980). In this study, a POLR model was used to characterize the odds that halibut fishermen will encounter (never, rarely, sometimes, or frequently) various incidental catch species conditioned on fishing characteristics and eigenvectors of the Hessian matrix of fishermen's observations (the sorting exercise) of incidental catch prevalence.

The POLR model for this work is comprised of a system of equations, three for each of the species (i) encountered as incidental catch in the halibut longline fishery. The three equations for each species represent the proportional odds of never, rarely, sometimes, or usually encountering that species as incidental catch. The proportional odds of encounter are conditional on characteristics of the fisherman, their vessel, their fishing practices, and latent associations (eigenvectors) among species. That is, for species i,

$$\begin{aligned} L_{1i} &= \alpha_{1i} + \beta_{1i}X_1 + \cdots + \beta_{ki}X_k + \cdots + \beta_{pi}X_p \\ L_{2i} &= \alpha_{2i} + \beta_{1i}X_1 + \cdots + \beta_{ki}X_k + \cdots + \beta_{pi}X_p \\ L_{3i} &= \alpha_{3i} + \beta_{1i}X_1 + \cdots + \beta_{ki}X_k + \cdots + \beta_{pi}X_p \end{aligned} \tag{1}$$

where

$$\begin{aligned} L_{1i} &= log\left(\frac{P(Y_i \le Never)}{P(Y_i > Never)}\right) \\ L_{2i} &= log\left(\frac{P(Y_i \le Rarely)}{P(Y_i > Rarely)}\right) \\ L_{3i} &= log\left(\frac{P(Y_i \le Sometimes)}{P(Y_i > Sometimes)}\right) \end{aligned}$$

The intercept, L_{1i}, represents the difference between never and rarely encountering species i while fishing for halibut, while L_{2i}, and L_{3i}, represent, respectively, the differences between rarely and sometimes and sometimes and usually encountering that species. The predictor variables, X_k, include categorical and continuous variables that represent characteristics of interviewees, their vessels, their fishing operations, and instrumental variables that reflect patterns of co-occurrence among incidental catch species. Because the sets of three equations share a common set of explanatory variables, the system can be estimated using the Seemingly Unrelated Regression estimator (Zellner, 1962).

Odds ratio (OR) outputs from the POLR model display probabilities in terms of the odds that a predictor variable influences model reference categories (Agresti, 2013). An OR increases as the probability increases or vice versa. In this scenario, odds ratios are calculated as the probability that a given predictor variable will increase encounters with a given incidental catch species over the probability that it will decrease encounters with a given incidental catch species. When the probability of increasing encounters with a given incidental catch species is 50-50, for example, then the OR would be 1.

Where the OR is less than 1, the odds are lower than for the reference category; for categories with OR greater than 1, the odds are higher odds than for the reference category. In this model, which characterizes the likelihood of encountering one incidental catch species while fishing for halibut, we are also characterizing the likelihood of seeing every other incidental catch species. One of the things affecting those likelihoods is that there are associations among species. We have represented those associations as eigenvectors of the Hessian matrix of fishermen's observations (the sorting exercise) of incidental catch prevalence.

To facilitate estimation of the MFA and POLR models, interview and IPHC data were reorganized and normalized. In order to compare IPHC and interviewee encounters across the fishing characteristic, 'community of residence,' IPHC observations were grouped by stations corresponding to areas fished by interviewees from each of the four communities and assigned fishing characteristics (Appendix 2.B). Where fishing characteristic values were unavailable, IPHC observations were assigned the mean of the corresponding interviewee group. This resulted in four sets of unique observations for the IPHC, one each representing IPHC observations associated with each community's fishing grounds. Next, the median observations for each species (in each of the four groupings) from IPHC observations were mapped into ordered categories 0 through 3 based on the percent of years a given species was observed in the IPHC catch. Missing values from interviews (<1% of total) were replaced with mean (across interviewees) prevalence value for that species. The full dataset of categorical prevalence values used in the MFA and the POLR model therefore consisted of observations corresponding to 72 fishermen and four subsets of the IPHC survey stations. There was concern that some interviewees may have used the full range of prevalence categories while others used a more narrow range of choices. So we normalized prevalence scores among interviewees. In doing that, the relative rankings that each interviewee had for each species were maintained. The same was carried out for the IPHC values, in order to make it comparable with interviewee data. The data were normalized by subtracting the mean prevalence value for each interviewee/IPHC ordered category from their prevalence value for each species and dividing the difference by the standard deviation of their prevalence values across all species. Normalization minimized scaling differences among interviewees and between interviewees and the IPHC, making it possible to compare two very different datasets.

Results

Pearson's correlation tests indicated strong coherence in self-reported incidental catch among fishermen (Objective 1) and strong coherence in self-reported incidental catch between fishermen and IPHC survey observations in IPHC Area 2C (Objective 2). Correlograms representing estimated Pearson's correlation coefficients (Appendix 2.F) across all 51 incidental catch species depict extensive positive correlations, most of which are statistically significant (p-value < 0.05) and an absence of statistically significant negative correlations among interviewees and the IPHC. Weak or statistically insignificant correlations are not clustered across community or season. Across fishermen and the IPHC survey data on incidental catch by season, a majority of all correlations were statistically significant (p-value < 0.05), and all significant correlations were positive. These results suggest that the mix of incidental catch species and their prevalence as observed by one fisherman was representative of what other fishermen experienced. Further, what fishermen reported was positively correlated with what was observed in the IPHC setline survey. That is, fishermen and the IPHC observed similar distributions of incidental catch at the species level.

Similarity in observations continues to hold true when the data are partitioned by fishing characteristics. For example, fishermen's encounters with incidental catch species by season (Spring, Summer, Fall) were positively correlated with the IPHC survey which is only conducted during the summer months (June, July, and August). Therefore, although the IPHC conducts their survey during the summer, there is no indication that the IPHC survey is missing major seasonal variation in the prevalence of any of the 51 incidental catch species.

Chi-square tests for independence across fishing characteristics produced four relationships with p-values < 0.05. Those results indicate: (1) combo fishermen were more likely to have fished in spring than other fishermen (p-value = 0.001); (2) non-combo fishermen were more likely to have fished in summer (p-value = 0.009); (3) fishermen with vessels over 40 feet in length were more likely to use conventional gear (p-value = 9.70e-05); and, (4) fishermen from Petersburg and Sitka were more likely to fish during spring than fishermen from Hoonah and Juneau (p-value = 0.008).

ANOVA tests run across data from interviews indicated that community of residence was significantly related to IPHC stations fished across the four study communities (p-value = <2.0e-16). Additionally, visual review of stations fished by more than one respondent from each community overlaid on a map of Southeast Alaska shows that fishermen from Hoonah and Juneau exploit a smaller spatial fishing range than residents of Sitka and Petersburg; Petersburg residents exploit the widest fishing range (Appendix 2.D). Therefore, community of residence was used as a proxy for area fished in all analyses.

The preponderance of weak and statistically insignificant correlations (see gray areas, Appendix 2.F) suggests that for some incidental catch species, either random variability or differences in fishing characteristics may account for differences in the incidence of incidental catch. Chi-square tests further suggest covariation among fishing characteristics. Finally, ANOVA results suggest that residents in Hoonah and Juneau exhibit a statistically significant tendency to fish in areas that include the more northerly IPHC stations (closer to their corresponding communities), while residents of Sitka and Petersburg tend to fish in areas that include the more southerly IPHC stations. All of these findings suggest that multivariate analyses might be necessary to explore putative relationships among incidental catch and characteristics of fishing operations.

MFA results produced a set of dimensions, or latent factors that reflect underlying linear combinations of the data, which allowed us to explore putative relationships between fishing characteristics and prevalence of encounters with incidental catch species (Objective 3). Results from the KMO (Table 2.1) and Bartlett's tests (Budaev, 2010) led us to reduce the number of species to include in the MFA analysis from the 51 species presented in the sorting exercise to the 22 species of greatest management interest and highest encounter rates (starred species in Appendix 2.C). This group of 22 incidental catch species across 76 observations passed a Keyser-Meyer-Olkin test for sampling adequacy (measure of sampling adequacy = 0.65) run in the 'psych' package (Revelle, 2017) in the R software program, although some species measured below the 0.6 threshold (Table 2.1). The reduced list of 22 species also passed a Bartlett's test (Bartlett's K-squared = 86.623, df = 21, and a p-value = 6.132e-10). Results from a Horn's parallel analysis run in the 'paran' package (Dinno, 2009) and the 'estim_ncp' function in the

‘FactoMineR’ package (Josse and Husson, 2012) in the R software program indicated that four dimensions should be retained to explain variance in the MFA output (see Figure 2.4).

Table 2.1 Measure of sampling adequacy (MSA) output from Keyser-Meyer-Olkin test. Species that receive above 0.6 may be considered well sampled, above 0.5 may be considered adequately sampled; and, below 0.5 are may be considered potentially suspect, or exhibited low variance. In the case of Pacific cod, interviewees nearly uniformly indicated a high encounter rate with this species.

Species	MSA	Species	MSA
Arrowtooth flounder	0.51	Redbanded rockfish	0.68
Black rockfish	0.73	Rougheye/Shortraker rockfish	0.65
Canary rockfish	0.47	Sablefish	0.55
China rockfish	0.70	Silvergray rockfish	0.71
Copper rockfish	0.78	Skates	0.6
Dogfish shark	0.49	Sleeper shark	0.75
Dusky rockfish	0.79	Thornyhead rockfish	0.72
Lingcod	0.52	Tiger rockfish	0.51
Pacific cod	0.48	Walleye pollock	0.62
Pacific ocean perch	0.68	Yelloweye rockfish	0.56
Quillback rockfish	0.57	Yellowtail rockfish	0.75

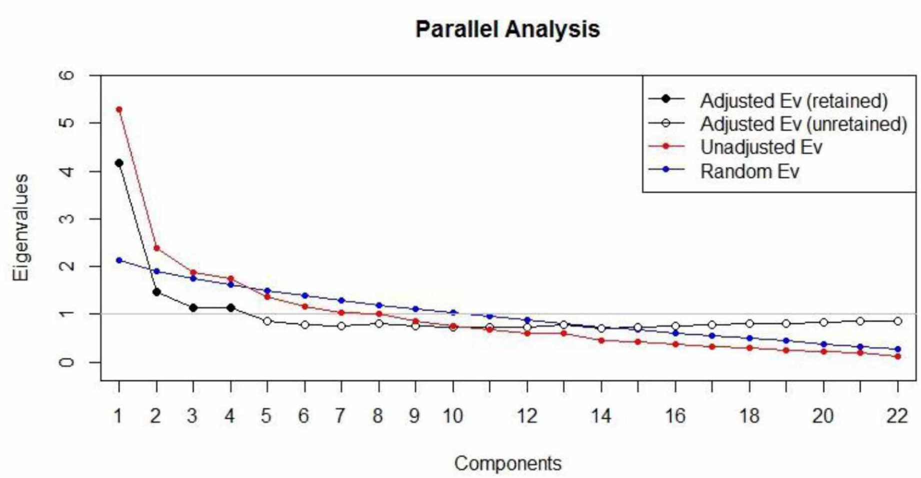

Figure 2.4 Output from Horn’s parallel analysis run using the ‘paran’ package in the R software program (Dinno, 2009). This output indicates four dimensions should be retained in the multiple factor analysis (MFA).

The first two dimensions of the MFA explain 34.89% of the total variance in the incidental catches. The four dimensions recommended for retention under parallel analysis explain 51.40% of the total variance in the data (Figure 2.4; Table 2.2). In an MFA, latent factors need not be descriptive of any single respondent but are instead reflective of the group as a whole. In this example, it is therefore useful to explore how fishing characteristics and incidental catch species group across dimensions as well as within each dimension, in order to understand putative relationships in the larger dataset.

Table 2.2 Multiple factor analysis (MFA) model output for the first four dimensions.

Eigenvalues	Dim.1	Dim.2	Dim.3	Dim.4
Variance	5.29	2.39	1.88	1.75
Percent variance explained	24.04	10.84	8.54	7.97
Cumulative percent variance	24.04	34.89	43.43	51.40

Visual representations were used for understanding dimensional grouping, as well as putative relationships among fishing characteristics and incidental catch species (Figure 2.5; Appendix 2.G) and numeric analyses were used for understanding the statistical significance of those relationships (Appendix 2.H). A value of 1 across a given dimension indicates a strong association with that dimension, while a value of 0 indicates no association. Vessel length is strongly associated with the first dimension; community of residence is strongly associated with the second dimension, and whether a fisherman uses conventional or snap-on gear is associated with both the first and second dimensions (Figure 2.5a). Years of fishing experience, on the other hand, has no association with the first two dimensions, as shown by it falling near the origin in Figure 2.5a. Arrowtooth flounder and walleye pollock have strong negative associations with the first and second dimensions (Figure 2.5b); while lingcod and yelloweye rockfish are both positively associated with the first and second dimensions (Figure 2.5b).

a b

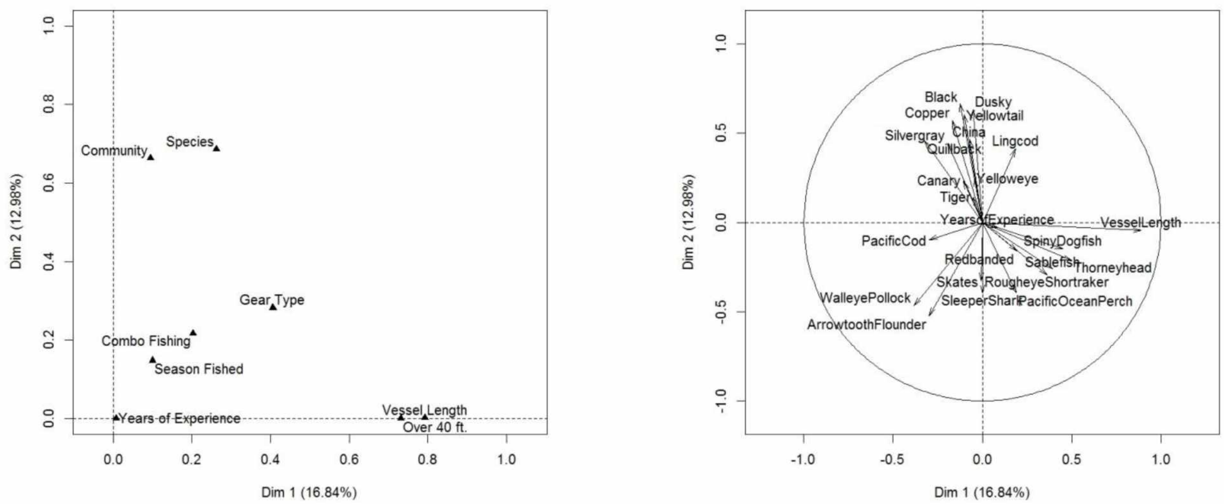

Figure 2.5 Group graphic (**a**) and correlation circle (**b**) representing relationships between first and second dimensions in the multiple factor analysis (MFA).

The first dimension reflects statistically significant positive latent associations among thornyhead rockfish, dogfish, sablefish, rougheye and shortraker rockfish, vessels more than 40 feet long, conventional longline gear, combo fishing, and fishing during spring (values significant at a p-value of 0.05). The first dimension reflects significant negative latent associations among arrowtooth flounder, Pacific cod, quillback rockfish, walleye pollock, residing in Hoonah, not fishing during spring, not combo fishing, using snap-on gear, and fishing on vessels less than 40 feet long (Appendix 2.G; Appendix 2.H).

The second dimension reflects statistically significant positive latent associations among black rockfish, dusky rockfish, yellowtail rockfish, copper rockfish, China rockfish, quillback rockfish, silvergray rockfish, lingcod, yelloweye rockfish, canary rockfish, residing in Sitka, using snap-on gear, combo fishing, and fishing during spring. The second dimension reflects significant negative latent associations among sablefish, rougheye and shortraker rockfish, skates, Pacific ocean perch, sleeper shark, walleye pollock, arrowtooth flounder, using both gear types, residing in Juneau, residing in Hoonah, residing in Petersburg, using conventional gear, not fishing during spring, and not combo fishing (Appendix 2.G; Appendix 2.H).

The third dimension reflects statistically significant positive latent associations among years of halibut fishing experience, tiger rockfish, fishing during summer, not fishing during spring, not fishing during fall, and residing in Hoonah. The third dimension reflects significant negative latent associations among Pacific cod, fishing during fall, fishing during spring, not fishing during summer, and residing in Petersburg (Appendix 2.G; Appendix 2.H).

The fourth dimension reflects statistically significant positive latent associations among years of halibut fishing experience, residing in Hoonah, fishing during fall, and not fishing during summer. The fourth dimension reflects significant negative latent associations among silvergray rockfish, fishing during summer, not fishing during fall, and residing in Juneau (Appendix 2.G; Appendix 2.H).

MFA describes patterns in the data that suggest associations between characteristics of fishermen, their vessels, and how, where, and when they fish with species caught. A POLR model allows for *predictions* about the likelihood of encounter with different incidental catch species while halibut fishing. That is, the POLR model suggests causal relationships between species caught, fishing characteristics, and the probability of encountering a specific incidental catch species.

The POLR model for this work is comprised of a system of 66 equations, three for each of the 22 species (i) encountered as incidental catch in the halibut longline fishery. A total of 34 predictor variables were included in the initial model specification. Discrete, binomial predictors included: community of residence; gear type; season fished; and, whether a respondent combo fishes for sablefish and halibut at the same time are discrete. Continuous predictor variables included: vessel length; years of fishing experience; and, age. As in the MFA model, guided by the results of parallel analysis, only the first four eigenvectors from eigenvalue decomposition of the covariance matrix of the 22 species were included as predictor variables used to account for patterns of co-occurrence among species caught incidental to halibut fishing.

The overall model passes the likelihood ratio test (p-value < 2.2e-16). Model results characterize relationships between fishing characteristics and prevalence of encounters with incidental catch species. In fact, the model allows for prediction of incidental catch prevalence based on catch composition and fishing characteristics. The model provided results that could be looked at for any combination of the categorical variables for every species. Coefficient estimates, standard errors, and p-values for all 22 incidental catch species are reported in Appendix 2.I. Most of the estimated coefficients in most of the models are statistically significant (p-value < 0.05). We illustrate one such scenario, picking Sitka as our reference category and the encounter probabilities of sablefish as a reference species. This scenario poses the following question: What are encounter probabilities of sablefish for Sitka fishermen?

Table 2.3 Coefficient estimates, standard errors, and p-values for prevalence categories in a proportional odds cumulative ordered logistic regression model (POLR) of sablefish incidental catch with Sitka as the reference category for community.

Prevalence categories	Value	Std. Error	p value
Never|Rarely	-2.848	0.436	6.51E-11
Rarely|Sometimes	-1.012	0.429	1.85E-02
Sometimes|Usually	1.110	0.429	9.68E-03

In this scenario, the model measures proportional odds of encountering sablefish. The coefficients for shifting prevalence categories give the log odds of falling into or below the prevalence categories (Table 2.3). These tell us that for Sitka fishermen there is an extremely low log odds of rarely or never encountering sablefish; a low log odds of only encountering sablefish sometimes, rarely, or never; and, a higher log odds of usually encountering sablefish (or falling into the other prevalence categories). All of these coefficients are statistically significant.

Coefficient values provide information about how each predictor variable is related to the prevalence of sablefish as incidental catch, in terms of the log odds scale (Table 2.4). This is useful for understanding the general magnitude and direction of any relationship. A positive coefficient for a predictor variable indicates a tendency for sablefish prevalence to increase as that predictor increases. For example, for a one-unit increase in vessel length, we expect rather weak 0.027 unit increase in the expected value of prevalence for sablefish on the log odds scale, given all other variables in the model are held constant. For a one unit increase in conventional gear type, from 0 to 1 (not using it to using it), we would expect a more powerful 0.560 decrease in the expected value of prevalence for sablefish on the log odds scale, given that all of the other variables in the model are held constant. Significant variables with positive coefficient values in relation to sablefish caught by fishermen from Sitka include: eigenvectors 1 and 4, arrowtooth flounder, dogfish, lingcod, rougheye/shortraker rockfish, Pacific cod, skates, yelloweye rockfish, all communities, vessel length, and fishing during summer. Significant variables with negative coefficient values include: eigenvector 3, years of fishing experience, conventional gear, fishing during spring or fall, sleeper sharks, walleye pollock, and rockfish (black, China, canary, copper, dusky, Pacific ocean perch, quillback, redbanded, silvergray, tiger, and yellowtail). The remaining variables did not have a statistically significant relationship with sablefish in the predictive model (age, combo fishing, fishing during spring or summer, eigenvector 2, spiny dogfish, thornyhead rockfish, lingcod, quillback rockfish, redbanded rockfish, rougheye/shortraker rockfish, and yelloweye rockfish).

Table 2.4 Coefficient estimates, standard errors, p-values, and odds ratios (OR) for all variables in a proportional odds cumulative ordered logistic regression model (POLR) of sablefish incidental catch with Sitka as the reference category for community.

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals	
					2.5%	97.5%
Eigenvector 1	7.659	1.879	4.57E-05	2,121	54	85,570
Eigenvector 2	-1.436	0.773	6.32E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.77E-09	0.023	0.007	0.081
Eigenvector 4	2.713	0.559	1.24E-06	15.073	5.036	45.146
Arrowtooth flounder	1.015	0.313	1.19E-03	2.760	1.497	5.118
Black rockfish	-1.794	0.303	3.36E-09	0.166	0.092	0.301
Canary rockfish	-0.699	0.299	1.92E-02	0.497	0.276	0.892
China rockfish	-2.105	0.302	3.25E-12	0.122	0.067	0.220
Copper rockfish	-1.958	0.301	8.25E-11	0.141	0.078	0.254
Dusky rockfish	-1.646	0.299	3.66E-08	0.193	0.107	0.346
Lingcod	0.028	0.301	9.25E-01	1.029	0.570	1.858
Pacific cod	1.717	0.333	2.47E-07	5.566	2.921	10.785
Pacific ocean perch	-1.223	0.313	9.46E-05	0.294	0.159	0.543
Quillback rockfish	-0.544	0.298	6.76E-02	0.580	0.323	1.040
Redbanded rockfish	-0.148	0.301	6.23E-01	0.862	0.477	1.557
Rougheye/Shortraker rockfish	0.160	0.306	6.00E-01	1.174	0.644	2.138
Skates	0.910	0.309	3.27E-03	2.484	1.358	4.571
Sleeper shark	-1.094	0.307	3.73E-04	0.335	0.183	0.611
Silvergray rockfish	-1.022	0.300	6.57E-04	0.360	0.199	0.647
Spiny dogfish	0.472	0.304	1.20E-01	1.604	0.885	2.912
Thornyhead rockfish	-0.536	0.313	8.71E-02	0.585	0.316	1.081
Tiger rockfish	-2.029	0.309	4.87E-11	0.131	0.072	0.240
Walleye pollock	-1.788	0.307	5.92E-09	0.167	0.091	0.305
Yelloweye rockfish	0.548	0.301	6.88E-02	1.729	0.960	3.125
Yellowtail rockfish	-2.020	0.307	4.44E-11	0.133	0.073	0.241
Hoonah	0.689	0.190	2.86E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.442
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.16E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.37E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825

The strongest predictor variables for sablefish incidental catch are the first and fourth eigenvectors, representing latent ecological and technical associations among species. All else equal, ecological and technical variation that leads to an increase in the prevalence of species that contribute to eigenvector 1 makes it vastly (OR = 2120.545) more likely that a halibut fisherman from Sitka will experience incidental catches of sablefish (Table 2.4). Ecological and technical variation that leads to an increase in the species that contribute to the fourth eigenvector have a similar (OR = 15.073) influence on the likelihood of sablefish incidental catch. Together, the magnitude of these coefficients in contrast to other coefficients suggests that sablefish incidental catch in the halibut fishery is primarily dependent on ecological and technological overlap among halibut, sablefish, and certain species.

In addition to the complex latent relationships represented by the eigenvectors, the model also reflects simple direct relationships among species. For example, for a one-unit increase in arrowtooth flounder (from any category to any higher category) the odds of usually encountering sablefish (from any category to any higher category) are 2.760 times greater, given that all other variables in the model are held constant. Similarly, for a one-unit increase in Pacific cod, the odds of usually encountering sablefish are 5.566 times greater and for a one-unit increase in skates, the odds of usually encountering sablefish are 2.484 times greater, given that all else is held constant (Table 2.4). In contrast, increased prevalence of sleeper sharks in the incidental catch of halibut fishermen lower the odds (OR = 0.335) of encountering sablefish, all else constant. Similarly, increased incidental catches of a suite of primarily shallow and demersal rockfish species (black rockfish, China rockfish, canary rockfish, copper rockfish, dusky rockfish, Pacific ocean perch, silvergray rockfish, tiger rockfish, and yellowtail rockfish) reduce the likelihood of incidental catch of sablefish, all else equal. Dogfish sharks and deeper rockfish like rougheye/shortraker rockfish and yelloweye rockfish all have positive odds ratios for sablefish (OR = 1.604, 1.174, and 1.729, respectively) but are not statistically significant in the model (Table 2.4). This indicates a potential for some unmeasured variable (e.g., a depth effect) that may be reflected in the eigenvectors.

Variables for vessel length and fishing experience were statistically significant in the model, but their ORs were not very large. For example, for a one-unit increase in vessel length, the odds of encountering sablefish usually versus the other categories are 1.027. For a one-unit increase in years of fishing experience, the odds of encountering sablefish decrease slightly (OR = 0.982).

Halibut fishermen residing in Hoonah were almost two times as likely to encounter sablefish (OR = 1.991) relative to Sitka-based fishermen; those in Petersburg were almost two and a half times as likely to encounter sablefish (OR = 2.435) as those in Sitka; and fishermen in Juneau were 1.710 times as likely to encounter sablefish as Sitka-based fishermen, given that all other variables in the model are held constant. The model also estimates that fishermen using conventional gear or targeting halibut during the fall were less likely to encounter sablefish (OR = 0.571 and 0.678, respectively), all else held constant.

Although one-way ANOVA suggests that there is a statistically significant (p-value = 0.0141) positive relationship between combo fishing (targeting sablefish and halibut at once) and sablefish prevalence, combo fishing is not statistically significant in the POLR model for sablefish (Table 2.4). Moreover, the estimated relationship has a seemingly inconsequential OR of 0.915. Thus, the apparent (to ANOVA) relationship between combo fishing and sablefish catch is more properly accounted for by other variables included in the model (e.g., the latent ecological and technical relationships represented by the first and fourth eigenvectors).

In this scenario, a less experienced fisherman from Sitka, using snap-on gear but not combo fishing or fishing during the fall, is more likely to encounter arrowtooth flounder, sablefish, Pacific cod, skates, and yelloweye as incidental catch than their counterparts. Additionally, their odds of encountering these species increases with vessel length (Table 2.4). Overall, the likelihood of seeing a given incidental catch species is governed by latent associations among species as conditioned by a suite of other variables, which include community, gear type, vessel characteristics, and operator characteristics.

The results show clear, strong relationships between incidental catch species that were included in the POLR model. Exploratory analyses indicated that species are correlated with one another and what one fisherman sees is representative of what others see. The POLR model therefore reiterates that incidental catch species tend to predict the other species that a given fishermen is likely to encounter while halibut fishing. The POLR sablefish scenario does not predict the likelihood of encountering sablefish in isolation, but instead predicts the likelihood of encountering sablefish with other species, given different fishing characteristics. In keeping with output from the MFA, the POLR model results also indicate that there is potential for those fishing characteristics to significantly influence the suite of incidental catch species that a fisherman might encounter while targeting halibut.

Discussion

In this project, we combined information drawn from interviews with fishermen with fishery-independent data generated during the IPHC stock assessment surveys. We found general agreement across experiences with incidental catch (a lack of statistically significant negative Pearson's correlation coefficients) among fishermen as well as between fishermen and the IPHC.

Community of residence was strongly predictive of grounds fished, and some fishing characteristics covaried with one another (ANOVA and Chi-square tests). At the same time, statistically significant relationships between fishing characteristics and incidental catch species were confirmed using MFA and POLR. We conclude that in the example of the Southeast Alaska halibut fishery, even relatively small numbers of interviews can characterize the experiences that fishermen have with incidental catch.

Eigenvectors in the POLR model represent inherent ecological and technical relationships (e.g., overlap in depth, location, time, and vulnerability to halibut fishing gear) among incidental catch species. They reflect a strong unavoidable component of incidental catch when fishing for halibut using baited demersal longline gear. Consequently, a substantial component of incidental catch in the halibut fishery will closely parallel patterns of incidental catch in the annual IPHC longline survey. Smaller but statistically significant relationships in the POLR model represent aspects of incidental catch that can be influenced by observable and controllable characteristics of fishing operations (i.e., fishing grounds, season, vessel length, gear configuration). This suggests that halibut catch levels and characteristics of individual fishing operations could be used to adjust IPHC survey incidental catches to yield operation-specific estimates of incidental catch by species. These findings have a number of important management implications. First, this work contributes to the development of strategies to combine self-reported fisheries-dependent data with fishery-independent data to increase the precision of estimates of catch and discard mortality of target and incidental species. Further, our results suggest that there may be limited scope for increased monitoring to contribute novel understanding about the general mix or relative prevalence of incidental species in the commercial halibut fishery in Southeast Alaska. In addition, the POLR model could provide a basis for using the IPHC survey and known characteristics of fishing operations to estimate incidental catch by halibut fishermen in Southeast Alaska. Finally, the POLR model results suggest that fisheries managers could influence the mix and level of incidental catch through policies that encourage modification of controllable characteristics of fishing operations, such as depth fished.

Our focus on a case study in Southeast Alaska provides one example of the potential to incorporate fishermen's local knowledge into management processes. As previously stated, demographic characteristics of interviewees beyond age and years of fishing experience were not considered during analyses. Interviewees were representative of quota share class distributions in their communities. Although findings from our study should not be expected to replicate across all regions or fishing fleets (especially those fleets where a fishery-independent survey differs extremely from commercial harvests in scope or technique), the *methods* employed in this research demonstrate a replicable way to document local knowledge in any fishery. This work demonstrates how data self-reported by fishermen can be assessed for consistency both among fishermen and with fishery-independent data.

The approach presented in this paper could serve as a template for incorporating semistructured interview data into fisheries management more broadly. Specifically, documenting observations of fishermen through interviews at the regional scale has the potential to supplement data gathered from fishery-independent data to: understand how fishing characteristics co-vary and influence incidental catch; inform the design of programs to estimate incidental catch; help to structure stratified sampling programs; and, provide a medium for gathering information in data poor fisheries.

Catches of target and incidental species can be self-reported by fishermen, monitored during offloads, or monitored at sea using cameras or human observers. Camera and human observer programs are often used to estimate target and incidental catch and to gather structured accounts of commercial fishing behaviors out at sea (Restrepo et al., 2014; Volstad et al., 1997). Despite their appeal to fisheries scientists and managers, onboard monitoring programs do not always ensure statistically random samples (SSC, 2017) and partial coverage may result in bias through under-representing portions of the fleet or through an observer-effect—altered fishing practices while an observer is onboard (Benoit and Allard, 2009). Monitoring using human observers aboard fishing vessels is costly and logistically challenging, especially on small vessels. In contrast, self-reporting is simple to implement and low cost, but may be difficult to verify. Where target or incidental catch are subject to binding limits there is concern that a conflict of interest that could lead fishermen to under-report actual catch and discard mortality of target and incidental species (Lordan et al., 2011).

Conclusions

Challenges to incorporating self-reported data into fisheries stock assessments and management may be related to prejudice against fishermen's local ecological knowledge (Hind, 2015; Soto, 2006) as well as a lack of tools for integrating that knowledge into conventional analyses. Some have argued that fishery-independent data may be more reliable than data collected from fisheries (Chen et al., 2003; Hilborn and Walters, 1992). Recent work by Bell et al. (2017) indicates that fishermen can accurately self-report information about discards. The research presented in this article contributes to these findings, as well as to a growing body of work demonstrating ways to incorporate fishermen's observations directly into management strategies at the data collection and monitoring/enforcement levels (Beaudreau and Levin, 2014; Carruthers and Neis, 2011; Figus et al., 2017; Macdonald et al., 2014; Neis, 1992; Neis et al., 1999; Saenz-Arroyo and Revollo-Fernandez, 2016). Our findings show not only how fishery-dependent data can be assessed for consistency, but also how fishery-dependent data collection may be stratified to account for fine scale variation in encounters with incidental catch.

This work offers a specific set of tools for integrating self-reported data into existing stock assessments and management. Methods presented here could be extended to explore interviews with fishermen documenting changes in encounters with fish species over time, including accounting for shifting patterns of spatial use (e.g., Macdonald et al., 2014; Beaudreau and Whitney, 2016; Chan et al., 2017), changes in types of gear used (e.g., Wilson et al., 2016), or other aspects of the fishery. Using inferential modelling, self-reported data can add to what we gather from fishery-independent surveys, throughout the North Pacific and around the world.

A corollary to our findings is that, for the Pacific halibut fishery in Southeast Alaska, fishery-dependent information is likely to yield similar understanding of trends in the abundance and distribution of incidental species as is generated in the longline survey. This might be attributed to the fact that fishery-independent data is generated using gear similar to that used in the halibut fishery. Future research might examine whether using commercial gear in other fishery-independent surveys significantly reduces the need for direct observation onboard fishing vessels or whether inclusion of fishery-dependent and fishery-independent observations generated with similar gear represents a form of pseudo-replication that could lead to underestimation of confidence bounds.

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Appendices

Appendix 2.A. Interview Protocol.

Please read this form carefully

You are being asked to take part in a study about at-sea monitoring in the Pacific halibut fishery. This project has been approved by the Institutional Review Board of the University of Alaska Fairbanks (Project # 600513-6).

The goal of this study is to document your observations and opinions about monitoring. You are being asked to take part in this study because of your fishing experience. You are invited to ask any questions at any time during your participation. The information that we collect might describe how at-sea monitoring affects the halibut fleet.

If you decide to take part, you will be asked to describe your fishing experience during an interview lasting about one hour. We will make every effort to hold the interview in a way that is comfortable for you. Some questions will include where you fish and what kinds of things you catch other than halibut. Other questions will focus on your opinions about at-sea monitoring. The interview may be recorded to help in taking notes. You may ask for the voice recorder to be turned off at any time.

We do not expect any risks to you if you take part in this study. At the same time, you may not get any benefits from taking part in this study. Information we get about you from the research will be kept confidential, and stored in a locked office. Information with your name attached will not be shared with anyone outside the research team. We will code your information with a number so no one can trace your answers to your name. Your name will not be used in reports, presentations, and publications.

Your decision to take part in the study is voluntary. If you decide to take part you can stop at any time. You may change your mind and ask to be removed from the study. You may also skip any questions. If you have questions now, feel free to ask. If you have questions, you may email UAF’s Institutional Review Board at fyori@uaf.edu.

STATEMENT OF CONSENT: I understand everything described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I am 18 years old or older. I have been provided a copy of this form.

____ Signature

____ Printed Name

Everything in this interview refers to the commercial fishery for Pacific halibut in Alaska. This means that even if you have experience fishing for halibut in a non-commercial way, I would like you to try to focus your answers on your commercial experiences. The interview is set up in two main parts. First I will ask about your fishing experiences. Then I will ask about the observer program and data collection at sea more generally.

Part 1: Fishing Experience

1. What year did you start commercial fishing?

2. What led you into commercial fishing [family tradition, first generation, etc.]?

3. What year did you start commercially fishing for halibut?

4. Has the boat you use changed over time? How?

5. What type of boat do you currently use to fish for halibut?

Type (e.g., schooner)	Length	Width	Engine Power	GT (Hold Capacity)	Number of bunks

6. Which regulatory areas do you currently hold quota in?

7. Have you ever held quota in another area?

8. When you think about your fishing experience, which area do you think of most of it as taking place?

9. What proportion of your halibut fishing takes place in Area 2C?

10. Which months do you currently fish for halibut commercially?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

11. How has this changed over time?

12. Please describe your typical gear setup

Snap-on?	Hook spacing	Hook type/size	Avg. # of skates	Length of avg. skate	Bait

13. How has this changed over time?

14. Do you combo fish black cod and halibut?

Great. Thank you. Now I would like to learn a bit about the different things that come up on your hooks when you are halibut fishing (Species Sorting Exercise).

Part 2: Non-target catch

1. I am really interested in how the things that come up on your hooks change. Do they change throughout the different months of the year? If so, how?
2. How do you decide how deep you fish? Why?
3. How do bycatch species change with depth?
4. Which species are undesirable?
5. How do you avoid undesirable species?
6. Looking into the future how do you think rules about retention of bycatch could change?
7. Are there species that you don’t currently sell, but wish that you could, or think there may be a market for in the future?

Part 3: Demographic Information

1. What year were you born? ______________________________
2. How did you obtain your IFQ? _____
3. Have you personally fished your 2C IFQ every year since obtaining it? YES NO
4. How long do you plan to keep fishing your IFQ? _________
5. Do you identify with an Alaska Native tribe? YES NO
6. How many people live in your household? ________

7. How satisfied are you with your financial situation?
   a) Very Unsatisfied
   b) Unsatisfied
   c) Satisfied
   d) Very Satisfied

8. What percent of your household income comes from fishing (household income includes your income as well as income from anyone else who lives in your household)?
   a) 1-24%
   b) 25-50%
   c) 51-74%
   d) 75-99%
   e) 100%

9. Do you own the fishing vessel that you fish halibut on? YES NO

10. Are you a member of a fisheries organization? If so, which one? YES NO

    ____

11. Are you a full time resident in ____________? YES NO

12. Is____________ currently dependent on commercial fishing? YES NO

13. Did you grow up in ____________? YES NO

14. Did one of your parents grow up in ____________? YES NO

15. Did one of your grandparents grow up in ____________? YES NO

May I contact you in the future with results and/or more questions? YES NO
If so, please provide contact Information
Email:
Phone number:
Address:

Part 5: Closing

5.1 Do you have any questions for me?

Thank you for your time ☺

Appendix 2.B. Summary of interviewee characteristics (n = 72) used in multiple factor analysis (MFA) and proportional odds cumulative ordered logistic regression (POLR) models.

Table 2.B.1. Number of interviewees across categorical variables for fishing characteristics.[2]

Characteristic	# Interviewees
Community	
Juneau	12
Hoonah	10
Petersburg	25
Sitka	29
Fishing season	
Spring fishing	53
Summer fishing	32
Fall fishing	36
Gear type	
Conventional gear	31
Snap-on gear	39
Both gear types	6
Combo fishing (for sablefish and halibut)	36

Table 2.B.2. Characteristics of sample size across continuous variables for fishing characteristics.

Characteristic	Min	Max	Median
Vessel length	16	86	45
Age	27	81	57
Years of experience	4	57	34

[2] Fishermen were allowed to report fishing during multiple categories for some characteristics (e.g., fishing season), so the numbers do not all add to 76.

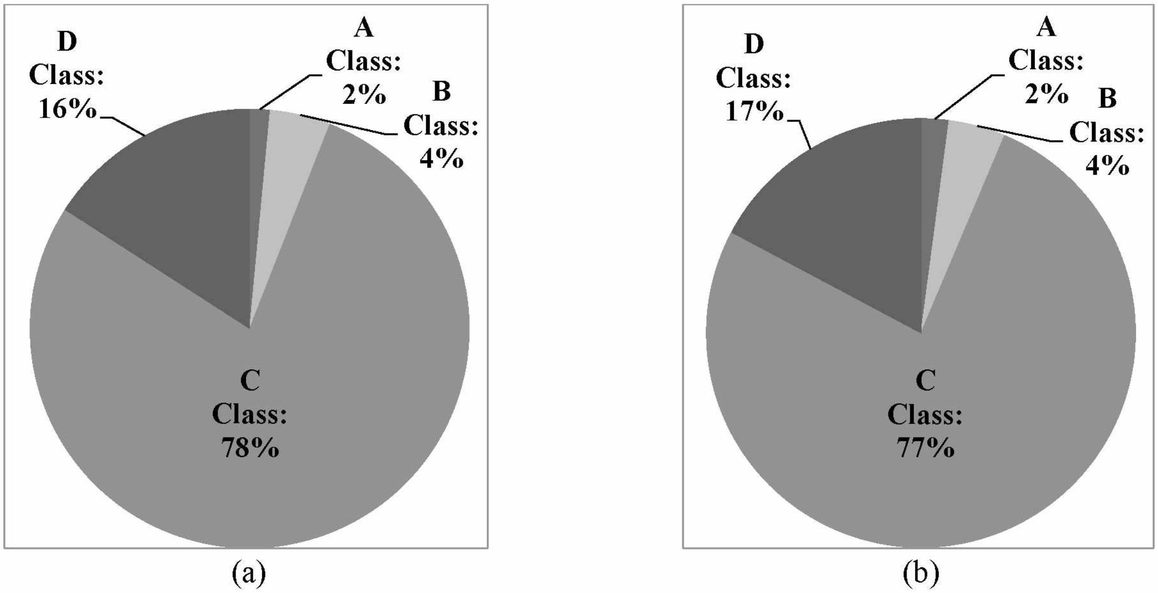


Figure 2.B.1. Halibut quota share holdings by category across (a) all four study communities (n = 804 blocks) and (b) within the interview group (n = 135 blocks).

Appendix 2.C. Summarized results from sorting exercise during interviews.

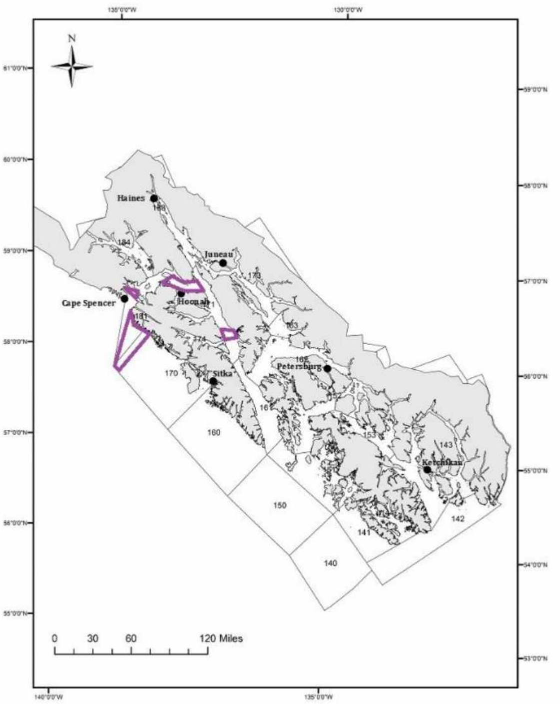
Table 2.C.1. Encounter prevalence for incidental catch species in the Southeast Alaska halibut fishery: 0 = 'Never', 1 = 'Rarely', 2 = 'Sometimes', and 3 = 'Usually'. Asterisks denote the 22 species included in the multiple factor analysis (MFA) and proportional odds cumulative ordered logistic regression model (POLR) models.

Species	Mean	Median	Min	Max
Alaska skate	2	2	0	3
Arrowtooth flounder*	2.4	2	1	3
Basket star	1.9	2	0	3
Big skate	2.2	2	0	3
Black rockfish*	1.2	1	0	3
Bocaccio	1	1	0	3
Brittle star	1.3	1	0	3
Brown rockfish	1.1	1	0	3
Canary rockfish*	1.7	2	0	3
China rockfish*	1	1	0	3
Chum salmon	0.1	0	0	1
Coho salmon	0.5	0	0	2
Copper rockfish*	1.1	1	0	3
Dogfish*	2.2	2	0	3
Dungeness crab	0.1	0	0	2
Dusky rockfish*	1.3	1	0	3
Great sculpin	1.6	1.5	0	3
Grenadier	0.6	0	0	3
Hermit crab	0.4	0	0	2
Humboldt squid	0.2	0	0	1
King crab	0.6	1	0	2
King salmon	0.1	0	0	1
Lingcod*	1.9	2	0	3
Longnose skate	2.2	2	0	3
Octopus	1.3	1	0	3
Pacific cod*	2.6	3	1	3
Pacific ocean perch*	1.5	2	0	3
Pink salmon	0.1	0	0	1
Quillback rockfish*	1.7	2	0	3
Ratfish	1.5	2	0	3
Red Irish lord	1.3	1	0	3
Redbanded rockfish*	1.9	2	0	3
Rougheye rockfish	2	2	0	3
Rougheye/Shortraker rockfish*	2	2	0	3

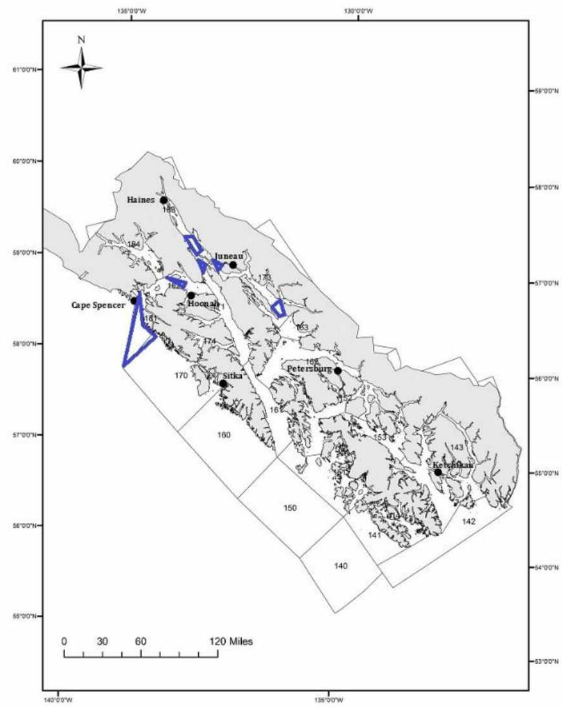
Species	Mean	Median	Min	Max
Sablefish*	1.9	2	0	3
Shortraker rockfish	1.9	2	0	3
Silvergray rockfish*	1.4	2	0	3
Skates*	2.3	2	0	3
Sleeper shark*	1.4	1	0	3
Sockeye salmon	0.1	0	0	1
Spider crab	0.3	0	0	2
Starry flounder	0.9	1	0	3
Sun star	1.6	2	0	3
Tanner crab	0.5	0	0	2
Thornyheads*	1.7	2	0	3
Tiger rockfish*	1.1	1	0	3
Tomcod	1.1	1	0	3
Walleye pollock*	1.1	1	0	3
White skate	1.8	2	0	3
Wolfeel	0.9	1	0	3
Yellow Irish lord	1.4	1	0	3
Yelloweye rockfish*	2.2	2	1	3
Yellowtail rockfish*	1.1	1	0	3

Appendix 2.D. Areas fished by study participants, organized by community of residence.

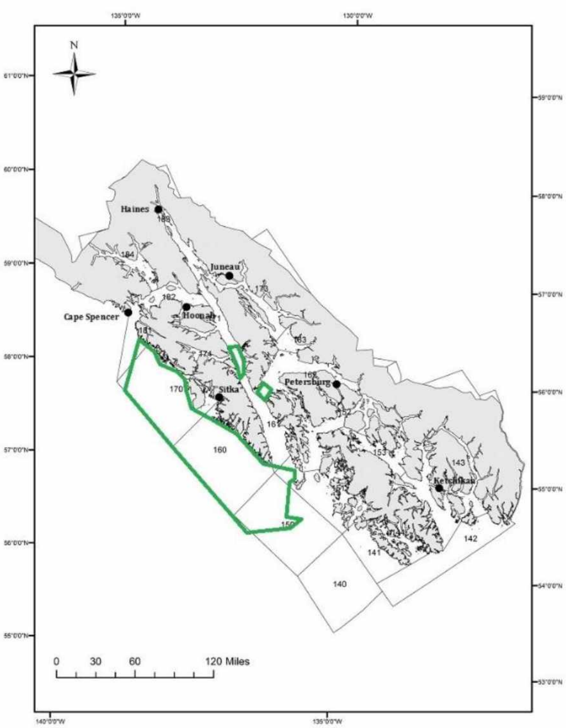
Figure 2.D.1. Areas fished by study participants from Hoonah, Juneau, Sitka, and Petersburg.



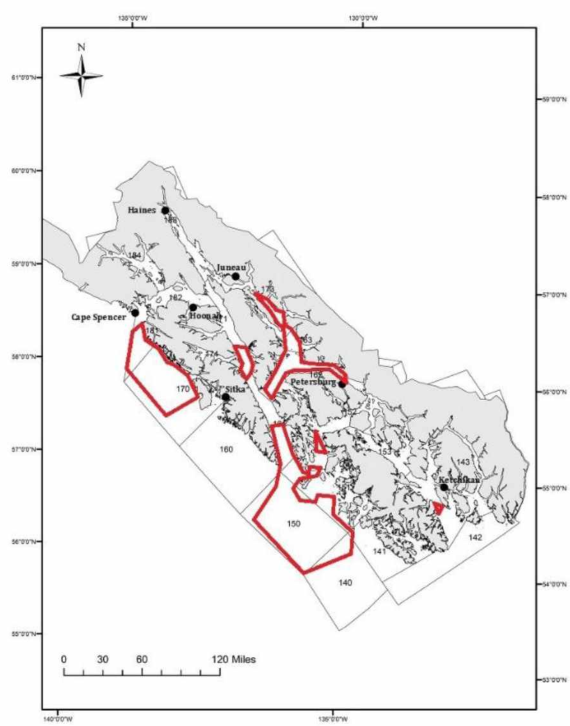
Hoonah



Juneau

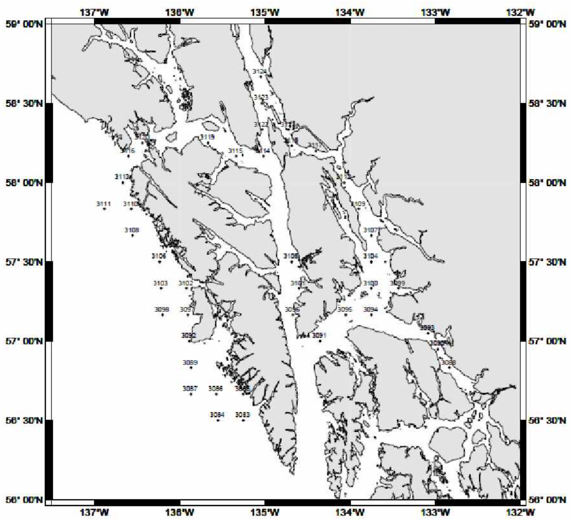


Sitka



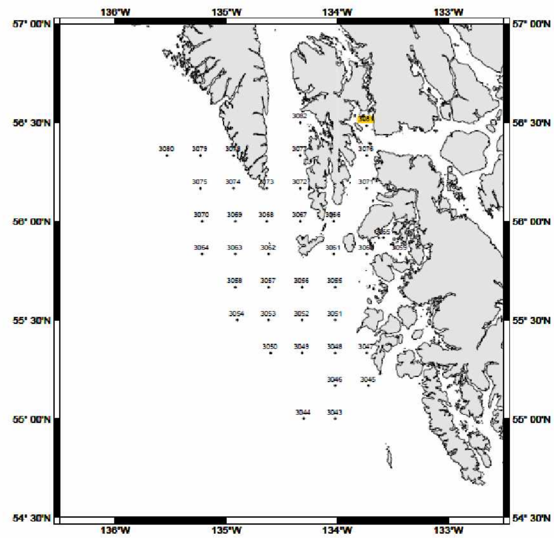
Petersburg

Appendix 2.E. A majority of the 124 stations that make up the IPHC setline survey in Area 2C were used by the fishermen who participated in this study. Unused stations were clustered in the southernmost region in 2C, and are highlighted below (Source: IPHC, edited by corresponding author).



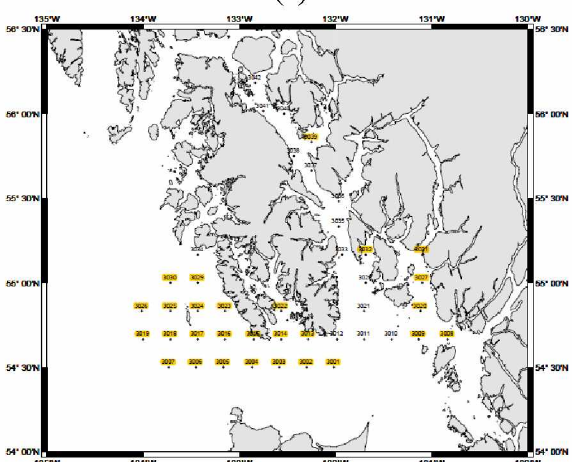
Sitka Station ID's

(a)



Ommaney Station ID's

(b)



Ketchikan Station ID's

(c)

Figure 2.E.1. International Pacific Halibut Commission (IPHC) setline survey stations near (a) Sitka, (b) Ommaney, and (c) Ketchikan.

Appendix 2.F. Correlograms representing estimated Pearson’s correlation coefficients across all 51 incidental catch species depict extensive positive correlations, most of which are statistically significant (p-value < 0.05) and an absence of statistically significant negative correlations among interviewees and the IPHC.

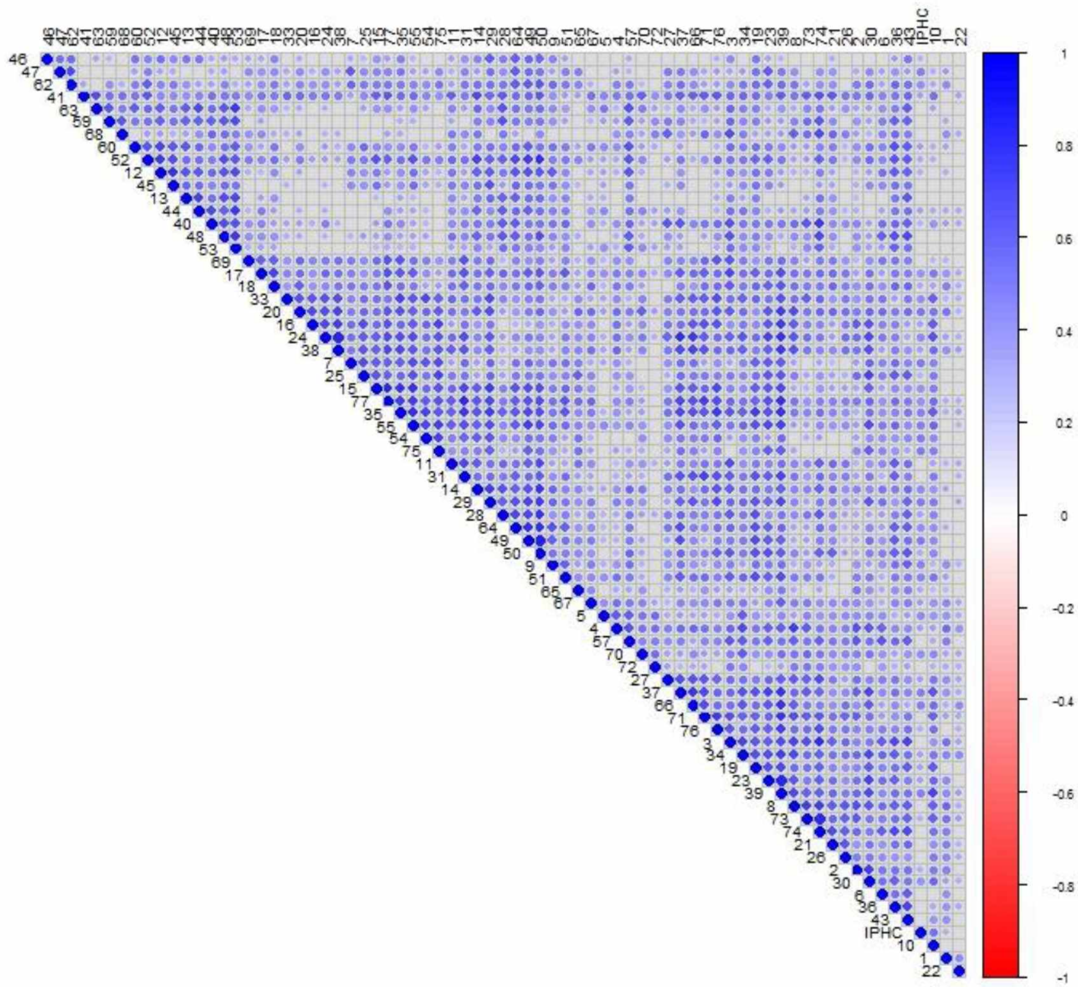


Figure 2.F.1 Correlogram of correlations among 72 Interviewees and a median of the IPHC survey across 51 species encountered by halibut fishermen and during IPHC surveys.

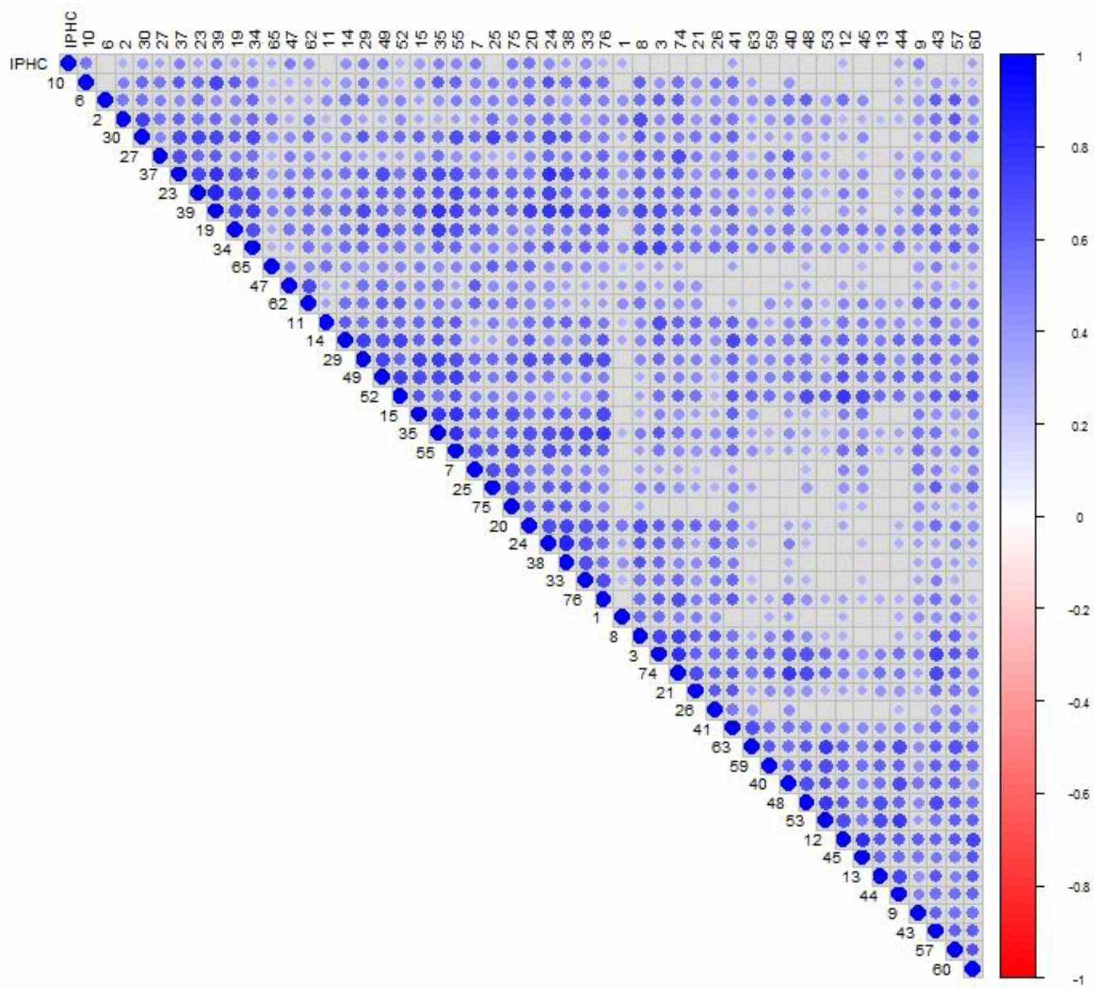


Figure 2.F.2. Correlogram of correlations among 49 Interviewees and a median of the IPHC survey across 51 species encountered by halibut fishermen and during IPHC surveys in Spring.

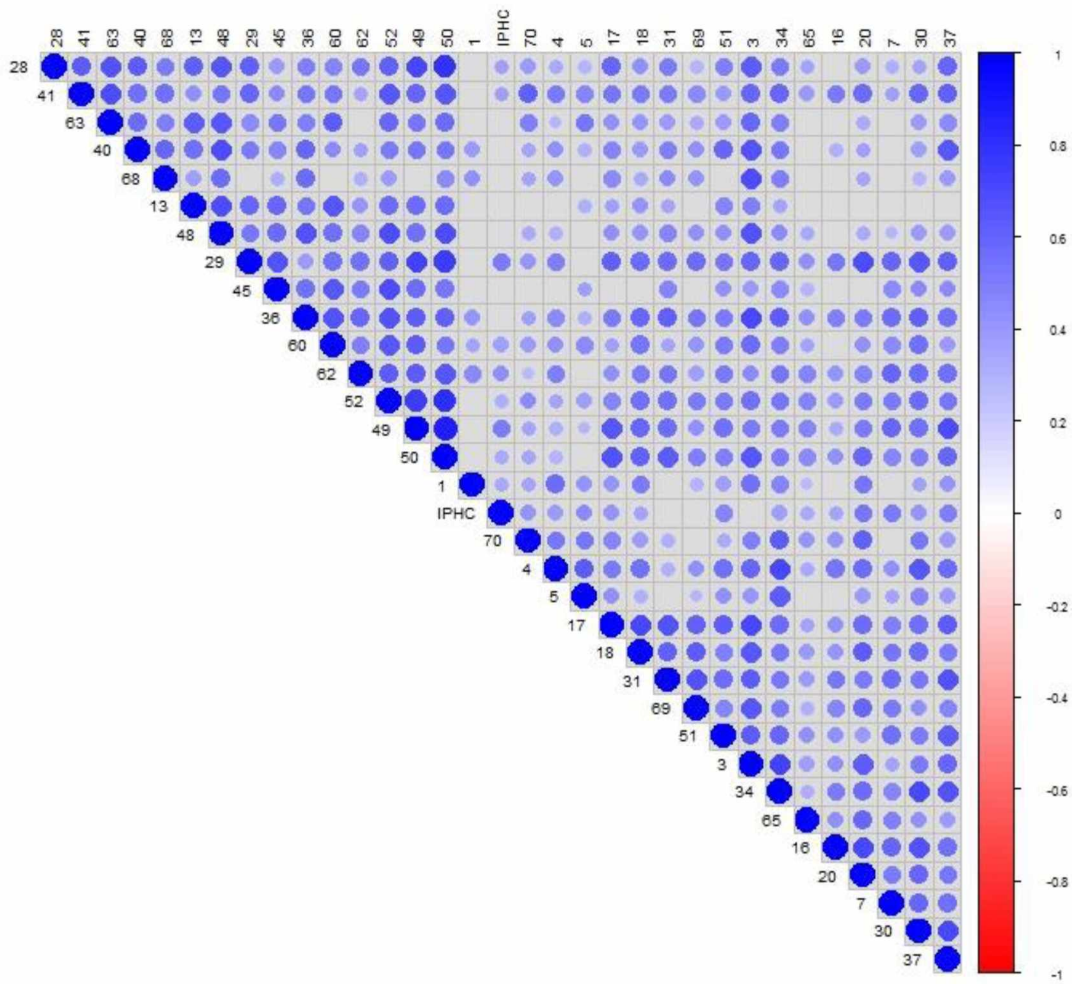


Figure 2.F.3. Correlogram of correlations among 32 Interviewees and a median of the IPHC survey across 51 species encountered by halibut fishermen and during IPHC surveys in Summer.

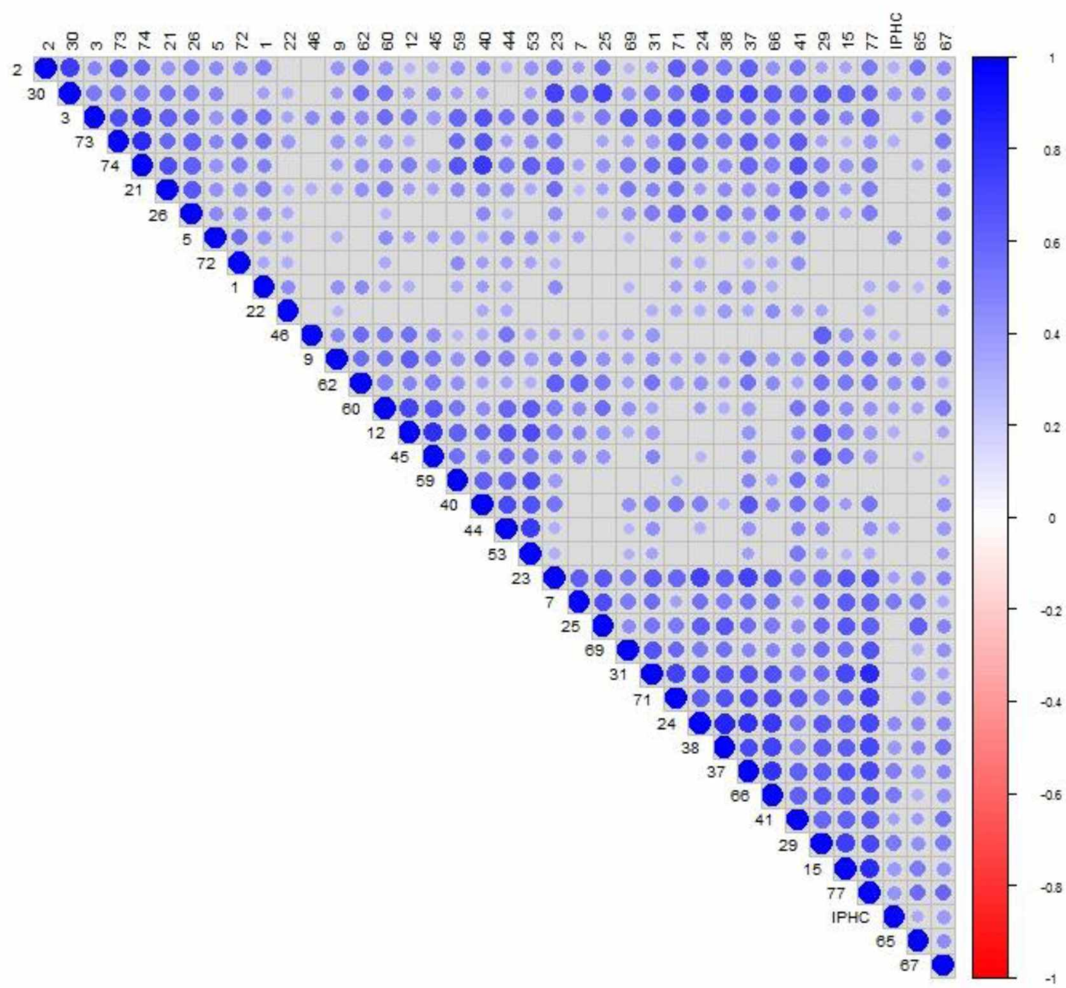
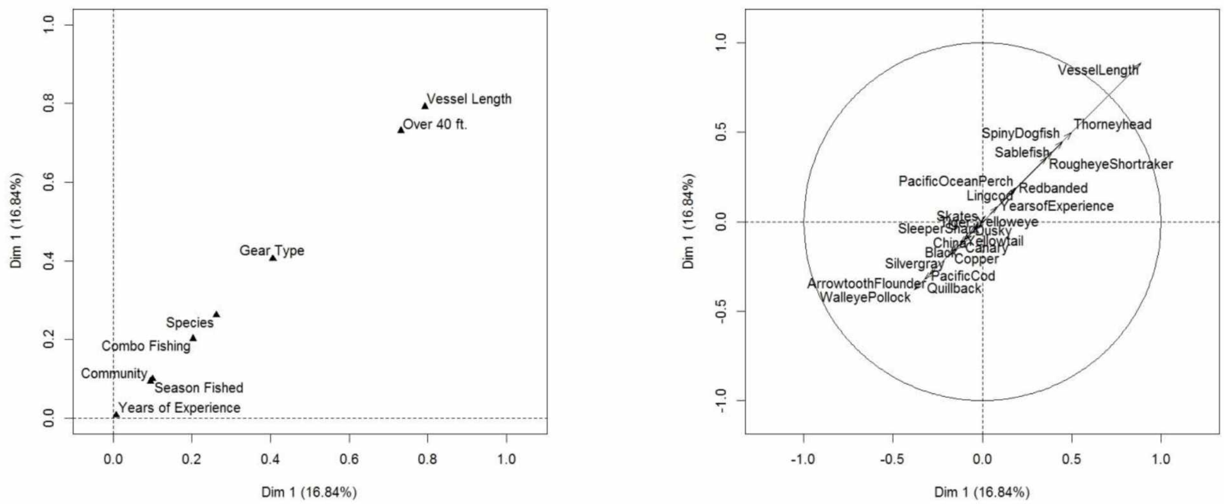


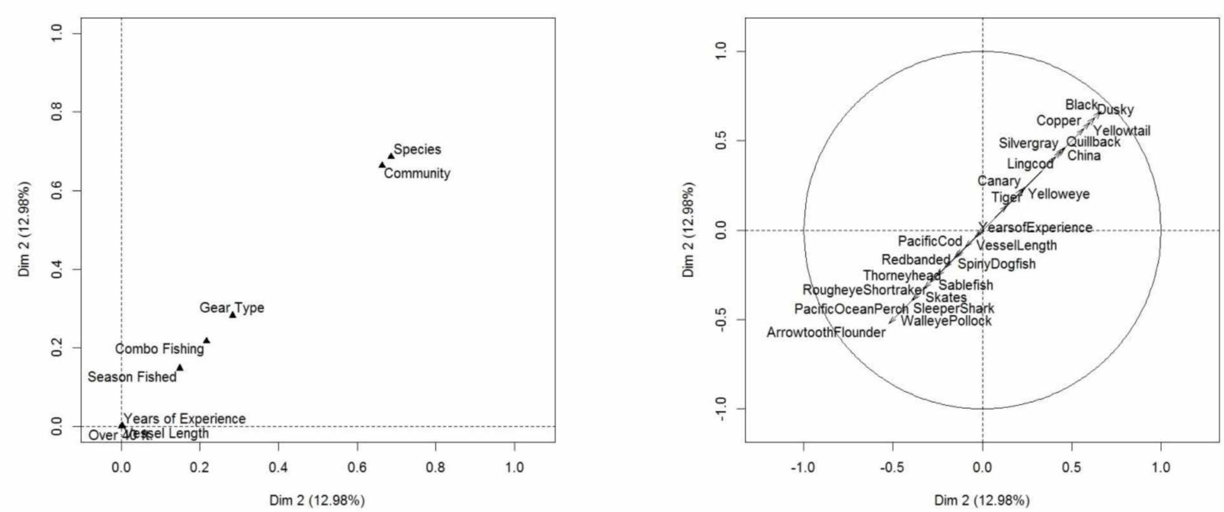
Figure 2.F.4. Correlogram of correlations among 37 Interviewees and a median of the IPHC survey across 51 species encountered by halibut fishermen and during IPHC surveys in Fall.

Appendix 2.G. Dimensions 1 – 4 of the MFA output plotted against themselves, in order to graphically highlight relationships between fishing characteristics, species, and the first four dimensions.



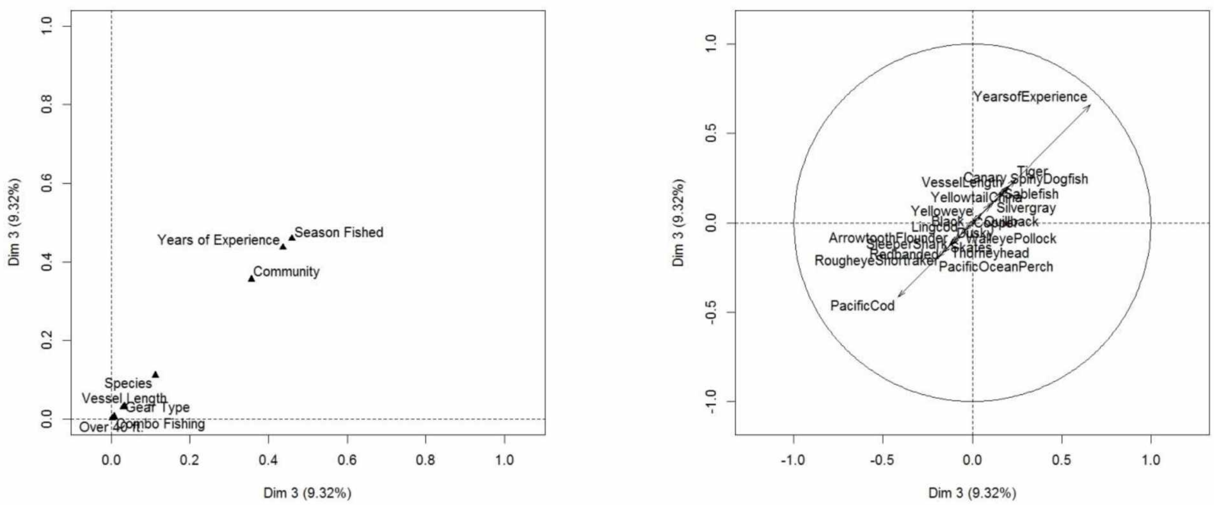
a b

Figure 2.G.1. Group graphic (a) and correlation circle (b) representing relationships across the first dimension in the multiple factor analysis.



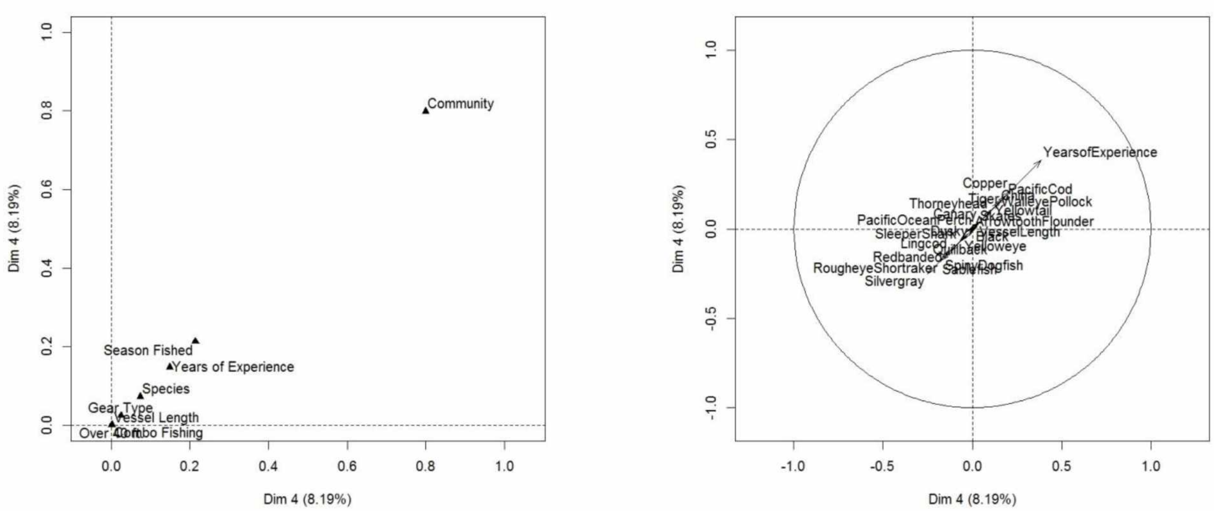
a b

Figure 2.G.2. Group graphic (a) and correlation circle (b) representing relationships across the second dimension in the multiple factor analysis.



a b

Figure 2.G.3. Group graphic (a) and correlation circle (b) representing relationships across the third dimension in the multiple factor analysis.



a b

Figure 2.G.4. Group graphic (a) and correlation circle (b) representing relationships across the fourth dimension in the multiple factor analysis.

Appendix 2.H. Multiple factor analysis (MFA) output from the ‘dimdesc’ command in the ‘FactoMineR’ package in the R software program.

Table 2.H.1. Results and output from MFA using the ‘dimdesc’ command. First dimension contributing variables, correlations, and associated p-values.

Quantitative Variables	correlation	p-value
Vessel length	0.890	6.48E-27
Thornyhead rockfish	0.499	4.45E-06
Spiny dogfish	0.449	4.65E-05
Sablefish	0.391	4.71E-04
Rougheye/Shortraker rockfish	0.364	1.23E-03
Arrowtooth Flounder	-0.298	9.02E-03
Pacific cod	-0.298	8.86E-03
Quillback rockfish	-0.324	4.31E-03
Walleye pollock	-0.383	6.43E-04

Categorical Variables	R^2	p-value
Over 40 ft.	0.731	8.47E-23
Gear type	0.406	5.64E-09
Combo fishing	0.203	4.52E-05
Spring fishing	0.124	1.83E-03

Categories	Estimate	p-value
Over 40 ft.	1.418	8.47E-23
Conventional gear	1.191	1.01E-09
Combo fishing	0.729	4.52E-05
Spring fishing	0.592	1.83E-03
Hoonah	-0.833	2.18E-02
No spring fishing	-0.592	1.83E-03
No combo fishing	-0.729	4.52E-05
Snap-on gear	-0.919	6.72E-09
Under 40 ft.	-1.418	8.47E-23

Table 2.H.2. Results and output from MFA using the 'dimdesc' command. Second dimension contributing variables, correlations, and associated p-values.

Quantitative Variables	correlation	p-value
Black rockfish	0.665	5.81E-11
Dusky rockfish	0.630	1.08E-09
Yellowtail rockfish	0.606	6.72E-09
Copper rockfish	0.570	7.87E-08
China rockfish	0.468	2.03E-05
Quillback rockfish	0.459	3.23E-05
Silvergray rockfish	0.445	5.75E-05
Lingcod	0.413	2.13E-04
Yelloweye rockfish	0.245	3.26E-02
Canary rockfish	0.230	4.54E-02
Sablefish	-0.258	2.43E-02
Rougheye/Shortraker rockfish	-0.294	9.98E-03
Skates	-0.328	3.81E-03
Pacific ocean perch	-0.394	4.32E-04
Sleeper shark	-0.398	3.77E-04
Walleye pollock	-0.467	2.10E-05
Arrowtooth flounder	-0.524	1.19E-06

Categorical Variables	R^2	p-value
Community	0.664	5.11E-17
Gear type	0.282	5.54E-06
Combo fishing	0.217	2.26E-05
Spring fishing	0.185	1.04E-04

Categories	Estimate	p-value
Sitka	1.830	1.24E-18
Snap-on gear	1.170	1.52E-06
Combo fishing	0.662	2.26E-05
Spring fishing	0.636	1.04E-04
Both gear types	-0.948	4.23E-02
Juneau	-0.655	7.86E-03
Hoonah	-0.814	3.19E-03
Petersburg	-0.361	2.35E-03
Conventional gear	-0.222	1.68E-04
No spring fishing	-0.636	1.04E-04
No combo fishing	-0.662	2.26E-05

Table 2.H.3. Results and output from MFA using the 'dimdesc' command. Third dimension contributing variables, correlations, and associated p-values.

Quantitative Variables	correlation	p-value
Years of experience	0.661	8.25E-11
Tiger rockfish	0.242	3.53E-02
Pacific cod	-0.417	1.79E-04
Categorical Variables	R^2	p-value
Summer fishing	0.293	4.35E-07
Community	0.356	5.53E-07
Spring fishing	0.161	3.25E-04
Fall fishing	0.159	3.68E-04
Categories	Estimate	p-value
Summer fishing	0.652	4.35E-07
No spring fishing	0.503	3.25E-04
No fall fishing	0.478	3.68E-04
Hoonah	0.684	9.22E-03
Fall fishing	-0.478	3.68E-04
Spring fishing	-0.503	3.25E-04
No summer fishing	-0.651	4.35E-07
Petersburg	-1.169	4.61E-08

Table 2.H.4. Results and output from MFA using the 'dimdesc' command. Fourth dimension contributing variables, correlations, and associated p-values.

Quantitative Variables	correlation	p-value
Years of experience	0.385	0.000603
Silvergray rockfish	-0.252	0.028128
Categorical Variables	R^2	p-value
Community	0.799	5.34E-25
Fall fishing	0.154	4.63E-04
Summer fishing	0.131	1.32E-03
Categories	Estimate	p-value
Hoonah	1.724	1.09E-09
Fall fishing	0.441	4.63E-04
No summer fishing	0.408	1.32E-03
Summer fishing	-0.408	1.32E-03
No fall fishing	-0.441	4.63E-04
Juneau	-1.890	7.06E-14

Appendix 2.I. Coefficient estimates, standard errors, p-values, odds ratio (OR) estimates, and 95% confidence intervals for proportional odds cumulative ordered logistic regression model (POLR) of 22 incidental catch species with Sitka as the reference category for community.

Table 2.I.1. Arrowtooth flounder

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.667	1.879	4.49E-05	2,137	54	85572
Eigenvector 2	-1.434	0.773	6.35E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.78E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.25E-06	15.056	5.036	45.147
Black rockfish	-2.809	0.318	9.70E-19	0.060	0.032	0.112
Canary rockfish	-1.714	0.312	3.88E-08	0.180	0.097	0.331
China rockfish	-3.121	0.317	6.97E-23	0.044	0.024	0.082
Copper rockfish	-2.972	0.316	5.36E-21	0.051	0.027	0.095
Dusky rockfish	-2.662	0.314	2.11E-17	0.070	0.038	0.129
Lingcod	-0.987	0.313	1.63E-03	0.373	0.201	0.687
Pacific cod	0.701	0.341	3.99E-02	2.017	1.037	3.964
Pacific ocean perch	-2.239	0.327	7.25E-12	0.107	0.056	0.202
Quillback rockfish	-1.560	0.311	5.20E-07	0.210	0.114	0.385
Redbanded rockfish	-1.163	0.314	2.08E-04	0.312	0.168	0.576
Rougheye/Shortraker rockfish	-0.855	0.317	7.00E-03	0.425	0.228	0.790
Sablefish	-1.015	0.313	1.19E-03	0.362	0.195	0.668
Skates	-0.105	0.319	7.42E-01	0.900	0.481	1.685
Sleeper shark	-2.111	0.321	4.86E-11	0.121	0.064	0.227
Silvergray rockfish	-2.037	0.314	8.34E-11	0.130	0.070	0.240
Spiny dogfish	-0.543	0.315	8.42E-02	0.581	0.313	1.075
Thornyhead rockfish	-1.551	0.325	1.88E-06	0.212	0.112	0.400
Tiger rockfish	-3.044	0.323	4.41E-21	0.048	0.025	0.089
Walleye pollock	-2.804	0.322	2.95E-18	0.061	0.032	0.113
Yelloweye rockfish	-0.468	0.312	1.34E-01	0.627	0.339	1.154
Yellowtail rockfish	-3.035	0.321	3.16E-21	0.048	0.025	0.090
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.03E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.14E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.83E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.39E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-3.864	0.450	8.86E-18			
Rarely|Sometimes	-2.028	0.443	4.75E-06			
Sometimes|Usually	0.094	0.439	8.30E-01			

Table 2.H.2. Black rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.664	1.879	4.52E-05	2,130	54	85569
Eigenvector 2	-1.435	0.773	6.34E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.78E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.24E-06	15.062	5.036	45.146
Arrowtooth flounder	2.809	0.318	9.71E-19	16.593	8.935	31.093
Canary rockfish	1.094	0.298	2.47E-04	2.985	1.665	5.369
China rockfish	-0.311	0.297	2.95E-01	0.733	0.409	1.311
Copper rockfish	-0.165	0.297	5.79E-01	0.848	0.474	1.518
Dusky rockfish	0.147	0.295	6.19E-01	1.158	0.649	2.068
Lingcod	1.822	0.303	1.86E-09	6.185	3.420	11.237
Pacific cod	3.510	0.338	3.04E-25	33.456	17.391	65.603
Pacific ocean perch	0.570	0.311	6.69E-02	1.769	0.961	3.259
Quillback rockfish	1.249	0.298	2.71E-05	3.488	1.948	6.263
Redbanded rockfish	1.645	0.303	5.60E-08	5.182	2.867	9.407
Rougheye/Shortraker rockfish	1.954	0.308	2.34E-10	7.054	3.862	12.942
Sablefish	1.793	0.303	3.38E-09	6.010	3.322	10.921
Skates	2.704	0.314	6.93E-18	14.933	8.105	27.760
Sleeper shark	0.699	0.306	2.24E-02	2.012	1.104	3.670
Silvergray rockfish	0.771	0.299	9.83E-03	2.163	1.205	3.890
Spiny dogfish	2.266	0.307	1.55E-13	9.641	5.296	17.656
Thornyhead rockfish	1.258	0.313	5.99E-05	3.518	1.905	6.515
Tiger rockfish	-0.235	0.304	4.39E-01	0.790	0.435	1.433
Walleye pollock	0.005	0.303	9.86E-01	1.005	0.555	1.822
Yelloweye rockfish	2.341	0.304	1.45E-14	10.396	5.740	18.949
Yellowtail rockfish	-0.227	0.302	4.53E-01	0.797	0.441	1.440
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.443
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.15E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.83E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.39E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-1.055	0.431	1.45E-02			
Rarely|Sometimes	0.782	0.430	6.94E-02			
Sometimes|Usually	2.903	0.436	2.63E-11			

Table 2.H.3. Canary rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.662	1.879	4.54E-05	2,126	54	85566
Eigenvector 2	-1.436	0.773	6.33E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.76E-09	0.023	0.007	0.081
Eigenvector 4	2.713	0.559	1.24E-06	15.070	5.036	45.145
Arrowtooth flounder	1.715	0.312	3.83E-08	5.557	3.025	10.285
Black rockfish	-1.094	0.298	2.45E-04	0.335	0.186	0.601
China rockfish	-1.405	0.297	2.21E-06	0.245	0.137	0.438
Copper rockfish	-1.258	0.296	2.16E-05	0.284	0.159	0.507
Dusky rockfish	-0.947	0.294	1.29E-03	0.388	0.218	0.690
Lingcod	0.728	0.299	1.48E-02	2.071	1.154	3.726
Pacific cod	2.416	0.332	3.37E-13	11.205	5.892	21.696
Pacific ocean perch	-0.523	0.309	9.04E-02	0.593	0.323	1.085
Quillback rockfish	0.156	0.294	5.97E-01	1.168	0.656	2.081
Redbanded rockfish	0.551	0.299	6.48E-02	1.736	0.967	3.119
Rougheye/Shortraker rockfish	0.860	0.303	4.60E-03	2.363	1.304	4.289
Sablefish	0.700	0.299	1.91E-02	2.013	1.122	3.620
Skates	1.610	0.308	1.72E-07	5.001	2.743	9.184
Sleeper shark	-0.395	0.304	1.94E-01	0.674	0.371	1.221
Silvergray rockfish	-0.322	0.296	2.76E-01	0.724	0.405	1.294
Spiny dogfish	1.172	0.302	1.02E-04	3.229	1.791	5.845
Thornyhead rockfish	0.164	0.310	5.97E-01	1.178	0.641	2.165
Tiger rockfish	-1.330	0.303	1.18E-05	0.265	0.146	0.479
Walleye pollock	-1.089	0.302	3.18E-04	0.337	0.186	0.608
Yelloweye rockfish	1.247	0.299	3.03E-05	3.480	1.941	6.272
Yellowtail rockfish	-1.320	0.301	1.19E-05	0.267	0.148	0.481
Hoonah	0.689	0.190	2.86E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.03E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.16E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.38E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-2.149	0.431	6.15E-07			
Rarely|Sometimes	-0.312	0.426	4.64E-01			
Sometimes|Usually	1.809	0.428	2.36E-05			

Table 2.H.4. China rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.664	1.879	4.53E-05	2,129	54	85568
Eigenvector 2	-1.435	0.773	6.34E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.77E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.24E-06	15.065	5.036	45.146
Arrowtooth flounder	3.120	0.317	7.08E-23	22.648	12.228	42.392
Black rockfish	0.311	0.297	2.95E-01	1.365	0.763	2.446
Canary rockfish	1.405	0.297	2.20E-06	4.077	2.282	7.311
Copper rockfish	0.147	0.295	6.18E-01	1.158	0.650	2.065
Dusky rockfish	0.458	0.293	1.18E-01	1.581	0.890	2.814
Lingcod	2.133	0.302	1.63E-12	8.444	4.683	15.315
Pacific cod	3.822	0.337	9.48E-30	45.676	23.793	89.458
Pacific ocean perch	0.881	0.309	4.40E-03	2.415	1.318	4.437
Quillback rockfish	1.561	0.296	1.37E-07	4.762	2.669	8.531
Redbanded rockfish	1.957	0.302	8.73E-11	7.075	3.926	12.817
Rougheye/Shortraker rockfish	2.265	0.307	1.67E-13	9.628	5.287	17.640
Sablefish	2.105	0.302	3.26E-12	8.206	4.549	14.885
Skates	3.015	0.313	5.54E-22	20.390	11.093	37.850
Sleeper shark	1.011	0.304	9.00E-04	2.747	1.514	4.997
Silvergray rockfish	1.082	0.297	2.69E-04	2.952	1.651	5.296
Spiny dogfish	2.577	0.306	3.58E-17	13.158	7.250	24.067
Thornyhead rockfish	1.569	0.312	4.95E-07	4.803	2.609	8.875
Tiger rockfish	0.076	0.302	8.01E-01	1.079	0.597	1.950
Walleye pollock	0.316	0.301	2.93E-01	1.372	0.761	2.479
Yelloweye rockfish	2.653	0.303	2.23E-18	14.191	7.858	25.830
Yellowtail rockfish	0.085	0.300	7.77E-01	1.089	0.605	1.959
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.443
Petersburg	0.890	0.140	2.03E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.15E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.83E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.38E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-0.744	0.431	8.41E-02			
Rarely|Sometimes	1.093	0.430	1.11E-02			
Sometimes|Usually	3.214	0.436	1.70E-13			

Table 2.H.5. Copper rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.665	1.879	4.51E-05	2,133	54	85570
Eigenvector 2	-1.435	0.773	6.35E-02	0.238	0.052	1.084
Eigenvector 3	-3.756	0.637	3.79E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.25E-06	15.060	5.036	45.147
Arrowtooth flounder	2.972	0.316	5.36E-21	19.535	10.569	36.541
Black rockfish	0.165	0.297	5.78E-01	1.180	0.659	2.110
Canary rockfish	1.259	0.296	2.14E-05	3.523	1.971	6.304
China rockfish	-0.147	0.295	6.18E-01	0.863	0.484	1.538
Dusky rockfish	0.312	0.293	2.87E-01	1.366	0.769	2.427
Lingcod	1.987	0.301	4.34E-11	7.291	4.047	13.201
Pacific cod	3.674	0.337	9.81E-28	39.423	20.566	77.122
Pacific ocean perch	0.733	0.309	1.77E-02	2.082	1.138	3.826
Quillback rockfish	1.414	0.296	1.72E-06	4.113	2.307	7.355
Redbanded rockfish	1.810	0.301	1.81E-09	6.110	3.393	11.049
Rougheye/Shortraker rockfish	2.117	0.306	4.87E-12	8.309	4.569	15.205
Sablefish	1.958	0.301	8.19E-11	7.089	3.932	12.829
Skates	2.869	0.312	3.78E-20	17.627	9.589	32.624
Sleeper shark	0.864	0.304	4.49E-03	2.372	1.308	4.310
Silvergray rockfish	0.935	0.297	1.62E-03	2.547	1.426	4.567
Spiny dogfish	2.430	0.305	1.67E-15	11.356	6.266	20.744
Thornyhead rockfish	1.422	0.312	5.02E-06	4.144	2.254	7.650
Tiger rockfish	-0.070	0.301	8.16E-01	0.932	0.515	1.682
Walleye pollock	0.169	0.301	5.75E-01	1.184	0.657	2.138
Yelloweye rockfish	2.506	0.303	1.21E-16	12.259	6.792	22.264
Yellowtail rockfish	-0.061	0.299	8.38E-01	0.941	0.522	1.690
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.03E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.14E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.83E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.39E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-0.891	0.431	3.87E-02			
Rarely|Sometimes	0.946	0.430	2.78E-02			
Sometimes|Usually	3.068	0.436	1.89E-12			

Table 2.H.6. Dusky rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.665	1.879	4.51E-05	2,133	54	85561
Eigenvector 2	-1.435	0.773	6.35E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.77E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.25E-06	15.061	5.036	45.146
Arrowtooth flounder	2.662	0.314	2.11E-17	14.323	7.778	26.625
Black rockfish	-0.147	0.295	6.19E-01	0.863	0.484	1.541
Canary rockfish	0.947	0.294	1.29E-03	2.578	1.449	4.596
China rockfish	-0.458	0.293	1.18E-01	0.632	0.355	1.124
Copper rockfish	-0.311	0.293	2.88E-01	0.733	0.412	1.301
Lingcod	1.675	0.299	2.09E-08	5.341	2.978	9.619
Pacific cod	3.363	0.334	7.73E-24	28.889	15.137	56.200
Pacific ocean perch	0.423	0.307	1.69E-01	1.527	0.836	2.792
Quillback rockfish	1.102	0.293	1.73E-04	3.011	1.696	5.362
Redbanded rockfish	1.498	0.299	5.25E-07	4.475	2.495	8.054
Rougheye/Shortraker rockfish	1.807	0.304	2.82E-09	6.091	3.361	11.081
Sablefish	1.647	0.299	3.64E-08	5.190	2.893	9.348
Skates	2.557	0.310	1.45E-16	12.898	7.056	23.771
Sleeper shark	0.552	0.302	6.74E-02	1.737	0.961	3.143
Silvergray rockfish	0.625	0.295	3.40E-02	1.867	1.048	3.330
Spiny dogfish	2.119	0.303	2.50E-12	8.324	4.611	15.114
Thornyhead rockfish	1.111	0.309	3.31E-04	3.037	1.657	5.580
Tiger rockfish	-0.382	0.300	2.03E-01	0.682	0.378	1.229
Walleye pollock	-0.142	0.299	6.36E-01	0.868	0.482	1.561
Yelloweye rockfish	2.194	0.300	2.60E-13	8.975	4.998	16.220
Yellowtail rockfish	-0.373	0.298	2.11E-01	0.689	0.383	1.235
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.03E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.15E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.83E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.39E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-1.202	0.429	5.05E-03			
Rarely|Sometimes	0.635	0.427	1.37E-01			
Sometimes|Usually	2.756	0.432	1.72E-10			

Table 2.H.7. Lingcod

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.648	1.879	4.69E-05	2,097	54	85618
Eigenvector 2	-1.438	0.773	6.28E-02	0.237	0.052	1.084
Eigenvector 3	-3.758	0.637	3.74E-09	0.023	0.007	0.081
Eigenvector 4	2.715	0.559	1.22E-06	15.101	5.035	45.153
Arrowtooth flounder	0.989	0.313	1.59E-03	2.689	1.455	4.973
Black rockfish	-1.824	0.303	1.81E-09	0.161	0.089	0.292
Canary rockfish	-0.728	0.299	1.48E-02	0.483	0.268	0.866
China rockfish	-2.134	0.302	1.61E-12	0.118	0.065	0.214
Copper rockfish	-1.985	0.301	4.45E-11	0.137	0.076	0.247
Dusky rockfish	-1.675	0.299	2.10E-08	0.187	0.104	0.336
Pacific cod	1.689	0.333	3.84E-07	5.412	2.838	10.479
Pacific ocean perch	-1.248	0.313	6.84E-05	0.287	0.154	0.528
Quillback rockfish	-0.573	0.298	5.41E-02	0.564	0.314	1.010
Redbanded rockfish	-0.178	0.301	5.55E-01	0.837	0.464	1.513
Rougheye/Shortraker rockfish	0.132	0.306	6.65E-01	1.142	0.626	2.078
Sablefish	-0.030	0.301	9.21E-01	0.971	0.538	1.755
Skates	0.878	0.309	4.52E-03	2.407	1.319	4.442
Sleeper shark	-1.123	0.307	2.60E-04	0.325	0.178	0.594
Silvergray rockfish	-1.050	0.300	4.68E-04	0.350	0.194	0.629
Spiny dogfish	0.444	0.304	1.44E-01	1.558	0.860	2.830
Thornyhead rockfish	-0.563	0.313	7.23E-02	0.570	0.307	1.050
Tiger rockfish	-2.058	0.309	2.52E-11	0.128	0.070	0.233
Walleye pollock	-1.816	0.307	3.42E-09	0.163	0.089	0.296
Yelloweye rockfish	0.519	0.301	8.45E-02	1.680	0.932	3.036
Yellowtail rockfish	-2.051	0.306	2.19E-11	0.129	0.070	0.234
Hoonah	0.689	0.190	2.85E-04	1.992	1.373	2.890
Juneau	0.536	0.182	3.17E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.05E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.20E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.43E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.34E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.914	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.10E-04	0.678	0.557	0.825
Never|Rarely	-2.876	0.437	4.53E-11			
Rarely|Sometimes	-1.039	0.430	1.58E-02			
Sometimes|Usually	1.082	0.430	1.18E-02			

Table 2.H.8. Pacific cod

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.636	1.879	4.81E-05	2,072	54	85592
Eigenvector 2	-1.444	0.773	6.17E-02	0.236	0.052	1.084
Eigenvector 3	-3.756	0.637	3.81E-09	0.023	0.007	0.081
Eigenvector 4	2.716	0.559	1.20E-06	15.125	5.036	45.148
Arrowtooth flounder	-0.700	0.341	4.02E-02	0.496	0.252	0.964
Black rockfish	-3.510	0.338	3.06E-25	0.030	0.015	0.058
Canary rockfish	-2.416	0.332	3.37E-13	0.089	0.046	0.170
China rockfish	-3.821	0.337	9.67E-30	0.022	0.011	0.042
Copper rockfish	-3.675	0.337	9.66E-28	0.025	0.013	0.049
Dusky rockfish	-3.364	0.334	7.65E-24	0.035	0.018	0.066
Lingcod	-1.688	0.333	3.86E-07	0.185	0.095	0.352
Pacific ocean perch	-2.938	0.346	2.14E-17	0.053	0.027	0.103
Quillback rockfish	-2.261	0.331	8.25E-12	0.104	0.054	0.198
Redbanded rockfish	-1.865	0.333	2.17E-08	0.155	0.080	0.296
Rougheye/Shortraker rockfish	-1.556	0.336	3.69E-06	0.211	0.108	0.405
Sablefish	-1.717	0.333	2.44E-07	0.180	0.093	0.342
Skates	-0.808	0.338	1.68E-02	0.446	0.228	0.862
Sleeper shark	-2.811	0.341	1.58E-16	0.060	0.031	0.116
Silvergray rockfish	-2.739	0.334	2.30E-16	0.065	0.033	0.123
Spiny dogfish	-1.243	0.334	1.95E-04	0.288	0.149	0.551
Thornyhead rockfish	-2.251	0.345	6.40E-11	0.105	0.053	0.205
Tiger rockfish	-3.746	0.343	9.43E-28	0.024	0.012	0.046
Walleye pollock	-3.504	0.342	1.17E-24	0.030	0.015	0.058
Yelloweye rockfish	-1.168	0.331	4.18E-04	0.311	0.161	0.591
Yellowtail rockfish	-3.737	0.341	5.96E-28	0.024	0.012	0.046
Hoonah	0.689	0.190	2.83E-04	1.992	1.373	2.890
Juneau	0.537	0.182	3.15E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.19E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.43E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.39E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.54E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-4.562	0.462	5.84E-23			
Rarely|Sometimes	-2.725	0.455	2.20E-09			
Sometimes|Usually	-0.603	0.449	1.79E-01			

Table 2.H.9. Pacific ocean perch

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.665	1.879	4.51E-05	2,132	54	85567
Eigenvector 2	-1.435	0.773	6.34E-02	0.238	0.052	1.084
Eigenvector 3	-3.756	0.637	3.78E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.25E-06	15.060	5.036	45.146
Arrowtooth flounder	2.238	0.327	7.30E-12	9.379	4.963	17.881
Black rockfish	-0.570	0.311	6.70E-02	0.565	0.307	1.040
Canary rockfish	0.524	0.309	8.99E-02	1.689	0.921	3.097
China rockfish	-0.882	0.309	4.37E-03	0.414	0.225	0.759
Copper rockfish	-0.734	0.309	1.76E-02	0.480	0.261	0.879
Dusky rockfish	-0.423	0.307	1.69E-01	0.655	0.358	1.196
Lingcod	1.252	0.313	6.44E-05	3.498	1.897	6.478
Pacific cod	2.940	0.346	2.04E-17	18.916	9.673	37.662
Quillback rockfish	0.679	0.309	2.77E-02	1.972	1.078	3.615
Redbanded rockfish	1.075	0.313	5.91E-04	2.931	1.588	5.422
Rougheye/Shortraker rockfish	1.383	0.318	1.37E-05	3.987	2.141	7.456
Sablefish	1.224	0.313	9.36E-05	3.401	1.841	6.294
Skates	2.133	0.323	3.87E-11	8.443	4.500	15.970
Sleeper shark	0.128	0.317	6.86E-01	1.137	0.611	2.119
Silvergray rockfish	0.201	0.310	5.16E-01	1.223	0.666	2.246
Spiny dogfish	1.696	0.316	8.37E-08	5.452	2.937	10.166
Thornyhead rockfish	0.688	0.324	3.37E-02	1.989	1.055	3.756
Tiger rockfish	-0.806	0.316	1.08E-02	0.447	0.240	0.829
Walleye pollock	-0.565	0.315	7.29E-02	0.568	0.306	1.054
Yelloweye rockfish	1.771	0.314	1.69E-08	5.879	3.183	10.912
Yellowtail rockfish	-0.797	0.314	1.12E-02	0.451	0.243	0.834
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.443
Petersburg	0.890	0.140	2.04E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.15E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.83E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.39E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-1.625	0.441	2.30E-04			
Rarely|Sometimes	0.211	0.438	6.29E-01			
Sometimes|Usually	2.333	0.442	1.27E-07			

Table 2.H.10. Quillback rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.663	1.879	4.53E-05	2,129	54	85571
Eigenvector 2	-1.435	0.773	6.34E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.77E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.24E-06	15.065	5.036	45.147
Arrowtooth flounder	1.559	0.311	5.22E-07	4.756	2.594	8.783
Black rockfish	-1.248	0.298	2.74E-05	0.287	0.160	0.513
Canary rockfish	-0.156	0.294	5.96E-01	0.856	0.481	1.524
China rockfish	-1.561	0.296	1.37E-07	0.210	0.117	0.375
Copper rockfish	-1.414	0.296	1.72E-06	0.243	0.136	0.434
Dusky rockfish	-1.102	0.293	1.72E-04	0.332	0.186	0.590
Lingcod	0.574	0.298	5.39E-02	1.775	0.990	3.182
Pacific cod	2.261	0.331	8.27E-12	9.593	5.054	18.532
Pacific ocean perch	-0.679	0.309	2.78E-02	0.507	0.277	0.928
Redbanded rockfish	0.397	0.298	1.82E-01	1.487	0.829	2.665
Rougheye/Shortraker rockfish	0.704	0.302	1.99E-02	2.022	1.118	3.663
Sablefish	0.546	0.298	6.67E-02	1.726	0.962	3.092
Skates	1.454	0.307	2.16E-06	4.279	2.353	7.843
Sleeper shark	-0.551	0.303	6.89E-02	0.577	0.318	1.044
Silvergray rockfish	-0.478	0.295	1.05E-01	0.620	0.347	1.106
Spiny dogfish	1.017	0.301	7.13E-04	2.765	1.536	4.993
Thornyhead rockfish	0.009	0.309	9.78E-01	1.009	0.550	1.849
Tiger rockfish	-1.485	0.303	9.49E-07	0.227	0.125	0.410
Walleye pollock	-1.244	0.302	3.73E-05	0.288	0.159	0.520
Yelloweye rockfish	1.093	0.298	2.44E-04	2.982	1.665	5.357
Yellowtail rockfish	-1.476	0.301	9.22E-07	0.229	0.126	0.411
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.15E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.83E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.39E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-2.304	0.432	9.87E-08			
Rarely|Sometimes	-0.467	0.427	2.74E-01			
Sometimes|Usually	1.654	0.429	1.15E-04			

Table 2.H.11. Redbanded rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.660	1.879	4.56E-05	2,122	54	85565
Eigenvector 2	-1.436	0.773	6.33E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.77E-09	0.023	0.007	0.081
Eigenvector 4	2.713	0.559	1.24E-06	15.071	5.036	45.146
Arrowtooth flounder	1.164	0.314	2.07E-04	3.201	1.736	5.942
Black rockfish	-1.645	0.303	5.58E-08	0.193	0.106	0.349
Canary rockfish	-0.551	0.299	6.49E-02	0.576	0.321	1.034
China rockfish	-1.957	0.302	8.71E-11	0.141	0.078	0.255
Copper rockfish	-1.810	0.301	1.82E-09	0.164	0.091	0.295
Dusky rockfish	-1.498	0.299	5.28E-07	0.224	0.124	0.401
Lingcod	0.177	0.301	5.57E-01	1.193	0.661	2.157
Pacific cod	1.865	0.333	2.18E-08	6.456	3.384	12.524
Pacific ocean perch	-1.075	0.313	5.94E-04	0.341	0.184	0.630
Quillback rockfish	-0.396	0.298	1.84E-01	0.673	0.375	1.206
Rougheye/Shortraker rockfish	0.308	0.306	3.13E-01	1.361	0.747	2.481
Sablefish	0.148	0.301	6.23E-01	1.160	0.642	2.095
Skates	1.059	0.310	6.34E-04	2.882	1.574	5.307
Sleeper shark	-0.946	0.307	2.09E-03	0.388	0.212	0.708
Silvergray rockfish	-0.874	0.300	3.56E-03	0.417	0.231	0.750
Spiny dogfish	0.621	0.304	4.11E-02	1.860	1.026	3.380
Thornyhead rockfish	-0.387	0.313	2.16E-01	0.679	0.367	1.254
Tiger rockfish	-1.881	0.308	1.03E-09	0.152	0.083	0.278
Walleye pollock	-1.640	0.307	9.09E-08	0.194	0.106	0.353
Yelloweye rockfish	0.696	0.301	2.08E-02	2.006	1.113	3.627
Yellowtail rockfish	-1.872	0.306	9.63E-10	0.154	0.084	0.280
Hoonah	0.689	0.190	2.86E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.16E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.38E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-2.700	0.436	5.73E-10			
Rarely|Sometimes	-0.863	0.430	4.45E-02			
Sometimes|Usually	1.258	0.430	3.41E-03			

Table 2.H.12. Rougheye/Shortraker rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.654	1.879	4.63E-05	2,109	54	85569
Eigenvector 2	-1.438	0.773	6.28E-02	0.237	0.052	1.084
Eigenvector 3	-3.757	0.637	3.78E-09	0.023	0.007	0.081
Eigenvector 4	2.714	0.559	1.23E-06	15.086	5.036	45.146
Arrowtooth flounder	0.855	0.317	6.98E-03	2.352	1.266	4.393
Black rockfish	-1.954	0.308	2.33E-10	0.142	0.077	0.259
Canary rockfish	-0.859	0.303	4.66E-03	0.424	0.233	0.767
China rockfish	-2.265	0.307	1.67E-13	0.104	0.057	0.189
Copper rockfish	-2.118	0.306	4.77E-12	0.120	0.066	0.219
Dusky rockfish	-1.806	0.304	2.86E-09	0.164	0.090	0.297
Lingcod	-0.132	0.306	6.66E-01	0.877	0.481	1.597
Pacific cod	1.557	0.336	3.67E-06	4.743	2.471	9.253
Pacific ocean perch	-1.383	0.318	1.38E-05	0.251	0.134	0.467
Quillback rockfish	-0.703	0.302	2.01E-02	0.495	0.273	0.894
Redbanded rockfish	-0.308	0.306	3.14E-01	0.735	0.403	1.338
Sablefish	-0.160	0.306	6.01E-01	0.852	0.468	1.552
Skates	0.750	0.313	1.67E-02	2.117	1.148	3.925
Sleeper shark	-1.255	0.312	5.91E-05	0.285	0.154	0.525
Silvergray rockfish	-1.183	0.305	1.05E-04	0.306	0.168	0.557
Spiny dogfish	0.312	0.308	3.11E-01	1.366	0.748	2.502
Thornyhead rockfish	-0.695	0.318	2.86E-02	0.499	0.267	0.929
Tiger rockfish	-2.189	0.314	2.92E-12	0.112	0.060	0.207
Walleye pollock	-1.948	0.312	4.39E-10	0.142	0.077	0.262
Yelloweye rockfish	0.388	0.305	2.04E-01	1.473	0.811	2.685
Yellowtail rockfish	-2.180	0.311	2.60E-12	0.113	0.061	0.208
Hoonah	0.689	0.190	2.86E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.17E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.17E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.37E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.54E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-3.007	0.439	7.51E-12			
Rarely|Sometimes	-1.171	0.433	6.85E-03			
Sometimes|Usually	0.951	0.431	2.75E-02			

Table 2.H.13. Sablefish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.659	1.879	4.57E-05	2,121	54	85570
Eigenvector 2	-1.436	0.773	6.32E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.77E-09	0.023	0.007	0.081
Eigenvector 4	2.713	0.559	1.24E-06	15.073	5.036	45.146
Arrowtooth flounder	1.015	0.313	1.19E-03	2.760	1.497	5.118
Black rockfish	-1.794	0.303	3.36E-09	0.166	0.092	0.301
Canary rockfish	-0.699	0.299	1.92E-02	0.497	0.276	0.892
China rockfish	-2.105	0.302	3.25E-12	0.122	0.067	0.220
Copper rockfish	-1.958	0.301	8.25E-11	0.141	0.078	0.254
Dusky rockfish	-1.646	0.299	3.66E-08	0.193	0.107	0.346
Lingcod	0.028	0.301	9.25E-01	1.029	0.570	1.858
Pacific cod	1.717	0.333	2.47E-07	5.566	2.921	10.785
Pacific ocean perch	-1.223	0.313	9.46E-05	0.294	0.159	0.543
Quillback rockfish	-0.544	0.298	6.76E-02	0.580	0.323	1.040
Redbanded rockfish	-0.148	0.301	6.23E-01	0.862	0.477	1.557
Rougheye/Shortraker rockfish	0.160	0.306	6.00E-01	1.174	0.644	2.138
Skates	0.910	0.309	3.27E-03	2.484	1.358	4.571
Sleeper shark	-1.094	0.307	3.73E-04	0.335	0.183	0.611
Silvergray rockfish	-1.022	0.300	6.57E-04	0.360	0.199	0.647
Spiny dogfish	0.472	0.304	1.20E-01	1.604	0.885	2.912
Thornyhead rockfish	-0.536	0.313	8.71E-02	0.585	0.316	1.081
Tiger rockfish	-2.029	0.309	4.87E-11	0.131	0.072	0.240
Walleye pollock	-1.788	0.307	5.92E-09	0.167	0.091	0.305
Yelloweye rockfish	0.548	0.301	6.88E-02	1.729	0.960	3.125
Yellowtail rockfish	-2.020	0.307	4.44E-11	0.133	0.073	0.241
Hoonah	0.689	0.190	2.86E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.442
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.16E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.37E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-2.848	0.436	6.51E-11			
Rarely|Sometimes	-1.012	0.429	1.85E-02			
Sometimes|Usually	1.110	0.429	9.68E-03			

Table 2.H.14. Skates

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.662	1.879	4.54E-05	2,127	54	85581
Eigenvector 2	-1.436	0.773	6.33E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.77E-09	0.023	0.007	0.081
Eigenvector 4	2.713	0.559	1.24E-06	15.069	5.035	45.148
Arrowtooth flounder	0.105	0.319	7.43E-01	1.111	0.594	2.080
Black rockfish	-2.704	0.314	6.81E-18	0.067	0.036	0.123
Canary rockfish	-1.609	0.308	1.73E-07	0.200	0.109	0.365
China rockfish	-3.016	0.313	5.37E-22	0.049	0.026	0.090
Copper rockfish	-2.867	0.312	4.05E-20	0.057	0.031	0.104
Dusky rockfish	-2.557	0.310	1.46E-16	0.078	0.042	0.142
Lingcod	-0.881	0.309	4.39E-03	0.414	0.225	0.758
Pacific cod	0.807	0.338	1.70E-02	2.240	1.160	4.376
Pacific ocean perch	-2.134	0.323	3.84E-11	0.118	0.063	0.222
Quillback rockfish	-1.455	0.307	2.12E-06	0.233	0.127	0.425
Redbanded rockfish	-1.058	0.310	6.39E-04	0.347	0.188	0.635
Rougheye/Shortraker rockfish	-0.750	0.313	1.67E-02	0.472	0.255	0.871
Sablefish	-0.909	0.309	3.30E-03	0.403	0.219	0.737
Sleeper shark	-2.007	0.317	2.49E-10	0.134	0.072	0.250
Silvergray rockfish	-1.933	0.310	4.37E-10	0.145	0.079	0.265
Spiny dogfish	-0.438	0.311	1.59E-01	0.645	0.350	1.186
Thornyhead rockfish	-1.446	0.322	6.96E-06	0.236	0.125	0.441
Tiger rockfish	-2.938	0.319	3.29E-20	0.053	0.028	0.098
Walleye pollock	-2.700	0.318	1.98E-17	0.067	0.036	0.125
Yelloweye rockfish	-0.363	0.308	2.38E-01	0.695	0.380	1.273
Yellowtail rockfish	-2.929	0.317	2.39E-20	0.053	0.029	0.099
Hoonah	0.689	0.190	2.86E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.17E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.03E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.16E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.37E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-3.759	0.446	3.66E-17			
Rarely|Sometimes	-1.922	0.439	1.21E-05			
Sometimes|Usually	0.199	0.435	6.47E-01			

Table 2.H.15. Sleeper shark

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.664	1.879	4.52E-05	2,130	54	85573
Eigenvector 2	-1.435	0.773	6.34E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.77E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.24E-06	15.064	5.036	45.147
Arrowtooth flounder	2.110	0.321	4.93E-11	8.251	4.411	15.545
Black rockfish	-0.699	0.306	2.24E-02	0.497	0.272	0.905
Canary rockfish	0.395	0.304	1.94E-01	1.484	0.819	2.694
China rockfish	-1.011	0.304	9.00E-04	0.364	0.200	0.660
Copper rockfish	-0.864	0.304	4.49E-03	0.422	0.232	0.765
Dusky rockfish	-0.552	0.302	6.74E-02	0.576	0.318	1.041
Lingcod	1.123	0.307	2.61E-04	3.073	1.685	5.629
Pacific cod	2.811	0.341	1.58E-16	16.625	8.597	32.756
Pacific ocean perch	-0.128	0.317	6.87E-01	0.880	0.472	1.637
Quillback rockfish	0.550	0.303	6.93E-02	1.733	0.958	3.142
Redbanded rockfish	0.946	0.307	2.09E-03	2.575	1.412	4.714
Rougheye/Shortraker rockfish	1.254	0.312	5.94E-05	3.505	1.903	6.481
Sablefish	1.094	0.307	3.74E-04	2.986	1.637	5.470
Skates	2.003	0.317	2.68E-10	7.413	4.000	13.884
Silvergray rockfish	0.072	0.304	8.13E-01	1.075	0.592	1.953
Spiny dogfish	1.567	0.311	4.57E-07	4.793	2.612	8.836
Thornyhead rockfish	0.559	0.318	7.89E-02	1.749	0.938	3.266
Tiger rockfish	-0.935	0.311	2.64E-03	0.393	0.213	0.722
Walleye pollock	-0.693	0.310	2.52E-02	0.500	0.272	0.917
Yelloweye rockfish	1.642	0.308	9.77E-08	5.168	2.831	9.482
Yellowtail rockfish	-0.926	0.309	2.71E-03	0.396	0.216	0.725
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.04E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.15E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.83E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.39E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-1.754	0.437	5.94E-05			
Rarely|Sometimes	0.082	0.432	8.49E-01			
Sometimes|Usually	2.204	0.436	4.35E-07			

Table 2.H.16. Silvergray rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.662	1.879	4.54E-05	2,127	54	85569
Eigenvector 2	-1.435	0.773	6.34E-02	0.238	0.052	1.084
Eigenvector 3	-3.756	0.637	3.79E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.24E-06	15.062	5.036	45.147
Arrowtooth flounder	2.037	0.314	8.50E-11	7.664	4.162	14.255
Black rockfish	-0.771	0.299	9.84E-03	0.462	0.257	0.830
Canary rockfish	0.323	0.296	2.76E-01	1.381	0.773	2.469
China rockfish	-1.083	0.297	2.67E-04	0.339	0.189	0.606
Copper rockfish	-0.935	0.297	1.61E-03	0.392	0.219	0.701
Dusky rockfish	-0.624	0.295	3.41E-02	0.536	0.300	0.954
Lingcod	1.051	0.300	4.60E-04	2.861	1.590	5.159
Pacific cod	2.739	0.334	2.30E-16	15.469	8.108	30.066
Pacific ocean perch	-0.203	0.310	5.13E-01	0.817	0.445	1.501
Quillback rockfish	0.478	0.295	1.06E-01	1.613	0.904	2.880
Redbanded rockfish	0.874	0.300	3.56E-03	2.397	1.333	4.320
Rougheye/Shortraker rockfish	1.182	0.305	1.07E-04	3.260	1.796	5.942
Sablefish	1.022	0.300	6.58E-04	2.780	1.545	5.014
Skates	1.934	0.310	4.28E-10	6.915	3.776	12.727
Sleeper shark	-0.072	0.304	8.13E-01	0.930	0.512	1.690
Spiny dogfish	1.495	0.303	8.25E-07	4.457	2.465	8.099
Thornyhead rockfish	0.486	0.311	1.18E-01	1.626	0.884	2.996
Tiger rockfish	-1.006	0.304	9.25E-04	0.366	0.201	0.662
Walleye pollock	-0.767	0.303	1.13E-02	0.465	0.256	0.841
Yelloweye rockfish	1.570	0.301	1.76E-07	4.806	2.673	8.690
Yellowtail rockfish	-0.997	0.302	9.44E-04	0.369	0.204	0.665
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.19E-03	1.709	1.198	2.444
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.15E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.38E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.77E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-1.826	0.431	2.27E-05			
Rarely|Sometimes	0.010	0.427	9.81E-01			
Sometimes|Usually	2.132	0.430	7.15E-07			

Table 2.H.17. Spiny dogfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.660	1.879	4.56E-05	2,122	54	85569
Eigenvector 2	-1.436	0.773	6.32E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.78E-09	0.023	0.007	0.081
Eigenvector 4	2.713	0.559	1.24E-06	15.071	5.036	45.146
Arrowtooth flounder	0.543	0.315	8.44E-02	1.721	0.930	3.197
Black rockfish	-2.266	0.307	1.54E-13	0.104	0.057	0.189
Canary rockfish	-1.172	0.302	1.02E-04	0.310	0.171	0.558
China rockfish	-2.577	0.306	3.55E-17	0.076	0.042	0.138
Copper rockfish	-2.430	0.305	1.64E-15	0.088	0.048	0.160
Dusky rockfish	-2.119	0.303	2.52E-12	0.120	0.066	0.217
Lingcod	-0.444	0.304	1.44E-01	0.642	0.353	1.163
Pacific cod	1.244	0.334	1.93E-04	3.470	1.815	6.733
Pacific ocean perch	-1.695	0.316	8.49E-08	0.184	0.098	0.340
Quillback rockfish	-1.016	0.301	7.21E-04	0.362	0.200	0.651
Redbanded rockfish	-0.620	0.304	4.11E-02	0.538	0.296	0.974
Rougheye/Shortraker rockfish	-0.312	0.308	3.10E-01	0.732	0.400	1.337
Sablefish	-0.472	0.304	1.20E-01	0.624	0.343	1.130
Skates	0.437	0.311	1.60E-01	1.549	0.843	2.856
Sleeper shark	-1.566	0.311	4.61E-07	0.209	0.113	0.383
Silvergray rockfish	-1.495	0.303	8.19E-07	0.224	0.123	0.406
Thornyhead rockfish	-1.008	0.316	1.41E-03	0.365	0.196	0.677
Tiger rockfish	-2.502	0.312	1.12E-15	0.082	0.044	0.151
Walleye pollock	-2.261	0.311	3.58E-13	0.104	0.056	0.191
Yelloweye rockfish	0.075	0.303	8.04E-01	1.078	0.595	1.954
Yellowtail rockfish	-2.492	0.310	9.22E-16	0.083	0.045	0.151
Hoonah	0.689	0.190	2.86E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.16E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.83E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.38E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-3.320	0.439	4.04E-14			
Rarely|Sometimes	-1.484	0.433	6.03E-04			
Sometimes|Usually	0.638	0.430	1.38E-01			

Table 2.H.18. Thornyhead rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.663	1.879	4.53E-05	2,128	54	85460
Eigenvector 2	-1.435	0.773	6.34E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.77E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.24E-06	15.066	5.036	45.146
Arrowtooth flounder	1.551	0.325	1.88E-06	4.715	2.499	8.962
Black rockfish	-1.258	0.313	6.00E-05	0.284	0.153	0.525
Canary rockfish	-0.164	0.310	5.98E-01	0.849	0.462	1.559
China rockfish	-1.569	0.312	4.94E-07	0.208	0.113	0.383
Copper rockfish	-1.422	0.312	5.01E-06	0.241	0.131	0.444
Dusky rockfish	-1.111	0.309	3.32E-04	0.329	0.179	0.603
Lingcod	0.564	0.313	7.15E-02	1.759	0.952	3.253
Pacific cod	2.252	0.345	6.27E-11	9.511	4.877	18.863
Pacific ocean perch	-0.688	0.324	3.36E-02	0.503	0.266	0.948
Quillback rockfish	-0.008	0.309	9.78E-01	0.992	0.541	1.818
Redbanded rockfish	0.388	0.313	2.16E-01	1.473	0.798	2.724
Rougheye/Shortraker rockfish	0.696	0.318	2.85E-02	2.005	1.077	3.742
Sablefish	0.536	0.313	8.69E-02	1.709	0.925	3.161
Skates	1.446	0.322	6.99E-06	4.245	2.266	8.006
Sleeper shark	-0.559	0.318	7.89E-02	0.572	0.306	1.067
Silvergray rockfish	-0.487	0.311	1.18E-01	0.615	0.334	1.131
Spiny dogfish	1.008	0.316	1.41E-03	2.741	1.478	5.100
Tiger rockfish	-1.493	0.318	2.75E-06	0.225	0.120	0.419
Walleye pollock	-1.253	0.317	7.88E-05	0.286	0.153	0.532
Yelloweye rockfish	1.084	0.313	5.39E-04	2.956	1.602	5.474
Yellowtail rockfish	-1.484	0.316	2.70E-06	0.227	0.122	0.421
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.04E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.16E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.38E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.86E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-2.313	0.441	1.52E-07			
Rarely|Sometimes	-0.476	0.436	2.74E-01			
Sometimes|Usually	1.645	0.437	1.65E-04			

Table 2.H.19. Tiger rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.657	1.879	4.59E-05	2,116	54	85574
Eigenvector 2	-1.437	0.773	6.30E-02	0.238	0.052	1.084
Eigenvector 3	-3.758	0.637	3.74E-09	0.023	0.007	0.081
Eigenvector 4	2.714	0.559	1.23E-06	15.084	5.036	45.147
Arrowtooth flounder	3.045	0.323	4.30E-21	21.002	11.197	39.768
Black rockfish	0.235	0.304	4.39E-01	1.265	0.698	2.298
Canary rockfish	1.330	0.303	1.18E-05	3.779	2.088	6.865
China rockfish	-0.077	0.302	8.00E-01	0.926	0.513	1.675
Copper rockfish	0.071	0.301	8.14E-01	1.074	0.595	1.940
Dusky rockfish	0.382	0.300	2.03E-01	1.466	0.814	2.643
Lingcod	2.057	0.309	2.57E-11	7.826	4.285	14.375
Pacific cod	3.746	0.343	9.44E-28	42.355	21.802	83.841
Pacific ocean perch	0.806	0.316	1.08E-02	2.238	1.206	4.165
Quillback rockfish	1.485	0.303	9.53E-07	4.413	2.442	8.012
Redbanded rockfish	1.881	0.308	1.02E-09	6.559	3.593	12.032
Rougheye/Shortraker rockfish	2.189	0.314	2.96E-12	8.922	4.839	16.557
Sablefish	2.029	0.309	4.84E-11	7.610	4.163	13.971
Skates	2.939	0.319	3.20E-20	18.900	10.156	35.512
Sleeper shark	0.935	0.311	2.63E-03	2.548	1.385	4.692
Silvergray rockfish	1.006	0.304	9.23E-04	2.736	1.510	4.973
Spiny dogfish	2.500	0.312	1.16E-15	12.185	6.636	22.586
Thornyhead rockfish	1.493	0.318	2.75E-06	4.451	2.388	8.330
Walleye pollock	0.240	0.308	4.36E-01	1.271	0.696	2.328
Yelloweye rockfish	2.576	0.310	9.06E-17	13.145	7.192	24.244
Yellowtail rockfish	0.009	0.306	9.77E-01	1.009	0.553	1.840
Hoonah	0.689	0.190	2.85E-04	1.992	1.373	2.890
Juneau	0.536	0.182	3.17E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.03E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.17E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.36E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-0.819	0.434	5.91E-02			
Rarely|Sometimes	1.018	0.433	1.89E-02			
Sometimes|Usually	3.139	0.439	8.66E-13			

Table 2.H.20. Walleye pollock

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.664	1.879	4.52E-05	2,130	54	85572
Eigenvector 2	-1.435	0.773	6.34E-02	0.238	0.052	1.084
Eigenvector 3	-3.756	0.637	3.79E-09	0.023	0.007	0.081
Eigenvector 4	2.712	0.559	1.25E-06	15.061	5.036	45.147
Arrowtooth flounder	2.803	0.322	3.01E-18	16.494	8.820	31.174
Black rockfish	-0.005	0.303	9.87E-01	0.995	0.549	1.803
Canary rockfish	1.089	0.302	3.15E-04	2.972	1.644	5.382
China rockfish	-0.316	0.301	2.93E-01	0.729	0.403	1.314
Copper rockfish	-0.169	0.301	5.73E-01	0.844	0.468	1.522
Dusky rockfish	0.142	0.299	6.35E-01	1.153	0.641	2.073
Lingcod	1.817	0.307	3.35E-09	6.154	3.376	11.262
Pacific cod	3.505	0.342	1.14E-24	33.280	17.177	65.728
Pacific ocean perch	0.564	0.315	7.33E-02	1.758	0.949	3.266
Quillback rockfish	1.245	0.302	3.70E-05	3.472	1.923	6.280
Redbanded rockfish	1.640	0.307	9.08E-08	5.156	2.830	9.432
Rougheye/Shortraker rockfish	1.948	0.312	4.41E-10	7.017	3.812	12.977
Sablefish	1.789	0.307	5.89E-09	5.982	3.280	10.951
Skates	2.699	0.318	1.99E-17	14.872	8.001	27.836
Sleeper shark	0.694	0.310	2.50E-02	2.002	1.091	3.678
Silvergray rockfish	0.766	0.303	1.14E-02	2.151	1.189	3.899
Spiny dogfish	2.260	0.311	3.64E-13	9.583	5.227	17.704
Thornyhead rockfish	1.252	0.317	7.91E-05	3.499	1.882	6.531
Tiger rockfish	-0.240	0.308	4.35E-01	0.787	0.429	1.437
Yelloweye rockfish	2.337	0.308	3.53E-14	10.349	5.668	18.999
Yellowtail rockfish	-0.232	0.306	4.48E-01	0.793	0.435	1.444
Hoonah	0.689	0.190	2.87E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.19E-03	1.709	1.198	2.444
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.14E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.83E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.39E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-1.060	0.434	1.46E-02			
Rarely|Sometimes	0.777	0.432	7.24E-02			
Sometimes|Usually	2.898	0.438	3.63E-11			

Table 2.H.21. Yelloweye rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.658	1.879	4.58E-05	2,118	54	85569
Eigenvector 2	-1.436	0.773	6.31E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.77E-09	0.023	0.007	0.081
Eigenvector 4	2.713	0.559	1.23E-06	15.077	5.036	45.146
Arrowtooth flounder	0.468	0.312	1.34E-01	1.596	0.867	2.949
Black rockfish	-2.342	0.304	1.43E-14	0.096	0.053	0.174
Canary rockfish	-1.247	0.299	3.02E-05	0.287	0.159	0.515
China rockfish	-2.653	0.303	2.18E-18	0.070	0.039	0.127
Copper rockfish	-2.506	0.303	1.24E-16	0.082	0.045	0.147
Dusky rockfish	-2.194	0.300	2.61E-13	0.111	0.062	0.200
Lingcod	-0.520	0.301	8.41E-02	0.595	0.329	1.072
Pacific cod	1.169	0.331	4.15E-04	3.218	1.692	6.211
Pacific ocean perch	-1.771	0.314	1.71E-08	0.170	0.092	0.314
Quillback rockfish	-1.092	0.298	2.46E-04	0.336	0.187	0.601
Redbanded rockfish	-0.696	0.301	2.08E-02	0.498	0.276	0.899
Rougheye/Shortraker rockfish	-0.388	0.305	2.04E-01	0.679	0.372	1.233
Sablefish	-0.548	0.301	6.84E-02	0.578	0.320	1.042
Skates	0.362	0.308	2.40E-01	1.437	0.786	2.634
Sleeper shark	-1.642	0.308	9.86E-08	0.194	0.105	0.353
Silvergray rockfish	-1.571	0.301	1.74E-07	0.208	0.115	0.374
Spiny dogfish	-0.076	0.303	8.03E-01	0.927	0.512	1.680
Thornyhead rockfish	-1.083	0.313	5.43E-04	0.338	0.183	0.624
Tiger rockfish	-2.577	0.310	8.92E-17	0.076	0.041	0.139
Walleye pollock	-2.336	0.308	3.60E-14	0.097	0.053	0.176
Yellowtail rockfish	-2.567	0.308	7.09E-17	0.077	0.042	0.140
Hoonah	0.689	0.190	2.86E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.18E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.04E-10	2.435	1.853	3.208
Vessel length	0.027	0.005	5.16E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.37E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.915	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-3.396	0.437	7.38E-15			
Rarely|Sometimes	-1.559	0.430	2.85E-04			
Sometimes|Usually	0.562	0.427	1.88E-01			

Table 2.H.22. Yellowtail rockfish

Explanatory Variables	Coef. Values	Std. Error	p-value	OR	Conf. Intervals 2.5%	97.5%
Eigenvector 1	7.658	1.879	4.58E-05	2,117	54	85622
Eigenvector 2	-1.437	0.773	6.31E-02	0.238	0.052	1.084
Eigenvector 3	-3.757	0.637	3.76E-09	0.023	0.007	0.081
Eigenvector 4	2.713	0.559	1.23E-06	15.080	5.035	45.154
Arrowtooth flounder	3.038	0.321	2.91E-21	20.869	11.141	39.253
Black rockfish	0.225	0.302	4.57E-01	1.252	0.694	2.269
Canary rockfish	1.319	0.301	1.21E-05	3.741	2.077	6.778
China rockfish	-0.086	0.300	7.73E-01	0.917	0.510	1.653
Copper rockfish	0.062	0.299	8.35E-01	1.064	0.592	1.915
Dusky rockfish	0.373	0.298	2.11E-01	1.452	0.810	2.609
Lingcod	2.048	0.306	2.30E-11	7.754	4.265	14.189
Pacific cod	3.737	0.341	6.06E-28	41.964	21.694	82.761
Pacific ocean perch	0.801	0.314	1.08E-02	2.227	1.200	4.112
Quillback rockfish	1.475	0.301	9.40E-07	4.369	2.430	7.908
Redbanded rockfish	1.872	0.306	9.53E-10	6.501	3.575	11.878
Rougheye/Shortraker rockfish	2.181	0.311	2.51E-12	8.857	4.815	16.343
Sablefish	2.020	0.307	4.38E-11	7.541	4.143	13.791
Skates	2.926	0.317	2.55E-20	18.657	10.107	35.048
Sleeper shark	0.926	0.309	2.71E-03	2.525	1.378	4.631
Silvergray rockfish	0.998	0.302	9.39E-04	2.712	1.503	4.909
Spiny dogfish	2.492	0.310	9.36E-16	12.080	6.603	22.295
Thornyhead rockfish	1.486	0.316	2.66E-06	4.417	2.377	8.223
Tiger rockfish	-0.010	0.306	9.74E-01	0.990	0.543	1.808
Walleye pollock	0.233	0.306	4.47E-01	1.262	0.693	2.298
Yelloweye rockfish	2.565	0.308	7.31E-17	13.007	7.157	23.927
Hoonah	0.689	0.190	2.86E-04	1.991	1.373	2.890
Juneau	0.536	0.182	3.17E-03	1.710	1.198	2.444
Petersburg	0.890	0.140	2.03E-10	2.436	1.853	3.208
Vessel length	0.027	0.005	5.17E-08	1.027	1.017	1.037
Years of experience	-0.018	0.007	1.42E-02	0.982	0.969	0.996
Age	0.006	0.007	3.84E-01	1.006	0.993	1.019
Conventional gear	-0.560	0.139	5.38E-05	0.571	0.435	0.749
Combo fishing	-0.089	0.125	4.76E-01	0.914	0.715	1.169
Spring fishing	-0.050	0.124	6.85E-01	0.951	0.745	1.213
Summer fishing	0.107	0.115	3.53E-01	1.113	0.888	1.396
Fall fishing	-0.389	0.100	1.09E-04	0.678	0.557	0.825
Never|Rarely	-0.828	0.432	5.52E-02			
Rarely|Sometimes	1.009	0.432	1.95E-02			
Sometimes|Usually	3.130	0.437	7.93E-13			

Chapter 3 Using preferences of fishermen to inform decision making in the Pacific halibut (*Hippoglossus stenolepis*) fishery off Alaska[1]

Abstract

Decision-making in commercial fisheries management takes place in the context of uncertainty. One way of addressing uncertainty is to collect information about preferred management actions directly from fishermen. We interviewed Pacific halibut fishermen in four communities across Southeast Alaska, in order to document their preferences about different types of data collection methods on their vessels. We evaluated whether it was possible to gather reliable preference data from a relatively small group of fishermen for conducting decision analysis in a fleet using one event of semistructured one-on-one interviewing. Pairwise comparisons from interviews were analyzed using the analytic hierarchy process. Results shed light on how incorporating fishermen's preferences might produce a different preferred solution to the original decision problem of which data collection methods to use in the halibut fleet, as well as how to improve upon adjustments to the existing data collection program.

Introduction

Decision making in commercial fisheries management takes place in the context of uncertainty. Fisheries scientists and managers have made strides in assessing biological uncertainty and adopting management strategies that are robust to the presence of biological uncertainty and environmental variation (Francis and Shotten, 1997; Rice and Richards, 1996; Punt et al., 2014; Punt, 2015). Progress has also been made in the development of methods to

[1] Figus, E. C., and K. R. Criddle. Using preferences of fishermen to inform decision-making in the Pacific halibut (*Hippoglossus stenolepis*) fishery off Alaska. Prepared for submission to *Ocean and Coastal Management.*

document stakeholder perceptions and preferences to incorporate those into the design of management strategies (Hampton and Lackey, 1976; Soma, 2003; Fulton et al., 2011; Wadsworth et al., 2014; Raymond-Yakuobian et al., 2017; Stephenson et al., 2017). However, it remains uncommon for fisheries managers to systematically analyze fishermen's preferences *during* the decision-making process. This may occur because agency personnel are unfamiliar with social science methods (Huntington, 2000), because the human dimensions objectives of a management strategy are undefined (Stephenson et al., 2017), or because the data collection methods such as the public comment process may assign disproportionate weights to input from particular stakeholders (Wadsworth et al., 2014).

Determining the sustainable use of fisheries resources is dependent on multiple objectives held by society (Mardle and Pascoe, 1999). At the same time, different stakeholder groups within a society (e.g., industry, scientists, managers) may hold different preferences, or assign different weights to management objectives (Aanesen et al., 2014). This research explores the possibility of incorporating input directly from a fishing fleet to guide the regulatory decision-making process. The goal of this paper is to present results of a study measuring the support fishermen have for four different methods being considered for collecting data about their catch and discards. We have four specific objectives: (1) Determine the strength of fishermen's ranked preferences between four potential types of data collection on their vessels (called 'alternatives'); (2) Parse the decision problem into a hierarchy of elements with the overall goal at the top, followed by comparisons of the data collection alternatives, and what influenced the preferences fishermen had about each alternative (called 'criteria'), resulting in a preferred solution; (3) Determine the strength of fishermen's preferences across pairwise comparisons of the four data collection alternatives, while considering attributes of fishing operations that may underlie those preferences; and, (4) Determine how well each alternative performs in relation to a suite of criteria that influenced fishermen's preferences. We show that using semistructured interviews (Bernard, 2011), it is possible to gather the information necessary to understand the strength of preferences fishermen have concerning data collection on their vessels, as well as criteria affecting those preferences.

Case Study

The commercial fishery for Pacific halibut involves over 1,000 vessels, most of which are less than 60 feet (18 meters) in length overall (Witherell et al., 2012). The halibut fishery is managed across ten regulatory areas set by the International Pacific Halibut Commission (IPHC; Figure 3.1). For this study, we focused on IPHC regulatory Area 2C, which covers the Southeast Alaska region. Focusing our study in one region allowed us to analyze preferences while controlling for factors that vary across the regulatory areas (e.g., incidental catch/discard regulations). Southeast Alaska includes 28 different communities that land a combined 250-300 million lbs. of fish each year, with an ex-vessel value of about $250 million.

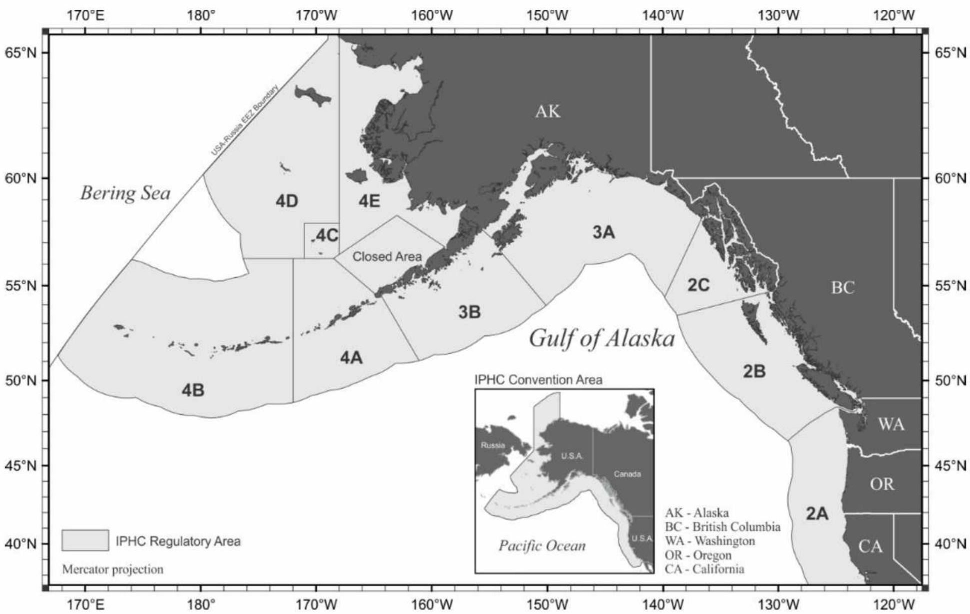


Figure 3.1 IPHC Regulatory Areas (courtesy of IPHC).

In 2013, the North Pacific Fishery Management Council (Council) extended the federal fisheries observer program to include vessels commercially fishing for Pacific halibut (*Hippoglossus stenolepis*) off Alaska (77 FR 70061, 2017). Specifically, the program was extended to incorporate a diverse fleet of mainly small vessels (< 60 ft. length overall) that had previously been excused from participation and to expand observer coverage on vessels > 60 ft. length overall. The Pacific halibut fishery off Alaska is managed under as system of Individual Fishing Quotas with mandatory dockside monitoring of all landings and very low incidence of illegal or unreported catch (NMFS, 2016a). The observer program aims to collect data on catch, bycatch, and discards of fish, interactions with protected species, and biological samples to inform the conservation and management of federal groundfish fisheries (77 FR 70061, 2017). The current system requires that halibut IFQ holders fishing on vessels over 40 feet in length register to be randomly selected to carry a human observer on a trip basis. The observer is carried on the fishing vessel for the duration of a trip, and records characteristics of fishing sets, while keeping a tally of the different species that come up on each hook of the longline gear. In the halibut fishery, the observer program is intended to systematically collect data about undersized halibut and other fish species discarded at sea by halibut fishermen. Expansion of the observer program to small vessels was costly to vessel operators (over $1,000 per day of fishing observed in 2015) and created logistical and operational challenges (NMFS, 2016b). For example, the Alaska Longline Fishermen's Association (ALFA) explained:

> ....our members support at-sea monitoring and are willing to pay a fair share of at-sea monitoring costs.... however, small boats represent 90% of the vessels directly regulated under the new observer program, and placing human observers on these vessels presents special problems (ALFA, 2013).

During the first years of the restructured observer program, exemptions were granted to vessels unable to accommodate observers for reasons related to bunk space and life raft capacity (NMFS, 2015). The large number of these exemptions resulted in data that was not spatially representative across the halibut fleet (NMFS, 2015; NMFS, 2016b), and led to changes in sampling design (e.g., re-organizing deployment categories, such that vessels targeting halibut were subject to carrying observers on a trip-by-trip basis, instead of for months at a time). In addition, the North Pacific Fishery Management Council has made steps to implement an electronic monitoring (EM) alternative for the halibut fleet (82 FR 36991, 2017).

In this case study, we conjectured that systematic *ex ante* analysis of fishermen's preferences might have provided reliable insights into specific characteristics of potential data collection alternatives that were desirable, objectionable, or important, in the judgement of fishermen. This knowledge could have facilitated consideration of additional alternatives with higher likelihoods of meeting program objectives with less disruption to fishing operations and lifestyles, as well as higher levels of acceptance and compliance from the fishing fleet. For this research, we wanted to evaluate whether it was possible to gather preference data from a relatively small group of fishermen for conducting decision analysis in a fleet using one event of semistructured one-on-one interviewing, in order to get a reliable snapshot of preferences across an entire region.

Materials and Methods

We interviewed halibut fishermen in four communities across Southeast Alaska, in order to document their preferences about data collection (Figure 3.2). Three of the communities—Juneau, Petersburg, and Sitka—are the ports with the largest offloads of halibut in the region (Witherell et al., 2012). The fourth community—Hoonah—was chosen as an example small rural coastal community with a strong historical connection to the halibut fishery, but with low participation in the commercial fishery today. During the winter of 2014, we sent a letter to every halibut IFQ holder in the four study communities informing them of our project and inviting them to participate in an interview. Over 100 IFQ holders responded to those letters. We then set up semistructured interviews with respondents who were available to meet during the spring of 2015, and used snowball sampling to recruit other fishermen from the study communities to participate in interviews (Appendix 3.A). Between February and May 2015, we recorded one-on-one interviews with 76 halibut fishermen residing in Juneau, Petersburg, Sitka, and Hoonah (Figure 3.2; Appendix 3.B). Interview sampling was not stratified for demographic characteristics (although information about age, years of fishing experience, gender, ethnicity, and fisheries income was collected). There were not enough responses from underrepresented groups in the interview group to be able to explore subgroup differences beyond age and years of fishing experience in any quantitatively or qualitatively meaningful way. There was, however, ample representation across vessel size categories and fishing operation characteristics to allow for testing of differences in preferences across these variables. After the fact, the interview group was found to comprise an average of 20% of the IFQ shares held by residents across all the study communities. Delineations of quota types—class A, B, C, or D—for the interview group were also reflective of the communities as a whole (see Appendix 3.B).

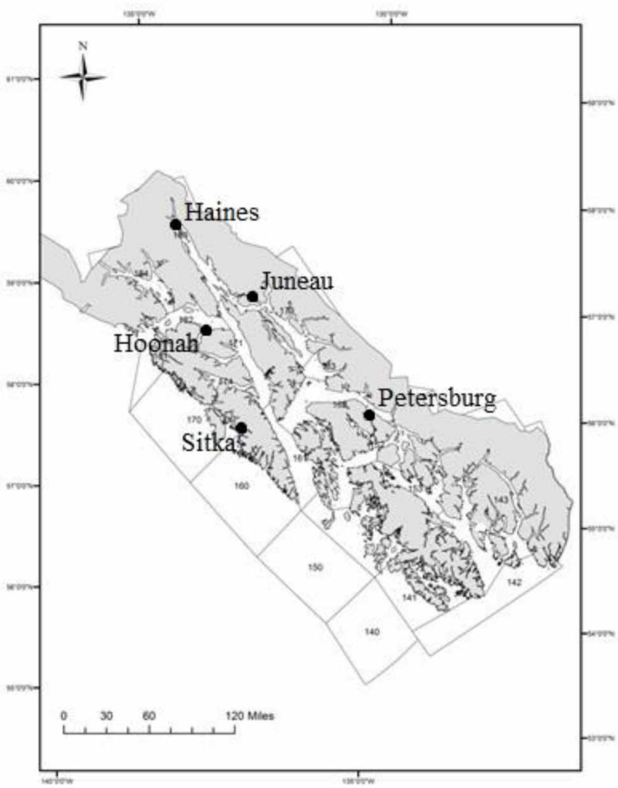


Figure 3.2 Map of Regulatory Area 2C, Southeast Alaska, with study communities labeled (created by corresponding author).

During interviews, fishermen described characteristics of their fishing operations (Appendix 3.B; Appendix 3.C), as well as their preferences about data collection methods on their halibut fishing vessels. Interviewees were asked to carry out basic ranking as well as pairwise comparisons across four alternative methods for data collection: 1) agency-contracted human observers to record everything that comes up on a random sample of hooks; 2) agency specified electronic monitoring using cameras to record everything that comes up on every hook; 3) detailed logbooks (submitted to the management agency), a system where the fisherman would be responsible for recording everything that comes up on every hook; and, 4) status quo ante, meaning maintenance of basic logbook records (submitted to the management agency) as required before the 2013 restructuring of the observer program. The four potential data collection alternatives were developed at the onset of the research and reflect alternatives that might be considered at early stages in the development of regulatory analyses for extension of the observer program to the small-vessel fleet. Categories were general, but meant to elicit responses highlighting overall preferences of the project participants. While ranking and comparing the four alternatives, participants were encouraged to explain what influenced their decisions (called 'criteria'). In other questions, fishermen were asked about their general thoughts concerning the observer program, previous experiences with observers, and data collection more generally (Appendix 3.A). All interviewees completed the rank and compare exercises. We hypothesized that preferences about data collection methods might be related to characteristics of fishing operations. Therefore, we also gathered information on each interviewee's attributes of age and experience, as well as fishing grounds (Appendix 3.D), study community, vessel length, gear type, seasons fished, and whether they also target sablefish (*Anoplopoma fimbria*; Appendix 3.B).

The analytic approach applied in this paper is the Analytic Hierarchy Process (AHP; Saaty, 1980; Saaty, 1990; Saaty 2008), a multiple criteria decision analysis (MCDA) approach to structured decision making. Decision analysis methods have traditionally treated social preferences in terms of an overarching objective such as the maximization of expected monetary benefits subject to a set of technological constraints. This has been recognized as an oversimplification of how individuals or groups might go about making decisions in fisheries management to achieve socially preferred outcomes (McDaniels, 1995; Hilborn, 2007). MCDA, on the other hand, can reflect a plurality of objectives, not all of which can be monetized (Estevez and Gelcich, 2015). For this research, we applied quantitative analytic methods to qualitative data provided by fishermen during semistructured interviews (Bernard, 2011).

AHP is a broadly used decision tool (Vaidya and Kumar, 2006), and has long been recognized as useful in the context of fisheries management (DiNardo et al., 1989; Merritt and Criddle, 1993; Mardle et al., 2004; Himes, 2007), as it solves for policy alternatives that are likely to receive the most support and the least opposition within or across stakeholder groups. AHP was designed for implementation in a series of face-to-face meetings (Saaty, 2001) but can also be carried out using a multiple survey/questionnaire approach (Merritt and Criddle, 1993; Leung et al., 1998; Wadsworth et al., 2014). Instead of meeting or communicating multiple times with groups of fishermen to gather information about their preferences, we developed a protocol for one-time, one-on-one interviews that can be used to determine how different alternatives satisfy criteria that are important to fishermen. As opposed to multiple phases of surveys or meetings, we gathered all of the information needed for running the AHP model in one semistructured interview with each fisherman. A key advantage of one-on-one interviews is that each participant could spend as much time as they wanted answering open-ended questions about the criteria impacting their preferences about data collection on their vessel.

We explored the criteria that influenced the preferences fishermen had, in order to determine how well each alternative performs in relation to those criteria. We defined the suite of criteria through deductive content text analysis (Bernard, 2011), carried out in the Atlas.ti 8 software program (Atlas.ti, 2017; Muhr, 1991). During text analysis recurrent themes were grouped and counted in order to weight each one relative to the number of times it was mentioned. The following quote is one example of a response to the open-ended question relating to how the observer program has affected an interviewee's outlook on the future of the halibut fishery:

> I've seen a lot of changes in a lot of regulations, and -- you know, and I've rolled with them, and I've just reached the point where if now I have to sleep on the floor to go fishing, I just -- I just won't do it.

This quote was identified during text analysis in a code group titled, 'Space.' Text analysis results were then used to expand simple pairwise comparisons into a multilevel AHP model that considers weighted criteria. Finally, weighted criteria for preferences about the alternatives were added into the AHP model. The multilevel AHP represents a structured solution that can be used to explore the underlying basis for preferences. The AHP model results identify the strength of preferences for the four data collection alternatives from the perspective of halibut fishermen interviewed for this research.

The one-on-one interview data were used to structure an AHP decision model. Our AHP model acts as an avenue for parsing the decision problem into a hierarchy with the overall decision problem at the top, followed by comparisons criteria impacting preferences across four alternatives for data collection, and preferences, resulting in a preferred solution (Figure 3.3). First, we assessed the median and mean central tendencies of responses, as well as the spread of responses across the interview group, in order to determine the strength of fishermen's ranked preferences between four data collection alternatives. Then, we analyzed pairwise comparisons from interviews using the AHP. The pairwise comparisons were then mapped into numerical values (weights), which were used to calculate a score for each alternative (Saaty, 1980).

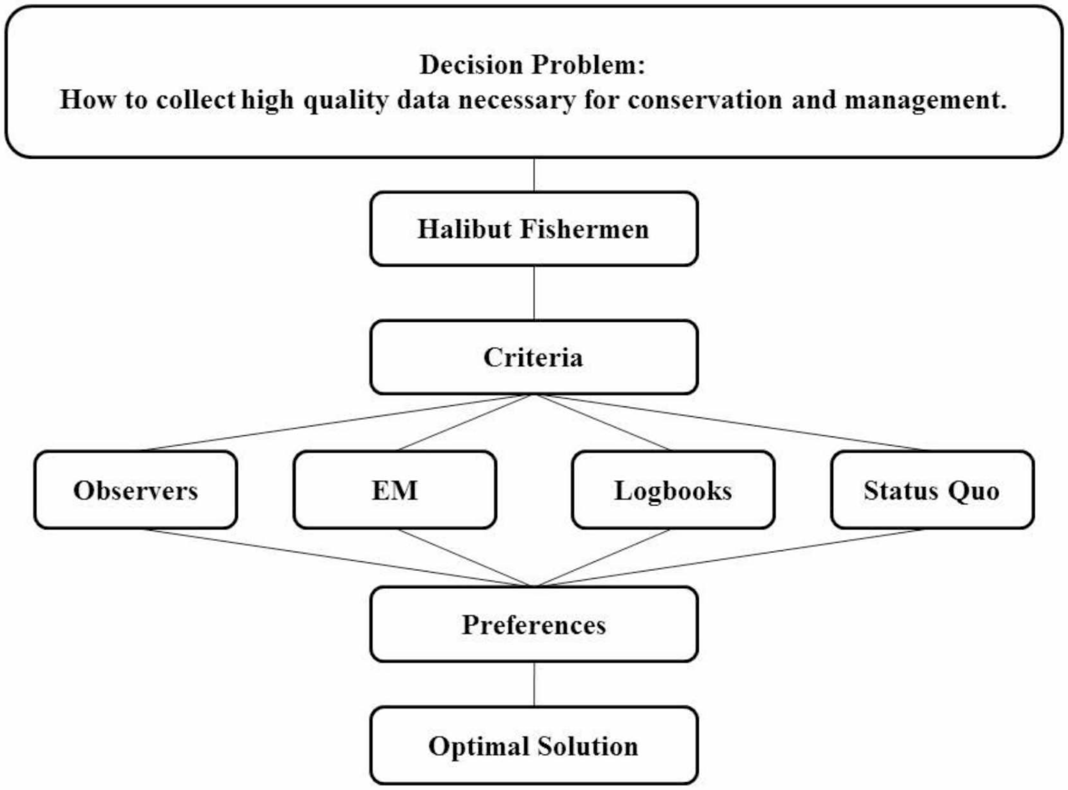


Figure 3.3 Schematic representation of the decision problem addressed in this research, with the overall goal at the top, followed by comparison criteria as they related to four data collection alternatives (observers, EM, logbooks, and the status quo), and preferences, resulting in a preferred solution (based on Saaty, 1990).

For the AHP, we summed the values from pairwise comparisons of each data collection alternative in each column of a pairwise matrix. We then divided each alternative by its column total to generate a normalized pairwise matrix. Then we divided the sum of the normalized column of the matrix by the number of alternatives (n = 4 in this example) used to generate a weighted matrix. We multiplied the pairwise matrix by the weighted matrix, to produce a consistency vector, $\lambda_{\max}$. We calculated a consistency index (CI) from these scores to measure the extent to which the decisions are internally consistent in line with the Independence Axiom (Arrow, 1963; Equation 1). We then produced a consistency ratio (C_r) from the ratio of the CI to a random index[2] (RI) acceptable at values ≤ 10 for our example ($RI = 0.9$ for $n = 4$ alternatives; Saaty, 1990):

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

$$C_r = \frac{CI}{RI} \quad (2)$$

We hypothesized that outcomes from the pairwise comparisons across alternatives might depend on characteristics of fishing operations. Therefore, we examined the sensitivity of our findings across fishing characteristics. We split the interview group into subgroups, in order to explore how preferences measured using pairwise comparisons might shift across attributes of fishing operations. Subgroups included the seven characteristics that were recorded during interviews: age; experience; fishing grounds (Appendix 3.D); study community; vessel length; gear type; seasons fished; and, whether they also target sablefish (Appendix 3.B).

Results and Discussion

Asking fishermen to rank a suite of alternatives provides more information than simply asking them to identify their preferred alternative. Rankings and pairwise comparisons allow them to further identify their perceptions of second-best and third-best alternatives. This can be important to decision-makers who may find convergence on a second-best alternative as more viable than choosing among disparate first-choice alternatives. Asking fishermen to further express their preferences between each pair of alternatives (pairwise comparisons) provides even more information about the strength, or weight, and consistency of those preferences. However,

[2] The random index for this research is a theoretical matrix where the alternatives have been assigned random rankings/comparison values, and therefore is expected to be highly inconsistent (Saaty, 1990).

even pairwise comparisons do not shed light on the basis for preferences. We follow our presentation of simple rankings and pairwise comparisons across the alternatives with presentation of the results of an AHP model. The AHP model identifies a preferred alternative based on fishermen's judgements about the importance of decision criteria and their assessment of the performance of the alternatives in relation to those criteria.

Ranking Alternatives

Rank outputs tended to favor the status quo option, as well as keeping a detailed logbook. This suggests that people were mostly interested in self-reporting[3]. Graphical likert analysis (Figure 3.4) highlighted diversity in responses and showed that a vast majority of interview participants exhibited 'no support' for carrying human observers on their own vessel. Only 22% of interviewees had at least 'some support' for the human observer alternative. In contrast, over 50% of interviewees had at least 'some support' for the other alternatives (status quo: 80%; detailed logbooks: 72%; and, electronic monitoring: 54%)

[3] Vessels in this fishery are subject to random boarding at sea by U.S. Coast Guard or NOAA Enforcement officers. During the inspections, among other things, the boarding officers review permits, logbook entries, and retained catch.

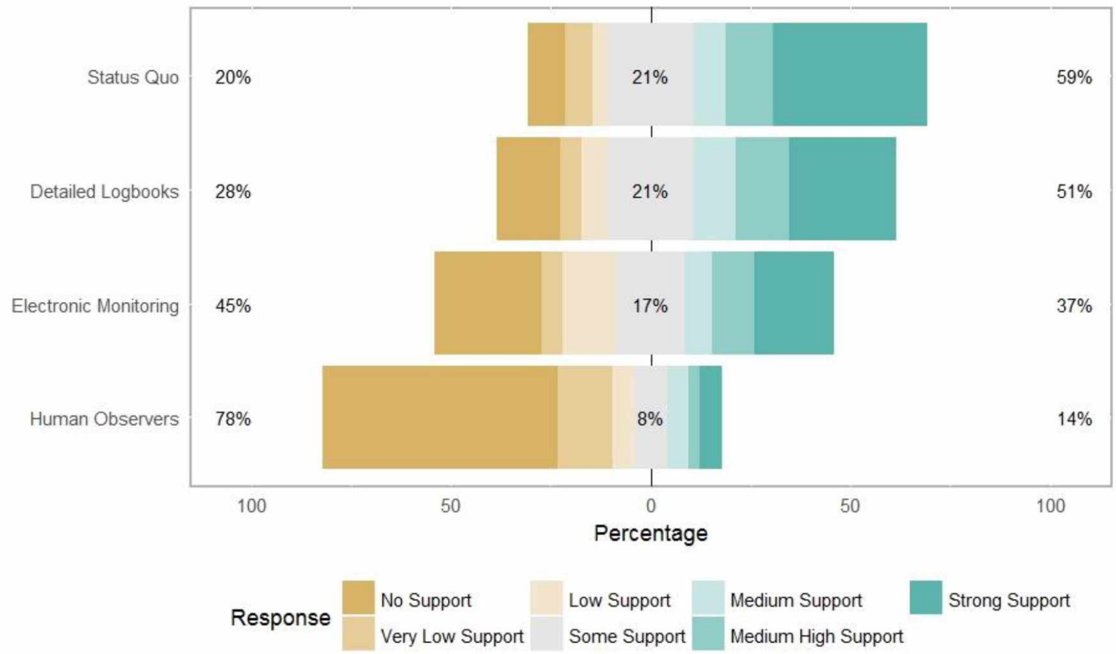


Figure 3.4 Likert analysis of rankings data across human observers, electronic monitoring, detailed logbooks, and the status quo alternatives for data collection at sea, from semistructured interviews (*n* = 75). This graphic was created using the 'likert' package (Bryer and Speerschneider, 2016) in the R software program (R Core Team, 2016).

For each alternative, at least one interviewee assigned 'no support' or 'strong support' (see Minimum and Maximum values in Table 3.1). However, mean and median rank values (Table 3.1) both show that interviewees had strong preferences towards the status quo alternative and away from carrying human observers. Further, mean and median values for the interview groups as a whole both show 'low support' or 'no support' for human observers, while the other three alternatives received at least 'some support' (status quo: 5-6 out of 7; detailed logbooks: 4.5-5 out of 7; and, electronic monitoring: 3.8-4 out of 7).

Table 3.1 Summary of basic rankings across four alternatives for data collection (*n* = 75) across human observers ('Observers'), electronic monitoring ('EM'), detailed logbooks ('Logbooks'), and the status quo ('Status Quo') alternatives for data collection at sea. Numbers represent categories of support ranging from 1 to 7, with 1 being 'no support' and 7 being 'strong support.' A value of 4 represents 'some support.' Median is a measure of central tendency less sensitive to outliers than is the arithmetic mean.

	Observers	EM	Logbooks	Status Quo
Minimum	1.0	1.00	1.00	1.00
1st Quartile	1.0	1.00	3.00	4.00
Median	1.0	4.00	5.00	6.00
	(no support)	(some support)	(medium support)	(high support)
Mean	2.2	3.84	4.52	5.03
3rd Quartile	3.0	6.00	7.00	7.00
Maximum	7.0	7.00	7.00	7.00

Pairwise Comparisons

Analysis of pairwise comparisons produced straightforward results that were extremely consistent. Results of simple pairwise comparisons produced the highest amount of support for status quo, followed by detailed logbooks, then electronic monitoring, and finally human observers (Table 3.2). The consistency ratio for pairwise comparisons across the four alternatives was 1%, indicating extremely consistent preferences (Saaty (1990) explains that if the value of the consistency ratio is smaller or equal to 10%, the inconsistency is acceptable). This result may be due, in part, to a tendency towards consistent and extreme preferences across the pairwise comparisons (e.g., interviewees commonly chose a value near the end of either side of the comparison spectrum). These results implied the strong and consistent support for the data collection option that produced the least amount of change or disruption in the lives of halibut fishermen.

Table 3.2 AHP using the geometric mean, across pairwise comparisons of human observers ('Observers'), electronic monitoring ('EM'), detailed logbooks ('Logbooks'), and the status quo ('Status Quo') alternatives for data collection at sea.

	Observers	EM	Logbooks	Status Quo	Scores	Consistency Measure
Observers	0.08	0.06	0.08	0.10	0.08	4.01
EM	0.24	0.18	0.19	0.16	0.19	4.03
Logbooks	0.33	0.31	0.33	0.33	0.32	4.03
Status Quo	0.34	0.45	0.41	0.41	0.40	4.05
Scores	0.25	0.25	0.25	0.25	1.00	
Consistency Ratio						0.01

At the same time, certain fisherman in the interview group indicated strong support for human observers. Fishermen who ranked observers highly explained their preferences in a number of ways:

> When we're fishing halibut we have more room because we don't have the racks in for the black cod gear. So we have room then for them to do their samples and we can, you know, accommodate them a hell of a lot easier. (Interviewee who indicated strong support for observers.)
>
> …one observer trip…. It was great. He bonded well with the crew, wasn't in the way at all. Good personality. Didn't -- yeah, didn't get in the way. (Interviewee who indicated strong support for observers.)
>
> I sort of like having someone keeping track of what's going on out there, a scientist who can like keep track of the health of the whole environment, because it all affects each other. (Interviewee who indicated strong support for observers.)

We wondered if the stronger acceptance of human observers among interviewees with longer vessels might be correlated with their prior experience with onboard observers in other fisheries. So we tested the sensitivity of results from pairwise comparisons in the full interview group across subgroups of interviews clustered on demographic and fishing characteristics. Seven demographic and fishing characteristics were assessed across subgroups, including: season(s) fished out of 3 possible seasons; gear type used; whether or not they combo fish; community of residence out of 4 possible communities; under/over median age, vessel length, or years of experience; and, vessel length cutoffs at 40 ft., 55 ft., and 60 ft. (Appendix 3.B; Appendix 3.C). There were no evident differences among these subgroups except for interviewees who fished on vessels over 55 feet in length. Interviewees who fished on vessels over 55 feet in length had more than twice the support for human observers (Table 3.3).

Table 3.3 Weight of preference among full interview group compared with subgroup of interviewees fishing on vessels greater than 55 feet in length, across human observers ('Observers'), electronic monitoring ('EM'), detailed logbooks ('Logbooks'), and the status quo ('Status Quo') alternatives for data collection at sea.

	Full Group (*n* = 75)	Vessels > 55ft. (*n* = 13)
Observers	0.08	0.17
EM	0.19	0.23
Logbooks	0.32	0.28
Status Quo	0.40	0.32
Consistency Ratio	0.01	0.00

However, chi-square and ANOVA tests comparing vessel length and previous experiences with human observers were not statistically significant. Eleven interviewees preferred human observers to electronic monitoring, six preferred humans to detailed logbooks, and eight preferred humans to the status quo. However, the interviewees that indicated a preference for humans were mixed in terms of vessel length. This suggests that vessel size may simply reflect a lower opportunity cost of space needed to accommodate a non-contributing extra person onboard the larger vessels.

The three pairwise comparisons of data collection alternatives that included human observers had higher coefficients of variation than the three other pairwise comparisons (Table 3.4). Higher coefficients of variation indicated greater levels of disagreement among interview participants about carrying human observers, as compared with preferences about the three other data collection methods (a coefficient of variation equal to zero would indicate complete consensus among interviewees).

Table 3.4 Coefficient of variation across six pairwise comparisons of human observers ('Obs.'), electronic monitoring ('EM'), detailed logbooks ('Log'), and the status quo ('SQ') alternatives for data collection at sea.

Pairwise Comparison	Obs.-EM	Obs.-Log	Obs.-SQ	EM-Log	EM-SQ	Log-SQ
Coefficient of Variation	1.85	2.21	2.15	1.42	1.66	1.14

Nevertheless, the order of preferences for data collection alternatives was consistent and clear across the interview group as a whole. While interesting, these results do not shed light on how the four data collection alternatives would compare if a decision were focused on specific criteria. For example, it is clear that project participants preferred the status quo alternative overall, but how might they feel if they were asked to choose the most accurate data collection strategy, or the least intrusive one?

Criteria

Questions like the one posed above can be answered by incorporating an understanding of what criteria affect preferences fishermen have about each data collection alternative. Criteria affecting preferences of fishermen were extracted from interview transcripts using the inductive coding method of text analysis (Bernard, 2011). Interviews were coded into six code groups and 58 total codes. Codes for each alternative were cross-referenced with 33 codes related to preference criteria (Appendix 3.D). The list of 33 codes related to 16 criteria themes and were assigned positive, negative, or neutral values (Appendix 3.D). For example, if an interviewee cited space as an important consideration when thinking about an alternative, but did not accompany that statement with a directional qualifier, that portion of their transcript was coded simply as ‘Space.’ If an interviewee cited an alternative as taking up too much space, that portion of their transcript was coded as ‘Space -,’ in relation to the given alternative. An example of a description of space with a negative qualifier for the human observer alternative would be:

> Q: Is there any other way that this observer program has affected your outlook on the future of the halibut fishery?
> A: I’ve seen a lot of changes in a lot of regulations, and -- you know, and I’ve rolled with them, and I’ve just reached the point where if now I have to sleep on the floor to go fishing, I just -- I just won’t do it.

If an interviewee cited an alternative as being a space-saver, that portion of their transcript was coded as, ‘Space +,’ and so on.

<u>AHP Solution</u>

We condensed the 33 multidirectional codes into16 unidirectional positive criteria listed in Table 3.5, below. Condensing the multidirectional criteria into unidirectional criteria facilitated weighted comparisons across criteria. Each criterion was assigned a weight, relative to how often it was mentioned during interviews (see the ‘Total’ column in Appendix 3.D; Figure 3.5). Then, each alternative was assigned a weight for each criterion, relative to how often the alternative was mentioned in relation to the given criterion (Table 3.5; Appendix 3.D).

Figure 3.5 A word cloud created in the Atlas.ti program presents16 unidirectional criteria themes arranged by size, according to their weight—how often each one was mentioned during interviews.

Overall rankings were calculated as the sumproduct of the weights of the criteria and alternatives across the suite of criteria and alternatives (Table 3.5).The resulting solution differs from that of a simple pairwise comparison, because criteria are allowed to influence the solution. The criterion for how much an alternative impacted the logistics of fishing was mentioned by more interviewees than any other criterion (Figure 3.5; Table 3.5). This suggests that whether or not a data collection method was perceived as easy or difficult to implement was the most important factor influencing whether fishermen would support that alternative. Other key criteria included: whether or not fishermen believed that an alternative would produce accurate data; whether or not fishermen felt that more data was a good thing; how much space fishermen thought an alternative would take up; and, whether or not a data collection method caused an intrusion on fishermen's privacy (Figure 3.5; Table 3.5).

Table 3.5 Weighted criteria and overall rank of human observers (‘Obs.’), electronic monitoring (‘EM’), detailed logbooks (‘Log’), and the status quo (‘SQ’) alternatives for data collection at sea across 16 criteria.

Theme	Specific Criteria	Weight	Obs.	EM	SQ	Log
Accuracy	Accurate/Efficient/Reliable Method	0.107	0.246	0.265	0.276	0.213
Change	Change is Accepted	0.044	0.212	0.306	0.224	0.257
Goals	Data Collection Goals are Clear	0.032	0.076	0.357	0.303	0.264
Data	More Data is a Good Thing	0.104	0.212	0.251	0.245	0.291
Use	Data Use is Clear	0.036	0.119	0.236	0.428	0.217
Enforcement	Positive Enforcement/Trust	0.079	0.257	0.280	0.234	0.230
Cost	Lower Cost	0.075	0.173	0.272	0.225	0.330
Intrusiveness	Less Intrusive	0.084	0.147	0.238	0.275	0.340
Liability	Lower Potential for Legal Liability	0.029	0.188	0.320	0.237	0.254
Lifestyle	Fewer Alterations to Lifestyle/Fishing Behavior	0.070	0.153	0.279	0.276	0.292
Logistics	Fewer Logistical/Technical Inconveniences	0.147	0.176	0.247	0.309	0.267
Realistic	Realistic Option	0.016	0.343	0.343	0.101	0.214
Safety	Safe Method	0.022	0.067	0.169	0.382	0.382
Space	Space Saver	0.086	0.158	0.380	0.228	0.234
Time	Minimal Time Commitment	0.025	0.118	0.260	0.473	0.149
Uncertainty	Certainty/Understanding of Method	0.046	0.172	0.172	0.385	0.272
Overall Rank			0.183	0.271	0.279	0.267

When preference criteria such as data accuracy and ability to positively enforce fishing behavior are allowed to influence the decision problem, the overall rankings get closer to one another across all four alternatives, but the status quo again emerges as the best option. Overall, the fishermen interviewed for this project perceived the status quo option as a logistically easy, safe, well-understood method with clear goals that requires a minimal time commitment. Across the full suite of 16 weighted criteria, interviewees ranked the electronic monitoring alternative a close second (scoring 0.271 as compared to 0.279 for status quo). Relative to other alternatives, interviewees perceived electronic monitoring as a space-saving, realistic option, with a clear set of goals, and a low potential for causing legal liability issues (Table 3.5). Interviewees perceived electronic monitoring to be a change they could accept.

The decision problem solution for the AHP model presented in this paper—an overall rank for each alternative—may change depending on which criteria are maintained for consideration. For example, if a shorter list of criteria are considered across data collection alternatives, the preferred solution from the perspective of halibut fishermen shifts.

Table 3.6 Weighted criteria and overall rank of human observers ('Obs.'), electronic monitoring ('EM'), detailed logbooks ('Log'), and the status quo ('SQ') alternatives for data collection at sea across four criteria.

Theme	Specific Criteria	Weight	Obs.	EM	SQ	Log
Accuracy	Accurate/Efficient/Reliable Method	0.261	0.246	0.265	0.276	0.213
Lifestyle	Fewer Alterations to Lifestyle/Fishing Behavior	0.171	0.153	0.279	0.276	0.292
Logistics	Fewer Logistical/Technical Inconveniences	0.359	0.176	0.247	0.309	0.267
Space	Space Saver	0.210	0.158	0.380	0.228	0.234
Overall Rank			0.187	0.285	0.278	0.250

If accuracy, lifestyle, logistics, and space are the only criteria considered in our model, the preferred data collection alternative shifts from the status quo (scoring 0.278) to electronic monitoring (scoring 0.285).

Conclusions

When the restructured observer program was implemented in the halibut fleet during 2013, there was some anticipation that there would be challenges associated with the shift (McCluskey and Vechter, 2013). Some of those challenges were seen as unavoidable, but the methods used in this research suggest one approach that could have been used to gather information that could have led to consideration of modifications to the proposed alternative ahead of development of the regulatory documents required for the Council's decision. A greater understanding of fishermen's preferences and perceptions may have led to a less controversial choice that would have met data needs with less cost or inconvenience to the fishing fleet.

For this project, we wanted to test whether it was possible to develop a reliable description of the preferences of fishermen based on interviews with a relatively small sample. In order to do this, we collected preference data from a small group of halibut fishermen across four communities in a region and used traditional decision analysis methods to measure strength and consistency of responses across the study group. Findings were representative of regional opinions across quota share classes (Appendix 3.B), and demonstrated extremely consistent responses characterizing preferences fishermen had about data collection methods on their vessels.

We illustrate a process that could have been used to integrate fishermen's preferences into quantitative analyses of the impacts of alternatives to a human observer program in Southeast Alaska. An AHP decision-making process similar to the one presented in this paper would have provided insights into specific characteristics of the alternatives that were, in the judgement of halibut fishermen in Southeast Alaska, particularly desirable, objectionable, or important. This knowledge could have facilitated consideration of additional alternatives that had high likelihood of meeting program objectives with least disruption to fishing operations and lifestyles.

In addition, our results suggest that managers could increase acceptance of particular alternatives by stressing how well a certain alternative performs in relation to a given criteria and how important that criterion is to meeting data needs. Managers could look at where proposed alternatives fare poorly on the given criteria and work to assure that the proposed alternatives better reflect the fishermen's preferences and judgements. We have shown that it is possible to systematically pull together preferences and perceptions as part of one-on-one semistructured interviews with fishermen and to characterize the variability of that information for informing the decision-making process.

It has been shown that documenting preferences and perceptions of stakeholders may improve marine spatial planning (Hooper et al., 2015), help to define social objectives in fisheries management (Pascoe et al., 2009; Pascoe et al., 2013; Pascoe et al., 2014), and to evaluate investment strategies in the fishing industry (Chiou et al., 2005). This research suggests that documenting preferences commercial halibut fishermen have about at-sea data collection in a structured manner could be used to inform decisions about regulation in a case study of the halibut fishery off Alaska. A basic ranking of criteria across data collection methods may have provided managers with the tools necessary to anticipate some of the major alterations to program design that emerged during the first few years of the observer program in the halibut fleet (NMFS, 2015 NMFS, 2016b). The expanded AHP model (Figure 3.3; Figure 3.6) described in this paper goes one step further and scores 16 criteria across four potential alternative methods for data collection on halibut boats.

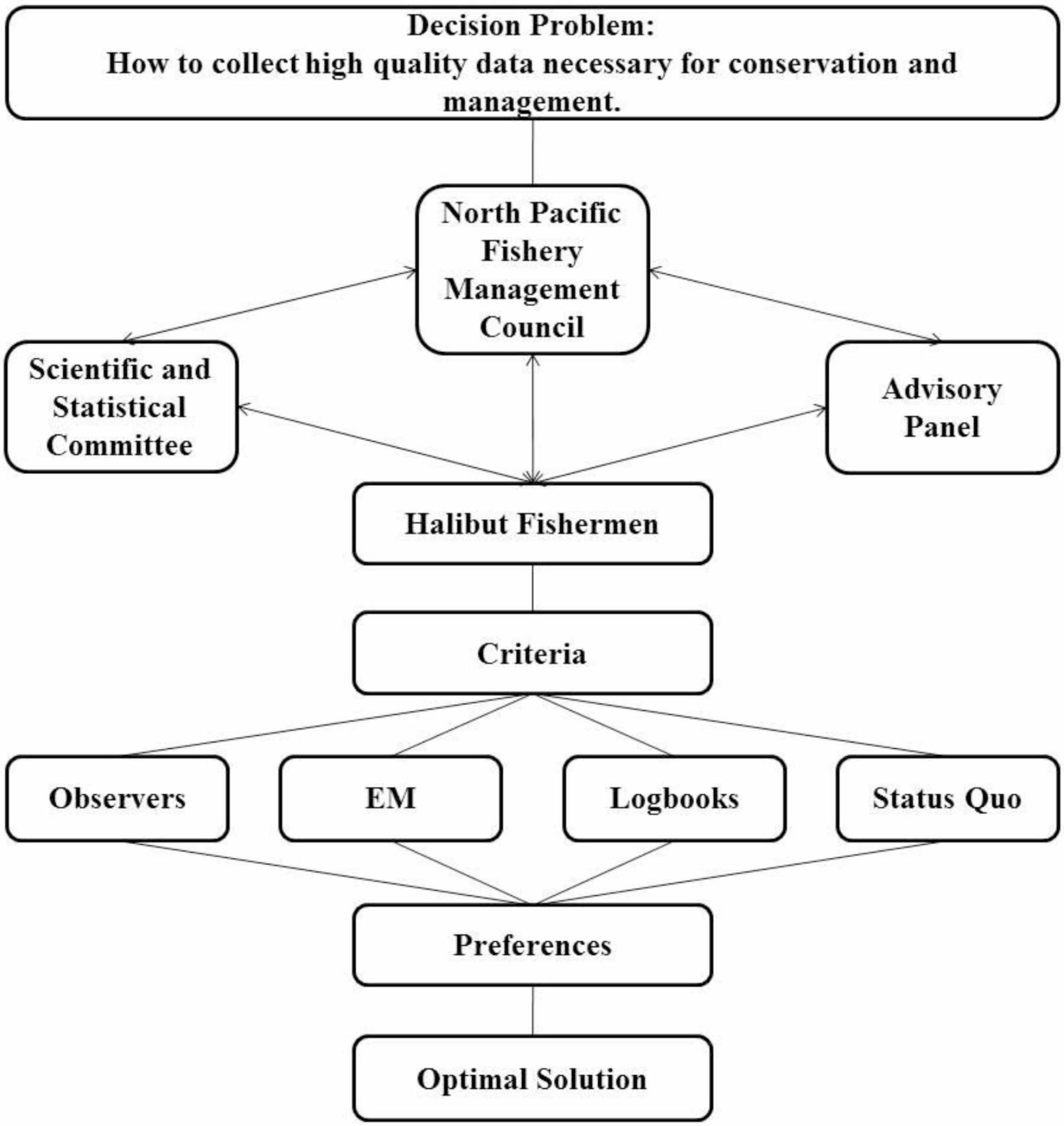


Figure 3.6 Decision hierarchy illustrating how results from semistructured interviews with commercial halibut fishermen might fit into the decision making structure of the North Pacific Fishery Management Council.

Currently, the North Pacific Fishery Management Council relies heavily on the public comment process for gathering input from fishermen. The Council does not regularly analyze that input in a systematic way. In the context of the Council process (Figure 3.6), AHP could be a useful tool for highlighting perceptions fishermen have about alternatives and to determine what drives those perceptions, which may inform future modifications of the alternatives for data collection in the halibut fleet. Future alterations may not influence how accurately a given alternative gathers data, for example, but may reduce the personal and monetary costs associated with each one.

Shifts in fisheries governance are related to shifts in the beliefs among stakeholders and fisheries actors (Valman, 2016). Recent attempts to analyze and mitigate uncertainty in fisheries management have taken place through Management Strategy Evaluations (MSE; Smith et al., 2007; Punt et al., 2014). The MSE framework outlines strategies and policies for effectively managing uncertainty in decision making. Within the MSE framework, there is increased space for considering fishermen's preferences in a systematic way, and for allowing social outcomes to play a direct role in decision making. Increased stakeholder participation in the regulatory process may increase regulatory compliance in a fishing fleet (Martin et al., 2007). AHP modeling of fishermen's preferences may be one way for fisheries managers to decrease uncertainty during the decision-making process, while increasing compliance on fishing grounds. For this project, sampling was not stratified for gender or ethnic distributions, and there were not enough responses from underrepresented groups to be able to explore subgroup differences in any meaningful way. However, future AHP studies could be stratified in order to allow for these demographic comparisons. The methods described in this paper could be used to improve management practices in the Pacific halibut fishery and other fisheries around the world.

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Appendices

Appendix 3.A. Interview Protocol.

Please read this form carefully

You are being asked to take part in a study about at-sea monitoring in the Pacific halibut fishery. This project has been approved by the Institutional Review Board of the University of Alaska Fairbanks (Project # 600513-6).

The goal of this study is to document your observations and opinions about monitoring. You are being asked to take part in this study because of your fishing experience. You are invited to ask any questions at any time during your participation. The information that we collect might describe how at-sea monitoring affects the halibut fleet.

If you decide to take part, you will be asked to describe your fishing experience during an interview lasting about one hour. We will make every effort to hold the interview in a way that is comfortable for you. Some questions will include where you fish and what kinds of things you catch other than halibut. Other questions will focus on your opinions about at-sea monitoring. The interview may be recorded to help in taking notes. You may ask for the voice recorder to be turned off at any time.

We do not expect any risks to you if you take part in this study. At the same time, you may not get any benefits from taking part in this study. Information we get about you from the research will be kept confidential, and stored in a locked office. Information with your name attached will not be shared with anyone outside the research team. We will code your information with a number so no one can trace your answers to your name. Your name will not be used in reports, presentations, and publications.

Your decision to take part in the study is voluntary. If you decide to take part you can stop at any time. You may change your mind and ask to be removed from the study. You may also skip any questions. If you have questions now, feel free to ask. If you have questions, you may email UAF's Institutional Review Board at fyori@uaf.edu.

STATEMENT OF CONSENT: I understand everything described above. My questions have been answered to my satisfaction, and I agree to participate in this study. I am 18 years old or older. I have been provided a copy of this form.

____ Signature

____ Printed Name

Everything in this interview refers to the commercial fishery for Pacific halibut in Alaska. This means that even if you have experience fishing for halibut in a non-commercial way, I would like you to try to focus your answers on your commercial experiences. The interview is set up in two main parts. First I will ask about your fishing experiences. Then I will ask about the observer program and data collection at sea more generally.

Part 1: Fishing Experience

1. What year did you start commercial fishing?

2. What led you into commercial fishing [family tradition, first generation, etc.]?

3. What year did you start commercially fishing for halibut?

4. Has the boat you use changed over time? How?

5. What type of boat do you currently use to fish for halibut?

Type (e.g., schooner)	Length	Width	Engine Power	GT (Hold Capacity)	Number of bunks

6. Which regulatory areas do you currently hold quota in?

7. Have you ever held quota in another area?

8. When you think about your fishing experience, which area do you think of most of it as taking place?

9. What proportion of your halibut fishing takes place in Area 2C?

10. Which months do you currently fish for halibut commercially?

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

11. How has this changed over time?

12. Please describe your typical gear setup

Snap-on?	Hook spacing	Hook type/size	Avg. # of skates	Length of avg. skate	Bait

13. How has this changed over time?

14. Do you combo fish black cod and halibut?

Part 2: Understanding monitoring experiences and preferences

Thank you. Now I would like to focus on the observer program.

1. Did you participate in an observer program in a different fleet besides halibut before 2013?
2. What is your understanding of the purpose of the observer program [and how it works]?
3. What are some positive outcomes of the observer program? What are some negative outcomes of the observer program?
4. Have you been chosen to host an observer since 2013, during halibut fishing trip(s)?
5. If so, please describe the experience.
6. Federal fisheries managers have voiced an interest in collecting biological data at sea in the halibut fishery. How would you feel about a system where you were asked to bring samples into port for scientists on land?
7. How has the halibut observer program affected your outlook on the future?

For this section, I would like you to imagine that all of the types of monitoring described below could apply to you. Even if none of them have ever applied to you, please pretend that they all could during this exercise.
This page is just for you to read. You do not need to write on it.

1. **Human Observers**: currently in place, using only human observers to document all of your fishing practices at-sea

2. **Electronic Monitoring**: instead of humans, cameras would be installed on your vessel to record all of your fishing practices at-sea

3. **Detailed Logbooks**: the fisherman is responsible for recording everything they catch (not just halibut) in a logbook

4. Before 2013: the way things were; halibut are reported and port sampled but no other species are recorded

For the next exercise, I would like you to think about the strengths and weaknesses of these four different monitoring alternatives. Using the prompts on the next two pages, please rate the different types of at-sea monitoring: EM, human observer, detailed logbooks, same as before 2013.

Please circle the number that shows how much you support each type of monitoring.

1. Human Observers

1	2	3	4	5	6	7
No Support			Some Support			Strong Support

2. Electronic Monitoring

1	2	3	4	5	6	7
No Support			Some Support			Strong Support

3. Detailed Logbooks

1	2	3	4	5	6	7
No Support			Some Support			Strong Support

4. Before 2013

1	2	3	4	5	6	7
No Support			Some Support			Strong Support

Please circle number that shows your relative preferences between each pair of options

1. Human Observers | **Electronic Monitoring**

1	2	3	4	5	6	7
Strongly Preferred			No Difference			Strongly Preferred

2. Human Observers | **Detailed Logbooks**

1	2	3	4	5	6	7
Strongly Preferred			No Difference			Strongly Preferred

3. Human Observers | **Before 2013**

1	2	3	4	5	6	7
Strongly Preferred			No Difference			Strongly Preferred

4. Electronic Monitoring | **Detailed Logbooks**

1	2	3	4	5	6	7
Strongly Preferred			No Difference			Strongly Preferred

5. Electronic Monitoring | **Before 2013**

1	2	3	4	5	6	7
Strongly Preferred			No Difference			Strongly Preferred

6. Detailed Logbooks | **Before 2013**

1	2	3	4	5	6	7
Strongly Preferred			No Difference			Strongly Preferred

8. Please tell me a bit about why you ranked the way that you did.

Part 3: Demographic Information

1. What year were you born? ______________________________

2. How did you obtain your IFQ? _____

3. Have you personally fished your 2C IFQ every year since obtaining it? YES NO

4. How long do you plan to keep fishing your IFQ? _____

5. Do you identify with an Alaska Native tribe? YES NO

6. How many people live in your household? _____

7. How satisfied are you with your financial situation?
e) Very Unsatisfied
f) Unsatisfied
g) Satisfied
h) Very Satisfied

8. What percent of your household income comes from fishing (household income includes your income as well as income from anyone else who lives in your household)?
    f) 1-24%
    g) 25-50%
    h) 51-74%
    i) 75-99%
    j) 100%

9. Do you own the fishing vessel that you fish halibut on? YES NO

10. Are you a member of a fisheries organization? If so, which one? YES NO

    ____

11. Are you a full time resident in ____________? YES NO

12. Is____________ currently dependent on commercial fishing? YES NO

13. Did you grow up in ____________? YES NO

14. Did one of your parents grow up in ____________? YES NO

15. Did one of your grandparents grow up in ____________? YES NO

May I contact you in the future with results and/or more questions? YES NO

If so, please provide contact Information
Email:
Phone number:
Address:

Part 5: Closing

5.1 Do you have any questions for me?

Thank you for your time ☺

Appendix 3.B. Summary of interviewee characteristics (n = 76) used in Ranking and AHP.

Table 3.B.1. Number of interviewees across categorical variables for fishing characteristics.[4]

Characteristic	# Interviewees
Community	
Juneau	12
Hoonah	10
Petersburg	25
Sitka	29
Fishing season	
Spring fishing	53
Summer fishing	32
Fall fishing	36
Gear type	
Conventional gear	31
Snap-on gear	39
Both gear types	6
Combo fishing (for sablefish and halibut)	36

Table 3.B.2. Characteristics of sample size across continuous variables for fishing characteristics (n = 76).

Characteristic	Min	Max	Mean	Median
Vessel length	16	86	44	42
Age	27	81	56	59
Years of experience	4	57	34	35

[4] Fishermen were allowed to report fishing during multiple categories for some characteristics (e.g., fishing season), so the numbers do not all add to 76.

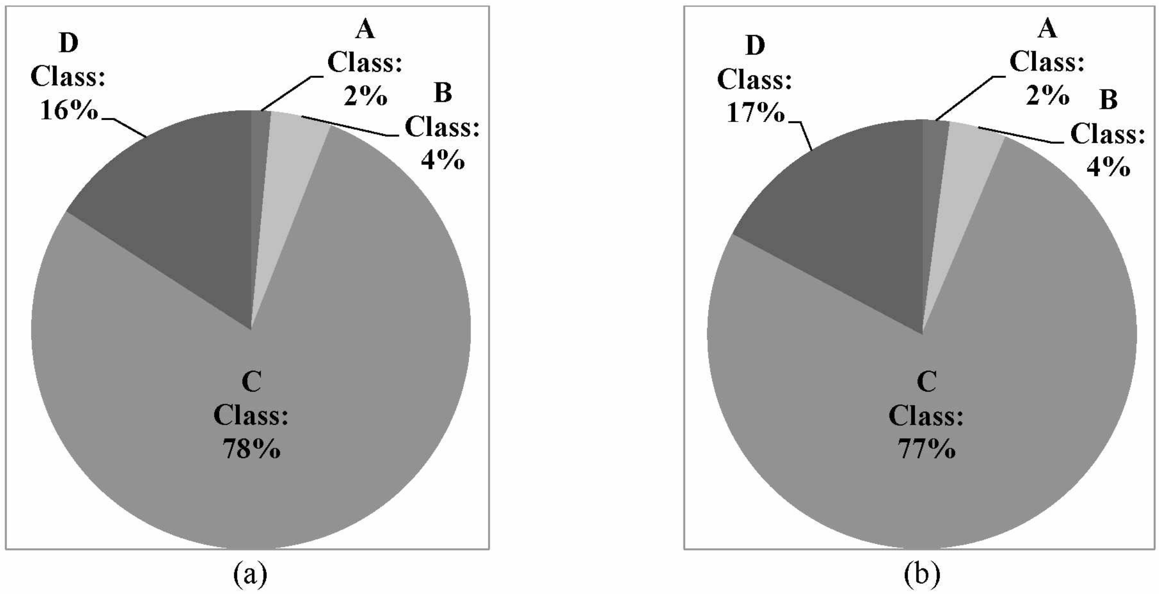
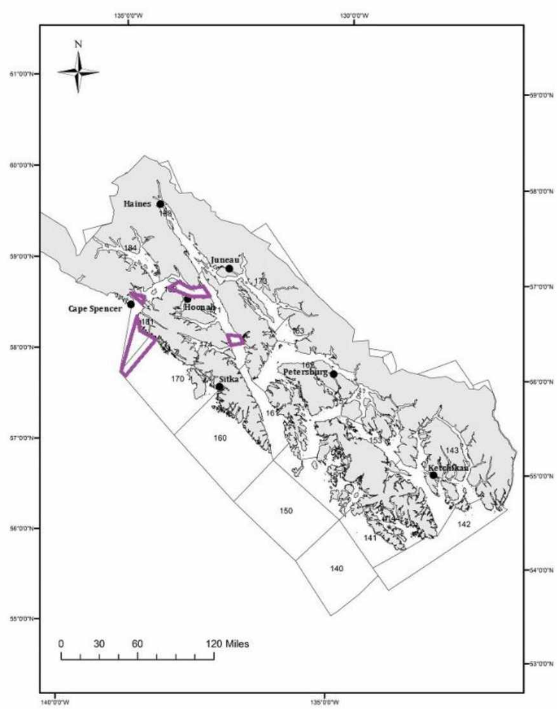


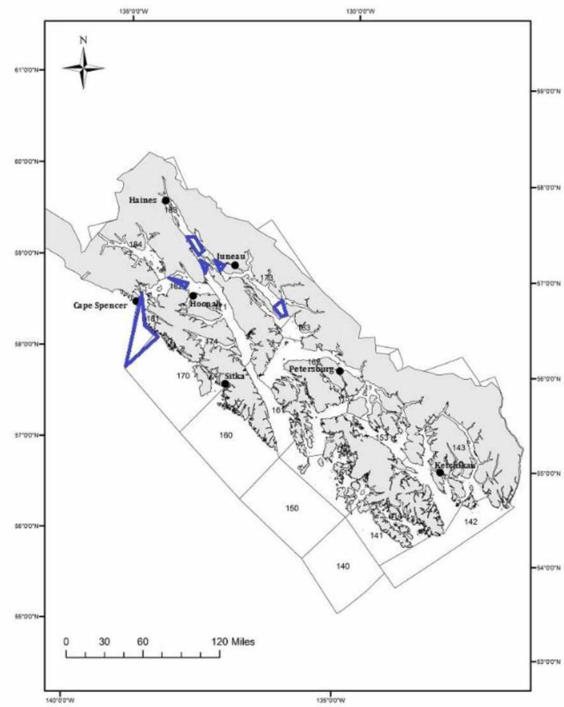
Figure 3.B.1. Halibut quota share holdings by category across (a) all four study communities (n = 804 blocks) and (b) within the interview group of 76 IFQ holders (n = 135 blocks).

Appendix 3.C. Areas fished by study participants, organized by community of residence (n = 76).

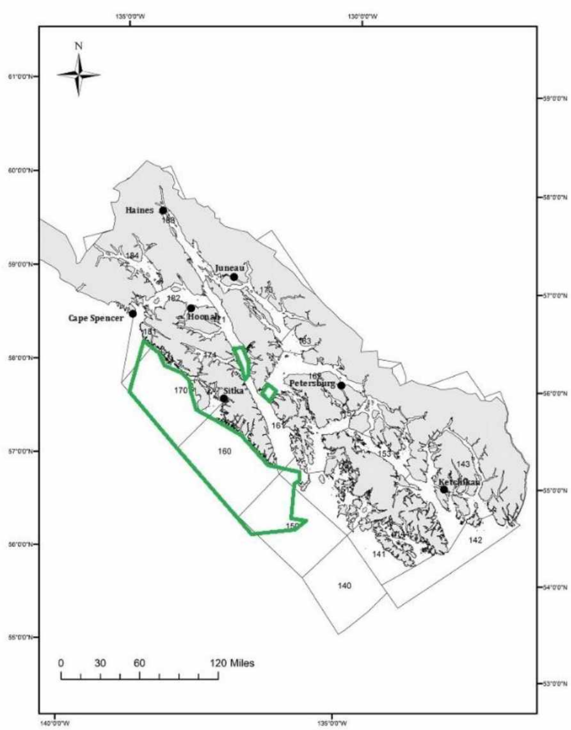
Figure 3.C.1. Areas fished by study participants from Hoonah, Juneau, Sitka, and Petersburg.



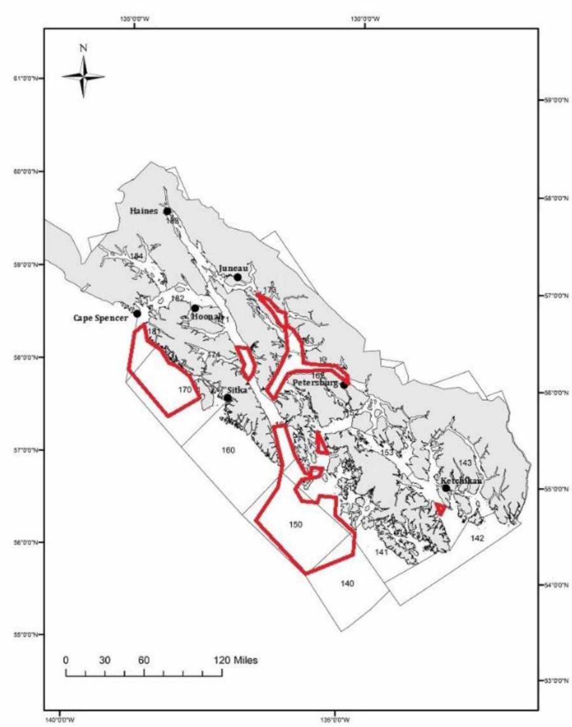
Hoonah



Juneau



Sitka



Petersburg

Appendix 3.D. Multi-directional criteria (n = 33) from interviews with halibut fishermen (n = 75).

Table 3.D.1. 33 criteria are presented along with how many interviewees mentioned each one.

Code Criteria	Obs.	EM	SQ	Log	Total
Accuracy_Efficiency_Reliability_	2	4	2	3	11
Accuracy_Efficiency_Reliability_-	22	11	0	12	45
Accuracy_Efficiency_Reliability_+	19	17	3	9	48
Change_Accepted	13	6	3	3	25
Change_Not Accepted	9	1	2	1	13
Data_Collection Goals Unclear	22	1	2	3	28
Data_More Good	21	8	14	14	57
Data_More Not Necessary	18	4	8	4	34
Data_Use Unclear	17	6	1	7	31
Enforcement_Trust	12	2	2	2	18
Enforcement_Trust_-	25	11	4	7	47
Enforcement_Trust_+	12	7	1	2	22
Financial_	10	10	1	0	21
Financial_-	40	11	0	1	52
Financial_+	5	5	0	3	13
Intrusiveness_Privacy_-	32	17	0	2	51
Intrusiveness_Privacy_+	4	9	2	7	22
Intrusiveness_Privacy_Neutral	7	1	0	0	8
Liability_-	11	3	0	1	15
Liability_+	4	5	0	1	10
Lifestyle_Altered Behavior_-	42	5	1	0	48
Lifestyle_Altered Behavior_+	5	4	2	2	13
Logistics_Technical_Inconvenience_Difficult	40	17	0	28	85
Logistics_Technical_Inconvenience_Easy	8	10	5	20	43
Politics_Inevitable	9	1	1	1	12
Politics_Unrealistic	1	1	9	3	14
Safety_	2	1	0	1	4
Safety_-	15	4	0	0	19
Space_	17	5	1	0	23
Space_-	49	7	0	3	59
Space_+	5	10	0	1	16
Time Commitment	11	3	0	8	22
Uncertainty	15	15	3	7	40

Table 3.D.2. Total number of occurrences of criteria for each data collection alternative.

Code Name	Total Number of Occurrences
Observer Program Criteria	466
Electronic Monitoring Criteria	169
Status Quo Criteria	53
Logbook Criteria	133

General Conclusion

Local knowledge is expert information, and worthy of documenting for its own sake. In this dissertation, I have focused on not only documenting local knowledge, but also interpreting it for use in existing fisheries science and management structures. Local knowledge is complementary to natural science and is essential in the formation of comprehensive understandings about any fisheries system. Fisheries management systems in Europe and the United States are guided by principles of using 'best available science' to inform regulatory decisions (NMFS, 2007; EU, 2013). While there is an emerging consensus around best practices for stock assessment and principles of ecosystem-based management (NRC, 1998; Smith et al., 2007), considerable work remains to be done concerning the development of best practices for collecting and interpreting local knowledge for use in fisheries science and management.

In Poland and Alaska, fishermen represent a vast resource of information that remains largely untapped by scientists and managers. Commercial fishermen are bearers of expert local knowledge, yet it remains uncommon for scientists and managers to integrate local knowledge into fisheries assessment or management. The act of documenting local knowledge is not always enough to make it useable within existing fisheries management structures. Interpreting that information into a useable format for management poses a great challenge. Furthermore, fishermen and management system laws are in agreement that more information is not automatically better. So much data is already collected in the Alaska halibut fishery, for example, that fishermen express concern for whether scientists and managers ever find the time or resources to use it all:

> I always feel like, it's like [the movie] 'Indiana Jones and Raiders of the Lost Ark.' Remember it going in that gold ark…and it never got seen. I don't know if the information gets used. I hope it does.
>
> – Halibut fisherman in Southeast Alaska, 2015

In the United States, federal fisheries management guidelines prohibit gathering superfluous data (NOAA, 2007). That is, in assessing potential social impacts of fishing regulations, "the idea is not to gather as much data as possible, but as little as necessary" (NOAA, 2007) for making sound decisions. A key challenge, therefore, lies not only in developing efficient methods for fishermen's local knowledge to be documented, but for that information to be succinctly *interpreted* for use in management. Against that background, this dissertation works to develop effective modes for documenting *and* interpreting local knowledge, for integration into mainstream fisheries science and management.

The case studies of two commercial fisheries described in this dissertation illustrate novel methods for semistructured interviews with fishermen to be systematically analyzed for use in science and management. This work demonstrates how local knowledge may be used to document ecological change (Chapter 1), trends in incidental catch (Chapter 2), and preferences fishermen have about data collection on their vessels (Chapter 3).This dissertation further contributes to the development of interdisciplinary methods for interpreting expert local knowledge held by commercial fishermen. Using case studies in Poland and Alaska, information is presented that could be used to develop well-informed policies geared towards building resilience and sustainability of fisheries ecosystems in Europe and the United States. In other words, this work develops new directions for incorporating fishermen's local knowledge into fisheries science and management.

Future research in the arena of local knowledge in fisheries science might build on existing work addressing mandates for 'best available *social* science' within the management arena (Charnley et al., 2017). Questions to be addressed include: Are case studies like those presented in this dissertation a useful framework for documenting and utilizing local knowledge? If so, how might case study examples be expanded or contracted to ensure they maintain relevance and support real-life regulatory applications across management areas? Demographic information about ethnicity, gender, and income differences among fishermen were not addressed in this dissertation, and in many cases the demographic data necessary for consideration of how minority and low-income people and communities are affected by policy are not available. At the same time, federal fisheries managers are required to consider demographic differences across minority groups, communities, and sectors (e.g., Executive Orders 12291, 12866, 12898, and 13175). What level of detail or demographic information might be necessary to fulfill information requirements for specific regulatory actions, without overwhelming managers during the decision-making process?

This dissertation combined qualitative and quantitative data collection and analysis methods. How do challenges differ between incorporating qualitative versus quantitative local knowledge information into existing European and US fisheries regulatory processes? What are the limitations of the current regulatory processes to incorporate in-depth qualitative information, and how might those limitations be mitigated? More broadly, how might the science of collecting and analyzing local knowledge information be designed to support regulatory processes? Alternatively, how might fisheries regulatory processes in Europe and the United States might be altered to provide more space for local knowledge to inform policy decisions?

Incorporating local knowledge into fisheries science and management is not a new idea but it has not yet become standard practice around the world. This dissertation emerges from a 'fifth wave' of fishers' knowledge research (Hind, 2015; Stephenson et al., 2017), that combines applied social science methods with methods from quantitative fisheries biology. Mixed qualitative and quantitative methods used in this dissertation bring an integrative focus to addressing policy objectives using fishermen's knowledge about ecosystems, as well as their preferences about regulations. Findings show how the inclusion of fishermen's local knowledge in fisheries management need not be limited to informal conversations or public testimony at meetings in order to be meaningfully interpretable by managers.

This dissertation also aims to improve community understandings of fisheries research by engaging commercial fishermen directly in research prioritization, planning, and implementation. Working directly with fishermen to carry out this dissertation work provided the project team with links to community-based information to support research and to assist and encourage the return of new ideas and research results to coastal communities. Use of interview and survey methods situates results within regional contexts, and contributes to a body of research that will help equip scientists and community members with the skills to develop comprehensive understandings of coastal community issues. In the short-term, this work provides policymakers and community members with innovative and up-to-date information about fisheries in Poland and Alaska. In the long-term, I hope that my work will help to strengthen ties between fishermen, scientists, and policymakers in both locations. I also hope this dissertation contributes to a larger shift in fisheries research in Europe and the United States that incorporates social impacts together with biological and economic impacts in policy analysis.

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