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Bridging expert knowledge and fishery data to examine changes in nearshore rockfish fisheries in the Gulf of Alaska over fifty years

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ABSTRACT

Rockfishes (*Sebastes* spp.) and the fisheries they support along the northeastern Pacific Ocean have undergone dynamic changes over the last century. The unique life history traits of rockfishes pose a host of challenges that make them difficult to monitor and susceptible to overfishing. Previous research has demonstrated that fishers' knowledge and scientific data can help to create a more complete picture of long-term changes in rockfish populations and nearshore ecosystems. In this study, we used a multiple evidence-based approach that draws together expert knowledge of fishers and fisheries agency staff with long-term harvest data to document recent changes in nearshore rockfish populations and fisheries in two regions along the Gulf of Alaska. Using quantitative and qualitative methods, we compiled and analyzed datasets from the Alaska Department of Fish and Game to summarize spatiotemporal trends in commercial and recreational rockfish harvest and interviewed fishers and agency staff about their observations of long-term changes in nearshore rockfish populations and fisheries. We focused on two communities in the eastern and central Gulf of Alaska for which rockfish issues have been at the fore of management in recent years: Sitka and Kodiak, Alaska. We synthesized harvest data and abundance indices from expert knowledge in the context of fishery regulation changes to gain a more holistic perspective on the recent history of Alaska rockfish fisheries. While increases in localized fishing pressure and declines in relative abundance underlie concerns about pelagic and yelloweye rockfish populations and fisheries, stable or high abundance and proactive management for some species and locations also yield an optimistic outlook about their status. Variables such as gear type, sector, time periods fished, regulatory changes, and species targeted influenced experts' perceptions of rockfish fisheries and populations. Our findings highlight the challenges of bringing together disparate data and the benefits of including multiple knowledge sources to produce a more complete understanding of complex fishery systems.

1. Introduction

The Pacific rockfishes (*Sebastes* spp.; hereafter, "rockfishes") are among the most prevalent and diverse demersal fishes along the Pacific coast of North America, with over 100 known species throughout their range and more than 30 species off the coast of Alaska and British Columbia (Love et al., 2002). This biological diversity is mirrored in the breadth of fisheries that rockfishes have sustained for generations. Indigenous peoples have harvested rockfishes for customary and traditional use along the Pacific coast for thousands of years (e.g., McKechnie, 2007, Folan, 1984, Drucker, 1951, Turek et al., 2009). Development of commercial and recreational rockfish fisheries took place throughout the 19th and 20th centuries, progressing at different times along the west coast of North America. Some of the earliest commercial rockfish fisheries occurred off the California coast, driven by an influx of immigrants to San Francisco during the Gold Rush in the 1850s (Skinner, 1962). Recreational fishing for bottomfish on charter vessels became popular in California in the 1920s (Clark and Croker, 1933) and by the 1950s, rockfishes comprised most of the recreational harvest in the state (Karpov et al., 1995). In British Columbia, rockfishes were initially caught as bycatch in the lingcod fishery (*Ophiodon elongatus*) in the mid-1800s (Yamanaka and Logan, 2010). In the 1970s, hook and line commercial rockfish fisheries in British Columbia and Washington became more prominent as Pacific salmon (*Oncorhynchus* spp.) fishing

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became limited (Palsson et al., 2009) and market demand for rockfishes grew (Yamanaka and Logan, 2010). Recreational fishing for rockfishes in the Pacific Northwest also expanded through the 1970s into the 1980s, due in part to efforts by state managers to promote bottom fishing to anglers (Williams et al., 2010) and to technological advances that allowed anglers to more efficiently target rockfishes (Pedersen and DiDonato, 1982). Along the Pacific Coast, rockfish fishery development has followed a general trend of increasing harvest and market demand, with subsequent concerns about depletion and more stringent regulations.

The life history traits of many rockfishes, including slow growth, late maturation, episodic recruitment, and small home ranges (Parker et al., 2000), make them vulnerable to overfishing and habitat disturbance. Additionally, bycatch mortality of rockfishes is high due to their susceptibility to barotrauma (Parker et al., 2000). Along the west coast of North America, depletion of rockfish stocks has largely been attributed to overfishing (Williams et al., 2010), as in Puget Sound, where rockfish abundance declined by around 70% from 1965 to 2007 and three species were listed for protection under the Endangered Species Act in 2010 (one has since been delisted; Drake et al., 2010, NMFS, 2017). An added hurdle for managers is that nearshore rockfishes are difficult to survey because rockfish often reside in rocky, high relief habitat that is not suitable for trawl gear (Easton et al., 2015). Harvest and effort-based indices of abundance, such as catch-per-unit-effort (CPUE), may be a poor reflection of underlying abundance due to aggregation of rockfish, which can lead to catches remaining high even if the population is declining (i.e., hyperstability; Hilborn and Walters, 1992). Because of the challenge and cost of assessing rockfishes, management decisions are often based on limited data, primarily fishery-dependent data and biological surveys that are restricted in their spatial and temporal scope. Fisheries agencies in British Columbia, Canada, and along the U.S. West Coast have addressed these challenges in rockfish assessment and management in multiple ways and to varying degrees of success. To reduce rockfish bycatch and overfishing, areas closed to commercial and recreational fishing, called "Rockfish Conservations Areas" (RCAs), have been in place since 2002 along the coasts of California, Oregon, Washington, and British Columbia (NOAA Fisheries, 2021).

While there has historically been less conservation concern regarding rockfishes at the northern extent of their range, similar challenges may be playing out in commercial and recreational rockfish fisheries in the Gulf of Alaska. In Alaska, rockfishes have been targeted in commercial fisheries since the early 1900s (Bracken, 1986). Harvest peaked in 1965 due to the development of the Pacific Ocean perch (*S. alutus*) trawl fishery, followed by a decline in the late 1960s (Heifetz et al., 1999; Spencer et al., 2000; Bracken, 1986). From 2000–2015, recreational harvest of rockfishes increased 450% in Sitka and 300% in Kodiak (Alaska Department of Fish & Game 2021a). Due to concerns about intensified fishing pressure during this period, the Alaska Department of Fish and Game (ADF&G) instituted increasingly restrictive measures to limit recreational and commercial rockfish harvest through bag limits, quota reductions, seasonal closures, and full fishery closures (O'Connell and Brylinsky, 2001; Howard et al., 2019a). In 2019, ADF&G reported a 60% decline in biomass, fewer older fish, and decreased reproductive potential for yelloweye rockfish (*S. ruberrimus*) in the eastern Gulf of Alaska since 1994, resulting in more fishery closures (Sport Fishing Emergency Order, 2020; Wood et al., 2020). These restrictions over the last 20 years were implemented to address known stock declines (i.e., yelloweye rockfish) and as a precautionary measure, to reduce mortality of other species for which there is limited biological data and no formal stock assessment (e.g., black rockfish, *S. melanops,* and dusky rockfish, *S. ciliatus*). Through the development of a Statewide Rockfish Initiative (SRI) in 2016, the ADF&G has made strides to synchronize data collection and rockfish assessment statewide (Howard et al., 2019b); however, a paucity of monitoring data limits understanding of population changes for nearshore rockfish species. Fishers hold extensive knowledge of changes in rockfish fisheries and populations, but their ecological observations have not yet been formally included in the SRI's work.

Developing management approaches that are both responsive to changes in rockfish populations and allow for continued harvest of nearshore rockfishes can benefit from a multiple evidence-based approach that generates new insights through complementation of diverse knowledge systems (Tengö et al., 2014). In the Pacific Northwest, expert knowledge, biological data, and harvest records have been brought together to reconstruct long-term trends in relative abundance and body size of rockfishes (Beaudreau and Levin, 2014; Eckert et al., 2018) and to document historical changes in rockfish fisheries (Williams et al., 2010). A large body of research has shown that the joint use of expert knowledge and scientific observations extends the breadth and depth of understanding about social-ecological change in fisheries and wildlife systems (e.g., Gagnon and Berteaux, 2009, Huntington et al., 2004, Johannes et al., 2000, Moreno-Báez et al., 2012, Neis et al., 1999, Thornton and Scheer, 2012, Raymond-Yakoubian et al., 2017). In this study, we brought together fisheries data and knowledge of fishers and resource management agency staff to reconstruct changes in rockfish populations and fisheries in two regions of the Gulf of Alaska since the 1970s. Two broad questions guided this work: (1) Is there evidence to suggest that nearshore rockfishes in Alaska are experiencing reduced abundance, demographic changes, or other ecological shifts? (2) Do fishermen and agency staff have concerns about the continued viability of rockfish fisheries? If so, what is the nature of these concerns? To address these questions, we compiled datasets from ADF&G to summarize spatiotemporal trends in commercial and recreational rockfish harvest and interviewed fishers and agency staff about their observations of long-term changes in nearshore rockfish populations and fisheries. We focused on two communities in the eastern and central Gulf of Alaska for which rockfish issues have been at the forefront of management in recent years. We synthesized harvest data and abundance indices from expert knowledge in the context of fishery regulation changes to gain a more holistic perspective on the recent history of Alaskan recreational and commercial rockfish fisheries. We conclude with a discussion of the management challenges and knowledge gaps for nearshore rockfish fisheries in the Gulf of Alaska and the complexities of bridging multiple bodies of knowledge in fisheries.

1.1. Study regions

Our research was conducted in two coastal communities in the Gulf of Alaska: Sitka and Kodiak (Fig. 1). Sitka was selected as a study community because of recent increases in harvest and targeting of rockfishes in recreational (also referred to as sport) fisheries (ADF&G, 2021a). Additionally, rockfishes are frequently caught as bycatch in Sitka's commercial troll and longline fisheries (Alaska Fisheries Science Center, 2013). Kodiak was included in the study because of its prominent directed black rockfish jig fishery (Howard et al., 2019a). Recreational harvest of rockfishes, especially pelagic species, has increased dramatically in Kodiak over the past few decades (ADF&G, 2021a).

Sitka (population 8458; U.S. Census Bureau, 2020) is located along the southeastern Gulf of Alaska on the west coast of Baranof Island (Fig. 1). Sitka, derived from the Tlingit name Shee At'iká, has been the homeland of the Tlingit people for approximately 10,000 years (Sealaska Heritage Institute, 2011; Sitka Tribe of Alaska, 2011). In Sitka Sound and surrounding waters, Tlingit fishers traditionally harvested yelloweye rockfish for subsistence in the winter and spring after Pacific halibut had moved offshore (Herman, 1998; Turek et al., 2009). Smaller fish were released and fishing locations were intentionally varied to prevent overfishing in a given area (Turek et al., 2009). Commercial fishing is an important component of Sitka's economy; in 2016–2017, Sitka ranked sixteenth in landings and tenth in revenue out of all major U.S. ports (NMFS, 2018). Recreational fishing in Sitka focuses primarily on Pacific halibut and Pacific salmon, with rockfishes increasingly targeted by guided recreational (i.e., charter) boats (Beaudreau et al.,

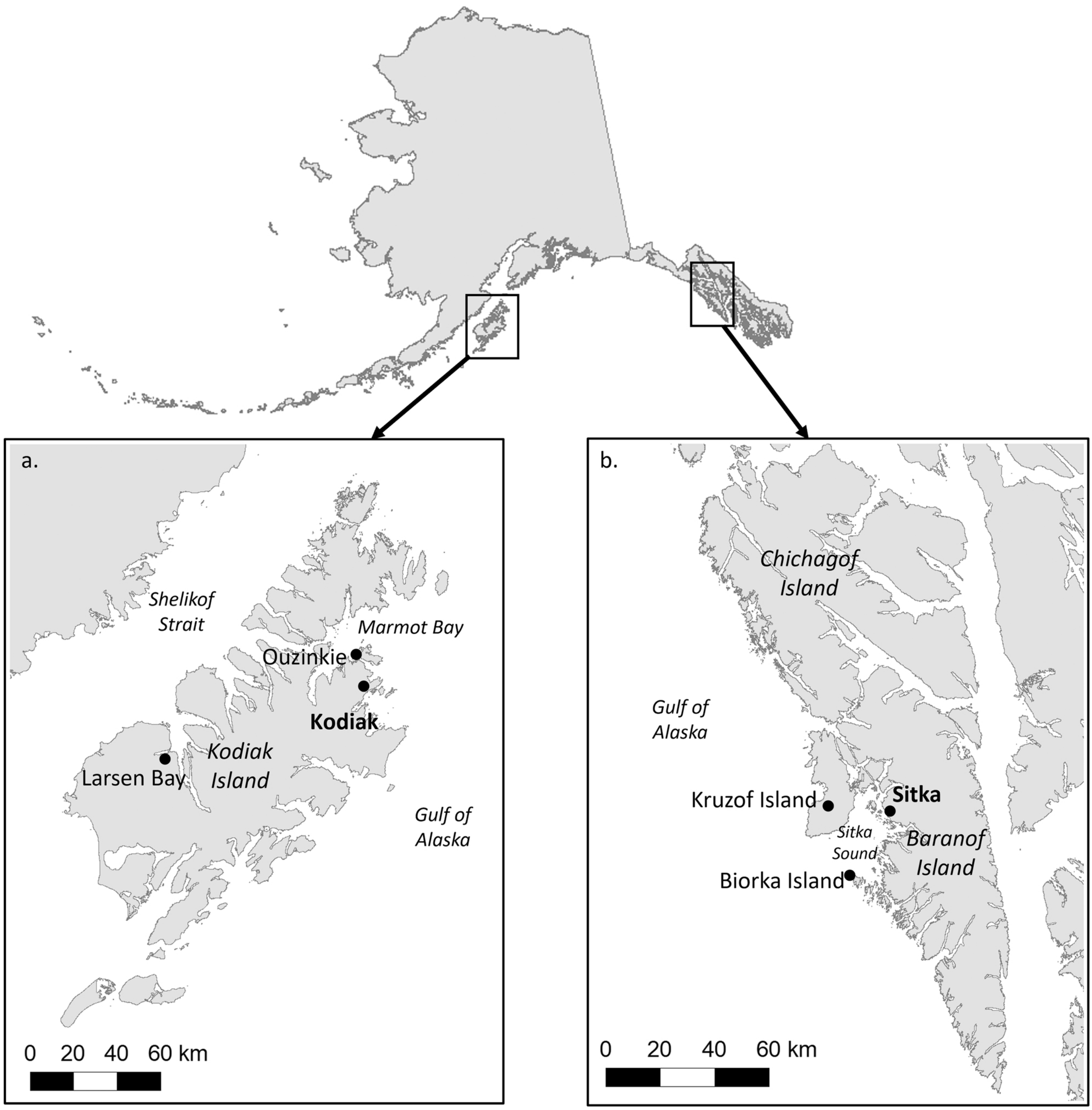

Fig. 1. Map displaying the two study regions, Kodiak (a) and Sitka (b). Commercial and sport fishing regulatory areas within each region are delineated in Table B.1.

2018).

The City and Borough of Kodiak Island (population 13,101; U.S. Census Bureau, 2020) is located in the western Gulf of Alaska (Fig. 1). Kodiak has been the traditional homeland of the Alutiiq/Sugpiaq for over 7500 years (Alutiiq Museum Archaeological Repository, 2020a). Although less commonly harvested than Pacific salmon, rockfishes also hold value to the Alutiiq/Sugpiaq people, who have been harvesting rockfishes in small quantities for at least two thousand years, most likely by fishermen using jig gear to target Pacific cod (*Gadus macrocephalus*) (Alutiiq Museum Archaeological Repository, 2020b). Black rockfish, also referred to as "black bass," have been noted as a species of importance by fishermen from Ouzinkie, and yelloweye rockfish, locally called "red snapper," are also harvested on occasion (Mishler, 2001). Commercial fishing has been an important aspect of Kodiak's economy at least since the 1800 s, when the Russians developed a commercial Pacific salmon fishery. In the late 1960 s, Kodiak became the largest fishing port (by ex-vessel value) in the United States (Alaska Fisheries Science Center, 2013). Kodiak reported the third highest landings for all fisheries and fourth highest ex-vessel revenue of all U.S. ports in 2016–2017 (NMFS, 2018). Saltwater recreational fishers in Kodiak primarily target Pacific salmon, as well as Pacific halibut, rockfishes, and lingcod (ADF&G, 2021b).

2. Methods

2.1. Overview of data sources and mixed-methods approach

Our synthesis weaves together multiple knowledge sources and methodologies (i.e., triangulation, Jick, 1979), using qualitative and quantitative data to explore attributes of rockfish populations and fisheries over the last 50 years. We conducted thematic analysis on expert knowledge from semi-structured interviews (Section 2.3) and quantitatively evaluated spatiotemporal time series information from expert knowledge and ADF&G harvest data (Section 2.4). In this study, the term "expert knowledge" encompasses the diverse body of experiential and intergenerational knowledge of the fishers and agency staff who participated in this research. Additionally, we synthesized existing technical reports and other publications detailing changes in rockfish fisheries and management in the study regions to provide context and interpretation of our data summaries. Both expert knowledge and fishery data possess strengths and limitations in terms of spatial and temporal extent and resolution, and are influenced by various biases (e.g., Huntington et al., 2004, Beaudreau and Levin, 2014). Together, these knowledge sources provide a more holistic understanding of changes in rockfish fisheries and populations than any one alone.

2.2. Focal rockfish assemblages and taxonomic groupings

This study focused on rockfishes in two coarse species assemblages, pelagic rockfishes and non-pelagic rockfishes (Table 1), that are primarily caught nearshore (i.e., primarily within Alaska state waters, within 3 nmi of shore). These assemblages reflect rockfish habitat associations, ADF&G species management groupings, and experts' naming and identification schemes for rockfishes (i.e., folk classifications; Beaudreau et al., 2011). For commercial fisheries, rockfishes are managed as the pelagic shelf rockfish (PSR), demersal shelf rockfish (DSR), and slope rockfish complexes (ADF&G, 2020a; Table 1). For recreational fisheries, rockfishes are managed as the pelagic rockfish assemblage and non-pelagic rockfish assemblage, which is comprised of the demersal shelf and slope rockfish complexes together (ADF&G, 2020b; Table 1).

Table 1
Rockfish species included in Alaska Department of Fish and Game (ADF&G) fishery data analysis and interview data analysis. Common names used by interview participants are marked with an asterisk.

Species group	Interview	Sport fishery	Commercial fishery
Pelagic rockfishes	*Species* Black rockfish Blue rockfish Dark rockfish Dark dusky rockfish Dusky rockfish Light dusky rockfish Silvergray rockfish Yellowtail rockfish *Aggregate groupings* Pelagic rockfish Black bass* Brown bomber*	*Species* Black rockfish Blue rockfish Dark rockfish Dusky rockfish Widow rockfish Yellowtail rockfish *Aggregate groupings* Pelagic rockfish	*Species* Black rockfish Dark rockfish Deacon rockfish Dusky rockfish Widow rockfish Yellowtail rockfish *Aggregate groupings* Pelagic shelf rockfish (PSR)
Non-pelagic rockfishes	*Species* Canary rockfish China rockfish Copper rockfish Quillback rockfish Redbanded rockfish Redstripe rockfish Yelloweye rockfish *Aggregate groupings* Demersal shelf rockfish Non-pelagic rockfish Red snapper*	*Species* Canary rockfish China rockfish Copper rockfish Quillback rockfish Silvergray rockfish Tiger rockfish Yelloweye rockfish Any other species not classified as pelagic *Aggregate groupings* Non-pelagic rockfish	*Species* Canary rockfish China rockfish Copper rockfish Quillback rockfish Rosethorn rockfish Tiger rockfish Yelloweye rockfish *Aggregate groupings* Demersal shelf rockfish (DSR)
Slope rockfishes	*Species* Northern rockfish Pacific Ocean perch Shortraker rockfish Shortspine thornyhead rockfish Slope rockfish Rougheye rockfish	*Species* N/A	*Species* Any species not listed in the PSR or DSR groups

Rockfish harvest was summarized for pelagic rockfishes (a grouping that includes multiple species; Table 1) and for yelloweye rockfish, the predominant species in the DSR (non-pelagic rockfish) complex (Table 2). Harvest was quantified for yelloweye rockfish, rather than the entire DSR complex or non-pelagic rockfish assemblage (Table 1), for several reasons: (1) current ADF&G biological assessments for DSR/non-pelagic rockfishes are yelloweye rockfish focused (Wood et al., 2019), (2) the majority of landings for DSR commercial fisheries are yelloweye rockfish, (3) patterns for yelloweye rockfish commercial and recreational harvest closely align with harvest levels for non-pelagic rockfishes combined, (4) species-specific recreational fishing bag limits are set for yelloweye rockfish (not a broader aggregate grouping) in Sitka and Kodiak (ADF&G, 2019a; ADF&G, 2019b), and (5) experts typically had a much clearer recall of abundance trends and harvest changes for yelloweye rockfish compared to other non-pelagic species.

2.3. Expert knowledge

2.3.1. Research participant recruitment and expertise

We recruited participants with long-term experience (typically > 10 years) in the management, science, and fisheries for rockfish in the Sitka and Kodiak areas. Potential research participants were initially identified through key contacts at ADF&G, fishing organizations, Alaska Sea Grant, University of Alaska Fairbanks, and our networks from previous research. Participants were also recruited during community meetings in Sitka and Kodiak, and by disseminating project flyers throughout the two communities and on social media platforms. The participant pool was expanded using snowball sampling (Bernard, 2018), in which interviewees were asked to recommend other individuals with relevant expertise. During early stages of project development, invitation letters were sent to the Sitka Tribe of Alaska and the Sun'aq Tribe of Kodiak to partner in the project; however, a focus on rockfish was not a priority of the tribes at the time of this study, due to the COVID-19 pandemic and other pressing fisheries concerns. This study was motivated by contemporary resource management issues associated with commercial and recreational rockfish fisheries, so the majority of participants were engaged in commercial and recreational fishing sectors. Rockfishes are also caught for subsistence and customary and traditional use in both regions; however, they are a relatively minor component of subsistence harvest.

Participants attributed their understanding of rockfish fisheries and ecology to their fishing, management and research experience; intergenerational knowledge; and conversations with other fishers, agency workers, and community members. Each participant was associated with a primary group (i.e., commercial, non-commercial, agency) for analysis purposes based on their reported experience and peer referencing (Davis and Wagner, 2003); however, the majority of individuals had experience fishing under a variety of regulations. For example, most ADF&G staff also had personal fishing experience and many fishers were actively engaged with the management of their fisheries through opportunities for public participation (Gordon et al. in review).

We conducted 38 in-person semi-structured interviews with 40 research participants in Kodiak (n = 17) and Sitka (n = 23) in 2019. Due to the COVID-19 pandemic, plans to conduct additional in-person interviews were canceled in 2020. Instead, the research team conducted three interviews via video conference and phone with participants who fished or worked in management in Kodiak (n = 1) and Sitka (n = 2). Interview participants included commercial fishers (Sitka n = 13, Kodiak n = 8), non-commercial fishers (i.e., recreational and subsistence; Sitka n = 8, Kodiak n = 5), and ADF&G management and research staff (Sitka n = 4, Kodiak n = 5). Two supplemental interviews were conducted with additional experts outside of the Sitka and Kodiak areas to enhance our broader understanding of rockfish fishery issues

Table 2
Summary of available rockfish fishery dependent data, fishery independent data, and expert knowledge. Most data were provided by the Alaska Department of Fish and Game (ADF&G); sources noted parenthetically under the dataset name. Data sources varied in availability of catch and effort data, as well as their temporal and spatial resolutions. Catch per unit effort metrics were calculated for the purposes of this study.

Dataset (Source)	Type	Time period	Catch metric (units)	Temporal resolution	Catch per unit effort metric	Spatial resolution / Extent	Speciation
Commercial fish ticket (ADF&G Division of Commercial Fisheries)	Commercial catch	1985–2019	whole weight (lb)	trip (variable duration)	whole weight / trip	Groundfish statistical area / Gulf of Alaska	Individual species
Charter logbook (ADF&G Division of Sport Fish)	Guided sport catch and effort	2006–2018	number of fish	day, year	n fish / angler -trip	Groundfish statistical area or salmon statistical area if groundfish area not recorded / Gulf of Alaska	Pelagic rockfishes; Non-pelagic rockfishes; Yelloweye rockfish
Statewide Harvest Survey (ADF&G Division of Sport Fish)	Guided and unguided sport catch	1977–1995	number of fish	year	n fish / year	Region / Kodiak (Area Q), Sitka (Area D)	Rockfishes
	Guided and unguided sport catch and effort	1996–2018		day, year	n fish / saltwater angler-day (or year)		
Kodiak creel surveys (ADF&G Division of Sport Fish)	Guided and unguided sport catch by interviewed anglers	1992–1999	number of fish	day, year	n fish / boat-trip / year	Region / Kodiak (Area Q)	Rockfishes (1992– 1999); Non-pelagic rockfishes (1995–2019); Pelagic rockfishes (1995–2019); Yelloweye rockfish (2011–2019)
	Guided and unguided sport catch and effort by interviewed anglers	2000–2019	number of fish	day, year	n fish / angler-trip / day (or year)		
Sitka creel surveys (ADF&G Division of Sport Fish)	Guided and unguided sport catch and effort by interviewed anglers	2006–2019	number of fish	day, year	n fish / angler-trip / day (or year)	Region / Sitka (Area D)	Pelagic rockfishes; Non-pelagic rockfishes; Yelloweye rockfish; Individual species from pelagic, non-pelagic assemblages; See Table 1
Interview data (this study)	Index of fish abundance	1970–2019	relative fish abundance score (unitless)	decade or 5-year period	N/A	Region / Kodiak, Sitka	SeeTable 1
Hydroacoustic surveys (ADF&G Division of Commercial Fisheries)	Index of fish abundance	2007–2019	fish density (n fish / km^2)	year	N/A	Region / Kodiak	Black rockfish; All rockfishes
Biomass index (Wood et al., 2019)	Index of fish abundance	1994–2019	biomass (t)	year	N/A	Region / Southeast Alaska	Yelloweye rockfish

throughout Alaska; these were not included in analyses. Interviews typically lasted 30–90 min and were audio recorded and transcribed. The research protocol was reviewed and approved by the University of Alaska Fairbanks Institutional Review Board (#1422965).

2.3.2. *Interview protocol and analysis*

To develop the interview guide, the research team sought feedback through meetings with 14 individuals who are experienced in management, research, fishing, and tribal governance. The research team also received feedback from fishers during community meetings. Minor revisions to the interview guide were made after the first four interviews to improve clarity and eliminate redundancy among questions. The interview guide included questions regarding perceptions of rockfish management, changes in rockfish fisheries, and observations about rockfish abundance, size, and other aspects of their ecology (Appendix A).

To elicit expert knowledge about changes in rockfish abundance, participants were asked to score the abundance level for each species or species group on a seven-point scale, from very low to very high, for each five to 10-year period that they had been fishing (Beaudreau and Levin, 2014; Chan et al., 2018). These questions about relative abundance were omitted for interviews conducted over phone (n = 2), since they were difficult to communicate without the use of a visual timeline. Participants provided relative abundance scores for individual rockfish species or based on their own groupings, which were then reclassified into pelagic rockfishes, non-pelagic rockfishes, and yelloweye rockfish for analysis. To prepare data for analysis, we first assigned numerical indices to the abundance categories (1 = very low, 7 = very high). Then, numerical indices were standardized for each participant by subtracting the mean abundance score (across species and decades) and dividing by the standard deviation. This standardization was done to account for differences in individuals' baseline perceptions of what constitutes 'high' or 'low' abundance, which can vary based on their age or years of experience (Beaudreau and Levin, 2014), thus allowing for comparison of relative abundance trends among experts. A correlation analysis was conducted to summarize directional trends in experts' observations of abundance by region and species. For each individual participant and rockfish group, the directional change in relative abundance was categorized based on the sign of the correlation coefficient (r) between the abundance index and year (i.e., midpoint of the time period for which the abundance index was reported). We calculated the percentage of experts who perceived declining trends ($r < 0$), no trend ($r = 0$), and increasing trends ($r > 0$) in relative abundance for rockfish assemblage.

Open-ended interview questions provided context for understanding changes in rockfish harvest and perceptions of abundance (e.g., "Have you seen any changes in rockfish size, habitat, diet, or other aspects of their ecology?", "Do you have concerns about the health of rockfish populations?", "Have you noticed any other changes in the ecosystem or environment?"; Appendix A). Thematic analysis was performed on qualitative data from interviews (Attride-Stirling, 2001) by two researchers using NVivo 12 software (QSR International, Burlington, U.S. A). The first author performed a combination of inductive (open) and deductive (closed) coding (Bernard, 2018) to detect common themes as they emerged in the text and to assign text to codes that were informed by the research questions, respectively. In a second round of coding, two researchers separately coded the transcripts using the codebook built in the first round of coding, made small adjustments to the codebook, and calibrated their codes for each transcript. Development of the codebook and organization of themes were discussed throughout the analysis process amongst the larger research team.

2.4. Harvest and biological survey data

2.4.1. Data sources

We summarized spatiotemporal changes in commercial and recreational harvest of nearshore rockfishes using all available datasets, including commercial fish tickets, charter logbooks, and angler surveys (Table 2). Together, these datasets include information on the weight and numbers of rockfish harvested from 1977 to 2019 and the spatial location of harvest, reported by groundfish statistical area for commercial fisheries (ADF&G, 2018), statistical/area or logbook area for charter fisheries (ADF&G, 2010), or survey area for unguided recreational anglers (ADF&G, 2021a; Table 2, Table B.1). Commercial fish tickets are generated for each commercial fishing trip and include a record of the total whole weight (lbs) for each species landed, statistical area of harvest, gear type, permit type, port, and confidential vessel and permit holder information (eLandings, 2021). Commercial landings were filtered by species code (ADF&G, 2020c) and statistical area where fish were caught (ADF&G, 2018; Table B.1). Charter logbook records are submitted for each guided recreational fishing trip and include the number of fish caught, kept, and released by species or species group, primary statistical area (Kodiak) or logbook area (Sitka) of harvest (Table B.1), time spent fishing, number of anglers on board, and confidential vessel and permit holder information (ADF&G, 2021c). Dockside creel surveys are conducted by ADF&G staff, who collect information on each boat-trip regarding species or assemblages and numbers of fish caught, kept and released, statistical area or logbook area of harvest, and time spent fishing (ADF&G, 2021d). The Statewide Harvest Survey (SWHS) is an annual mail-in survey that is sent to a stratified random sample of households with resident and non-resident anglers who bought an Alaska state recreational fishing license and provides the longest time series of recreational harvest available in Alaska (Romberg et al., 2018). Anglers are asked to recall species and numbers of fish kept and caught (including releases), number of days fished for all species the entire year, and the general locations where fish were caught aggregated into recreational management areas for reporting purposes (Romberg et al., 2018; Table 2, Table B.1). The SWHS estimates for rockfish were for all species combined. To complement observations of relative abundance from interviews, we also examined data from two fishery-independent surveys (Table 2). Hydroacoustic and video surveys conducted in seven Kodiak management districts by ADF&G generated density estimates (number of fish/km^2) for black rockfish and rockfishes in aggregate, from 2007 to 2019 (Tschersich and Gaeuman, 2019). Yelloweye rockfish biomass estimates in Southeast Alaska were based on surveys conducted for the DSR complex (Table 1) by manned submersible (1994–2009) and remotely operated vehicle (ROV) (2012–2018) (Wood et al., 2019).

2.4.2. Data preparation

Total annual round weight of landed pelagic and yelloweye rockfish was calculated from commercial fishery harvest tickets for Sitka and Kodiak (Fig. 1). All trips with reported landings of rockfish (directed and incidental) were included from both nearshore state waters (<3 nmi offshore) as well as the adjacent statistical areas within the U.S. Exclusive Economic Zone (federally managed waters, 3–200 nmi offshore; Table B.1). Most landings were from directed rockfish jig and longline fisheries, Pacific halibut and sablefish (*Anoplopoma fimbria*) longline fisheries, and Pacific salmon troll fisheries. Other fisheries and gear types with rockfish landings included groundfish trawl, lingcod dinglebar, and pot gear.

Recreational fishery harvest data were reported as the number of fish caught and/or retained and datasets varied in terms of whether and how fishing effort was reported (e.g., angler-hours, trips; Table 2). For consistent comparisons across datasets, we calculated annual harvest as the total number of fish retained in each year of the available time series. Charter logbook and creel survey (charter and unguided recreational) data were reported for all state and federally managed statistical areas in a given year within the respective survey areas (Fig. 1, Table B.1; ADF&G, 2021a). Records for Kodiak creel surveys from 1992 to 1994 were not included in data summaries because all rockfish species were aggregated until 1995. Because yelloweye rockfish were not speciated for Kodiak creel harvest surveys until 2011, we summarized harvest of non-pelagic rockfishes (assumed to be primarily yelloweye rockfish) for 1995–2010. Finally, the annual number of rockfishes recreationally harvested by resident and non-resident anglers from 1977 to 2018 was calculated from the SWHS. Rockfish records in the SWHS are not speciated, so metrics were reported for rockfishes in aggregate.

2.4.3. Data visualization and trend analysis

Time series of rockfish harvest were plotted for commercial and recreational fisheries for each of the study regions. In addition to data visualization of time series, we described temporal trends in harvest using linear regression models fitted to each data set, separately for each species group and region. Regression fits were generated only for those datasets that met regression assumptions of normally distributed errors and constant variance of residuals, based on diagnostic plots. To infer spatial shifts in rockfish fishing over time, choropleth maps were generated from commercial fish ticket and charter logbook data using ArcGIS 10.8.1 (ESRI West Redlands, U.S.A). We calculated total harvest (lb) for each groundfish statistical area (commercial) in 10-year periods and total harvest (number of fish) for each statistical/logbook area (charter) in 5-year periods (Table B.1). Choropleth maps used the Jenks Natural Breaks classification (Esri, 2007) to define bins for symbolizing the intensity of harvest. Groundfish statistical areas encompass both state and federal waters.

3. Results

Our results address the overarching goal of the study—to reconstruct changes in rockfish populations and fisheries in two Gulf of Alaska regions since the 1970s—by first presenting a synthesis of historical changes in Sitka (Section 3.1) and Kodiak (Section 3.2), drawn from a joint analysis of expert knowledge, fishery data, and technical documents (e.g., government reports) about regulatory and fishery changes. To address our first guiding question about ecological changes in nearshore rockfish populations, we summarized and qualitatively compared fishery-independent survey data and abundance indices from interviews for Sitka (Section 3.1.1) and Kodiak (Section 3.2.1). To address our second guiding question, regarding fishers' and managers' concerns about rockfish fisheries, we present results from the thematic analysis of interviews (Section 3.3) to contextualize observed fishery changes from survey data and expert knowledge.

3.1. Changes in Sitka area rockfish populations and fisheries

3.1.1. Rockfish populations: trends from surveys and expert knowledge

Fishery-independent surveys and experts' perceptions of temporal trends in rockfish abundance indicated changes in nearshore rockfish populations in the Sitka region. Estimates of biomass (t) for yelloweye rockfish for the Southeast Outside district, a state management area that includes the west side of Baranof Island (ADF&G, 2021e), indicated a decline from 1994 to 2020 (Wood et al., 2019). From the interviews, a majority of Sitka-based experts reported an overall decrease in relative abundance of pelagic rockfishes and yelloweye rockfish (Table 3); however, perceptions of changes in rockfish abundance varied among individuals and among groups of participants with different types of expertise. Median relative abundance of pelagic rockfishes was observed

Table 3
Summary of trends in pelagic rockfish and yelloweye rockfish abundance from the 1970s to late 2010s observed by interview participants in Sitka and Kodiak. The number and percentage of participants who observed an increase, decrease, or no change in relative abundance of rockfishes are reported.

Direction	Sitka		Kodiak	
	Pelagic rockfishes (n = 20)	Yelloweye rockfish (n = 20)	Pelagic rockfishes (n = 14)	Yelloweye rockfish (n = 3)
Increase	5 (25%)	2 (10%)	2 (14%)	0 (0%)
Decrease	11 (55%)	12 (60%)	6 (43%)	1 (33%)
No change	4 (20%)	6 (30%)	6 (43%)	2 (67%)

to decline from the late 2000s through the late 2010s by agency staff, increase from the 1990s through the late 2010 s by commercial fishers, and decline from the 1980s through the late 2010s by non-commercial fishers (Fig. 2). Median relative abundance of yelloweye rockfish did not show a substantial change for agency participants, commercial fishers, and non-commercial fishers from the 1970s through the late 2010s (Fig. 2).

3.1.2. *Commercial fisheries: harvest and regulation changes*

Commercial rockfish fisheries in the Sitka region have undergone a multitude of changes since the mid-1980s. Landings from the directed pelagic rockfish fishery (mechanical jigs, dinglebar, and hand troll gear) comprised most of the commercial harvest prior to 2005 and, in recent years, most pelagic rockfishes have been caught incidentally in the Pacific salmon troll fishery (Howard et al., 2019a). Pelagic rockfish harvest in Sitka generally increased from 1985 to 1996, followed by a steep decline (Fig. 3), with black rockfish making up the majority of commercial pelagic rockfish landings in Sitka (Howard et al., 2019a). Commercial harvest of pelagic rockfishes in the Sitka area has been relatively flat since the mid-2000s (Fig. 3). The majority of yelloweye rockfish commercial landings were from directed longline DSR fisheries

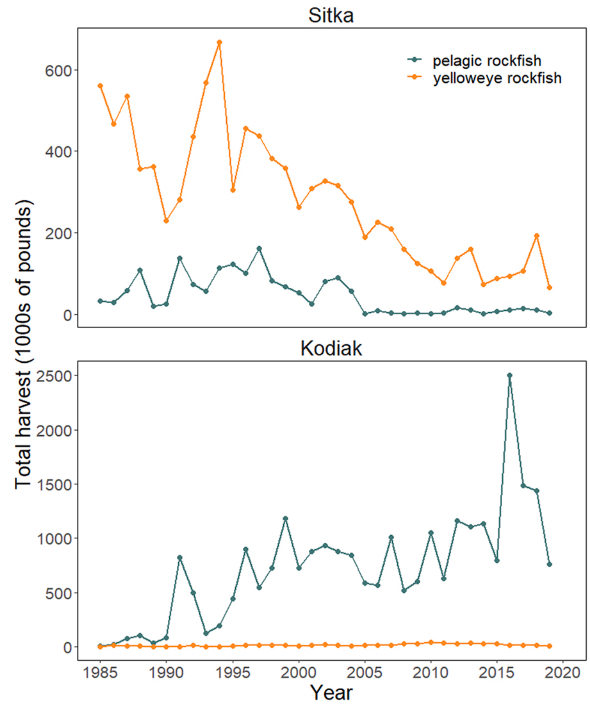

Fig. 3. Total commercial harvest of pelagic rockfishes and yelloweye rockfish in Sitka and Kodiak regions based on commercial fish ticket data. Harvest records were assigned to regions based on the Groundfish Statistical Areas (Table B.1) where fish were caught. The y-axis scales differ between Sitka and Kodiak.

prior to the 1990s, then were primarily from Pacific halibut longline bycatch beginning in the 1990s (Howard et al., 2019a). Yelloweye rockfish harvest declined in the late 1980s, peaked in 1994, and declined through the late 2010s (Fig. 3). This latter period of decline reflects

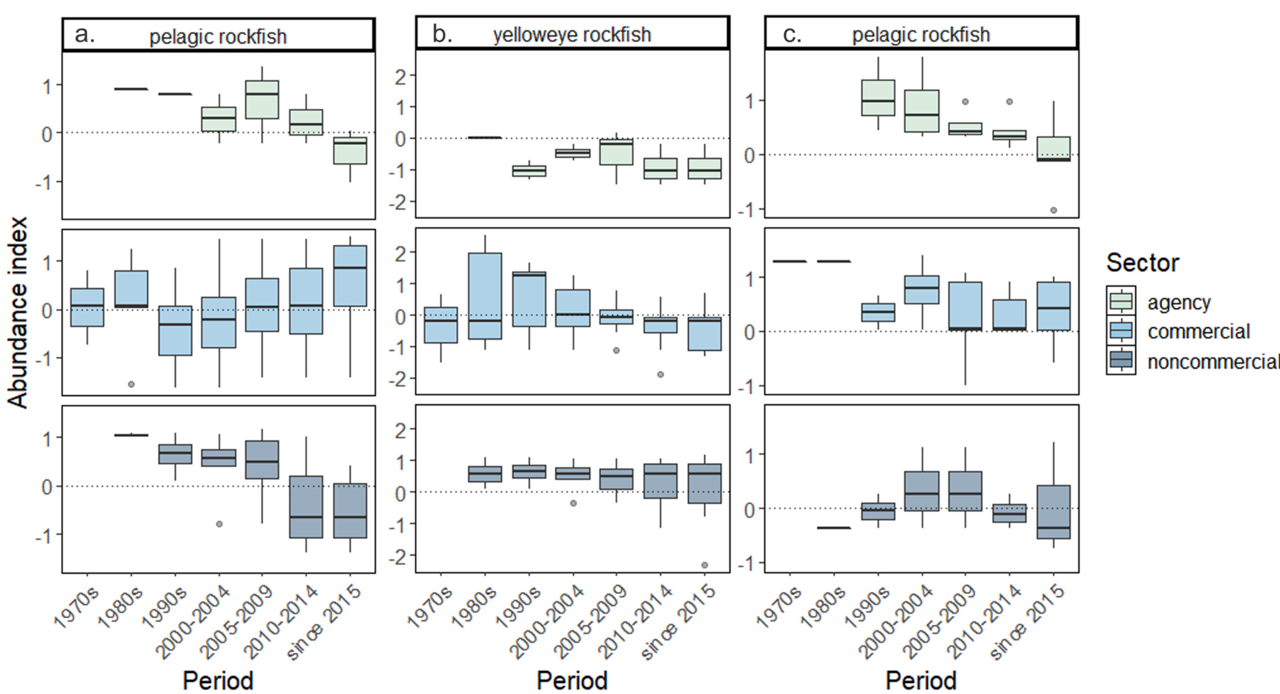

Fig. 2. Changes in relative abundance of pelagic rockfishes and yelloweye rockfish in the Sitka region (a, b) and pelagic rockfishes in the Kodiak region (c) since the 1970s. Abundance indices were derived from semi-structured interviews and are reported separately for each expert group (agency staff, commercial fishers, noncommercial fishers). Boxes show the interquartile range (IQR), with the median abundance index shown as a line within each box. Whiskers show + /- 1.5*IQR. The dotted line denotes the midpoint of the 7-point relative abundance scale.

management efforts to reduce rockfish bycatch in the directed Pacific halibut longline fishery (Howard et al., 2019a). Harvest above the 10% bycatch allowance had to be donated or kept for personal use, or profits could be forfeited to the state for rockfish caught in state waters, while fish harvested in federal waters were prohibited from entering commerce (Brylinsky et al., 2008; Howard et al., 2019a). Throughout the 1990s and 2000s, openings and closures for the directed DSR fishery were determined based on a variety of factors, including DSR abundance estimates, bycatch mortality in the halibut fishery, and increases in recreational catch (Brylinsky et al., 2008; Howard et al., 2019a). More recently, the directed DSR fishery has been managed on a more consistent area rotation system until the fishery closure in 2020 (Howard et al., 2019a; ADF&G, 2019c).

Over the period from 1985 to 2019, commercial fishing effort for rockfishes, both directed and incidental (i.e., bycatch from halibut longline and salmon troll fisheries), was largely concentrated in federal statistical areas, with most fishing trips occurring west of Kruzof Island and Biorka Island (Fig. 1, Figure B.1). Spatial distribution of commercial rockfish harvest has not been static over this period, with changes driven by state and federal regulatory changes, management plans, and area closures. A notable decrease in commercial catch of pelagic and yelloweye rockfishes from state waters within Sitka Sound and adjacent federal waters to the west occurred during the mid to late 2000s, and harvest from those areas remained low through the 2010s (Fig. 4). These spatial shifts coincided with the implementation of the Sitka Local Area Management Plan (LAMP) in 1999 that prohibits commercial and charter fishing for Pacific halibut in Sitka Sound (NOAA Fisheries, 2019) and the closure of select areas as part of the directed black rockfish fishery management plan established in the early 2000s (Howard et al., 2019a). From 2015 to 2019, harvest was highest in state waters near Biorka Island for pelagic rockfishes and in the adjacent federal waters for yelloweye rockfish (Fig. 4).

3.1.3. *Recreational fisheries: harvest and regulation changes*

Growth of recreational rockfish harvest in Sitka since the late 1970s is largely attributed to charter and non-resident anglers (Fig. 5, Fig. 6); charter customers are most often non-residents and must adhere to lower bag limits than resident anglers. Charter harvest of pelagic rockfishes increased significantly based on a linear regression ($P = 0.003$, $R^2 = 0.57$) from 2006 to 2018 (Fig. 6), with a drop in harvest in 2016 that

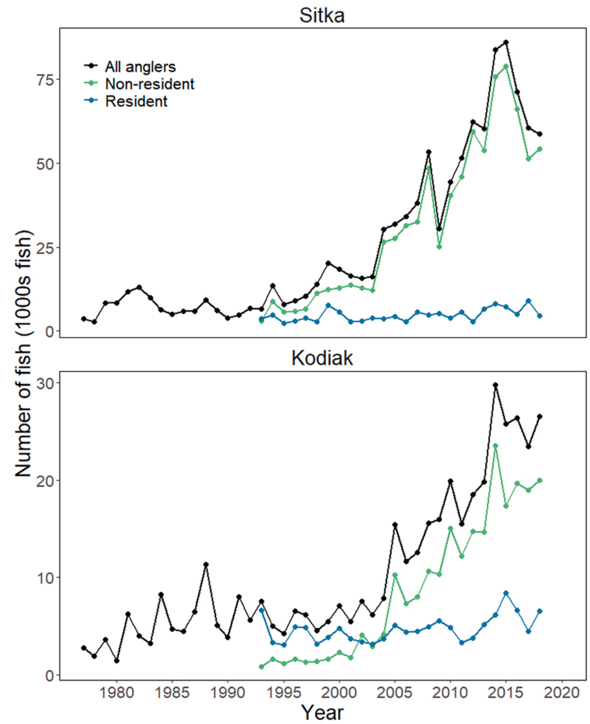

Fig. 5. Numbers of rockfish caught in the sport fishery from 1977 to 2019 for resident, non-resident, and all anglers (sum of resident and non-resident) based on the Statewide Harvest Survey in Sitka and Kodiak. Angler residence was not specified prior to 1993. The y-axis scales differ between Sitka and Kodiak.

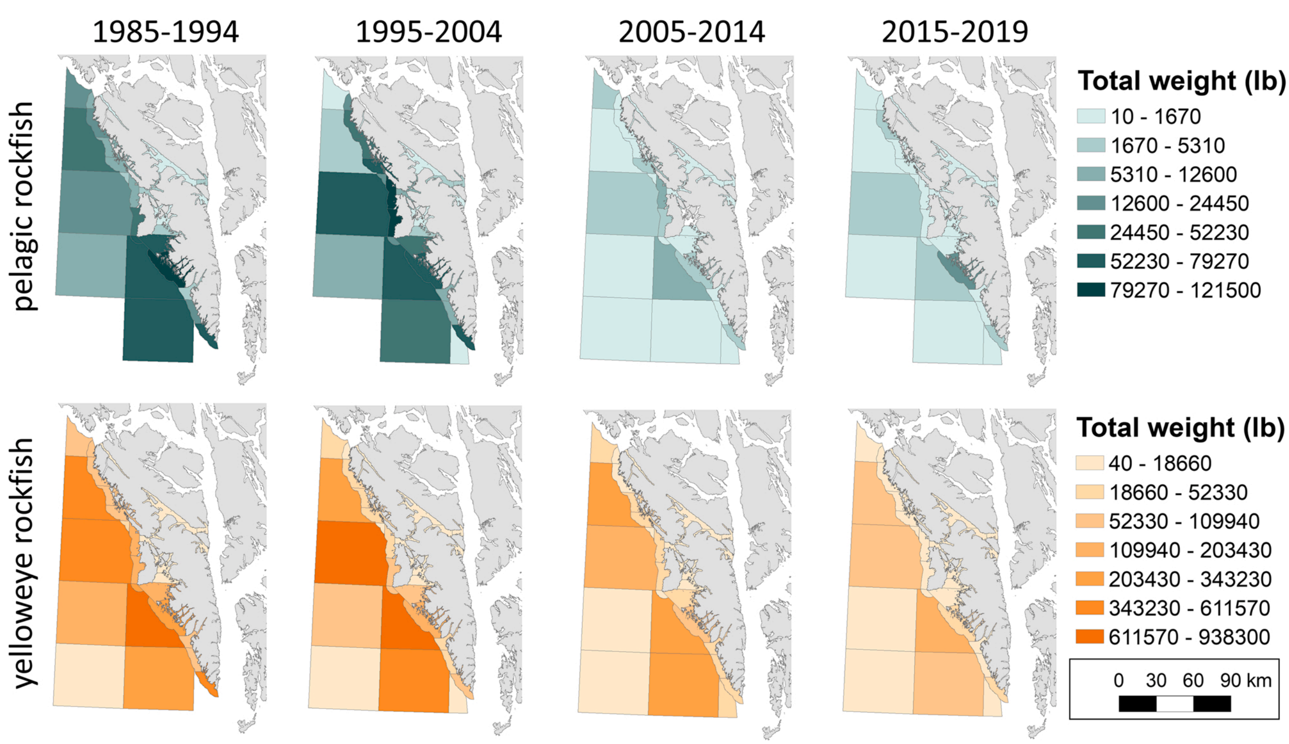

Fig. 4. Total commercial harvest per 5–10-year period for pelagic (green) and yelloweye (orange) rockfishes by Groundfish Statistical Area, based on commercial fish ticket data for the west side of Baranof Island and Chichagof Island. Major water bodies and land masses are labeled in Fig. 1.

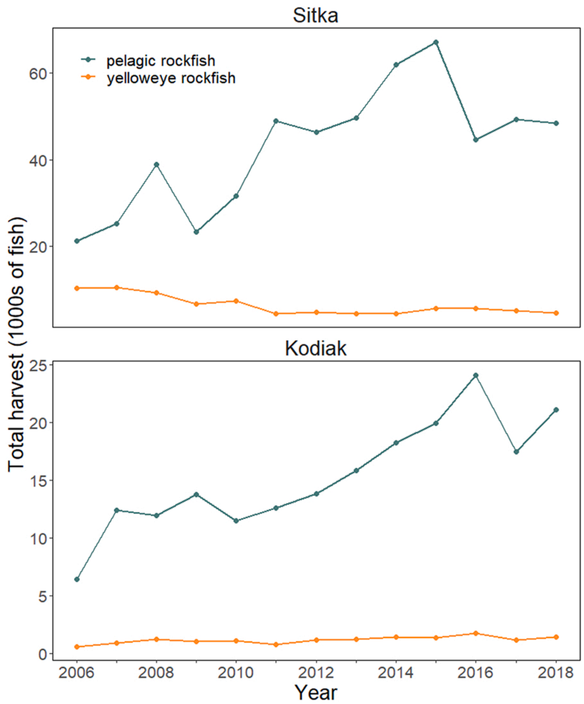

Fig. 6. Number of pelagic rockfish and yelloweye rockfish reported caught in charter angler logbook data for Sitka and Kodiak from 2006 to 2018. The y-axis scales differ between Sitka and Kodiak.

corresponded to a daily bag limit reduction from 5 to 3 rockfishes per person (Howard et al., 2019a). Charter harvest of yelloweye rockfish decreased ($P = 0.001$, $R^2 = 0.63$) from 2006 to 2018 (Fig. 6), due to a series of increasingly conservative regulations, including 3- to 5-week non-pelagic rockfish retention bans during July and August of 2017–2019 and a bag limit reduction for non-resident anglers in 2018 (Howard et al., 2019a). The majority of harvest from private and charter anglers is comprised of pelagic rockfishes and the proportion of yelloweye rockfish harvested by charter anglers declined from 2006 to 2019, according to creel surveys (Figure B.2).

Over the period from 2006 to 2018, the majority of charter fishing trips occurred in nearshore waters west of Kruzof Island and Biorka Island (Fig. 1, Figure B.1). Charter harvest of pelagic rockfishes increased in both nearshore and offshore areas from 2006 to 2018 (Figure B.3). Charter harvest of yelloweye rockfish declined in Sitka Sound and offshore waters near Biorka Island, but remained consistent in all other statistical areas (Figure B.3). Although fishing had occurred in federal waters prior to 2010, recreational harvest was assigned to the nearest state statistical area and not assigned to federal statistical areas until 2010 (J. Wieliczkiewicz, ADF&G, personal communication, December 2020). Due to the LAMP, non-commercial rockfish harvest after 1999 likely only reflects unguided anglers fishing under recreational or subsistence regulations, because charter anglers were primarily catching rockfish opportunistically while targeting halibut and salmon outside of the LAMP boundaries (Chan et al., 2017; Beaudreau et al., 2018).

3.2. Changes in Kodiak area rockfish populations and fisheries

3.2.1. Rockfish populations: trends from surveys and expert knowledge

Surveys of abundance and expert knowledge suggest that pelagic rockfish abundance in the Kodiak region has remained relatively stable since the 1990s. Densities of black rockfish and rockfishes in aggregate estimated from hydroacoustic surveys varied little from 2007 to 2019 (Fig. B.4). From our interviews, 43% of experts observed a decrease in pelagic rockfish abundance, 43% observed no change, and 14% reported an increase (Table 3). The median relative abundance of pelagic rockfishes reported by agency staff declined, but showed no clear trend for commercial and non-commercial fishers (Fig. 2). In Kodiak, only three experts provided observations about yelloweye rockfish abundance, which was insufficient for analysis.

3.2.2. Commercial fisheries: harvest and regulation changes

Commercial harvest records in Kodiak reflect changing fishery dynamics and rockfish regulations. Commercial black rockfish harvest largely occurs in the directed black rockfish jig fishery and as bycatch in the Pacific cod jig fishery (Howard et al., 2019a). Dark and dusky rockfishes are more frequently caught as bycatch in the bottom trawl fishery (Howard et al., 2019a). Black rockfish harvest in the Westward region, which includes Kodiak, decreased from a peak in 1991 (Howard et al., 2019a), but commercial harvest for the entire pelagic rockfish assemblage showed an increasing trend from 1986 to 2019 (Fig. 3). In Kodiak, there is no directed yelloweye rockfish commercial fishery; most harvest occurs as bycatch in the Pacific halibut longline and groundfish bottom trawl fisheries. In 2010, the North Pacific Fishery Management Council implemented the Central Gulf of Alaska Rockfish Program, which resulted in increased directed harvest of groundfish and, consequently, higher bycatch of yelloweye rockfish (Howard et al., 2019a).

The majority of commercial fishing trips from 1985 to 2019 in which rockfishes were landed occurred along the east and northeast sides of Kodiak Island (Fig. B.1). Commercial rockfish harvest was consistently highest on the east side of Kodiak Island and increased in federal waters from the mid- to late-1990s (Fig. 7). Most commercial pelagic rockfish harvest occurred in the nearshore waters close to Ouzinkie and the City of Kodiak (Fig. 1, Fig. 7). Harvest of yelloweye rockfish was not recorded in the nearshore waters around Larsen Bay along the west side of Kodiak Island (Fig. 1) until the late 1990s, and increased in these areas through the early 2010s (Fig. 7).

3.2.3. Recreational fisheries: harvest and regulation changes

The growth of recreational fishing in Kodiak from 1996 to 2018 is largely attributed to non-resident anglers on charter vessels (Fig. 5, Fig. 6). An increasing trend in recreational harvest of pelagic rockfishes is reflected in charter logbook records ($P < 0.001$, $R^2 = 0.78$; Fig. 6). Charter harvest of pelagic rockfishes dropped in 2017 (Fig. 6), when the daily bag limit in Chiniak Bay and Marmot Bay was reduced from five to three rockfish per person, with a maximum of two non-pelagic rockfish and one yelloweye rockfish (Howard et al., 2019a). Charter logbook data also show an increase in charter harvest of yelloweye rockfish since 2006 ($P = 0.003$, $R^2 = 0.57$; Fig. 6). Creel survey data show that rockfish harvest from private and charter anglers was mostly comprised of pelagic rockfishes, with a low (<10%) but relatively consistent contribution of yelloweye rockfish to the catch (Figure B.2), although creel survey data may not capture charter boats fishing on the west side of Kodiak Island.

From 2006 to 2018, the majority of recreational charter fishing trips occurred in nearshore waters near the City of Kodiak on the east side of Kodiak Island and Larsen Bay on the west side of the island (Fig. 1, Figure B.1). Recreational harvest was highest near the City of Kodiak for pelagic rockfishes and highest in Larsen Bay and near the City of Kodiak for yelloweye rockfish (Figure B.5). Offshore charter harvest of rockfishes east of the City of Kodiak increased from the late 2000s to the 2010s (Figure B.5).

3.3. Perspectives on rockfish fishery viability in Sitka and Kodiak

Expert knowledge of fishers and agency staff provided additional context for understanding changes in rockfish populations and fisheries. Of the 35 interview participants who responded to the question regarding concerns about rockfish populations, 23 expressed concern (Sitka n = 13, Kodiak n = 10), while 12 were not concerned (Sitka n = 7, Kodiak n = 5) about the health of rockfish populations. Most participants who viewed rockfish populations as healthy based their

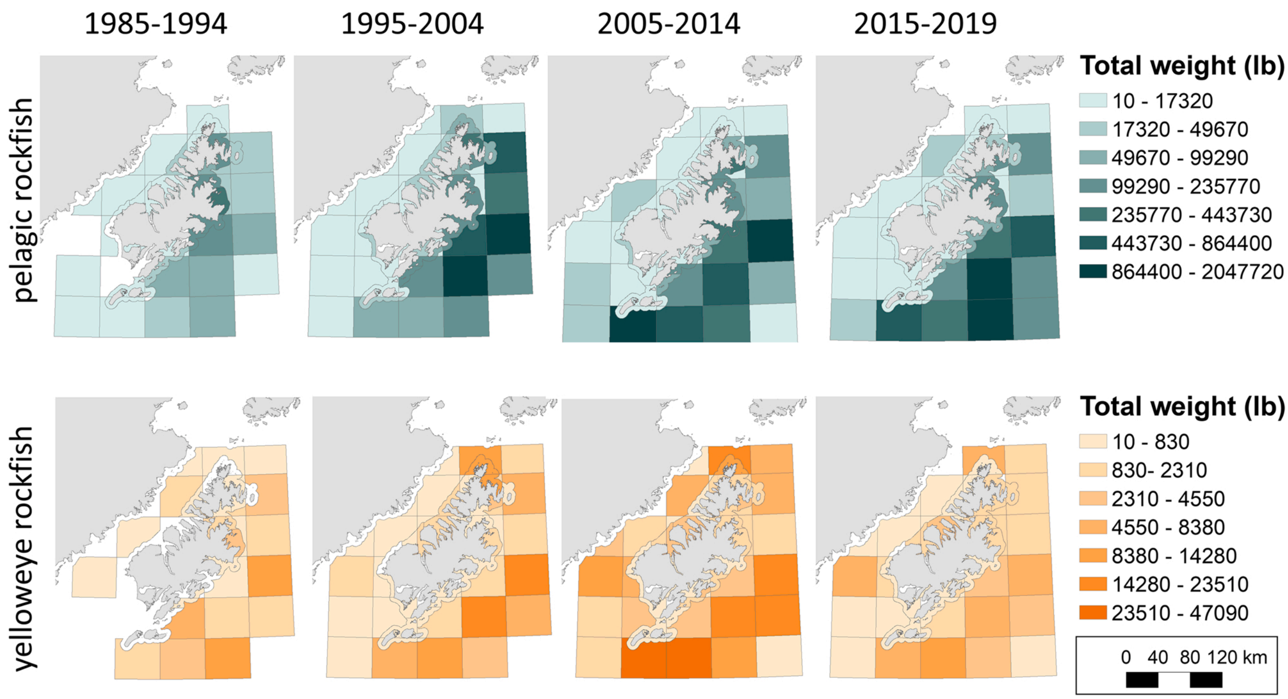

Fig. 7. Total commercial harvest (lb) per 5–10-year period for pelagic and yelloweye rockfishes by Groundfish Statistical Area, based on commercial fish ticket data for Kodiak Island. Major water bodies and land masses are labeled in Fig. 1.

assessment on both direct observations of rockfish abundance and perceptions of effective management. For example, one Kodiak charter operator with 35 years of experience explained:

> I'm fairly optimistic about the rockfish. The population in my experience at least along the Pacific side of Kodiak Island is really healthy, there's a lot of abundance, it seems like they're not difficult to find and so, I'm optimistic about that. Another thing that makes me optimistic is kind of the proactive management that's happened over the years of people paying attention and keeping an eye on them.

The perception of increased fishing pressure on rockfishes was the leading cause for concern about rockfish populations, with growth of the charter fleet mentioned most frequently. This was particularly viewed as a concern in Southeast Alaska. A Sitka charter operator with 10 years of experience described their observations of these changes as related to declines or shifts in timing of Chinook (king) salmon (*O. tshawytscha*) and coho salmon (*O. kisutch*), which are preferred target species for charter anglers (Beaudreau et al., 2018):

> I mean anyone who's been at the Sitka Airport and seen outgoing planes and seen fish boxes upon fish boxes upon fish boxes and then you get a couple years in a row where king numbers are really, really low and the coho are showing up late, these charter guys have, I mean they have clients they have to keep happy and people want to fill their freezer, that's why they come up here, so I have no doubt that rockfish and halibut—especially in Sitka Sound closer to town—are probably getting hit pretty hard.

More restrictive Pacific halibut regulations for anglers fishing from charter boats was also noted as an impetus for increased rockfish harvest in Sitka (Beaudreau et al., 2018) and Kodiak (Howard et al., 2019a). Some interview participants also noted that body size has declined for pelagic rockfishes and yelloweye rockfish, which they attributed to greater fishing pressure from recreational and commercial fishers. However, several individuals, mostly agency staff, said they had not seen a change in pelagic rockfish size based on their fishing experience and the available data.

Participants discussed directed and incidental catch of rockfishes in commercial fisheries, with increases in pressure attributed to climate-induced shifts in other species and management policies. A marine heatwave from 2014 to 2016 (Di Lorenzo and Mantua, 2016), also known as "The Blob", was a driver of declines in Pacific cod stocks in the Gulf of Alaska (Dorn et al., 2017; Barbeaux et al., 2020). Fishers in Kodiak commented that the Pacific cod collapse contributed to the growth of the commercial pelagic rockfish jig fishery. As explained by a commercial fisherman in Kodiak with over 30 years of experience:

> When cod was really abundant, there was a lot of emphasis on catching cod, and now … cod abundance has decreased there's been a more awareness of how good rockfish are to eat. And the market development has gotten better and better both for duskies and blacks.

Some experts in Kodiak expressed concerns about increased fishing pressure from commercial fleets, particularly related to the substitution of pelagic rockfishes for Pacific cod. In Sitka, interviewees attributed most commercial fishing pressure on rockfishes to bycatch from Pacific halibut longline and salmon troll fisheries. The Pacific halibut fishery transitioned from a derby-style fishery to management under an individual fishing quota (IFQ) system in 1995 (Pautzke and Oliver, 1997), which extended the fishing season. Some fishers expressed concern that the DSR bycatch allowance in the halibut IFQ fishery, intended to limit bycatch mortality of rockfish, had actually incentivized rockfish retention. A Sitka commercial fisherman with over 40 years of experience explained that "IFQs impacted all of this. If there is one point where you can really, really say that things really changed, it was IFQs. [That is] when they started targeting the rockfish." Concerns about ongoing effects of commercial trawl fisheries on rockfish populations and habitats were raised by Kodiak participants. In contrast, fishers in Sitka noted the positive effects on rockfishes resulting from a 1998 trawl ban in Southeast Alaska (Witherell and Coon, 2000).

Technology advancements for both commercial and recreational fishing were described by participants as contributing to greater precision when targeting rockfishes. Participants mentioned that many charter guides have increased fishing efficiency by purchasing higherpowered boats and more advanced technology, such as electric reels and sonar technology. The Alaska Longline Fishermen's Association (ALFA) has developed a bathymetry database that allows commercial fishers to more effectively avoid rockfish bycatch (ALFA, 2020). Some experts noted that shifts in fishing areas were associated with rockfish movement patterns, explaining that while rockfishes aggregate and exhibit site fidelity, they also move laterally, and that the extent of their movements may be underestimated. One commercial fisherman from Kodiak with over 40 years of experience noted that there may be variation in movements among different subsets of rockfish populations: "I think you have rock piles with fish that hang out there pretty much the whole time, then I think you have groups of fish that go from different rock piles and move around."

Observations about rockfish ecology were frequently brought up in the context of local to global environmental changes. In Sitka, fishers noted that seabirds have declined and disappeared in certain areas and forage fish populations have shifted spatially and temporally. Most interviewees who discussed environmental changes noted that the climate has become warmer and ocean temperatures have risen. In addition to rockfish and Pacific cod jig fishery impacts, marine heat waves have also yielded broader impacts on forage species. As shared by a commercial fisherman in Kodiak with over 35 years of experience:

> The circumstances of 2014 to 2017, The Blob and the marine heat wave, were just so devastating. We lost the bait fish, we used to catch the rockfish. and I remember, 2016… late in the fall I caught a rockfish with feed falling out of his mouth. That was so noteworthy I posted it to Instagram.

In summary, the qualitative analysis of interview data suggested that changes in rockfish populations and fisheries over the last fifty years are related to multiple, overlapping drivers, ranging from global climate change to shifts in management policies to changing consumer demand for rockfishes and other species.

4. Discussion

4.1. Synthesis of findings

When considered together, expert knowledge, harvest data, fishery independent surveys, and published literature provide a more holistic understanding of patterns and drivers of change in commercial and recreational rockfish fisheries than any single knowledge source alone. In Sitka, commercial harvest of pelagic rockfishes and yelloweye rockfish has decreased overall since the early to mid-2000s, as landings shifted from directed catch to bycatch (Howard et al., 2019a). Over the period when commercial rockfish harvest declined, recreational harvest increased for pelagic rockfishes and declined for yelloweye rockfish. More than half of Sitka participants in this study observed an overall decline in pelagic rockfishes and yelloweye rockfish abundance in the Sitka region over their lifetime of fishing experience; however, nearly half of participants reported no change or an increase in abundance of both rockfish groups. Biomass surveys for yelloweye rockfish corroborate a declining trend in the Sitka region. In Kodiak, commercial harvest of pelagic rockfishes and yelloweye rockfish has increased overall since the 1980s, with landings attributed to bycatch from Pacific salmon and groundfish fisheries and directed catch in the black rockfish jig fishery (Howard et al., 2019a). Recreational harvest of pelagic rockfishes and yelloweye rockfish has generally increased in Kodiak since the mid-2000s. Kodiak-based experts expressed varying perspectives about abundance of pelagic rockfishes. Over two thirds of Kodiak experts observed that populations had either decreased or remained unchanged (approximately split between those categories), while very few suggested that pelagic rockfishes had increased over their lifetime experience. Fishery-independent surveys indicate that black rockfish abundance has remained relatively stable since at least 2007. Only three experts provided observations about yelloweye rockfish abundance in Kodiak, reflecting that yelloweye rockfish are not a major component of the region's rockfish fisheries compared to pelagic rockfishes.

Some of the concerns and optimism raised by experts about rockfish populations and fisheries were strongly place-based, while others were shared between regions. From the longest time series of recreational harvest available (i.e., SWHS data), we saw that recreational harvest of rockfishes has increased since the late-1970s in both regions. Recreational harvest of pelagic rockfishes has occurred at much higher levels than yelloweye rockfish in both regions. Changes in harvest are reflected in experts' stated concerns about growth of charter fleets and unguided recreational fishing and subsequent increased fishing pressure on rockfish. Experts in both regions also expressed concerns about realized or potential increases in rockfish bycatch and directed landings in commercial fisheries. Across sectors, experts described localized depletion of rockfishes due to heavy fishing in certain areas, especially closer to town in both Sitka and Kodiak. Over time, charter harvest has become more heavily concentrated in nearshore and federal waters adjacent to the cities of Sitka and Kodiak. Spatial data from charter logbooks and commercial fish tickets corroborate experts' observations of localized fishing. In both Sitka and Kodiak, experts cited reasons for optimism about rockfish. In areas where fishing pressure is lower, populations appear to be abundant. Additionally, proactive management actions such as bag limit reductions and fishery closures were perceived by some experts to be beneficial for the future viability of rockfish fisheries.

4.2. Bridging bodies of knowledge: strengths and limitations

Our work contributes to a broader body of literature that weaves together fishers' knowledge, scientific observations, and historical records to reconstruct changes in fisheries and marine ecosystems. Many of these studies, like ours, emphasize the complementary nature of local ecological knowledge and scientific knowledge, particularly with respect to their spatial-temporal scales, while acknowledging that both are incomplete and socially and ecologically situated (e.g., Murray et al., 2007, 2008, Huntington et al., 2004). For example, Murray et al. (2008) found that fishers' knowledge of Atlantic cod (*Gadus morhua*) movement patterns complemented long-term tagging studies by providing local-scale information about stock structure. In another study, interviews with resource users provided a long-term (60–70 years) decadal record of fish abundance, while survey data captured interannual fluctuations in population abundance over a shorter period (30–40 years; Beaudreau and Levin, 2014). Differences in perceptions of change among fishers, scientists, and managers can also provide insights into potential sources of conflict in fisheries management arising from differences in people's information environments, or the ways in which individuals acquire and process information (Verweij et al., 2010; Beaudreau et al., 2011). Examining differences and complementarities across diverse bodies of knowledge can strengthen a shared understanding of change in natural resource systems (Huntington et al., 2004) and increase the relevance of research to communities and stakeholders (Tengö et al., 2014). In the following sections, we discuss the strengths of fisheries data and expert knowledge in this study and the partial perspectives that they each provide on changes in Gulf of Alaska rockfish fisheries.

4.2.1. Fishery data and biological surveys

The fishery-dependent datasets included in this study have strengths and limitations in terms of their reliability for assessment and applications to management. Of the five datasets used in our study, the SWHS provides the longest-term record, spanning back to 1977, yet does not report harvest levels for individual species or species groups. Charter logbook data, creel surveys, and commercial fish ticket data are more limited in their temporal scope. The joint analyses of recreational and commercial fisheries data can be challenging due to differences in harvest metrics, regulatory areas, and agency divisions responsible for monitoring. Harvest metrics align with the regulatory structure for each sector, in which recreational harvest is managed according to daily bag limits and possession limits that set the number of fish allowed per person (ADFandG, 2019a; ADFandG, 2019b) and commercial harvest is regulated according to a weight-based total allowable catch (ADFandG, 2020a). The scale and resolution of spatial data also differ between recreational and commercial sectors. For example, charter guides are instructed to mark the statistical or logbook area where they fished for their target species, which may not include rockfish caught as non-target catch in other statistical areas on a given trip (K. Howard, ADF&G, personal communication, August 2021).

Regional differences in how fishery-dependent data are collected and used added to the complexity of combined analyses for Sitka and Kodiak regions. For example, creel survey data serve different primary purposes across regions. In the Sitka area, creel surveys are used to determine catch composition and generate estimates of recreational harvest in the summer, whereas in the Kodiak area they are primarily used to assess catch composition and estimate spatial distribution of effort and harvest. The Kodiak creel surveys also underwent changes in rockfish speciation that made analysis of the full dataset challenging: pelagic and non-pelagic rockfishes were not separately recorded until 1995 and yelloweye rockfish was not separately recorded until 2011. Spatial data also differ between regions. In Southeast Alaska (including Sitka), commercial harvest is recorded by Groundfish Statistical Area and recreational harvest records are assigned to logbook areas, but in Kodiak both commercial and recreational harvest data are assigned to Groundfish Statistical Area (Table B.1). Overall, these incongruences highlight a need for coordination between recreational and commercial management of rockfishes. In recognition of this need, ADF&G created the Statewide Rockfish Initiative in 2016 to bring together agency staff throughout the state and across Commercial and Sport Divisions to unify research and management efforts for Alaska's black rockfish and yelloweye rockfish fisheries (Howard et al., 2019b).

While harvest data will remain a critical tool for management and assessment of rockfish stocks in the Gulf of Alaska, it is important to address the challenges in estimating biomass or inferring biological trends from fishery-dependent data (Ovando et al., 2021). In a study comparing biomass data from stock assessments to catch data from U.S. West Coast fisheries, the authors found that a smaller percentage of fisheries were deemed overexploited or collapsed based on biomass estimates (4–17%) compared to catch data (49%; Branch et al., 2011). Factors that can contribute to overestimation of collapsed fisheries from catch data include changes in taxonomic resolution of reporting, market interest, management policies, oil prices, fish movement and spatial distribution, and exclusion of certain fleets (e.g., foreign vessels; Branch et al., 2011, Murawski et al., 2007, Longhurst, 2007, de Mutsert et al., 2008). Our findings also suggest that it may be difficult to tease apart effects of changing fish abundance from regulations that influence trends in harvest data. For example, charter harvest records showed that pelagic rockfish catch in Sitka declined following a bag limit reduction in the late 2010s, a period when non-commercial fishers also reported observed declines in pelagic rockfish abundance. More recently, bans on retention of non-pelagic rockfishes and demersal shelf rockfishes were instituted in 2020 for recreational and directed commercial fisheries in Southeast Alaska, respectively. As a result, the only harvest and biological data for these rockfish species in Southeast Alaska were collected from commercial bycatch, primarily from groundfish longline fisheries in 2020.

As for fishery-independent data, the biological surveys included in this study also offer advantages and disadvantages for assessing rockfish fisheries and populations in the Gulf of Alaska. A benefit of the Kodiak-based hydroacoustic surveys is that they sample areas that are not necessarily targeted by fishing vessels, thus broadening the spatial scope of knowledge about black rockfish. However, their temporal scope is more limited, as these surveys began in 2007 and do not provide historical information on rockfish stocks. Additionally, while the survey is conducted in management districts throughout Kodiak Island, each district is not sampled annually, and some districts are sampled less frequently than others. The yelloweye rockfish assessment in Southeast Alaska spans back to 1984, but like the hydroacoustic survey, management districts and habitat types were not surveyed consistently (e.g., the Northern Southeast Outside district was not surveyed from 1984 to 1987 and no districts were surveyed from 2006 to 2007; Wood et al., 2019). Despite these limitations, biological surveys that use acoustic and video technology are an important tool for small-scale monitoring of rockfish populations, particularly in areas of low abundance or where fishing is prohibited (Yamanaka and Logan, 2010). Tagging studies can also aid in resolving movement patterns and site fidelity of rockfishes, which several expert fishers in our study suggested was an area needing more research focus. For example, studies along the California coast used acoustic telemetry (Green and Starr, 2011) and tag-recapture methods (Starr and Green, 2007) to study movement patterns of black rockfish and evaluate implications for management. Researchers found that 10–40% of black rockfish exhibit low site fidelity and possibly migrate long distances (Starr and Green, 2007; Green and Starr, 2011), suggesting that small marine protected areas may be effective in protecting only the more sedentary portion of the population (Green and Starr, 2011).

4.2.2. *Expert knowledge*

Expert knowledge from interviews provided a long-term understanding of changes in relative abundance of rockfishes since the 1970s. Experts' observations of relative abundance were influenced by environmental and demographic factors, which contributed to differences in perspectives. When asked about changes in rockfish abundance, many participants noted that their perceptions of abundance were dependent on their fishing behavior at a given time. Most commonly, fishers stated that their perceptions of rockfish abundance were based on whether they were targeting a certain species of rockfish, or if they were targeting another fish such as Pacific halibut, Pacific salmon, or sablefish. Multiple fishers and agency staff discussed how rockfishes have been historically viewed as "trash fish," but a growing commercial and charter interest, greater preference for consumption, and limited fishing opportunities for other species like Pacific salmon or Pacific halibut has increased the market and personal value of rockfishes. Additionally, experts noted that their observations differed based upon gear used, depth fished, fishing technique or skill level, size selectivity, or regulatory changes. Two agency staff attributed their perceptions of abundance to the management context for some species. Similarly, Farr et al. (2018) found that regulations and species targeted affect fishers' perceptions of the environment. Management actions that limited fishing opportunities reduced fishers' interactions with their environment, and those who diversified their fishing portfolios, thus increasing time spent on the water and gaining experience in varied habitats, tended to have a richer knowledge of their ecosystem (Farr et al., 2018). Other research has shown that stakeholders' perceptions of their environment are influenced by sector (Verweij et al., 2010), locations and spatial scale of fishing grounds (Chan et al., 2018; Verweij et al., 2010), and their duration of fishing experience (Beaudreau and Levin, 2014; Chan et al., 2018). The time frame over which fishers are asked to recall ecological changes (e.g., over a week, month, year) can also influence perceptions of abundance or catch (Aylesworth and Kuo, 2018). In this study, small sample sizes within individual user groups (e.g., gear groups, years of experience), meant that we were unable to analyze the influence of these factors on perceptions of rockfish abundance.

Limitations in the types and range of expertise represented in this study are reflective of broader, systemic issues with representation in research that includes local knowledge holders. For example, in a review of traditional knowledge studies in the Arctic, Hitomi and Loring (2018) found that research participants tended to be more representative of older, male knowledge holders. This also holds true in our work, in which most fishers we interviewed self-identified as white (91%) and male (79%). The research participants reflected expertise in multiple fisheries and gear groups, though the majority of participants fished primarily under commercial regulations. This research focused primarily on fishers and agency staff within commercial and recreational rockfish fisheries, which comprise the majority of rockfish harvest in the Gulf of Alaska. The demographics of interview participants in this study may be reflective of participation within the commercial and recreational rockfish fisheries as a whole, but we did not have data to assess this. We did not directly explore Indigenous knowledge and stewardship of rockfishes in this study and are, therefore, reflecting a limited perspective through the lens of recreational and commercial fisheries, as well as management priorities of state and federal agencies. Traditional approaches to bottomfish harvest by Alaska Natives, which emphasized taking only what was needed by the community, rotating fishing effort among areas, and releasing small fish, ensured sustainable harvest of rockfish, halibut, and other species for thousands of years (Turek et al., 2009). This longstanding system of Indigenous stewardship, which was disrupted by Western systems of resource management, offers lessons for how rockfish fisheries may be sustained today.

4.3. Impacts of COVID-19 pandemic and regulatory changes

Two major issues emerged during our study, which had the potential to affect people's views of and concerns regarding rockfish fisheries. Regulatory closures for non-pelagic rockfishes in Southeast Alaska and the COVID-19 pandemic both had major impacts on rockfish fisheries in the Gulf of Alaska. At the beginning of 2020, ADF&G announced a prohibition on the retention of non-pelagic rockfishes in recreational and personal use fisheries, as well as demersal shelf rockfishes in directed commercial fisheries in Southeast Alaska (ADF&G, 2019c; Sport Fishing Emergency Order, 2020). Travel prohibitions and COVID-19 safety measures meant that we were unable to conduct in-person interviews after the non-pelagic rockfish bans. Since some participants stated that their concerns about rockfishes were affected by current regulations and management structure, awareness of these impending fishery closures may have influenced the degree to which stakeholders were concerned about rockfishes. Several participants noted that their perceptions of rockfish abundance changed based on whether they were targeting rockfishes; therefore, bans on rockfish retention would have likely affected fishers' observations of abundance in 2020. Additionally, bans on rockfish retention mean that fishery-dependent data for non-pelagic rockfishes, especially yelloweye rockfish, would be limited to bycatch from the IFQ halibut fisheries in Southeast Alaska.

5. Conclusion

Through triangulation of multiple forms of knowledge, we found that increases in localized fishing pressure, growth of charter fishing, and declines in rockfish biomass underlie concerns about future sustainability of rockfish populations and fisheries. Because of the complexity of assessing rockfishes, no single knowledge source provides a complete understanding of their population status. Fishery-dependent data and biological surveys revealed changes in fishing effort, harvest patterns, and fish abundance. Expert knowledge offered longer term perspectives on abundance trends and provided contextual understanding of how environmental, socioeconomic, and regulatory change interacted to affect rockfish fisheries over the last fifty years. The goal of our study was not to determine an exact truth about rockfishes, but to convey a plurality of perceptions, enrich our understanding about rockfish fisheries, and provide a basis for further inquiry. Through the inclusion of multiple perspectives, we hope that this work helps to generate a shared understanding of patterns and drivers of change in rockfish populations and fisheries and lends support to place-based, community-driven stewardship of nearshore rockfish fisheries.

CRediT authorship contribution statement

Jesse Y. Gordon: Conceptualization, Methodology, Formal Analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration. **Anne H. Beaudreau:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Benjamin C. Williams:** Conceptualization, Methodology, Formal analysis, Data Curation, Writing – review & editing, Funding acquisition. **Scott C. Meyer:** Conceptualization, Methodology, Writing – review & editing, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.fishres.2022.106333.

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