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Socioeconomic considerations of the commercial weathervane scallop fishery off Alaska using SWOT analysis

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A B S T R A C T

We conducted a socioeconomic assessment of the commercial weathervane scallop (*Patinopecten caurinus*) fishery off Alaska. The research was structured within the framework of an SWOT (strengths, weaknesses, opportunities, threats) analysis, a strategy commonly used to analyze the internal (strengths, weaknesses) and external (opportunities, threats) components of an industry. Specifically, we focused on five categories: social, technological, economic, environmental, and regulatory. Semi-structured interviews were conducted with 27 participants who had detailed knowledge of the fishery, including industry members, fishery managers, biologists, and members of coastal communities who interact with the fishery. We addressed topics such as attitudes of the Alaskan public towards scallop dredging, impacts of the scallop industry on Alaskan coastal communities, market influences of U.S. east coast and imported scallops, changes in the management of the fishery, and a number of environmental considerations. Several unifying opinions emerged from this study, including a lack of awareness of the fishery in many Alaskan communities and fears about rising fuel costs and diminishing harvest levels. Whereas the data-poor status of the stock appears to be the fishery's biggest weakness, the greatest strengths come in the form of conservative management, industry self-regulation, and the small footprint of the fishery. Impending threats include stock decline, unknown long-term detrimental effects of dredging, and changes in the management and structure of the fishery with the sunset of the State of Alaska's limited entry permit program. Most participants consider the fishery to be managed sustainably, although lack of data on scallop recruitment and abundance is a large concern. This analysis provides relevant information to both fishery managers and scallop industry members to contribute to the environmental, economic, and social sustainability of the scallop fishery.

1. Introduction

Due to the inseparable link between humans and the natural environment, biological and physical resources must be managed in the context of human use, development, and dependence, with sustainability being the key objective. Because of the view that oceans are a public domain and not the sole dominion of resource user groups, there are increasing appeals for more transparency and broader stakeholder involvement in marine resource management (Berghöfer et al., 2008; Mikalsen and Jentoft, 2001; Pomeroy and Douvere, 2008). Incorporation of stakeholder opinions has, in fact, become institutionalized into ecosystem-based management (EBM) of marine fishery resources, and in the U.S., public comment periods are required for federal fisheries managed under the Magnuson-Stevens Fishery Conservation and Management Act. The North Pacific Fishery Management Council, with approval from the National Marine Fisheries Service (NMFS), manages federal waters off the coast of Alaska, and is a global leader in EBM, having been one of the first to implement EBM strategies for groundfish fisheries in the U.S. (Witherell et al., 2000). However, major gaps in EBM remain for data-limited fisheries. Weathervane scallops (*Patinopecten caurinus*) constitute one of the most data-poor fisheries off the coast of Alaska. Despite four and a half decades of fishing for weathervane scallops, biological information on this species is sparse. Consequently, it is critical to capitalize on what information is known, largely being the knowledge of fishery stakeholders. Many stakeholders, including industry members,

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fishery managers, and biologists, have accumulated a wealth of knowledge, as they have been involved with the fishery for decades. This study therefore endeavored to address the current socioeconomic status of the fishery, identify some of the most recent changes, and gather baseline stakeholder knowledge that can be used to evaluate a future course of action for improved fishery management. We used a method for analyzing stakeholder opinions in a commercial fishery that is not commonly used for biological systems, but is gaining recognition as a useful approach for evaluating socioeconomic issues for fisheries worldwide.

2. Background

The commercial weathervane scallop fishery in Alaska began in 1967. Prominent scallop beds are located in the Gulf of Alaska off Yakutat Bay, southeast of Prince William Sound (near Kayak Island), in lower Cook Inlet, off Kodiak Island, along the Alaska Peninsula and Aleutian Islands, and in the eastern Bering Sea (Fig. 1). Approximately 80% of commercial scallop beds lie in federal waters off Alaska's coast (3-200 miles), while 20% occur in state waters (0-3 miles). The weathervane scallop fishery is small, with annual harvests averaging 210 mt (460,000 lbs) over the past decade. In comparison, the fishery for Atlantic sea scallops (*Placopecten magellanicus*) off the east coast of the United States harvested over 26,000 mt (58 million lbs) in 2010 (NEFSC, 2010).

The history of the weathervane scallop fishery in Alaska was reviewed by Kruse et al. (2005). In brief, the weathervane scallop fishery had an open-access, open-season management structure until 1993, at which point the State of Alaska developed a fishery management plan. Until then, the fishery experienced common patterns of discovery (1967–1973), fallback (1974–1979), redevelopment (1980–1989) and bandwagon growth (1990–1993, Kruse et al., 2005, Fig. 2). Numbers of vessels varied from 2 to 19, with a transition from small, multi-purposed vessels in the early days of the fishery to larger vessels mainly dedicated to scallop fishing in the late 1980s and early 1990s. Ex-vessel value peaked at \$11.7 million (inflation-adjusted 2013 dollars) in 1992. During 2010–2013, exvessel value ranged over \$4.0–4.7 million. Vessels typically carry 8–12 crewmembers. Additional details on employment and income associated with direct, indirect, and induced impacts of this fishery are unknown (NPFMC, 2014b).

Currently, the fishery is managed jointly by the National Marine Fisheries Service and the Alaska Department of Fish and Game (ADF&G) under the auspices of a federal fishery management plan

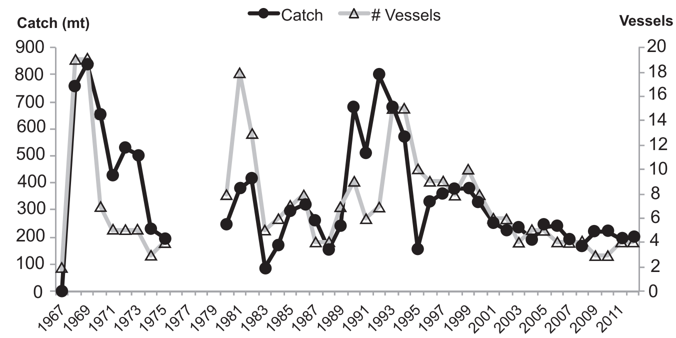

Fig. 2. Catch (mt) and number of vessels fishing in the weathervane scallop fishery off Alaska over 1967–2012. Landings for 1967–1993 come from Barnhart (2003), and those for 1993–2012 come from NPFMC (2014b). Data from 1976 to 1979 were excluded due to confidentiality constraints caused by few participating vessels and a closed fishery in 1978.

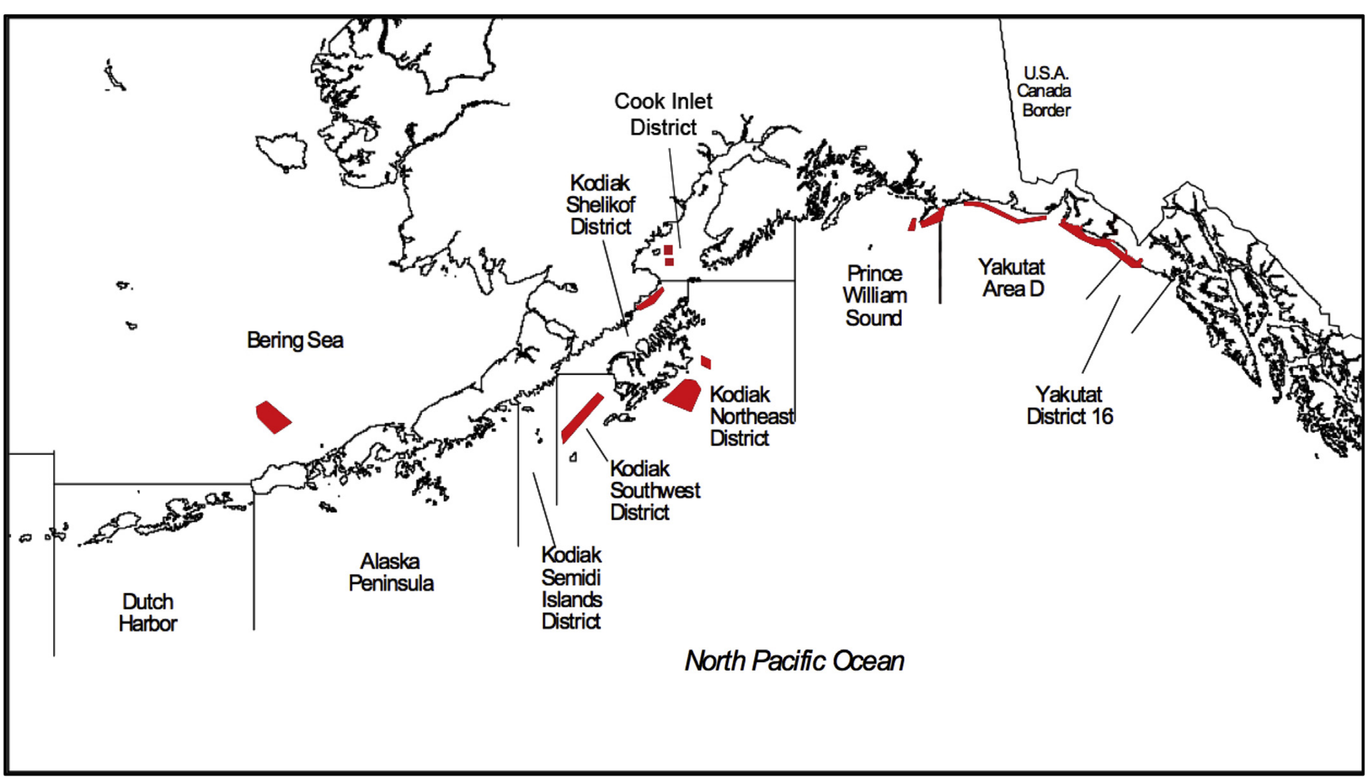

Fig. 1. Map of Alaskan weathervane scallop fishery registration districts and general areas of scallop fishing effort, indicated by red polygons. Modified from Rosenkranz and Spafard (2013). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(NPFMC, 2014a), although most of the day-to-day management is handled by the state. Guideline harvest limits are determined by managers from three different regional offices of ADF&G: Southeast (District 16 and Yakutat), Central (Prince William Sound and lower Cook Inlet), and Westward (Kodiak, Alaska Peninsula, Aleutian Islands, and Bering Sea). Each region maintains autonomy in setting harvest quotas, or guideline harvest levels (GHLs), provided that they do not exceed annual catch limits and overfishing limits established under the federal fishery management plan. A federal license limitation program (LLP) was recommended by the North Pacific Fishery Management Council and approved by NMFS in 2000. The federal LLP restricted the fishery in federal waters to nine vessels, two of which were granted exclusive rights to fish small Kamishak Bay beds in the Cook Inlet registration area on the west side of lower Cook Inlet (NPFMC, 2014a). A state limited entry permit (LEP) program was initiated in 2004 and also permitted nine vessels statewide, of which two were allowed to fish in Cook Inlet. In 2000, six out of the nine permit holders formed the North Pacific Scallop Cooperative, a marketing cooperative, now known as the Alaska Scallop Association, which was incorporated as an Alaska Cooperative Corporation in 2011. The cooperative functions by sharing observer data among vessels to avoid crab bycatch, and to allocate quota and crab bycatch to individual vessels (Brawn and Scheirer, 2008). In recent years, to improve economic efficiency of their operations, only four of the nine available permits have been actively fishing, with three out of those four vessels belonging to the cooperative (NPFMC, 2014b).

Weathervane scallop vessels tow two New Bedford style dredges, typically 4.57 m (15 ft) wide (Barnhart, 2003). Two permit-holders are limited to a single 1.8 m dredge while fishing in the Cook Inlet registration area (owing to the small local resource), and two 3 m dredges outside of Cook Inlet. Attached to the frame is a bag made of 10.16 cm (4 inch) steel rings, the diameters of which are regulated to prevent the catch of small scallops. Aside from scallops, other species caught as bycatch include benthic invertebrates (e.g., sea stars, anemones, brittle stars, crab, and octopus) and fishes (e.g., skates, Pacific cod [*Gadus macrocephalus*] and flatfishes). Strict bycatch limits are established for Tanner crab (*Chionoecetes bairdi*), snow crab (*C. opilio*), and red king crab (*Paralithodes camtschaticus*) in the Central and Westward management regions. Throughout the geographic range of the commercial weathervane scallop fishery, many areas are closed to dredging, primarily to protect king and Tanner crab. All vessels catching and processing scallops off Alaska are required to carry onboard observers at their expense, with the exception of vessels fishing in Cook Inlet (NPFMC, 2014b). Onboard observer duties include the collection of biological information and fishery data, including bycatch information (Rosenkranz and Spafard, 2013).

Political tension has arisen recently concerning the amount of consolidation that has taken place in the fleet. As a result, the Alaska State Legislature did not renew the LEP program, leading to a reversion to an open-access fishery in state waters in 2014. Failure to extend the program was driven by the perception of some legislators that consolidation within the Alaska Scallop Association hindered economic opportunities for Alaskan residents. Aside from resource allocation issues, there are other recent concerns about stock status, as GHLs for all management districts have generally declined since 1993 (NPFMC, 2014b). On the other hand, some areas containing viable scallop beds were closed in the 1960s to protect king and Tanner crab. Yet, many crab populations have failed to recover; ongoing closures may inhibit weathervane scallop fishery development with little or no benefits to crab stocks. Prompted by such concerns, our goal was to identify a comprehensive suite of social and economic factors influencing the current state and future prospects of the commercial weathervane scallop fishery in Alaska.

3. Methods

To gather socioeconomic information about the weathervane scallop fishery, we conducted an analysis of the strengths, weaknesses, opportunities, and threats (SWOT). An SWOT analysis is a simple and flexible tool, consisting of gathering opinions from a knowledgeable body of people familiar with a particular business or industry to help evaluate internal strengths and weaknesses, as well as external opportunities and threats (Helms and Nixon, 2010). An SWOT is commonly used to initiate strategic planning in the fields of business and management. Recent uses of SWOT analyses in business journals were reviewed by Helms and Nixon (2010), who identified its broad utility as a planning tool and for recommending strategic actions by businesses, industries, non-profit organizations, and countries. However, SWOT has been criticized because it does not provide implementation strategies, nor adequate context for strategy optimization, and thus there is a need to link SWOT analysis to other follow-up strategic tools and methodologies (Helms and Nixon, 2010). Nevertheless, despite some criticism, there seems to be general agreement that SWOTs are useful in early stages of long-term strategic planning (Helms and Nixon, 2010). Applications of SWOT to marine and freshwater fisheries have appeared in recent years in peer-reviewed journals (Çelik et al., 2012; Panigrahi and Mohanty, 2012; Stead, 2005) and government reports (e.g., GSGislason & Associates Ltd. 2004; Loefflad et al., 2014). Applications of SWOT analyses to aquaculture systems are more prevalent (Ahmed and Luong-Van, 2009; Bolton et al., 2009; Cowx et al., 2010; Garza-Gil et al., 2009; Rimmer et al., 2013). Recently, SWOT analysis was used to compare the strengths and weaknesses of alternative discard mitigation approaches to achieve mandates under the 2012 reform of the European Union's Common Fisheries Policy that bans future fishery discards (Sigurðardóttir et al., 2015). That analysis provided useful contrasts and uncovered potential unintended consequences of some mitigation alternatives. Moreover, it revealed that mitigation may be most successful when measures are used in combination, rather than isolation, and concluded by formulating guidelines to design a comprehensive discard mitigation strategy.

In Alaska, numerous socioeconomic analyses utilizing other methods have been conducted for commercial, subsistence, and sport fisheries, and other marine resources, with varying levels of quantification (e.g., Carothers et al., 2010; Pollnac et al., 2006; Seung and Zhang, 2011; Wadsworth et al., 2014). However, the only economic analysis of the weathervane scallop fishery to date is an appendix of the annual stock assessment and fishery evaluation (SAFE) report of the Scallop Plan Team of the North Pacific Fishery Management Council (Miller, 2006), with some additional socioeconomic aspects related to the scallop cooperative discussed in Brawn and Scheirer (2008). The SAFE appendix addresses vessel landings and product value dating back to the fishery's inception in 1967, as well as turnover in vessel permits, and economic consequences of fleet consolidation. Subsequent annual SAFEs (e.g., NPFMC, 2014b) include more abbreviated overviews of fishery economics. Our study enabled us to explore in more depth some of the socioeconomic issues and dynamics discussed by Miller (2006), as well as to update changes that have occurred in recent years. To encourage follow-up action, we conclude by proposing a roadmap with recommendations for strategic planning of weathervane scallop fishery management. We are not aware of an SWOT analysis for any other wild fishery in Alaska, or even in the United States. The small size of the weathervane scallop fishery makes it amenable for gathering opinions from essentially all relevant stakeholders.

We conducted semi-structured interviews with 27 participants who were identified as having detailed knowledge of the fishery through professional involvement. The participant group consisted of industry members ($n = 8$), fishery managers ($n = 7$), biologists ($n = 8$), and "others" ($n = 4$). Within the "others" category were those who could not be classified in the first three categories, including members of coastal communities affected by the fishery. Participants were interviewed from communities in Alaska, including Anchorage, Cordova, Juneau, Kodiak, Homer, and Yakutat. One participant was interviewed in Seattle, Washington, where many scallop vessels were formerly home-ported. Respondents were asked to answer questions from a single questionnaire, developed by the authors (see Appendix B), and were interviewed in person, over the phone, or in writing.

Our questionnaire focused on five SWOT themes: social, technological, economic, environmental, and regulatory. Social aspects included questions related to stakeholder perceptions of weathervane scallop fishery impacts on Alaskan coastal communities, as well as current and historical changes in public perception of the fishery. Technological questions involved vessel technology, industry efficiency, gear types, and bycatch avoidance – anything related to harvesting, processing, and market delivery. Economic questions addressed the value and stability of the weathervane scallop market, market competition, industry expansion, aquaculture, and latent permits. Environmental aspects addressed the biology of scallops and their habitat, including meat condition, bycatch species, climate change, and respondents' perceptions of the sustainability of the fishery. Regulatory aspects included fishery management and legislation, including expected outcomes of the LEP program expiration.

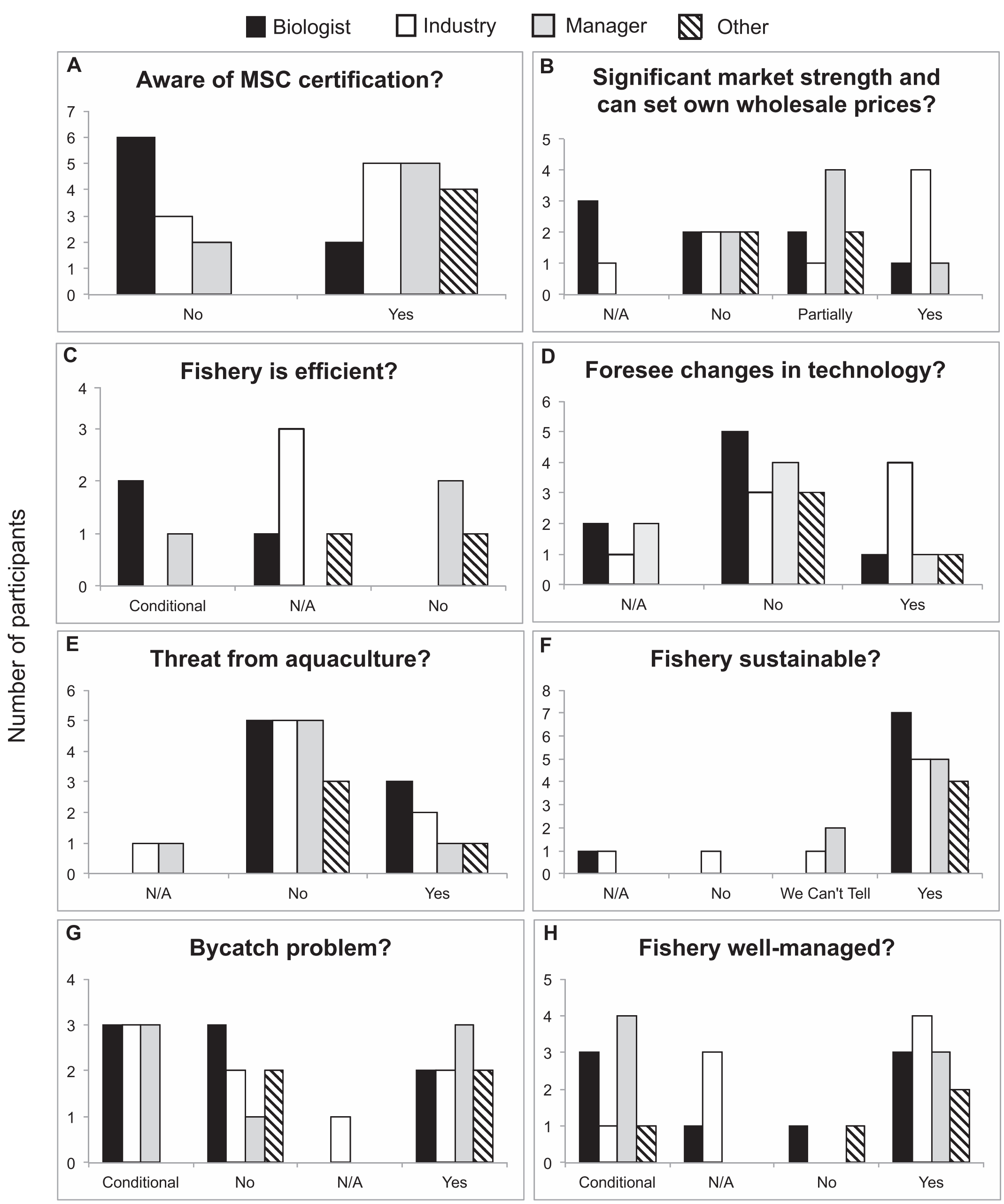

Fig. 3. Summary of responses to selected survey questions soliciting a "yes" or "no" answer, grouped by stakeholder category. Survey questions are listed in Appendix B. We included the following question numbers (with corresponding graph in parentheses): 4 (A), 5 (D), 6 (C), 9 (B), 10 (E), 15 (F), 18 (G) and 20 (H). Responses classified as N/A were those where respondents either did not answer or indicated they were unsure of the answer. Conditional responses implied that the answer could be either "yes" or "no."

Interviews were recorded ($n = 25$) unless respondents requested otherwise ($n = 2$). Interviews were transcribed and responses from each section of the questionnaire (e.g., social, technological, etc.) were grouped into SWOT categories and entered into a spreadsheet. Statements that were known to be false were recorded as misperceptions, but not included in the compilation of information. When respondents were unsure of a particular answer or subject area, this was noted. Statements were summarized in tables as strengths, weaknesses, opportunities, and threats for each social, technological, economic, environmental, and regulatory theme (Appendix A). In addition, questions that solicited an explicit "yes" or "no" answer were quantified by stakeholder category and location and portrayed graphically (Fig. 3). To maintain confidentiality, responses by location cannot be revealed.

Categorization of responses is a challenging part of the SWOT process (Helms and Nixon, 2010), and we recognize that there is overlap among topics. For instance, some issues can represent both opportunities and threats at the same time, and other issues apply to multiple themes, such as many social and economic topics. To address this, in addition to detailed tables of SWOT results under the five themes, we aggregated our results into cross-cutting common topics under which results and discussion are presented: (1) public perceptions of the fishery, (2) marketing, (3) fishery efficiency, (4) fishery expansion, (5) marketing cooperative members versus non-members, (6) expiration of the LEP program, (7) environmental impacts, and (8) research needs and data gaps.

4. Results and discussion

4.1. Public perceptions of the fishery

Most participants were aware that all weathervane scallop vessels are home-ported in Kodiak and employ mostly Alaskan crewmembers, both of which were viewed as strengths. Also, many participants noted socioeconomic benefits to certain Alaskan coastal communities through landing taxes, vessel expenditures (e.g. fuel, equipment, repairs, food), crew earnings, deliveries, and processing. Indeed, all scallop catches are landed in Alaskan ports, including Kodiak, Homer, Dutch Harbor, Sitka, and occasionally Juneau, Yakutat and Cordova (NPFMC, 2014b). Significant historical landings also occurred in Seward, Petersburg, and Whittier; during the 1960s scallop vessels were primarily based out of Seward (Turk, 2000). Participants generally noted an improved public perception of the fishery in recent years through industry community involvement (e.g., seafood festivals, sponsoring community events), and promotion of direct scallop sales in farmer's markets, road-side stands, and grocery stores in some Alaskan communities. In-state sales by the cooperative reportedly increased since fishery inception. Homer residents identified Cook Inlet scallops as "local" and formerly enjoyed dockside purchases. As one participant from Homer stated, *"[The vessel captain] sold right off the boat [in Homer], and so the people came down by the hundreds. Socially it was unreal. They got a good price because they got the boat price … it was just an amazing thing."* That vessel no longer sells most of its product dockside, but scallops are available from a local processing plant and at the Homer farmer's market.

However, most participants indicated that, because the fishery is small, the benefits and awareness of the fishery in Alaska are limited; no community in Alaska depends heavily on scallop fishing. Due to confidentiality restrictions associated with too few operators, landings data cannot be released by port (NPFMC, 2014b). Moreover, no economic data have been collected to quantify employment, crew wages, or other effects of the fishery on local economies. Many respondents thought that the public is generally unaware of the fishery unless someone happens to know a vessel captain or a crewmember. However, there is a perception that Homer residents are more aware of the fishery than residents of other communities. Some communities infrequently receive scallop deliveries and hardly interact with fishery participants. In general, weaknesses are rooted in many misconceptions about the fishery (e.g., how it operates, where the fleet is based, amount of bycatch), even among some SWOT survey participants. For instance, in reference to the LEP program, one Alaska legislator was quoted by the *Homer Tribune* in April 2013 as saying, "*That policy led to a rapid and extreme consolidation, leaving 90% of the scallop fishery in the hands of a Washington-based corporation*" (Klouda, 2013). Some participants held negative perceptions of the fishery due to its environmental impacts, including bycatch (particularly crab), and a professed history of rowdy scallop fishermen coming to town. This was particularly true in Yakutat, where some members of the public mistakenly attributed the scallop fishery to the collapse of local Tanner and Dungeness crab (*Metacarcinus magister*) fisheries.

We identified some opportunities for the fleet to improve the overall image of the fishery in Alaska, including increasing public awareness of the Alaska-based nature of the fleet, as well as ongoing bycatch reduction practices that result in low crab bycatch rates. Also, there are opportunities for the fishery to reallocate revenues to Alaska by expanding the in-state proportion of product sales and increasing markets to more communities across the state.

4.2. Marketing

Survey participants in all stakeholder groups consider weathervane scallops to be high-quality, valuable products that are rendered more desirable through branding as "Alaskan" or "Kodiak" weathervane scallops. They perceived the "Alaskan" label as a better marketing strength in Alaska than the Monterey Bay Aquarium's Seafood Watch "Best Choice" rating, which the Alaskan weathervane scallop fishery earned in 2012. Sixty-eight percent of all participants, particularly biologists, were not even aware that the fishery had earned this certification (Fig. 3A). Most of whom that were aware believed the Seafood Watch label is not effective in Alaska because Alaskans generally do not pay attention to national and international seafood sustainability ratings and some even distrust them, given recent controversies within the Alaskan salmon fishery about the Marine Stewardship Council's certification program (Bauman, 2012). As one respondent said, "*Alaskans have a deeper understanding of the seafood industry and not brand loyalty, but locale loyalty. They don't care about green, yellow or red, they want 'Alaskan this' or 'Alaskan that'.*" However, we note that the Seafood Watch rating is important to restaurants and other markets outside of Alaska, and the weathervane scallop industry reportedly benefits both socially and economically by promoting both "Alaskan" and "Best Choice" labels.

Weathervane scallops are often sold to four-and five-star restaurants or other high-end, luxury markets, particularly along the U.S. west coast. Since the cooperative began marketing the product, domestic demand for, and price of, weathervane scallops has steadily increased (NPFMC, 2014b). Some respondents reported that demand for Alaskan scallops in foreign markets is also growing, particularly in Europe and Asia, with the depression of the dollar making the product more affordable overseas. Targeting niche markets and promoting the large size and high quality of Alaskan scallops (e.g., hand-shucked, not soaked in chemicals) has reportedly helped the industry distinguish its product from Atlantic sea scallops, farmed scallops, and foreign scallops. For instance, in 2012, prices paid for shucked weathervane meats averaged \$10.63/lb (NPFMC, 2014b) compared to \$9.83/lb for Atlantic sea scallops (NMFS, 2014). The value-added benefit of promoting these scallops as luxury items can be compared to the salmon industry's successful marketing of "Copper River Reds," an early season run of sockeye salmon (*Oncorhynchus nerka*), which commands high prices in fresh seafood markets in the U.S. Pacific Northwest and Alaska, despite heavy competition from the farmed salmon industry (Babcock and Weninger, 2004). Another reported strength is that the scallop industry has exhibited excellent product traceability, of which restaurants, seafood markets, and even governments internationally are becoming increasingly aware.

When asked directly about the market strength of the fishery, participants gave a wide range of responses (Fig. 3B). Some remarked that weathervane scallops command high prices that are relatively robust to market fluctuations. One respondent colorfully stated, "*These [scallops] are kind of inflation-proof. The '1-percenters,' they're the ones who buy this stuff.*" However, other participants pointed out that, due to its small volume, the fishery is dwarfed by landings from the U.S. east coast and international fisheries, and prices continue to depend heavily on other markets. For example, increased supplies of foreign scallops or products that quickly enter and overrun the market, such as diver-caught or farmed scallops, can drive prices down, creating worrisome, unpredictable market changes. In the near future, prices of scallops may continue to increase if quotas remain low because of rising demand, an improving global economy after the 2008 recession, as well as declining quotas in the Atlantic sea scallop fishery (NMFS, 2013). We feel there are opportunities to expand niche markets, both domestic and internationally, to raise the price of weathervane scallops and increase market strength. We sense that a quantitative economic analysis would resolve misconceptions about the true market strength of the fishery, but such an analysis is prohibited under state and federal confidentiality constraints, given the small number of fishery participants.

Interestingly, economic benefits may come at a social cost to Alaskan communities (e.g., jobs, product availability) due to increased fleet consolidation or increased amounts of product going out-of-state. Processing plants that want to keep products in Alaska are already finding it difficult to compete with international markets, according to one industry respondent. We suggest that one means to expand local markets and awareness would be for the industry to join a Community Supported Fishery (CSF) as an alternative business model for selling fresh, locally-sourced seafood. Many respondents contended that re-establishment of direct marketing by vessels to local communities, as was formerly much more extensive in Homer, would enhance product demand and positive perceptions of the fishery in that community.

4.3. Fishery efficiency

Technology was identified as the greatest strength contributing to efficiency of the modern weathervane scallop industry. Adoption of onboard freezing technology revolutionized the fishery in the early 1990s by drastically improving product quality, and also by allowing longer trips between landings. Also, implementation of the LLP and LEP programs in federal and state waters, respectively, led to reduced fishing effort and an increase in efficiency and profits for those vessels remaining in the fishery. Moreover, in the past two decades, improvements in sonar and global positioning systems (GPS) reportedly enabled captains to readily relocate prime fishing beds, fish in poorer weather, and make better-informed decisions to avoid bycatch. Crew retention is a strong aspect of the fishery, promoting reliable processing rates. While current vessel captains professed to routinely share catch and bycatch information among cooperative members and non-members alike, some other respondents suggested that communication among skippers and fishery managers can be improved. One technological weakness is that onboard observers still record data on paper forms; adoption of modern electronic recording systems may significantly reduce transcription errors, data processing time, and data entry costs.

There were mixed views on the efficiency of the fishing gear that were not attributed to any one stakeholder group (Fig. 3C). Fifty nine percent of respondents considered the gear to be efficient. In supporting a case for gear efficiency, one respondent noted that just four boats are able to catch the entire harvest limit (see Miller, 2006). In fact, contrary to trends during the 1980s and 1990s (Kruse et al., 2005), only one of four currently active vessels fishes full-time for scallops; the rest participate in other fisheries. Other respondents disagreed with this premise about efficiency, noting that vessels tow repeatedly over an area to harvest scallops. The survey dredge used by the ADF&G Central Region has an estimated efficiency of 0.83, which is used in setting GHLs for the Kayak Island and Kamishak Bay areas (Gustafson and Goldman, 2012). That dredge is a scaled-down version of the standard commercial dredge. Also, it was widely reported that gear efficiency varies with factors such as weather, tides, vessel operator, and bottom type.

Few participants (26%) foresee any major future changes in technology (Fig. 3D). Many mentioned that the main gear type, the New Bedford-style dredge, has hardly changed over the last four decades, particularly because there are currently few forces (e.g. industry competition, regulations, funding) driving innovation. As one respondent stated:

> A lot of innovation and development is going on [worldwide], in terms of gear design. Often it's driven by the price of fuel, but in many cases it's also driven by spatial boundary closures and benthic impacts, and those haven't landed heavily on the fishery in Alaska.

Some increased efficiencies of scale are not possible, as fishery regulations prevent the use of dredges larger than 4.57 m wide, ban operation of automatic shucking devices, and limit crew size to a maximum of 12 (NPFMC, 2014a). However, some participants noted that vessel captains could adopt small changes to make their vessels more efficient to reduce operating costs (e.g., improving engines to reduce fuel use) and lower bycatch (e.g., shorter tows). As one member of the industry expressed, "*[We are] always looking for a better harvesting method … we're fishermen, we'll never stop looking for a better way to do it.*" Long-term opportunities include further improvements in bottom mapping technology and navigation electronics, freezing technology, and research to develop dredge modifications that reduce habitat impacts and reduce bycatch. One participant wondered whether fishermen could minimize their seafloor impact by developing a technology for finding scallops without having to dredge the seafloor searching for them. A research program to do exactly that was implemented on Browns Bank on the Scotian Shelf off Nova Scotia, Canada, where Atlantic sea scallops were found to be closely associated with surficial gravel sediments identified by multibeam bathymetric sonar (Kostylev et al., 2003). Results enabled fishermen to maintain catches with much less fishing effort, less fuel, decreased habitat impacts, and reduced bycatch of small scallops and nontarget species (Taylor, 2003). Harvesting scallops using methods other than dredging (e.g., diving, trawling, aquaculture) were also suggested to be viable long-term opportunities.

4.4. Fishery expansion

Survey participants, particularly many industry members, frequently mentioned possibilities for fishery expansion. These include discovering new beds, re-opening closed beds, or increasing the harvest limit on already exploited but highly productive beds. However, the scallop fishery is considered resource-limited, particularly with recent declines in harvest limits in some areas (e.g., Yakutat district) and current fishery closures in other areas owing to conservation concerns (e.g., Cook Inlet and Prince William Sound districts). Some closed beds were re-opened for exploratory fishing in the past few years; yet, prospects of exploring new beds are limited due to opportunity costs, concerns about habitat impacts, and bycatch. The latter two reasons have also prevented re-opening other long-standing closed areas. It was pointed out that some of those closures might be archaic and no longer necessary, given the lack of recovery in crab stocks and likely contraction of crab distributions. Scallop surveys do not offer opportunities to discover new beds because they are conducted on actively fished beds only. Apart from routine surveys in the Cook Inlet and Prince William Sound districts, a statewide scallop survey has not been conducted since the 1960s (Turk, 2000). Also, NMFS biennial bottom trawl surveys reveal some information about weathervane scallop distribution, but these groundfish surveys are unsuccessful at identifying commercial-scale beds (Turk, 2000). Given the bleak outlook for increased fishery catches, it was almost unanimous among participants that the current fishery cannot support any more fishing effort.

Long-term opportunities exist for expanding the fishery to other scallop species, such as the Pacific pink scallop (*Chlamys rubida*) or purple-hinged rock scallop (*Crassadoma gigantea*), although the current dredge gear would require significant modifications. Another opportunity for potential expansion is aquaculture. There are existing aquaculture ventures involving both purple-hinged rock scallops in Alaska (Brenner, 2011) and weathervane scallop – Japanese scallop (*Patinopecten yessoensis*) hybrids in British Columbia (Lauzier and Bourne, 2006; Saunders and Heath, 1994). From our review, we conclude that farmed scallops might facilitate new product types (e.g., fresh, roe-on) that might command higher prices and avoid bycatch and some habitat issues. Partnerships between aquaculture organizations and weathervane scallop fishery participants could lead to efficiencies in marketing and distribution. However, successful large-scale aquaculture operations run the risk of price depression. Most respondents (67%) did not perceive aquaculture to be a threat (Fig. 3E), but were not very familiar with aquaculture ventures using weathervane scallops. Other threats to the development of new products, especially fresh (not frozen) scallops, include increased shipping and operating costs and additional requirements and permits from the State of Alaska.

4.5. Marketing cooperative members versus non-members

Significant differences in fishery operations exist among members and non-members of the North Pacific Scallop Cooperative. Members are catcher processors, capable of realizing efficiencies gained from shucking, freezing and packaging all products at sea. Freezing at sea ensures a high product quality and allows for longer fishing trips, fuel reduction, and product consistency. In recent years, the cooperative modified its product type by packaging scallops in smaller quantities to suit customer needs. Those who have chosen not to become members of the marketing cooperative technically operate as catcher vessels; however, while they do not process into frozen form, they do shuck and ice scallops on board. These vessels experience economic weaknesses that constrain their operations, such as transit distance between ports of landing and fishing grounds, associated fuel costs, and product quality. For smaller vessels with lower catch rates, observer costs pose a disproportionately higher operating cost than for catcher processors. In addition, catcher vessels have greater constraints on marketing. For instance, they have a limited ability to target niche markets seeking only large scallops, because they do not have size-grading equipment onboard; size-grading by hand requires additional time and labor. Instead, size-grading is performed by the processing plants. Although catcher vessels are in a better position to deliver fresh product to local markets than catcher processors, and occasionally sell fresh product at the dock, it is too expensive to deliver fresh scallops to other domestic or international markets due to the high shipping costs from Alaska. Also, selling off of the local dock is difficult for scallop vessels because of inconsistent arrival times and the complexities of coordinating sales with limited time at shore. Delivery of fresh scallops to shoreside processing plants gives vessel owners less control of their product and prices. Finally, an impending threat to non-cooperative members is that they may experience disproportionately higher levels of competition than cooperative members once state waters become open access, because cooperative vessels are better able to operate in federal waters, and new entrants will only operate in state waters because they do not hold Federal LLP licenses. Data are unavailable to determine whether operating a catcher processor (specifically, freezing product on board) as a non-cooperative member is economically viable in Alaska. Catcher processors accrue economic benefits by removing the middleman from processing operations (De Alessi et al., 2014).

The pros and cons of the cooperative should be evaluated objectively. Generally speaking, the legal and economic frameworks behind marketing cooperatives both in the United States and internationally have been analyzed and debated since they were first developed, with evidence to support the view that cooperatives enable reduced costs, lead to higher product quality, and transform traditional approaches to fisheries management (De Alessi et al., 2014; Hughey et al., 2000; Kitts and Edwards, 2003). In some scallop fisheries worldwide, collective fishing groups have been established. The amount of self-regulation in these fisheries ranges from cooperatives being assigned quotas and playing an active role in management, such as in New Zealand and Canada (Hughey et al., 2000; Stevens et al., 2008), to allocating harvest limits assigned for different management regions, as in the case of Alaska (Brawn and Scheirer, 2008). In the New Zealand southern scallop fishery for *Pecten novaezalandiae*, industry members have operated a successful scallop enhancement program since quota owners formed the Challenger Scallop Enhancement Company in 1994 (Mincher, 2008).

From one perspective, the Alaska Scallop Association has elevated weathervane scallops to one of the premium seafood products from Alaska, while achieving bycatch reduction (Brawn and Scheirer, 2008; De Alessi et al., 2014). Yet, if the current structure of the fleet is indeed suppressing economic opportunities for others, there are political and perhaps even legal implications that must be addressed. As one participant summarized:

> The LEP [program] is both a threat and a strength. It has gotten so consolidated that you only have 2 or 3 boats fishing, and politically that's a threat because here you have a major resource that only 2 or 3 groups are benefiting from. [The fleet's] success is their weakness.

Similar to the weathervane scallop fishery, but on a much larger scale, the Canadian sea scallop fishery went through a period of fleet consolidation via the formation of the Enterprise Allocation (EA) program in 1986 (Stevens et al., 2008). The number of companies decreased from nine to six, vessels became more streamlined and fit for freezer-processing and, as a result, the industry lost over 700 jobs, mainly crew and onshore workers (Stevens et al., 2008). Thus, there were very real social costs with the implementation of this program that led to other benefits, including resource conservation, bycatch reduction, reduced catches of younger scallops through self-regulation, and an active role in industry research through habitat mapping and stock assessments, allowing industry members to make harvest recommendations (Stevens et al., 2008). Similar consolidation concerns have been expressed about New Zealand's Challenger Scallop Enhancement Company, which also conducts a significant amount of environmental research, to the benefit of the Minister of Fisheries (Hughey et al., 2000).

4.6. Expiration of the LEP program

The most frequently identified threat to the weathervane scallop industry was the sunset of the LEP program in state waters. All industry members perceived this as a threat, whereas views were more mixed in other stakeholder groups. A central argument of opponents versus proponents of the LEP sunset centered on profits versus jobs, respectively. For instance, as one respondent stated:

> You add more permits into the system and the individuals currently fishing will get less of a harvest, make less money, and it will be more capitalization in the fishery for the same end product. So, from a purely economic standpoint, it does not make sense; it would not be a benefit for the industry. On the other hand it would employ more people, so it's not necessarily just about efficiency.

However, other participants held negative impressions that the inactivity of five out of nine permits after the formation of the cooperative was too much consolidation, which is limiting economic and social opportunities. As one proponent of open access stated:

> Although it's an expensive fishery to get involved with … anytime you start limiting the number of participants, that causes the local people to feel that they're taking a public resource and privatizing it, and that goes back to why we [Alaska] became a state.

Proponents articulated additional arguments in favor of the open-access fishery in state waters. Some felt that an increase in vessels participating in the fishery would likely bring increased economic activity to Alaskan ports associated with increased taxes, crew wages, deliveries, supply purchases, and vessel maintenance. One participant in Yakutat considered the pending open-access state-waters fishery to be a potential opportunity for Yakutat, which has suffered substantially since the collapse of local crab fisheries. This respondent stated that if people in Yakutat were more involved with the fishery, there would likely be more community support for the scallop industry. Another respondent also suggested that more vessels in the fishery would, over the long term, increase the quality of catch per unit effort (CPUE) data used for management due to larger sample sizes. This respondent commented:

> You have so few boats now that the CPUE information is almost meaningless. In fact, it's worse than meaningless because you think you know something. If you track the CPUE off of Yakutat, all you do is see them searching, and then they find a bed and catch their allocation, and then they leave … it doesn't necessarily reflect anything [about] the stock in that region. So, having a few more boats could actually help.

Although many opponents of open access did not anticipate significant fleet restructuring to result, several concerns were expressed. A core fleet of just a few participants was viewed by many as a strength of this fishery. For example, representatives of the entire fleet often attend the annual meeting of the Scallop Plan Team of the North Pacific Fishery Management Council, a remarkable attribute for any fishery in Alaska, providing an effective way for industry and managers to connect and discuss issues. Fleet consolidation within the cooperative has fostered good communication among vessels with a fair amount of self-regulation. This has led to a cooperative fishing strategy in which effort is spread out over both space and time, alleviating pressure for a “race to fish.” Concerns were expressed that this race may return with an open-access fishery in state waters, possibly eroding communication, reintroducing competition, and leading to inefficient fishing and higher bycatch. Many respondents also worried that the LEP expiration could lead to state and federal fishery closures if fishing effort becomes unmanageable or state waters become overfished. Scallop abundances in state waters are not high enough to support a large number of new fishing participants, who would also struggle to overcome high overhead costs (e.g., mandatory onboard observers) and competition with current participants.

Another concern is that inexperienced entrants are more likely to catch Tanner crab and other bycatch species. Some respondents noted that small vessels fishing in the Cook Inlet registration area are not required to carry onboard observers, and a successful petition for exemption in other state waters could undermine the entire bycatch monitoring program. Owing to such concerns, some respondents worried that an open-access fishery in state waters could draw the attention of environmental groups, potentially leading to additional future regulatory actions limiting bottom contact fishing gear, such as new area closures. Additionally, although most respondents did not anticipate this occurring, some identified the threat of new vessels beginning to soak scallops in sodium tripolyphosphate, a chemical used in some other scallop fisheries to retain moisture in the adductor muscle. Soaking the scallops is a deceptive practice that leads to larger apparent meat-sizes, until cooked, and poses risks to market price and demand. Many respondents expressed additional concerns that the Alaska Legislature has introduced the destabilizing role of politics into fishery management, and that increased costs of fishery management associated with a larger fleet may threaten the viability of joint state-federal management, especially given the current high relative costs of management relative to fishery exvessel value (Kruse et al., 2005).

4.7. Environmental impacts

When asked if they considered the weathervane scallop fishery to be sustainable, most (78%) respondents agreed, stating that fishery management is conservative, the fishery has a small footprint, and large areas containing scallops are closed to dredging throughout the state (Fig. 3F). Interestingly, we note that 90% of participants who answered, “Yes,” immediately followed his or her response with reservations about stock status, lack of abundance estimates, and other fishery management unknowns (see *4.8 Research needs and data gaps*). Despite these reservations, the small fleet size, effective catch monitoring, and modest harvest limits, which have been reduced over the years to reflect changes in scallop size distributions and fishery CPUE, were mentioned as further evidence of sustainable fishery management. The predominance of landings from the Kodiak and Yakutat districts since the 1960s is offered as additional evidence of sustainability. Finally, the presence of scallops in unexplored beds and closed areas is viewed as providing an additional conservation buffer.

Bycatch was one of the more divisive topics revealed through survey responses, with 8 respondents saying it is not a problematic issue, 9 stating that it is, and 9 others stating that it is a conditional problem (Fig. 3G). Depending on registration area, species other than scallops accounted for 14–28% of the catch (by weight) during the 2010/2011 season (Rosenkranz and Spafard, 2013). Among those who thought bycatch was a problem, some community members made specific reference to Tanner crab, given failures of many crab stocks to recover from collapses in the 1980s and 1990s. Some participants expressed additional concerns about dredge impacts on crab during molting. However, crab bycatch is closely monitored and counted towards fixed area-specific bycatch caps, which are a small percentage (0.5–1.0%) of estimated crab abundance in each management district. Moreover, crab of all sizes count equally toward the cap, even though most Tanner crab caught are very small and experience high rates of natural mortality before being recruited to crab fisheries as adults. Most vessel captains have been involved with the scallop fishery for decades and portray a strong resource conservation ethic. There is much self-regulation within the industry, particularly after the formation of the cooperative, and the fleet actively avoids bycatch (Brawn and Scheirer, 2008). For example, it was mentioned that during the 2013–14 season, vessels unanimously agreed to leave Shelikof Strait and return later in the season due to higher than average catches of Tanner crab. Upon reflection, one industry participant mentioned politics as a threat to such self-regulated bycatch management:

> Obviously it is always a problem, and we're well aware of it. It's a political problem, a perception problem, it's a legitimate problem at times, and we work really hard to reduce it by working together. If the regulations change and encourage us to drop the work-together attitude and compete with each other, that will worsen the bycatch situation.

Some participants held negative perceptions of the effects of dredging on seafloor habitats. If these concerns lead to additional fishery restrictions (e.g., effort reductions, area closures) to further mitigate seafloor impacts, such actions would threaten fishery viability, given its small size and low quotas. Weathervane scallops are found on mobile substrates, such as silt, sand, and gravel, with strong currents and active sediment transport (Turk, 2001). These types of substrates are relatively tolerant of repeated dredging impacts and recover fairly quickly. However, scallops are also harvested from deeper clay and muddy substrates, which are less dynamic and take longer to recover from dredging or trawling (Hiddink et al., 2006; Kaiser et al., 2006). A study from 1998 to 1999 in the central Gulf of Alaska examined the impacts of trawling and dredging on sediments by comparing two areas open to fishing with two adjacent areas that had been closed since 1987 (Stone et al., 2005). The authors suggested that areas open to fishing showed signs of increased disturbance, as indicated by differences in epifaunal abundance between closed and open areas (Stone et al., 2005). The long-term effects of dredging on ecosystem function and benthic habitats are unknown. One participant remarked, "*I think the minute you say the word 'dredge,' people's hackles are going to go up. In some way, shape or form you're deforming the ocean floor. You can say they're not doing any damage, but how do you know? You don't*."

To address these questions, a few respondents recommended performing Before-After-Control-Impacts (BACI) studies to address the effects of dredging on known scallop beds that are currently closed to fishing, as well as more studies focused on discard mortality and fishery impacts on scallops and crab, including during the molting period. An additional intriguing option, if resulting from industry demand or environmental concerns, is the potential to keep and sell bycatch species so as to eliminate wastage. The U.S. Magnuson-Stevens Fishery Conservation and Management Act of 2006 defines bycatch as fish which are harvested in a fishery, but which are not sold or kept for personal use, and includes economic discards and regulatory discards. Thus, any retention of discards would reduce bycatch by definition. This, however, would require substantial restructuring of processing and storage facilities on vessels and regulatory changes.

4.8. Research needs and data gaps

Forty four percent of respondents consider the fishery to be well managed in spite of data limitations (Fig. 3H). One third said their opinion of scallop fishery management is conditional; that is, some aspects are strong whereas others need improvement. As apparent in Fig. 3H, these varying responses were not tied to one particular stakeholder group. One major weakness identified by many survey participants, namely fishery managers and biologists, was that the weathervane scallop fishery is one of the most data-poor fisheries in Alaska (see Kruse et al., 2005). Most glaring among these data limitations is a lack of fishery-independent surveys from which to derive abundance or biomass estimates. However, some participants pragmatically pointed out that the fishery is too small to command significant research and monitoring efforts. As one fishery manager commented, "*We have bigger issues all the time, so [the weathervane scallop fishery] really drops down in terms of spending staff time and effort when you have all of these other things to consider. It doesn't diminish it at all, but that's just the reality.*" One notable exception are dredge surveys that have been conducted routinely on scallop beds in Kamishak Bay and off Kayak Island since the mid 1990s (e.g., Gustafson and Goldman, 2012). An additional strength is that age-structured stock assessment models are currently being developed for these two Central Region stocks, which will improve the quality of management advice. Experimental scallop surveys were conducted in several areas using a CamSled, a towed underwater imaging system (NPFMC, 2014b; Rosenkranz and Byersdorfer, 2004; Rosenkranz et al., 2008). Although the resultant abundance estimates are considered too preliminary for use in fishery management, many participants felt that the CamSled provides a significant opportunity for specification of abundance-based harvest quotas in other fishing areas in the future. Development of a camera "sled-dredge," which consists of both a camera and a dredge, by the Central Region of ADF&G, poses additional opportunities, including the possibility to compare differences in selectivity among different survey methods.

Lacking comprehensive surveys, quota management using fishery CPUE from four boats is recognized as a weakness, particularly because all vessels do not fish all areas in any one year. As one respondent stated:

> Without having a population model or any idea of actual population size, CPUE is our best metric for percentage of extraction. It's a poor metric. It's definitely a poor metric. Fishery-dependent data does not give you a good metric of population size or population condition; there are too many variables there. [The fleet] are always looking for maximum production so you don't see the small scallops or the low density areas.

In the face of data limitations, declining fishery CPUE and a lack of small scallops have sparked conservation concerns in some areas among state fishery managers and the Scientific and Statistical Committee of the North Pacific Fishery Management Council (NPFMC, 2014b), prompting substantial cuts in weathervane scallop GHLs over the last 3–5 years. Reduced GHLs, coupled with increasing overhead costs, pose a large threat to the industry. As one industry member stated, "*The maintenance never stops,* *regardless of whether you fish more or less. The pay, the mortgage, insurance … everything is still there*."

A number of gaps in understanding weathervane scallop biology, life history, and ecology were noted. Source-sink dynamics and the metapopulation structure of the stock (i.e., retention and connectivity) are not understood; such knowledge, perhaps informed by studies of population genetics and oceanographic models of larval drift, would allow improved spatial fishery management (NPFMC, 2014b). Some participants observed stock fluctuations on approximately 10-year time frames due to natural mortality and unknown causes. Fluctuations observed in the Yakutat district are perceived as a strong threat, because of the perception that scallops from this area serve as a brood source for stocks throughout the rest of Alaska's continental shelf, owing to presumed larval drift with the westward-flowing Alaska Coastal Current. Weathervane scallops from some areas of the eastern Gulf of Alaska have adductor muscles characterized as "weak meats" that are off color with a stringy consistency that makes them unmarketable (NPFMC, 2014b). Compared to standard adductor muscles, weak meats have higher moisture content, lower glycogen content, and lower muscle condition indices (Brenner et al., 2012). The cause of weak meats is unknown and not well documented by observers or fishery participants. The prevalence of scallop boring worms is also poorly documented, although they have been recorded off Yakutat (Feder and Jewett, 1986), and recent studies have been initiated in Cook Inlet (B. Harris, Alaska Pacific University, pers. comm.). Increased prevalence of boring worms and mud blisters, both of which negatively affect meat quality, was viewed as a threat to the industry. Increasing the role of observers in recording the prevalence of boring worms, mud blisters and weak meats, as well as collecting environmental data that might correlate with these issues (e.g., temperature, pH) were suggested as opportunities.

A wide range of environmental threats to the industry were identified. Climate change poses threats to ocean circulation, seasonality and nature of food supply, larval development and recruitment, among other unknown ecological interactions, with resulting net negative economic impacts (Byrne, 2011; Narita et al., 2012). Likewise, future effects of ocean acidification on weathervane scallops are uncertain, as responses of marine calcifiers to acidic conditions have been shown to be species-specific (Byrne, 2011; Ries et al., 2009). The effects of climate change or ocean acidification on weathervane scallops have not been investigated and were suggested as research priorities. However, negative impacts of acidification have already been realized, as a mass die off of 10 million farmed hybrid weathervane-Japanese scallops in British Columbia, Canada, in 2014 was attributed to a sudden drop in ocean pH (Shore, 2014). Opportunities were identified for the industry to become involved in addressing research questions by contributing research funding, research using commercial scallop vessels (e.g., surveys), and collection of environmental data. Recently some scallop vessels have been chartered for CamSled surveys (G. Rosenkranz, Alaska Dept. of Fish and Game, pers. comm.), but they are otherwise not involved in additional research projects due to their participation in other fisheries.

5. Conclusions and recommendations

Our analysis served as a vehicle to solicit the opinions of those involved with the weathervane scallop industry in Alaska as a means to identify, clarify, and offer potential solutions to current socioeconomic issues, as well as to foster a more comprehensive dialogue about future fishery options among fishery participants, policy makers, scientists, fishery managers, community members, and other stakeholders. Many topics were not controversial, but others elicited a diversity of opinions. With few exceptions, divergent opinions were not identifiable to particular stakeholder groups (Fig. 3); they were sometimes associated with a geographic region, but mostly reflected individual opinions. This perhaps unique result highlights the ability for weathervane scallop stakeholders to work harmoniously and may underpin what is generally believed to be a successful fishery management program. In part, this is reflected in the very cooperative relationship between fishery managers and the scallop industry, which exhibits significant self-regulation. Some of the more strongly held differences of opinion (e.g., severity of bycatch, home ports of the fleet) are biased in part with misinformation, which indicates that resolution may be possible through improved education and communication. Because scallop fishery stakeholders are not generally polarized by stakeholder group, we are optimistic about the ability of this fishery to address future challenges, of which there are many. Crossroads include a bifurcation in management in state and federal waters with the sunset of the state's LLP program, stock conservation concerns and associated declining GHLs, bycatch and potential long-term dredging impacts, product quality, evaluation of efficacy of long-standing area closures, regional distribution of seafood products from this fishery, and data limitations on stock assessment and management.

Based on synthesis of results from our SWOT analysis, we recommend the following actions to help shape the future weathervane scallop fishery in Alaska:

1. Given split management between an open access fishery in state-waters and an LLP fishery in federal waters, improved in-season communication among state and federal fishery managers will be essential to prosecute an orderly joint fishery and to assure that that combined catches do not exceed annual catch limits.
2. Scallop fishery managers should consider newly developed toolkits for assessment and management of data-limited fisheries (e.g., Newman et al., 2014). Moreover, it may be possible to expand dredge surveys to other areas using commercial vessels under a cooperative cost-recovery program (i.e., sale of survey catches) to defray costs.
3. Reporting of fishery bycatch can be improved. Bycatch data could be made more readily available at a reduced cost by implementing electronic data entry by onboard observers. Moreover, expanding bycatch reporting from the current method (see Rosenkranz and Spafard, 2013), such as plotting trends in bycatch of certain taxa over time, should allay concerns and/or identify specific bycatch issues to be addressed.
4. If new bycatch issues emerge, a bycatch avoidance and advisory program could be developed, patterned after one developed to reduce bycatch of yellowtail flounder *(Limanda ferruginea)* in the U.S. east coast sea scallop fishery (O'Keefe and DeCelles, 2013).
5. Conduct follow-up interviews with fishery stakeholders to prioritize and rank research needs. One proposed method is the analytical hierarchy process, which has already been demonstrated effectively in Alaska (Saaty, 1986; Wadsworth et al., 2014). These prioritizations should be developed in conjunction with research priorities developed annually by the Scientific and Statistical Committee of the North Pacific Fishery Management Council.
6. Given limited agency funding, significant advancements on research priorities requires engagement of academic researchers and involvement of the fishing industry. Successful cooperative scallop research programs in New Zealand (Hughey et al., 2000; Mincher, 2008) and Canada (Stevens et al., 2008) provide examples of how industry involvement in research can lead to both economic and ecological benefits.

7. Mapping benthic marine resources and habitats off Alaska could enable significant gains in fishery economic efficiency, reduced bycatch, and decreased habitat effects, as reported off Atlantic Canada (Kostylev et al., 2003; Taylor, 2003).

Given the crossroads in the weathervane scallop fishery in Alaska, we believe we have contributed to next steps in strategic planning by identifying current and potential future issues, along with perspectives and options offered by a diversity of stakeholders. Moreover, the above implementation strategy is intended to help assure meaningful next steps. Ultimately, decisions about the future management of this fishery are a matter of public policy. We hope that we have provided a starting point from which the identified strengths can be reinforced, the weaknesses can be improved upon, the opportunities can be achieved, and the threats can be mitigated.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.ocecoaman.2015.01.005.

References

Ahmed, N., Luong-Van, J., 2009. Can rice-fish farming provide food security in Bangladesh? Aquac. Asia Mag. 16, 18–22.
Babcock, B.A., Weninger, Q., 2004. Can Quality Revitalize the Alaskan Salmon Industry?. Iowa State University Center for Agricultural and Rural Development Working Paper 04-WP-359.
Barnhart, J.P., 2003. Weathervane Scallop Fishery in Alaska with a Focus on the Westward Region, 1967-2002. Alaska Department of Fish and Game, Division of Commercial Fisheries. Regional Information Report 4K03-5, Kodiak, AK 99615.
Bauman, M., 1-Jan-2012. Marine Stewardship Council Losing Ground with Wild Salmon Fisheries. The Cordova Times. URL. http://www.alaskadispatch.com/article/marine-stewardship-council-losing-ground-wild-salmon-fisheries/ (accessed 30.4.2014).
Berghöfer, A., Wittmer, H., Rauschmayer, F., 2008. Stakeholder participation in ecosystem-based approaches to fisheries management: a synthesis from European research projects. Mar. Policy 32, 243–253.
Bolton, J.J., Robertson-Andersson, D.V., Shuuluka, D., Kandjengo, L., 2009. Growing *Ulva* (Chlorophyta) in integrated systems as a commercial crop for abalone feed in South Africa: a SWOT analysis. J. Appl. Phycol. 21, 575–583.
Brawn, T., Scheirer, K., 2008. The Alaskan weathervane scallop cooperative. In: Townsend, R., Shotton, R., Uchida, H. (Eds.), Case Studies in Fisheries Self-governance, pp. 349–360. FAO Fisheries Technical Paper 504, Rome.
Brenner, K.A., 2011. Quality Assessment of Weathervane Scallop and Purple-hinge Rock Scallop from Alaska. M.S. Thesis. University of Alaska Fairbanks.
Brenner, K., Oliveira, A.C.M., Rosenkranz, G., Burt, R., Spafard, M., Bechtel, P.J., Crapo, C.A., RaLonde, R., 2012. Quality of weathervane scallops (*Patinopecten caurinus*) from eastern and western Gulf of Alaska. J. Shellfish Res. 31, 1123–1132.
Byrne, M., 2011. Impact of ocean warming and ocean acidification on marine invertebrate life history stages: Vulnerabilities and potential for persistence in a changing ocean. In: Gibson, R.N., Atkinson, R.J.A., Gordon, J.D.M., Smith, I.P., Hughes, D.J. (Eds.), Oceanography and Marine Biology: an Annual Review. Taylor & Francis, pp. 1–42.
Carothers, C., Lew, D.K., Sepez, J., 2010. Fishing rights and small communities: Alaska halibut IFQ transfer patterns. Ocean Coast. Manag. 53, 518–523.
Cowx, I.G., Arlinghaus, R., Cooke, S.J., 2010. Harmonizing recreational fisheries and conservation objectives for aquatic biodiversity in inland waters. J. Fish Biol. 76, 2194–2215.
Çelik, A., Metin, İ., Çelik, M., 2012. Taking a photo of Turkish fishery sector: a SWOT analysis. Procedia Soc. Behav. Sci. 58, 1515–1524.
De Alessi, M., Sullivan, J.M., Hillborn, R., 2014. The legal, regulatory, and institutional evolution of fishing cooperatives in Alaska and the West Coast of the United States. Mar. Policy 43, 217–225.
Feder, H.M., Jewett, S.C., 1986. The subtidal benthos. In: Hood, D.W., Zimmerman, S.T. (Eds.), The Gulf of Alaska: Physical Processes and Biological Resources. US Dept of Commerce, NOAA, NOS, Office of Oceanography and Marine Assessment, Ocean Assessments Div, Alaska Office: US Dept of the Interior, MMS, Alaska OCS Region, Springfield, VA, pp. 347–396.
Garza-Gil, M.D., Varela-Lafuente, M., Caballero-Miguez, G., 2009. Price and production trends in the marine fish aquaculture in Spain. Aquac. Res. 40, 274–281.
GSGislason & Associates, Ltd, 2004. British Columbia Seafood Sector and Tidal Water Fishing: a Strengths, Resources, Opportunities and Threats Assessment. Final report, prepared for the British Columbia Ministry of Agriculture, Food and Fisheries, Victoria, BC. Available online at: http://www.al.gov.bc.ca/fisheries/cabinet/FULL_Report.pdf.
Gustafson, R.L., Goldman, K.J., 2012. Assessment of Weathervane Scallops in Kamishak Bay and at Kayak Island, 2004 through 2010. Alaska Department of Fish and Game, Anchorage, AK 99518. Fishery Data Series No. 12-62.
Helms, M.M., Nixon, J., 2010. Exploring SWOT analysis—where are we now? A review of academic research from the last decade. J. Strat. Manag. 3, 215–251.
Hiddink, J.G., Jennings, S., Kaiser, M.J., Queirós, A.M., Duplisea, D.E., Piet, G.J., 2006. Cumulative impacts of seabed trawl disturbance on benthic biomass, production, and species richness in different habitats. Can. J. Fish. Aquat. Sci. 63, 721–736.
Hughey, K.F.D., Cullen, R., Kerr, G.N., 2000. Stakeholder groups in fisheries management. Mar. Policy 24, 119–127.
Kaiser, M.J., Clarke, K.R., Hinz, H., Austen, M., Somerfield, P.J., Karakassis, I., 2006. Global analysis of response and recovery of benthic biota to fishing. Mar. Ecol. Prog. Ser. 311, 1–14.
Kitts, A.W., Edwards, S.F., 2003. Cooperatives in US fisheries: realizing the potential of the fishermen's collective marketing act. Mar. Policy 27, 357–366.
Klouda, N., 24-Apr. Rep. Seaton's Bill Breaks up Scallop Monopoly. The Homer Tribune. URL. http://homertribune.com/2013/04/rep-seatons-bill-breaks-up-scallop-monopoly/ (accessed 15.12.14.).
Kostylev, V.E., Courtney, R.C., Robert, G., Todd, B.J., 2003. Stock evaluation of giant scallop (*Placopecten magellanicus*) using high-resolution acoustics for seabed mapping. Fish. Res. 60, 479–492.
Kruse, G.H., Barnhart, J.P., Rosenkranz, G.E., 2005. Management of the data limited weathervane scallop fishery in Alaska. In: Kruse, G.H., Gallucci, V.F., Hay, D.E., Perry, R.I., Peterman, R.M., Shirley, T.C., Spencer, P.D., Wilson, B., Woodby, D. (Eds.), Fisheries Assessment and Management in Data Limited Situations, Alaska Sea Grant College Program, AK-SG-05-02. University of Alaska Fairbanks, pp. 51–68.
Lauzier, R.B., Bourne, N.B., 2006. Scallops of the west coast of North America. In: Shumway, S.E., Parsons, G.J. (Eds.), Scallops: Biology, Ecology and Aquaculture. Elsevier B.V., pp. 965–989.
Loefflad, M.R., Wallace, F.R., Mondragon, J., Watson, J., Harrington, G.A., 2014. Strategic Plan for Electronic Monitoring and Electronic Reporting in the North Pacific. US Dept Commer, NOAA Tech Memo. NMFS-AFSC-276.
Mikalsen, K.H., Jentoft, S., 2001. From user-groups to stakeholders? The public interest in fisheries management. Mar. Policy 25, 281–292.
Miller, S.A., 2006. Economic Factors in the Scallop Fishery off Alaska. Appendix A of Stock Assessment and Fishery Evaluation (SAFE) Report for the Weathervane Scallop Fishery off Alaska. North Pacific Fishery Management Council, 605 West 4th Ave, Suite 306. Anchorage, AK 99587.
Mincher, R., 2008. New Zealand's challenger scallop enhancement company: from reseeding to self-governance. In: Townsend, R., Shotton, R., Uchida, H. (Eds.), Case Studies in Fisheries Self-governance, pp. 349–360. FAO Fisheries Technical Paper 504, Rome.
Narita, D., Rehdanz, K., Tol, R.S.J., 2012. Economic costs of ocean acidification: a look into the impacts on global shellfish production. Clim. Change 113, 1049–1063.
NEFSC (Northeast Fisheries Science Center), 2010. 50th Northeast Regional Stock Assessment Workshop (50th SAW) Assessment Report. US Dept Commer. Northeast Fish Sci Cent Ref Doc. 10-09; 58 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at. http://www.nefsc.noaa.gov/nefsc/publications/.
Newman, D., Carruthers, T., MacCall, A., Porch, C., Suatoni, L., 2014. Improving the Science and Management of Data-limited Fisheries: an Evaluation of Current Methods and Recommended Approaches. R-14-09-B. Natural Resources Defense Council, New York, NY, 10011.
NMFS (National Marine Fisheries Service), 2013. Fisheries of the Northeastern United States; Atlantic Sea Scallop Fishery and Northeast Multispecies Fishery;

Framework Adjustment 24 and Framework Adjustment 49. National Marine Fisheries Service, pp. 27088–27112. Federal Register. 50 CFR Part 648, RIN 0648-BC81 78.
NMFS (National Marine Fisheries Service), 2014. Fisheries Economics of the United States, 2012. National Marine Fisheries Service, NOAA Tech. Memo. NMFS-F/SPO-137.
NPFMC (North Pacific Fishery Management Council), 2014a. Fishery Management Plan for the Scallop Fishery off Alaska. North Pacific Fishery Management Council, 605 West 4th Ave, Suite 306. Anchorage, AK 99587.
NPFMC (North Pacific Fishery Management Council), 2014b. Stock Assessment and Fishery Evaluation (SAFE) Report for the Weathervane Scallop Fishery off Alaska. North Pacific Fishery Management Council, 605 West 4th Ave, Suite 306. Anchorage, AK 99587.
O'Keefe, C.E., DeCelles, G.R., 2013. Forming a partnership to avoid bycatch. Fisheries 38, 434–444.
Panigrahi, J.K., Mohanty, P.K., 2012. Effectiveness of the Indian coastal regulation zones provisions for coastal zone management and its evaluation using SWOT analysis. Ocean Coast. Manag. 65, 34–50.
Pollnac, R.B., Abbot-Jamieson, S., Smith, C., Miller, M.L., Clay, P.M., Oles, B., 2006. Toward a model for fisheries social impact assessment. Mar. Fish. Rev. 68, 1–18.
Pomeroy, R., Douvere, F., 2008. The engagement of stakeholders in the marine spatial planning process. Mar. Policy 32, 816–822.
Ries, J.B., Cohen, A.L., McCorkle, D.C., 2009. Marine calcifiers exhibit mixed responses to CO_2-induced ocean acidification. Geology 37, 1131–1134.
Rimmer, M.A., Sugama, K., Rakhmawati, D., Rofiq, R., Hapbood, R.H., 2013. A review and SWOT analysis of aquaculture development in Indonesia. Rev. Aquacult. 5, 255–279.
Rosenkranz, G.E., Byersdorfer, S.C., 2004. Video scallop survey in the eastern Gulf of Alaska, USA. Fish. Res. 69, 131–140.
Rosenkranz, G.E., Gallager, S., Shepard, R., Blakeslee, M., 2008. Development of a high-speed, megapixel benthic imaging system for coastal fisheries research in Alaska. Fish. Res. 92, 340–344.
Rosenkranz, G.E., Spafard, M., 2013. Summary of Observer Data Collected during the 2010/11 Alaska Weathervane Scallop Fishery. Alaska Department of Fish and Game, Anchorage, AK 99815. Fishery Data Series No. 13-09.
Saaty, T., 1986. Axiomatic foundation of the analytic hierarchy process. Manag. Sci. 32, 841–855.
Saunders, R.G., Heath, W.A., 1994. New developments in scallop farming in British Columbia. Bull. Aquacul. Assoc. Can. 94, 3–7.
Seung, C., Zhang, C.I., 2011. Developming socioeconomic indicators for fisheries off Alaska: a multi-attribute utility function approach. Fish. Res. 112, 117–126.
Sigurðardóttir, S., Stefánsdóttir, E.K., Condie, H., Margerisson, S., Catchpole, T.L., Bellido, J.M., Eliason, S.Q., Goñi, R., Madsen, N., Palialexis, A., Uhlmann, S.S., Vassilopoulou, V., Feekings, J., Rochet, M.J., 2015. How can discards in European fisheries be mitigated? Strengths, weaknesses, opportunities and threats of potential mitigation methods. Mar. Policy 51, 366–374.
Shore, R., 25-Feb-2014. Acidic Water Blamed for West Coast Scallop Die-off. The Vancouver Sun. URL. http://www.vancouversun.com/life/Acidic+water+blamed+West+Coast+scallop/9550861/story.html (accessed 30.04.14.).
Stead, S.M., 2005. Changes in Scottish coastal fishing communities – understanding socio-economic dynamics to aid management, planning and policy. Ocean Coast. Manag. 48, 670–692.
Stevens, G., Robert, G., Burke, L., Poullioux, E., Roussel, D., Wilson, J.R., 2008. The evolution of management in Canada's offshore scallop fishery. In: Townsend, R., Shotton, R., Uchida, H. (Eds.), Case Studies in Fisheries Self-governance, pp. 349–360. FAO Fisheries Technical Paper 504, Rome.
Stone, R.P., Masuda, M.M., Malecha, P.W., 2005. Effects of bottom trawling on soft-sediment epibenthic communities in the Gulf of Alaska. Am. Fish. Soc. Symp. 41, 439–453.
Taylor, P.H., 2003. Mapping the Undersea Landscape: Technologically Advanced Maps of Sea Floor Habitats are Becoming Vital Tools for Ocean Management, vol. 7 (1). Gulf of Maine Times, Spring. http://www.gulfofmaine.org/times/spring2003/science_insights.html.
Turk, T.A., 2000. Distribution, Abundance and Spatial Management of the Weathervane Scallop (*Patinopecten caurinus*) Fishery in Alaska. M.S. Thesis. University of Washington, School of Fisheries.
Turk, T.A., 2001. Spatial distribution and selected habitat preferences of weathervane scallops in Alaska. In: Kruse, G.H., Bez, N., Booth, A., Dorn, M.W., Hills, S., Lipcious, R.N., Pelletier, D., Roy, C., Smith, S.J., Witherell, D. (Eds.), Spatial Processes and Management of Marine Populations, University of Alaska Sea Grant , AK-SG-01-02. Fairbanks, pp. 463–477.
Wadsworth, R.M., Criddle, K., Kruse, G.H., 2014. Incorporating stakeholder input into marine research priorities for the Aleutian Islands. Ocean Coast. Manag. 98, 11–19.
Witherell, D., Pautzke, C., Fluharty, D., 2000. An ecosystem-based approach for Alaska groundfish fisheries. ICES J. Mar. Sci. 57, 771–777.