Resilience and adaptive capacity of Oregon's fishing community: Cumulative impacts of climate change and the graying of the fleet

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1. Introduction

The dynamic nature of the marine and coastal environment presents complex and multi-faceted challenges to those whose livelihood depend on the ocean. Change is constant, requiring those who interact and live in these systems to succeed in oftentimes difficult and uncertain conditions (Young et al., 2019). The commercial fishing community embodies the ability to live and work in such a system (Conway, 2001; Kuonen et al., 2019). Change is not new for fishermen and families, they have always had to navigate variable weather and seasonal shifts in target populations. However, the current changes are unprecedented providing feedbacks among environmental, management, and social systems that must be navigated (Pomeroy et al., 2015; Flathers, 2017; Lam et al. 2016; Hanna & Hall-Arber 2000; Gilden et al., 1999). Climate change poses an alarming threat to the future of resource-dependent communities (McIlgorm et al., 2010; Brander, 2007). Management decisions targeted at and designed for ecologically sustainable practices are necessary but can have unforeseen rippling social-ecological consequences (Olson, 2011). This research focuses on the impacts of these intersectional changes on fishing communities. By focusing on this subject, this research could provide an important opportunity to explore the dynamics of a “ground zero” system; a system where environmental impacts on vital economic, cultural, and ecological services are experienced first as a result of time spent and proximity to the ocean, and consequently the need to find solutions to these challenges are of utmost importance (Marshall, 2010; IPCC AR4; Young et al., 2019). The fishing community provides an important lens with which to understand coupled social-ecological systems. As environmental changes occur, whether that be through warmer water, species migration, or fishery decline, our human systems also respond and, in turn, re-shape the natural systems.

As the larger sociological paradigms shift, and humans are seen as part of the environment rather than separate from it, information that incorporates this inherent and inseparable connection is needed (Levin et al., 2016; Miller et al., 2010). The interface between human and natural systems has been studied in recent years, especially in marine and coastal environments (Shackeroff et al., 2009; Folke et al., 2016; Benson & Stephenson, 2018). Fisheries science has typically focused heavily on the ecological dimension, leaving a gap in the equivalent social science (Hall-Arber et al., 2009; Marshall et al., 2018). Policy progress towards incorporation of the social dimension has been made. National Standard 8 of the amended

Magnuson-Stevens Fishery Management Act (MSA) enacted in 1996 requires the utilization of economic and social data to provide for sustained participation of fishing communities and to minimize adverse economic impacts (16 U.S.C. §1851(2)(8)). Additionally, Social Impact Assessments (SIA) as part of Fishery Impact Statements (FIS), which look at ways in which communities are affected by policy decisions, are required through The National Environmental Policy Act (Calhoun, 2015; NEPA; 42 U.S.C. § 4321; Colburn & Clay, 2012). Furthermore, Ecosystem-Based Management (EBM) is now widely prioritized due to its holistic approach, requiring the human dimension and adaptive management within the EBM framework (McLeod & Leslie, 2009; Long et al., 2015). Although qualitative social science that is practical and applicable to managers is now a top priority, due to time constraints, it is oftentimes difficult to accomplish (Charnley et al., 2017). Our research used a coupled-systems approach that explores social-ecological connections in order to inform the social dimension of fisheries and to support effective management decisions, positioning the oceans to be treated as peopled seascapes (Shackeroff et al., 2009).

1.1. Social-Ecological Resilience and Adaptation

The concept of ecological resilience first emerged in the 1960s and 1970s (Holling, 1961; Holling, 1973; Folke, 2006). Growing recognition of humans as agents of change within, rather than apart from, an ecosystem led to the concept of social-ecological resilience. Social-ecological resilience incorporates three key foundations: (1) the amount of disturbance a system can absorb and still retain the same structure and function, (2) the degree to which the system is capable of self-organization, and (3) the degree to which the system can build and increase the capacity for learning and adaptation (Carpenter et al., 2001; Folke, 2006). However, further research on resilience has revealed the complexity of measuring and defining the concept. Carpenter et al. (2001) emphasized the need to define specific resilience, the “resilience *of* what *to* what?” Specific resilience is the explicit identification of the system state that is being considered, and what change or stressor is of focus (Carpenter, 2001; Walker & Salt, 2006). Specific resilience can come at a cost to general resilience. For example, increasing resilience of communities specifically to drought may decrease the resilience of communities to floods. Therefore, both general and specific resilience are important to consider (Walker & Salt, 2006), as is using a community level lens to assess resilience (Berkes & Ross, 2013; 2016). Both prompted an examination of these facets of resilience in this study.

Adaptation and adaptive capacity are also crucial components to consider in the discussion of resilience. Adaptation can be defined as the decisions and actions taken to maintain the capacity to deal with changes in the social-ecological system, while maintaining basic structure and function (Nelson et al., 2007; Walker & Salt 2006; Berkes et al., 2003). Of particular interest to this study is the concept of adaptive capacity. Adaptive capacity “refers to the preconditions that are necessary to enable adaptation” (Nelson et al., 2007, p. 397), such as social, financial, and physical assets or capital (Nelson et al., 2007; Whitney et al., 2017).

Resilience, adaptation, and adaptive capacity are seen as three distinct but interrelated concepts. All three concepts are vital to a social-ecological system’s ability to embrace change and continue sustainably (Berkes et al., 2003). For this study, they provide the backdrop for the assessment, and, due to the complexity and multi-dimensionality of the environment in which this study takes place, all three concepts are considered in order to provide a more complete understanding of change and its impacts on the system. However, resilience and adaptive capacity are highlighted in this study. Therefore, the overall objective of this research is to understand how cumulative impacts from climate change and graying of the fleet affect the resilience and adaptive capacity of Oregon’s fishing community.

2. Oregon’s Commercial Fishing Community

This research explores the community resilience and adaptive capacity of Oregon’s commercial fishing community. The fishing community – a community of interest – is truly the “soul and image of Oregon’s coastal communities” – a community of place (Conway & Cramer, 2018, p. 219), and encompasses a deeply valued collective identity and culture (Gilden J, 1999). Although connected, a distinction is made between the fishing community, the coastal community, and the fishing industry. This research focuses specifically on the commercial fishing community, which is composed of members of the fishing industry, industry support, and their families (Conway et al., 2002).

Oregon’s three largest ports (by size, number of boats, poundage, dollar value, etc.) are Astoria/Warrenton, Newport, and Coos Bay/Charleston (Kuonen, 2018). Multiple vessel types exist; trawlers and some of the larger trap vessels are typically 50-90 ft in length. Smaller vessels, <50ft in length, are usually trollers, longliners, gillnetters, and trap and dive boats (Pomeroy et al., 2015).

The commercial fishing industry in Oregon is an important part of the state's economy. In 2016, commercial fishing contributed $544 million in household income and was responsible for about 10,000 jobs in rural coastal towns (ODFW, 2017, p. 4). Aside from distant water fisheries, which constitute harvests adjacent to Washington, Oregon, California, in Alaska waters, and in the western Pacific, the biggest source of landings revenue in 2017 was generated specifically by the Dungeness Crab ($62.75 million) and Groundfish ($35.67 million) fisheries. Pacific Whiting ($16.38 million) and Pink Shrimp ($12.69 million) followed closely behind in revenue. Pacific Whiting accounted for 201.50 million pounds landed in 2017 followed by Groundfish (48.22 million) and Pink Shrimp (23.06 million) (ODFW, 2019, p. 8). The industry generates additional income unaccounted for in the state summaries through tourism and other maritime activities such as boat building, research, and education (ODFW, 2017, p. 5). Ultimately, a resilient fishing community is intricately tied to the sustainability and strength of Oregon's commercial fishing industry and is the basis for a resilient coastal community (Conway & Cramer, 2018).

2.1. The Stressors

Although the fishing community faces many pressures, this research focuses on the two most salient to the future of the community: climate change and "graying of the fleet" (referred throughout as graying). The following is a brief background of the two stressors.

2.1.1. Graying of the Fleet

The term "graying of the fleet" was first used to describe shifting demographic and succession trends identified in many Alaskan fishing communities (Carothers, 2008, 2010; Donkersloot & Carothers, 2016; Ringer 2018; Lowe, 2012). In 2014, the average age of a fishing permit holder in Alaska was 50 years. This was significantly higher than the average age recorded in 1980, which was only 40 years old (Donkersloot & Carothers, 2016). A strong connection has been made between drivers of the graying phenomenon and fisheries privatization policies (Koslow, 1982; Carothers & Chambers, 2012; Carothers, 2015). Today the term is widely recognized in the U.S. and in many European countries as a reference to the increase in average age of commercial fishermen, largely due to a lack of youth entry (Chambers & Carothers, 2016; White, 2015; Johnson & Mazur, 2018).

Data from the Pacific Northwest trawl groundfish and whiting fisheries also show evidence of an aging workforce in Oregon's fishing community (Russell et al., 2014). From 2010 to 2012, the number of individuals 61 years old or older increased from 22.5% to 27.2%, and the number of individuals 30 years old or younger decreased from 10.4% to 5.8% (Russell et al., 2014). The 2014 study by Russell et al. was a catalyst for further research on graying of the fleet in Oregon's fishing communities. In a pilot study as part of a larger research program, Cramer et al. (2018) identified that graying was perceived as a threat in Newport and Port Orford by members of the fishing community (a community of interest) but was not identified as a problem by local community leaders (members of the related coastal community of place). Additionally, graying was perceived as a significantly more serious threat to the fishing industry by older-generation (over 50 yrs) than younger-generation (under 50 yrs) fishermen (Caracciolo, 2017), and perceptions of graying were also identified as differing among fisheries (Strawn, 2019). Specifically, Strawn's research concluded that fishing community research participants perceived Salmon and Groundfish fishery participation as graying but did not perceive the Albacore Tuna and Dungeness Crab participation as graying (2019).

The main drivers of graying include financial barriers to entry, rural to urban migration, lack of occupational knowledge, and loss of fishing rights tied to fisheries rationalization (the creation of markets to govern resource use by privatization) (Mansfield, 2004; Cramer et al., 2018; Himes-Cornell, 2015). Rationalization, or catch shares, drives graying through its contribution to fishing fleet consolidation and loss of jobs and infrastructure (Cramer et al., 2018). Motivations of youth to enter are affected by the perception that the fishery is overregulated and not lucrative (Russell et al., 2014). Impacts of graying include loss of local and traditional ecological knowledge, consolidation of the fleet, loss of individual and community income, and erosion of community sustainability (Donkersloot & Carothers, 2016; Russell et al., 2014). It is important to call out that graying acts as both a driver and response of change.

2.1.2. Climate Change Impacts

Global climate change impacts on the marine and coastal environment are numerous and include marine species variability, sea level rise, temperature increase, acidification, and deoxygenation (Hoegh-Guldberg et al., 2018; Cheung, 2009). The current ecosystems that we operate within are expected to change in unpredictable and uncertain ways. Focusing locally on Oregon’s marine environment reveals some of the similar impacts.

The Oregon coast is part of the greater California Current Larger Marine Ecosystem (CCLME) which runs from Baja California, Mexico up to British Columbia, Canada. Variability in water temperatures are common due to seasonal upwelling and interannual climatic shifts (Dalton et al., 2017). However, water temperatures have increased in the CCLME and is highly likely to continue to occur at an accelerated rate as seen in recent decades (Dalton et al., 2017; Mote et al., 2019). An increase in ocean acidification is also projected due to the ocean’s absorption of CO_2 (Feely et al., 2016), and has already affected oyster growers in the region (Barton et al 2015). Organisms with shells or skeletons of aragonite or calcite will encounter decreased saturation states, making formation more energetically expensive (Waldbusser et al., 2015). Although much remains unknown about the impacts of acidification on fisheries, it is likely that acidification will alter larval growth and change availability of food sources (Marshall et al., 2017). Another possible impact on Oregon’s waters stem from harmful algal blooms (HABs). Domoic acid events due to HABs are connected to warmer ocean waters, leading to the possibility of increased domoic acid events due to future climate change (McCabe, 2016; McKibben et al., 2017).

Indirect climatic impacts on fisheries result in distribution and location shifts of harvested species, as well as the possible arrival of new species as stocks move poleward (Cheung et al., 2015; Pinsky et al., 2012) or farther off the coast and deeper into cooler water (Cheung et al., 2015; 2018; Morley et al., 2018). Not all species will respond to change in the same way and current research is working towards further understanding the effects of climate change on fish productivity and distribution (Mote et al., 2019). It is certain that whole ecosystems will be affected, likely resulting in a system reorganization and increased variability of fish stocks (Woodworth-Jefcoats et al., 2016). Salmon, a once highly productive fishery on the West Coast, has declined and is projected to continue facing challenges due to changes both on land and in the ocean (Crozier, 2016). Salmon species in the Pacific Northwest will likely experience thermal stress and a reduced food supply (Mote et al., 2019; Wainwright & Weitkamp, 2013).

Although salmon specific projections remain uncertain, an increase in vulnerability is a likely response (Crozier, 2014; 2016).

At the interface between ocean and atmosphere lies the occurrence of storms and eventful weather (Kuonen et al., 2019). Winter precipitation amounts are projected to increase moderately (Mote et al., 2019). Seasonal climatic events such as El Niño - Southern Oscilation (ENSO) may become more extreme, amplifying wave energy and resultant coastal erosion (Barnard et al., 2015). Coastal erosion is projected to increase due to the combined sea level rise and increased wave energy (Barnard et al., 2015 Ruggiero, 2001; 2014). In the Pacific Northwest, weather conditions greatly impact a fishermen's ability to remain safe. Entering or leaving port, or "crossing the bar" presents a dangerous challenge as incoming wave heights are amplified in response to sediment accumulation on the bottom (Kuonen et al., 2018). Amplified wave energy and coastal erosion could change the dynamics of crossing the bar. As research is done to understand the ecological impacts of climate change, research on the impacts of and on humans is also needed.

3. Methods

The aim of this study is to inform, through the perspectives of fishing community research participants, the literature regarding cumulative impacts and feedbacks of climate change and graying of the fleet on the fishing community. The following questions guided the research: (1) With regard to the commercial fishing community in Oregon, what are the connections between climate change and graying of the fleet, and (2) How do these connections ultimately relate to the resilience and adaptive capacity of the community of interest?

3.1. Participant Recruitment and Data Collection

Combined oral history semi-structured interviews were conducted in ports along the Oregon coast from 2014 to 2018. Oral histories are valuable tools to preserve and share individuals lived experiences and memories (Olson & Pinto de Silva, 2018). Therefore, a combined oral history semi-structured interview method was chosen to allow both the individuals' stories to be captured uninterrupted and specific research-driven questions to be asked. Participants consisted of members of the fishing community (Caracciolo, 2017; Strawn, 2019; Calhoun, 2015). The initial group of interview participants was determined through local key informants, and additional participants were then identified through a snowball sampling technique (Auerbach & Silverstein, 2003; Berg, 2001; Bernard, 2011). Snowball sampling is a technique in which other research participants are recruited by current research participants, useful when potential subjects are hard to locate (Creswell & Poth, 2018). Interviews took place in the communities where the participants lived and worked. While the study was not designed to be a representative sample of all groups, efforts were made to engage diverse perspectives that reflect the depth of the fishing community. A range of age (from 18 to 70 years), vessel size (approx. 20ft to 90ft), top fishery representation (Groundfish, Dungeness Crab, Albacore Tuna, Salmon, Pacific Whiting, and Pink Shrimp), gear type (i.e. trawl, long-line, pots), and position (i.e. crew, owner, skipper) were engaged in order to capture overall industry perspectives (Caracciolo, 2017; Strawn, 2019; Calhoun, 2015). Interview questions were open-ended and asked about perceptions of the past and future of the industry, family dynamics, and changes in management and the environment. Interviews did not directly ask about climate change or use related terms (i.e. global warming, acidification) and this accomplished two goals: 1) The interviewers avoided the possibility of charged responses and incongruent communication, and 2) Interviewees were free to bring up the environmental terms or topics that were salient to them (Nisbett, 2010; Moser, 2010). Interviews ranged from 30-90 minutes long. 35 interviews were analyzed.

3.2. Data Analysis

Interviews were fully transcribed, and analysis was carried out through the use of the software MAXQDA 12. Auerbach and Silverstein's (2003) approach for grounded-theory guided analysis methods. Grounded-theory is a qualitative research method that is inductive, allowing the researcher to begin a study without first formulating a hypothesis to test. Rather, a theory or understanding of a process or phenomenon is generated from exploration of open questions (Auerbach & Silverstein, 2003).

Three rounds of analyses were completed in order to identify the connections between climate change and graying of the fleet. [Fig. 1] conceptually represents the three rounds of analysis completed. The first round of analysis involved selecting relevant text from the entirety of all the transcripts. For the purpose of this research, text was selected that referenced any type of environmental change. This ranged from direct references of climate change, to discussions of changes in fish stock and characteristics, water temperature and other ocean conditions, or weather. Relevant text regarding environmental changes were not separated to differentiate between natural cycles, climate change, responses from human pressure or management decisions. Rather, any mention from a participant of an environmental change regardless of the source of that change was included as relevant text. Additionally, in the first round of analysis, relevant text was analyzed in order to understand sets of important or repeating themes. The primary round of coding resulted in general idea groups such as: barriers and challenges, emotions/feelings, perceptions of the future, and types/results of changes. The second and subsequent rounds of coding further refined repeating ideas and clustered them into concise themes (Auerbach & Silverstein, 2003). The process of memoing was crucial to the process and further helped organize and identify themes and categories (Creswell & Poth, 2018). Memoing is the act of writing down ideas and thoughts as data are collected and analyzed (Creswell & Poth, 2018). From this inductive approach, five themes emerged as salient which were termed: Collective Knowledge; Rewiring Connections; Limitations; Flexibility; and Optimism. The scope of this article covers all themes except "optimism"[1].

Fig. 1 Here

The codes in each of these remaining four themes were then reorganized into "type of environmental change" and "participants response" in order to enable further analysis. Perceived environmental changes and participant responses obtained from the interview data were framed within the context of climate change in order to complete the second round of analysis. For example, an environmental change mentioned in the interviews was a domoic acid event and participants responded through a loss of income due to fishery closure or delay. Research has shown that domoic acid events are likely to increase in the future under climate change scenarios (McCabe, 2016; McKibben et al., 2017). Therefore, this analysis determined that a continued or increased loss of participant income was also likely to occur in the future as a result of increased domoic acid events. Climate change projections were determined from the literature and ranged in time scales and scenarios. The projections used in this study were based on a range of emission scenarios, such as those established by the Intergovernmental Panel on Climate Change

[1] The theme "optimism" is not included in this manuscript because it is covered in a partner manuscript to be io

(IPCC), as well as ocean condition models, such as the Earth System Model (ESM2.1) developed under NOAA (Cheung, 2018). The literature used in this study also included projections based on the expectations of the continuation of past trends.

In the third and final round of analysis, results from the second round of analysis were integrated with the results from previous research program analyses which looked at drivers and impacts of graying through youth barriers and motivations to entry. In this context, integration means identifying how the participant and/or industry response to a stated environmental change will likely change under climate change scenarios, and then identifying how this situation could impact the drivers of graying discovered in previous research program analyses.

The results from this research were not meant to be predictive, but rather projective. Furthermore, this framework projects future scenarios under four assumptions: 1) Current management systems continue under current conditions, 2) Social trends continue, 3) Graying trends continue, and 4) Climate change impacts are as projected from the latest research.

4. Results

The combined results reveal six prominent connections that link climate change with the graying of the fleet phenomenon. A natural division emerged from the data that separate the six connections into two conceptually distinct categories. The first category consists of the material dynamics of specific climate change impacts [Fig. 2] and refers to results regarding physical resources such as money and infrastructure. The second category consists of the relational dynamics of systemic climate change [Fig. 3] and refers to results regarding relationships and social networks. The connections between climate change and graying were determined from data in this study, previous research program analyses, and published literature on climate change.

4.1. Material Dynamics of Specific Climate Change Impacts

Fig. 2 Here

4.1.1. Water Temperature and Fish Distribution

Fishermen research participants described changes in fish distribution and location, oftentimes correlated with changes in water temperature. The following quote exemplifies these discussions: *(The) fish were scattered literally over three states, two countries; there were just not very many places where the fish were grouped up*. Fishermen discussed responses to these changes and described the need to be flexible and mobile enough to harvest the desired species that have moved. Under climate change scenarios reported in the literature, water temperature will increase off the coast of Oregon, resulting in further fish distribution and location changes (Cheung et al., 2015; Morley et al., 2018). It is projected that the majority of fish targeted by the commercial fishing industry will move north and/or move deeper into the water column and farther off the coast (Morley et al., 2018). Therefore, mobility is enhanced by owning or operating a bigger vessel that is fit for this type of travel. However, bigger vessels typically require a larger financial investment, possibly increasing the financial barrier for youth wanting to enter the industry. Financial barriers are one of the main contributors to graying of the fleet in Oregon, therefore a strong connection could be made, as outlined in the first row of [Fig. 2], between fish distribution shift due to climate change and a resultant exacerbation of contributors to graying of the fleet.

Additionally, the need to pursue fish that are farther away from port leads to longer times traveling on the water and away from home. Time away from home is one of the factors that negatively affect motivation to enter the industry, therefore likely intensifying graying of the fleet.

4.1.2. Domoic Acid

Around 20% of fishing community research participants discussed domoic acid events and described the loss of income opportunity due to resultant closures or delays. The following represents the sentiments of these participants:

> *It was a 'go' a week before the season was supposed to open. Then, all of a sudden, they're like, "Oh sorry, you guys ain't going (because) you've got domoic acid." That's when we had a nice volume of crab down here. Then between the time we were supposed to go and we were actually allowed to go, they shifted up towards Newport, and we're down here like 'where did all our crab go?'*

Elevated levels of domoic acid stemming from harmful algal blooms (HABs) are connected to warmer water temperatures, and the number of HABS is likely to increase in the future due to climate change (McCabe, 2016; McKibben et al., 2017). The Dungeness Crab fishery is one of the most lucrative fisheries in Oregon and closures in response to elevated domoic acid levels for human health concerns have economic impacts. Young workers are unmotivated to enter the industry if they perceive that the job will not be lucrative, therefore, a decrease or destabilization of income due to domoic acid events will likely discourage them from wanting to fish, contributing to graying of the fleet. This connection is demonstrated in the second row of [Fig. 2]. In the case of Oregon's crab fishery, previous research indicated that the fishery is not currently perceived as graying, however if domoic acid events increase, it is possible that scales will tip and graying could occur (Strawn, 2019).

4.1.3. Extreme Weather

Bad weather and storms are an integral part of any fishermen's occupational challenges. They are often reluctant or unable to fish when the weather is extremely bad due to dangerous conditions. Leaving port regardless during bad weather is not a desirable situation (Kuonen, 2018, Kuonen et al., 2019) and research participants reflected this in the following statement:

> *The winter is sometimes still and perfect. But it also comes with storms, some unpredictability, and often judgement calls. The most dangerous part of this job is crossing the bar when the swell is high, and the swells are only a factor during winter months. I don't like dealing with that at all.*

A change in weather patterns is projected to occur off the coast of Oregon as the climate changes. Larger wintertime waves are expected, and some studies have projected an increase in storm intensity (McCabe, 2001; Ruggiero, 2010). This change could result in a possible increased danger risk for fishermen (or decreased opportunities to fish). Danger is a factor that discourages youth from wanting to fish (Kuonen, 2018). Therefore, a change in weather and resultant danger could lead to a decrease in motivation to enter the industry, likely contributing to graying of the fleet [Fig. 2].

Damage to port infrastructure is also a result of an increase in wave energy and erosion, and this concern is reflected in statements such as:

[W]e've had some erosion lately around the harbor, around the periphery where it's starting to sluff into the harbor…there's kinda this thought that our infrastructure's gonna go away. I just read that they only expect our infrastructure to last another ten years, the Port Managers apparently came up with that.

Each port along the Oregon coast is unique and has the capability for certain fisheries. Additionally, some are more dangerous in bad weather than others. The consequence of the combination between bad weather and port infrastructure is that mobility is needed in order to cope. The following response demonstrates this situation:

…that port (name of port) is very difficult to get out in, especially in the winter time. I think most of the fisheries there were summer based, which would be salmon and rockfish and urchin. Folks that are going out crabbing (do so) in different ports; you just can't get out in (name of port). So even if they were crabbers, they would go out of a different port during the winter.

Going out of another port is a means of flexibility but results in increased time away from home and therefore decreased youth motivations to enter, as time away from home has been identified as negatively affecting desire to enter the industry (Caracciolo, 2017). Movement in order to temporarily launch from a different port, or longer-term coping mechanisms such as moving to a new town, could affect social capital through altered social relations and changing social fabric of that coastal fishing community.

Lastly, fishermen research participants referred to vessel size as a limiting factor in the face of stormy weather, noting that:

It was probably 6 months that I had my boat out here before people would see that I am going out to fish when the weather lets me, and chewing me out for going out during the times that I shouldn't have, because the weather was a little big for that small of a boat.

A larger vessel will be needed to stay safe and continue getting out to fish in the face of variable and uncertain weather. Again, bigger vessels generally require a larger financial investment, increasing the financial barrier young workers are already experiencing.

4.1.4. Salmon Stock Vulnerability and/or Fish Stock Variability

The topic of salmon stocks was brought up by about 40% of the fishing community research participants when asked to reflect on changes they experienced. They discussed the decline of the fishery and noted the complexity of factors that thus contributed, demonstrated in the following statement:

> *[A] lot of the boats down there were into salmon fishing, and, like we're experiencing right now, there's no salmon fishing on the South Coast in the ocean. So, part of it was there's less resources….*

The availability and yearly instability of the resource diminished desire and limited ability to enter the fishery.

Under climate change scenarios, there is a high probability that the vulnerability of salmon stocks will increase as temperatures rise and coupled land-ocean stressors are magnified (Crozier, 2014; 2016). Although it is difficult to say with certainty exactly how salmon and other fish stocks will change, it is likely that variability in stocks will increase due to shifts in ecosystem dynamics (Woodworth-Jefcoats et al., 2016). Therefore, based on the responses of community members to past fluctuations in salmon stocks due to environmental change, it is highly likely that limitations to enter (both physical and psychological) will increase, and graying will intensify. The fourth row in [Fig. 2] outlines this connection.

Another response to changes in salmon stocks that fishing community research participants discussed was the need to diversify and participate in multiple fisheries as explained in the following quote:

> *[Y]ou have to be diversified. You can't just buy a boat thinking "Well I'm just going to go salmon fishing" or "I'm just going to black cod." You have to be in there with as many options as possible to survive.*

However, the flexibility that diversification enables requires resources such as permits, quota, or different gear, all of which are costly. Increasing costs to enter the industry have been identified as a contributor to graying, therefore diversification (and flexibility) is limited by the resources and coincident costs needed to participate in that fishery.

4.2. Relational Dynamics of Systemic Climate Change

Fig. 3 Here

4.2.1. Tension

About 30% of fishing community research participants revealed social tension and defensiveness within the fishing community in response to myriad environmental factors such as domoic acid events, stock fluctuation, and fish movement or collapse. The most discussed areas of community tension were found between individual fishermen, and between fishermen and buyers. An example of this defensiveness is described in the following quote:

> *Tuna fishing right now is not limited. So, if shrimping gets horrible, all the shrimp boats will have to go tuna fishing. So, the tuna fleet feels like, "Jeez, if tuna goes bad, I don't get to come into your fishery because I don't have a permit for your fishery." So, you can see where people feel like they are boxed into a corner and they don't want their corner to get crowded.*

Overall, interview data indicated that the participants were aware and vocal about the inequalities between community members. Some of the respondents directly explained that fishermen often turned on each other in response to environmental change: *And what is the first thing we do? We turn on each other. I think it's a real problem.* The erosion of relationships and increased tension as a result of environmental change could likely increase with future climate change.

Fishing knowledge, such as how to tie a knot or fix a vessel engine, is vital to enter and remaining in the fishing industry. Oftentimes young workers learn theses skills through conversations and asking other fishermen questions, described in the following two, separate responses:

> *[J]ust keep your head down and work. And don't be afraid to ask questions. And if guys who you're working with don't want to answer your questions, you don't want to work with them because there's a lot going on and you need to learn. And in order to learn (you have to) ask questions.*

> *There's no safety net and that's just the way the timing worked. It's just the way things go. So, for these younger guys, you know, I try to tell them "You've gotta live within your means. If you can't pay cash, you don't need it."*

An erosion of relationships therefore limits the ability of younger workers to enter or remain in the industry as a result of a disconnect between the transfer of vital fishing knowledge, thus intensifying graying [Fig. 3].

4.2.2. Collaboration

While the data revealed that some relationships within the fishing community appear to be experiencing tension in response to environmental change, positive relationships with scientists and managers appear to be strengthening. Around 30% of the fishing community research participants mentioned the necessity of working with management and scientists in order to enable a successful fishing industry. Collaboration between these groups was either noted as a goal or noted as currently happening. Research participants talked about the positive results they experienced from collaboration. Interview responses also indicated that this type of collaboration was not always the case. The following quote demonstrates a common sentiment in which environmental changes further motivated the need for science and industry to work together:

> *[O]ne fisherman says, "I don't like the fact that the bottom of the ocean, the lower water, is getting warmer." So, they're looking to the science community to help them understand what the ocean is doing. I've noticed that.*

Collaboration was most often talked about in response to acidification, warming water, general climate change or global warming, and species stock variability. As climate change continues to drive an increase in oceanic variability and contribute to these environmental changes, although trust remains a barrier, increased collaboration is likely to continue.

Results indicate that as fishermen become more involved with science, politics, and management, they tend to describe the need to be able to fulfill multiple roles. The ability to successfully fish in modern times often means being involved in management decisions, politics, science and business. As roles shift and the skills necessary to fish successfully change, the type of education needed also shifts. For example, research participants shared that young family members were discouraged from entering the industry in order to obtain a higher education degree. Oftentimes the benefits of advanced training were emphasized so that they could return to the family business with the knowledge and skills required of the successful modern fishermen, such as being business and politically savvy and science literate. It is possible, then, that an increase in collaboration and continual shift towards these types of science and management roles, could exacerbate graying due to the need for youth to obtain a higher education degree before or instead of going into fishing (Cramer et al., 2018).

As previously noted, results from this research were divided into two categories [Fig. 2 and 3], the material and the relational. Material refers to results regarding physical resources such as money and infrastructure. Relational refers to results regarding relationships and social networks. Results show that, in terms of material dynamics, four specific climate change impacts emerge as connectors to graying: species shift; domoic acid events; increases in extreme weather; and fish stock variability or decline. In reference to relational dynamics, however, myriad of climate change impacts act as connectors. It is possible then that those four specific climate change impacts could be the most significant areas affecting the ability of younger workers to gain the necessary resources and finances necessary to enter the industry. Additionally, all climate change impacts could affect the ability of younger workers to develop the relationships and networks necessary to enter into the industry.

5. Discussion

Results from this exploratory research reveal that climate change may exacerbate or contribute to graying of the fleet in Oregon. In the following discussion these results are used to inform the overall objective: to understand how the cumulative impacts from climate change and graying might affect the resilience and adaptive capacity of the fishing community.

Results reveal that a shift in the location of fish may lead to an increase in the financial capital needed to enter the industry, with no indication of support provided to younger workers to cope with this elevated financial requirement. Accumulation of financial capital is foundational to a resilient community (Flora & Flora, 2008; Bennett et al., 2014). Without the necessary resources available, the fishing community could experience a harder time coping with and responding to changes (Scoones, 1998). Financial capital is also affected by domoic acid events, destabilizing income and therefore the resources needed to be resilient and adaptive. Previous research has shown that fishing dependent communities have suffered due to a further destabilization of traditional sources of income (Ritzman, 2018). Infrastructure capital is also a component of adaptive capacity and resilience (Flora & Flora 2008; Bennet et al., 2014). For fishing communities, an extremely important piece of infrastructure is the port itself. An increase in storm intensity and wave energy can lead to port infrastructure damage for places that lack infrastructure investment, thus likely decreasing the stability of infrastructure capital and subsequently the capacity to adapt or be resilient. Furthermore, movement out of or into another town in response to port infrastructure damage or a shifting target species could erode place attachment. Place attachment has been shown to be an important factor contributing to community resiliency (Faulkner et al., 2018; Amundson, 2015).

Variability or possible degradation of salmon and other fish stocks may lead to a decrease in resilience due to the decline in natural capital (i.e. fish) (Flora & Flora, 2008). If there are less fish to catch, there could be more tension between fishermen and/or less fishermen fishing. Additionally, an actual or perceived failure or decline in one fishery can result in, if possible, a diversification into another fishery (Johnson et al., 2014). Diversification has been shown to increase resilience due to this reason, if one fishery fails than a fisherman still has income from another fishery (Cline et al., 2017). However, barriers to entry associated with permit and quota costs may limit this flexibility/coping mechanism, and could inhibit adaptation and resilience.

An increase in social tension due to environmental change is consistent with previous research, and likely leads to an erosion of social capital (Dutra, 2015; Ford et al., 2006). Social capital and the relationships and networks that define it, are crucial to maintaining a resilient and adaptive system (Adger, 2003; Folke, 2006; Gutierrez et al., 2011; Dutra, 2015; Norris et al., 2008; Faulkner et al., 2018). Results show that an increase in collaboration and resultant role shift could lead to a decrease in young worker participation due to the perceived need for formal education first and/or instead, negatively impacting resilience as a result of continued graying (Cramer et al., 2018). However, an increase in collaboration could also lead to innovation and learning facilitated by these strengthened social networks and relationships (Gilden & Conway, 2002; Yochum et al., 2012). It is possible then that resilience could both strengthen or weaken in response to collaboration.

The previously-outlined impacts on resilience and adaptive capacity largely stem from climate change impacts. However, changes in resilience are of further concern when combined with impacts from an intensification of graying of the fleet. Previous studies have described the impacts of graying related changes in the fishing industry on coastal community resilience (Cramer et al., 2018; Johnson & Mazur, 2018). Although nuanced, a general decrease in resilience occurs due to shifting social networks, capital, and cultures. Specifically, relevant to this study, an intensification of graying results in the decreased transfer of adaptive knowledge. As older fishermen retire with all the skills and information they have learned over the years, and young workers and community members are not present to receive that knowledge, it can be lost (Johnson & Mazur, 2018). Therefore, as climate change necessitates an increase in adaptability and resilience, fishermen's ability to meet this need could decrease.

Although the disappearance or collapse of the fishing community is unlikely, it is difficult to say with certainty where the threshold line rests due to the complexity of nonlinear feedbacks (Nelson et al., 2007). There may come a time where costs to enter and remain in the industry do not outweigh the benefits for the majority of people. For some people, this situation already holds true, revealed through data that supports the presence of graying (Russell et al., 2014). This study does not specifically measure threshold proximity; however, results show that climate change will most likely continue to tip the cost benefit scale in unequal ways. The susceptibility of fishing communities to impacts of climate change is consistent with previous literature (Colburn et al., 2016), that indicates varied vulnerabilities of the communities might underscore their ability to adapt. Ultimately, graying of the fleet and climate change both separately impact resilience and adaptive capacity, however an understanding of the cumulative impacts provides further insight into future scenarios and possible erosion of resilience.

6. Implications for Management and Policy in Practice

This research aims to be useful in practice by identifying how management decisions might address the combined impacts of climate change and graying of the fleet, and to find specific target areas that enable solutions. An important limitation of this research is that analysis was not completed by initially separating interviews by participant role or fishery participation. Therefore, implications must be discussed broadly. Nonetheless, we suggest decisions focus on the following target areas; community relationships, knowledge and education transfer, financial support and stability, diversification, resource sustainability, and mobility. These focus areas are outlined further below.

Results from this study reveal that relationships within the fishing community are currently and could likely continue to erode. Therefore, it would be beneficial to strengthen community relationships (social capital) in order to facilitate transfer of knowledge. This could be done through an increase in formal or informal community organizations, networks or events. Organizations such as Newport Fishermen's Wives and Port Orford Ocean Resources Team are existing successful examples. Additionally, creating avenues of formal education specific to the occupation would relieve the pressure for vital knowledge to solely be gained informally from others in the industry or community. Addressing both of these areas would facilitate the transfer and use of adaptive knowledge in the face of climate change.

Results suggest that financial insecurity is another area to target management efforts. As costs to continue fishing increase, and seasons may become more unpredictable, financial security needs to be considered. For example, the connector in [Fig. 2] between domoic acid events and graying is the perception of a lucrative industry. Therefore, counteracting the possible real and perceived financial instability in response to domoic acid closures might help address both climate change impacts and the possibility of graying of the fleet. Financial security would ensure that the members of the fishing community do not go bankrupt from an inability to pay their debts due to domoic acid closures or costs associated with buying a bigger vessel. To be clear, this research does not indicate that a complete subsidization or absorption of financial costs associated with the fishing industry would be beneficial. It simply indicates that some type of monetary stability under future unstable conditions could mitigate the decline of adaptive capacity and resilience. One way to accomplish this would be to make decisions that directly or indirectly encourage a diversified economy and diversified income for those within the fishing industry (Young et al., 2019; Cline et al., 2017). Diversification among those within the industry through participation in multiple fisheries, use of varied gear types, or other income earning opportunities (e.g., cooperative fisheries research) might also contribute to increased resilience and adaptive capacity. However, this option is expensive for fishermen; it may not even be possible for some fishermen. Considerations of this cost prohibitive aspect could be useful to increase diversification efforts. Additionally, enabling programs that support the smart and responsible management of income for fishing families could also be useful in addressing financial instability.

A connector and contributor to the graying of the fleet for the salmon fishery was resource decline. Therefore, ongoing management efforts towards sustainable salmon stocks could enhance the perception that the resource presents a good investment. The connector between fish distribution shift and graying [Fig. 2] is the flexible response of mobility, therefore it is possible that decisions that support mobility might mitigate climate change impacts and enable flexibility. However, results also reveal negative feedbacks of a seemingly desirable response, namely that mobility could decrease motivations to enter. Therefore, this research partially illuminates tradeoffs of enabling or inhibiting this flexible option.

Ultimately, findings reveal a starting point for determining how preparation and action might contribute to future resiliency. Although many climate change impacts are projected, preparation specifically for stock distribution change and variability, domoic acid events, and increases in extreme weather might provide the best support to crucial vulnerabilities.

7. Conclusion

The findings of this research can inform EBM through the identification of connections that illuminate explicit trade-offs, the incorporation of local knowledge to understand community resilience, and providing information that supports adaptive management.

The nature of this study was largely exploratory and future research should expand on findings by assessing connections between climate change and graying of the fleet for specific ports, roles (such as crew members) and specific fisheries. Analysis at this scale would reveal highly localized scenarios that rest within larger state scenarios in order to assist with successful adaptation planning. Ultimately, combining perceptions of graying of the fleet and empirical climate change projections add a missing dimension to the existing body of literature surrounding drivers and impacts of social change in resource-dependent communities. Emphasis on interactions between the social and ecological systems provide a necessary lens to make decisions based on best available science. This research provides evidence that supports the need to address projected cumulative impacts from climate change and graying of the fleet. Relying on the responsive adaptability of fishing community members alone may not be sufficient, as their capacity to do so could be limited in the future. Collaborative planning and preparation are encouraged with specific attention given to cumulative impacts.

Acknowledgements

This work was supported by the Saltonstall-Kennedy Grants Program, Project: NA1677NMF4270258, from the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the authors and do not necessarily reflect the views of NOAA. The authors thank the coastal fishing families and community leaders for their cooperation and support by participating in this project.

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Figure Captions:

Fig. 1 Conceptual diagram of analysis framework.

Fig. 2 Material dynamics of specific climate change impacts. Note that “Mobility” is indicated twice. Mobility as a result of extreme weather has the same impact on graying as does mobility as a result of water temperature and fish distribution.

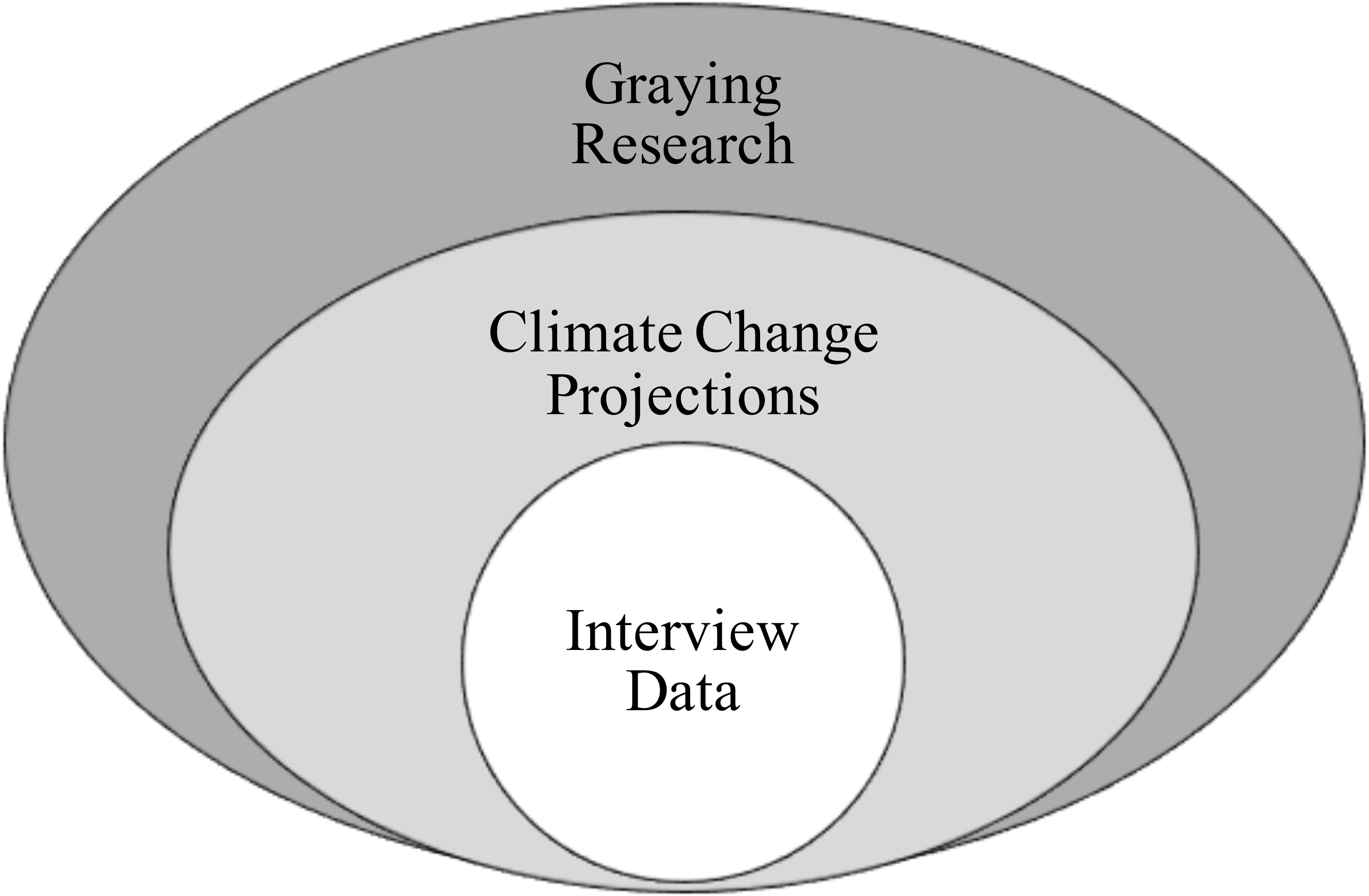
Fig. 3 Relational dynamics of systemic climate change.

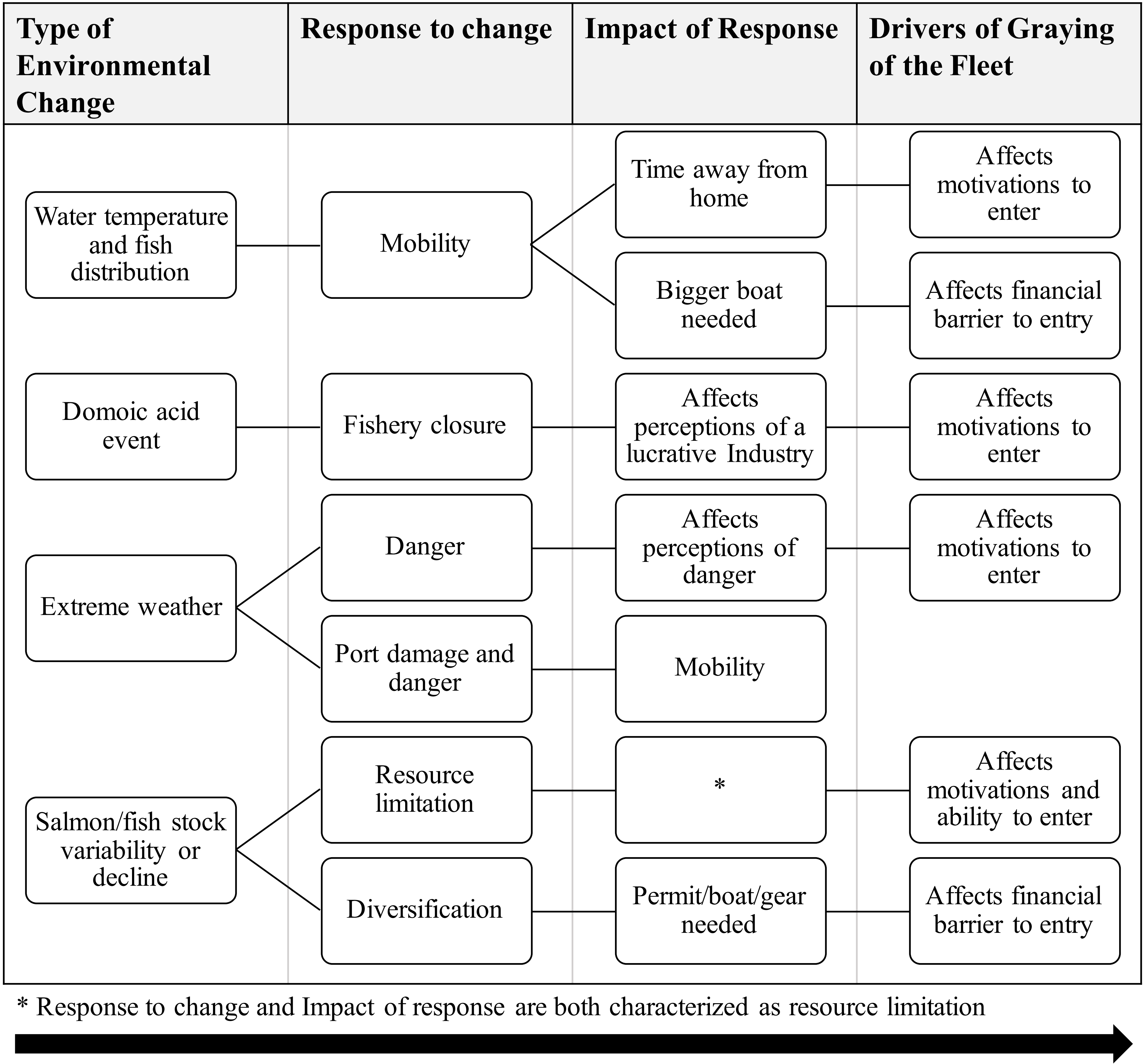
Column Indications:

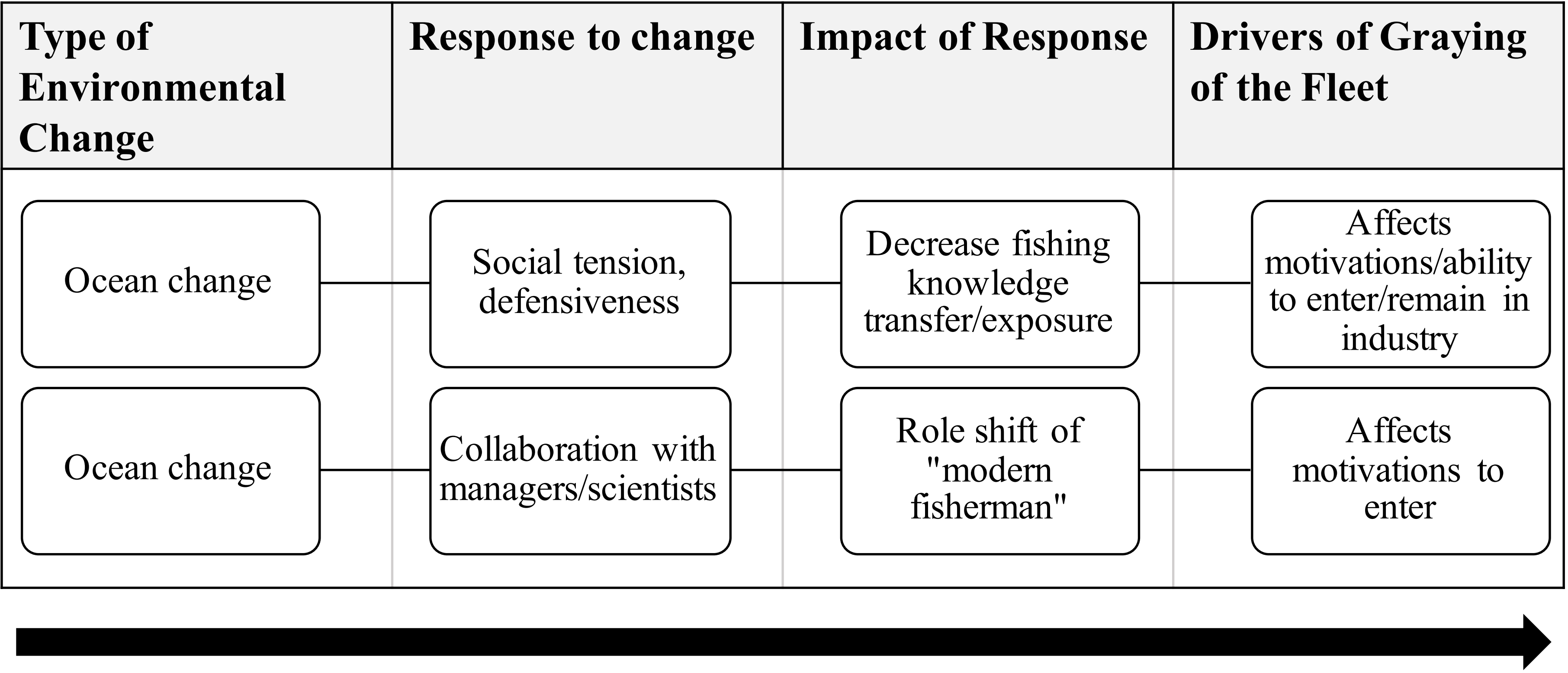
Fig. 1 - 0.5 column

Fig. 2 – 2 column

Fig. 3 – 2 column


Graying
Research
Climate Change
Projections
Interview
Data


Type of Environmental Change
Response to change
Impact of Response
Drivers of Graying of the Fleet
Water temperature and fish distribution
Mobility
Time away from home
Affects motivations to enter
Bigger boat needed
Affects financial barrier to entry
Domoic acid event
Fishery closure
Affects perceptions of a lucrative Industry
Affects motivations to enter
Extreme weather
Danger
Affects perceptions of danger
Affects motivations to enter
Port damage and danger
Mobility
Salmon/fish stock variability or decline
Resource limitation
*
Affects motivations and ability to enter
Diversification
Permit/boat/gear needed
Affects financial barrier to entry
* Response to change and Impact of response are both characterized as resource limitation



Type of Environmental Change
Response to change
Impact of Response
Drivers of Graying of the Fleet
Ocean change
Social tension, defensiveness
Decrease fishing knowledge transfer/exposure
Affects motivations/ability to enter/remain in industry
Ocean change
Collaboration with managers/scientists
Role shift of "modern fisherman"
Affects motivations to enter