Title

The Politics and Possibilities of Moving Pacific Herring from Boat to Plate in the United States: A Food Systems Approach to Understanding Seafood Security, Equitable Seafood Value Chains, and Consumer Seafood Preferences

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The politics and possibilities of moving Pacific herring from boat to plate in the United States: a food systems approach to understanding seafood security, equitable seafood value chains, and consumer seafood preferences.

A dissertation in partial satisfaction
of the requirements for the degree of
DOCTOR OF PHILOSOPHY
in
ENVIRONMENTAL STUDIES
by
Stephanie Ann Webb
September 2022

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Abstract

Stephanie Webb “The politics and possibilities of moving Pacific herring from boat to plate in the United States: a food systems approach to understanding seafood security, equitable seafood value chains, and consumer seafood preferences.”

Using forage fish for direct human consumption in the U.S. could reduce the social and environmental pressures associated with eating higher trophic species, increase jobs in the fishing industry, and improve seafood security. In the United States, one of the world’s largest importers and exporters of seafood, forage fish represent 31% of the total weight (volume) of fish harvested. However, they only represent approximately 4% of the value from all species harvested. This dissertation explores the opportunities and limitations of using forage fish for direct human markets in the U.S using California’s Pacific herring fishery as a case study. To do this, I developed an approach for integrating fisheries conservation and food security using literature from fisheries, political ecology, and global commodity chain studies. I collected ethnographic data, including participant observations and interviews, from the point of harvest in San Francisco, California, to consumption in the U.S., and Japan. I crossed referenced primary data with state and national landings (harvest) data, national export data, and several state archives. I found restricting gear diversity, a common fisheries harvest control tool, seafood product forms became more unified and seafood marketing channels narrowed (Chapter 1). Policy is not the only deterrent to more sustainable and equitable seafood systems. I also demonstrated that

the Pacific herring value chain governance structure – one built upon secrecy, reciprocity, and economic dependence on a few international buyers – perpetuated U.S. harvested seafood being exported (Chapter 2). Improving seafood systems requires a shift in social and economic barriers to entry, such as reducing investment risk for mid-chain intermediaries who play a vital yet under-recognized role in seafood chains. Lastly, my research showed that Californians enjoy the taste of Pacific herring but prefer more sophisticated product forms that require more processing (e.g., filleted or no bones) (Chapter 3). The mismatch of forage fish supply and consumer purchasing trends is not necessarily driven by taste, but rather by a series of environmental and political-economic conditions limiting seafood security in the U.S.

DEDICATION

For Donald Ray and Dax William

Acknowledgments

My family, friends, professors, and colleagues supported me throughout my doctoral studies. I am grateful for the endless support and encouragement from my parents, my loving partner Jeff Clark, and my sister, Amanda, to whom I turned for advice and countless peer edits on endless grant applications. She also always provided me with support and a cheerful attitude during several experiences of pressing deadlines and emotional unrest. My partner Jeff is incredible in many ways; I thank him for being present through the good and tough times and always providing invaluable support to our family. Jeff is my stable amongst the chaos. I could not have finished this degree without him.

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My research would not have been possible without the trust and openness of the California Department of Fish and Wildlife's staff, fishers, and industry wholesalers from Icicle Seafoods. I thank them for their invaluable time and sincerity. While working with this community, I learned that current and emerging ecological, economic, and social demands on small fish are universally experienced throughout the seafood industry.

Preface

I have always been drawn to and gained peace from being near or on the ocean. At 21, I moved from Missouri to Florida after completing a B.S. in Business Administration with an economics major. In 2008, while working as a derivatives trader in corporate finance and living in Florida, I went on one of many lovely beach runs, but that day was July 5th. My daily beach run quickly turned into a clean-up of July 4th celebratory debris. I was appalled at the types and amount of trash on the beach. After that, I centered my professional endeavors at the nexus of science and policy.

Six months later, I left a prosperous career in corporate finance for a Master's in Urban and Regional Planning in Spokane, Washington. Urban and regional planning combined my passion for the environment, expertise in economics, affinity for change (through public policy), natural leadership abilities, and interpersonal skills. It laid a foundation of transferable skills that could be for marine planning, such as facilitation and community development skills, analyzing economic and geographic information for assessing socio-ecological tradeoffs, and public policy analysis.

After that, I was awarded an AmeriCorps position in Southern Coastal Oregon, where I witnessed the trials and tribulations of coastal communities reliant on marine ecosystems for their livelihoods. I developed a participatory mapping process using geographic information systems and stakeholder focus groups. Forty stakeholders, including fishers, coastal homeowners, and wave energy representatives, collaboratively created a mixed-use marine spatial plan later adopted by the Oregon Department of Land Conservation and Development.

Despite my best efforts to make an inclusive process, fishers with bigger boats, more extensive fishing portfolios, and stronger market connections made personal threats to fishers in neighboring counties. This experience fostered a reimagining of who and deepened my desire to fight for the "underdogs" at our coastlines. Concluding this experience, I centered my research on addressing real-world problems that protected marine ecosystems and empowered typically disadvantaged stakeholders.

In 2012, I combined my passions and expertise in environmental entrepreneurship. I focused on improving small-scale fishers' representation in policy processes, fostering social capital, and building financial backbones in marginalized fishing communities. I was awarded over $350,000 to establish fisher cooperatives and alternative seafood networks in several fishing communities from Kodiak, Alaska, to San Pedro, California, that could economically incentivize fishers to use low-impact gear and cooperatively own waterfront property.

During this experience, I observed alternative seafood networks fail to scale economically, lack leadership with unified visions, and struggle to maintain the social capital or expertise necessary for long-term organizational sustainability. Alternative seafood networks were inflicted by unpredictable supply, perishability, inaccessible processing infrastructure, and a general lack of consumer awareness about sustainable seafood options. Those able to scale had the intellectual resources needed to seize outside funding. They also often strayed from their missions and became entrenched in the "get-big, or get-out" business model that put profits above people or the planet.

Grappling with these issues, I began a formal doctoral research program at the University of California, Santa Cruz, a reputable interdisciplinary program known for conservation biology, political ecology, sustainable food systems research, and environmental justice. I wanted to better understand why local seafood distributors, who self-proclaimed dedication to low volume, high-value paradigms that protected marine ecosystems and honored fisher livelihoods, could neither “succeed” nor scale without sacrificing their mission.

At the same time as my curiosity about the seemingly dualist idea of local vs. global and that local also meant sustainable, literature began to emerge about the wastefulness and underutilization of forage fish. Forage fish are ecologically abundant, nutritious, and affordable, yet they are used for aquaculture and livestock feed or bait rather than for human consumption (forage fish paradox).

I began exploring ways to investigate the forage fish paradox and the sustainability of fish as food networks. I began to question if alternative seafood networks could be catalysts for shifting demand towards forage fish. If not, why? And if so, how? Herein lies the impetus of my dissertation research and mindful choice of case study—Pacific herring. Notably, I didn’t choose a sardine case study because the fishery in California was closed, and frankly, understanding and attempting to change the distribution channels of anchovies seemed too far-reaching, cumbersome, and mechanized for practical, research-based solutions.

Using Pacific herring as my case study, my research highlighted the political, socioeconomic, environmental, and spatial complexities underpinning a mismatch of supply and demand for forage fish, an underutilized, ecologically abundant, nutritious seafood option. I investigated food availability and accessibility issues, power asymmetry in the global seafood economy, and consumer preferences for underutilized forage fish. I conducted a value chain assessment and examined the historical political and economic trends in the Pacific herring fishery in California.

The proceeding dissertation is a cumulation of my work experience in human dimensions of fisheries and seven years of research into vast bodies of literature about fisheries and food studies; painstaking grant writing and extensive ethnography starting in the U.S. and ending at a global seafood trade show in Hong Kong were seminal to my progress. I also used multiple analysis tools, including how to code in R and create pivot tables in Excel, to complete my dissertation.

I discovered that some harvest control mechanisms, such as gear restrictions, reduce catch by restricting participation in fisheries and are useful tools for protecting fishery resources and marine ecosystems. However, they can also perpetuate socio-economic instability in fisheries and limit seafood security in the U.S. In contrast, other harvest control tools such as quotas and seasonal and spatial restrictions can be used to limit catch, protect marine resources, and enable food availability in the long term without constraining the seafood value chain actors' flexibility to respond to socio-economic or market changes. I also found that consumers' preferences are not necessarily tied to buying trends.

As I step away from the dissertation process, I can now critically understand how alternative seafood networks are limited and propelled by policy, the global economy, and consumer preferences. I now understand that policy is not the only deterrent to more sustainable and equitable seafood systems.

Improving seafood systems requires a shift in social and economic barriers to entry, such as reducing investment risk for mid-chain intermediaries who play a vital yet under-recognized role in seafood chains. I see how moving forage fish species from boat to plate is inundated with extra challenges: their unpredictability of supply, high perishability, seasonality, and short bursts of gluts that require large labor input over a very short time. I also found that seafood illiteracy is shared among even the most knowledgeable fisheries and food scholars. Scholarly and political reform is vital for protecting fishery resources without alienating seafood value chain actors and moving forage fish from boat to plate sustainably and profitably.

Introduction

Fisheries sit at the intersection of many most pressing social and environmental challenges of our time: loss of marine biodiversity (Parsons et al., 2014), unprecedented global trade (Gephart et al., 2019; Kittinger et al., 2015; Stoll et al., 2018, 2021), labor inequities in food systems (Teh et al., 2019), and climate-vulnerable food systems (Costello et al., 2020; Smith et al., 2010; Ueber & MacCall, 1992). Fisheries are also crucial for food security[1], vital to livelihoods worldwide (HLPE, 2014; FAO, 2015; Kittinger et al., 2015; Tlusty et al., 2019) and deserve "a central position in food security and nutrition strategies" (HLPE, 2014, p. 18).

Fish provide half the world's population with almost 20% of their average intake of animal protein (Béné et al., 2015; FAO, 2019; HLPE, 2014; Naylor et al., 2021; Smith et al., 2010). Fisheries also contribute to food security through employment and income to buy food (Garcia Lozano et al., 2022; Garcia & Rosenberg, 2010; Wamukota & McClanahan, 2017). An estimated 39.0 million people were engaged in the capture fisheries in 2018 (FAO 2020) and produced a "first sale" value estimated at US$401 billion (World Bank, 2017).

Acknowledging that fish and fisheries are essential contributions to global food security has gained consensus from fishery scholars, the social sciences, and the humanities (Garcia & Rosenberg, 2010; Love et al., 2017; Tigchelaar et al., 2022). However, "fish as food" examinations rarely translate into social or

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[1] Food security is "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their needs and food preferences for an active and healthy life" (World Food Summit, 1996 p. 43).

economic innovation or political reform (Bennett et al., 2021). My research expands upon the need to break barriers between "fisheries, food, and health in the USA" (Love et al., 2017; Olson et al., 2014) by suggesting methodological, political, and practical interventions that could help increase direct human consumption of underutilized, forage fisheries harvested by small scale fishers in the U.S., namely in California.

Scholarship that discusses the challenges of equity and sustainability in fish as food systems (recently categorized as "blue food" by a consortium of international scholars) often describes fish as food from the lens of food security (Bennett et al., 2018; Fabinyi et al., 2017; Hicks et al., 2019), fisher livelihoods (Fabinyi, 2016; FAO, 2015; Jiménez-Toribio & García-del-Hoyo, 2006; Wamukota & McClanahan, 2017) or environmental sustainability (Brewer et al., 2009; Crona et al., 2016; Gephart & Pace, 2015). However, it rarely examines the relationship between fisheries management, power asymmetry in trade networks, consumer preferences, and their combined effects on seafood's economic and geographical distributions. In the face of unprecedented climate change, degradation of resources, marine pollution, and global seafood commerce (Smith et al., 2010), a better understanding of the connections between food studies and fisheries could help balance socio-ecological tradeoffs in the seafood system (Aguilera et al., 2015; Pavlowich et al., 2019; Sarker et al., 2018).

Forage fish could be a potentially viable source for reducing food insecurity and hunger. Forage fisheries represent over 31% of the total weight (volume) of fish harvested in the U.S., but they only represent approximately 4% of the value of all species harvested (Love et al., 2017; Msangi, S., et al. 2013;

NMFS 2020). Forage fish are often used for fishmeal, oil, or bait rather than for direct human consumption (forage fish paradox) (Cashion et al., 2017; Love et al., 2017). This is concerning because forage fish species are systematically being harvested in large volumes for very low economic values. Approximately 20% of U.S. harvested seafood is used for seafood products such as bait, pet food, fish meal, and oil (NMFS 2020; Stoll et al. 2022). Cashion et al., (2017) argue that "ninety percent of fish destined for fishmeal are food-grade fish" and are suitable for direct human consumption. They are high in micronutrients, such as Vitamin C, omega-3s, and minerals, and low in marine containments, such as mercury and bisphenol A (BPAs) from microplastics. Additionally, the United States Food and Drug Administration's 2015-2020 dietary guidelines (FDA.gov, 2021) and Monterey Bay Aquarium's Seafood Watch suggest forage fish such as anchovies, herring, and sardines as "best choices" for consumers. Nevertheless, forage fish rarely appear in nutrition assistance programs and are rarely favored by American consumers. (Love et al., 2019).

To address this challenge, my dissertation explores the entangled human-natural relationships resulting in present-day mismatches between forage fisheries production and consumers' seafood preferences, specifically, the lack of using forage fish for direct human consumption in the United States, namely California. My overarching question is, "what are the barriers and opportunities for moving commercially harvested Pacific herring into local and regional markets for human consumption in the United States?" To answer this question, I investigate this challenge in three contexts: policy (the state), commerce (trade, governance, and embeddedness), and consumption (consumer preferences) using the four pillars of food security (Ericksen, 2008) and a value chain analysis (Bevilacqua et al., 2019; Fabinyi, 2016; Gereffi et al., 2001) of the commercial Pacific herring fishery in California. First, I examined the effects of fisheries management on seafood security. Then, I investigated labor inequities in seafood value chains and the effects of the global seafood economy on the economic geography of seafood distribution. Lastly, I measured consumers' preferences for eating Pacific herring prepared in various ways to explore the viability of value-added markets for forage fish in the U.S.

Case Study Context

Stakeholders from fisheries, environmental sectors, and public health are interested in increasing the consumption of Pacific herring (*Clupea pallasii*) in the U.S. (Cashion et al., 2017; Levin et al., 2016; Love et al., 2017), but understanding the structural, political, and institutional barriers limiting its availability and accessibility as food is challenging (Levin et al., 2016).

First, Pacific herring are underutilized and understudied forage fish species with relatively short life cycles (five to nine years, some, but few exceeding 15 years) and reach sexual maturity at a relatively young age (two or three) (CDFW, 2019; Levin et al., 2016). The ecological contribution to marine food webs, life cycle characteristics, and sensitivity to oceanic conditions (Moser & Hsieh, 1992) increase fishery managers' challenges aimed at protecting the sustainability of the resources per several state and federal policies (e.g., Marine Life Management Act, Endangered Species Act, Marine Mammal Protection Act) (Thompson et al., 2017).

Secondly, the global market for commercially harvested Pacific herring and herring roe is shrinking– an industry in California valued at $400 million in the late 90s and now valued at less than $20,000 annually (CDFW 2019). Participation (employment) of fishers and dealers (first receivers) has declined from over 400 vessels and 35 dealers in 1981 to less than 50 vessels and two dealers in 2020. As global demand declines for Pacific herring, fishing communities whose portfolios are decreasing in volume, price, and participation are seeking alternative markets for their catch.

Thirdly, conservationists have increased their attention and efforts towards preserving forage fish species, such as Pacific herring. They turn plankton into digestible food energy for higher trophic species such as salmon, lingcod, and various marine birds and mammals (Isaacs, 2016; Pikitch et al., 2014); they are vital to marine food webs. Conservationists argue that new or revived markets for direct human consumption of Pacific herring– and forage fish more broadly– could reduce fishing pressure on higher trophic species and lower the carbon footprint occurring from global food transportation:

> *Eating small forage fishes instead of predators like tuna and billfish and most farmed fish and shrimp would make the ocean's resources go farther and perhaps last longer. Eating a pound of farmed shrimp or salmon requires using at least several pounds of forage fish, often recovery, as feed. So, you have this conundrum where if you just ate more forage fish in the first place, you'd be using less and leaving more in the water. Fishermen would be getting more money, consumers would be eating healthier seafood, and by eating fish caught in your backyard, you'd be lowering your carbon footprint.*
>
> (G. Shester in Bland, 2018)

Lastly, Pacific herring could be used to improve food security in California. The San Francisco Bay Area in California has one of the most productive Pacific herring spawning and fishing grounds along the U.S. Pacific Coast (CDFW 2019). Pacific herring spawning and commercial fishing can be seen from the shorelines of California, and their harvest locations are close to several urban centers of San Francisco Bay (e.g., Point Richmond) and even rural locations north of San Francisco (e.g., Tomales Bay, Humboldt Bay, and Crescent City) (CDFW 2018). More than half of all California residents live near the coast, and in the rural coastal counties north of San Francisco, residents experience 15 – 19% food insecurity (Feeding America.com). Hicks et al., (2019) determined that nutrients available in even a fraction of the fish harvested could help meet the dietary requirements for coastal residents living within 100km of the coast.

There seems to be an opportunity for Pacific herring consumer markets in California but seizing this opportunity has yet to occur. My dissertation provides political and theoretical insights into how marketable interventions could be developed for moving Pacific herring onto the plates of California consumers and into higher valued production activities that could improve the commercial Pacific herring industry through processing or increased pricing to fishers. Cashion et al. (2017) state– but do not provide evidence for– "new or revived markets for human consumption are being found for Pacific herring." My research also responds to Levin et al. (2016) call for more research on the human dimensions of the Pacific herring fishery. Using the Pacific herring fishery in California as a case study (*Clupea pallasii*), my dissertation answers the following questions:

- Chapter 1 questions how much, which types, and in what form is Pacific herring available and accessible using the four pillars of food security and several fisheries data sources, including harvest (landings), export data, and government archives.
- Chapter 2 questions how strong, equitable, and stable are Pacific herring value chain actors' relationships using a value chain analysis and governance theory from global commodity studies.
- Chapter 3 investigates the consumer or demand side of food access. It defines lead consumers' (early adopters) and examines the cultural appropriateness of various Pacific herring products using a sensory science survey.

Research Design

My dissertation engages literature on fisheries, aquaculture, political ecology, alternative food networks, global commodity chains, food science, and consumption. I combined these extensive literature reviews – which were often unproductively torn between fisheries and food systems – to explore the connections between fisheries, policy, and food system activities (e.g., production, exchange, and distribution) and outcomes (e.g., food security, income, employment, etc.), namely in terms of seafood security.

Seafood security is often used in the emerging fish as food literature (Kittinger et al., 2015; Mustafa et al., 2021; Pelletier et al., 2014) but rarely explicitly defines seafood security beyond seafood self-sufficiency (Helvey et al., 2017). Food security is "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their needs and food preferences for an active and healthy life" (World Food Summit, 1996, 43). The rise of the term food security emerged in response to the world food crisis in the 1970s. At that time, food security and food availability were synonymous. However, it was evident in agrifood systems that declines or rises in food availability (i.e., production) did not singularly create nor eliminate hunger and famine (Maxwell & Smith 1992). Today, food availability, access, utilization, and stability are the four pillars of food security (Bennett et al., 2021; FAO, 2020; Love et al. 2017). These pillars provide a robust and fluid lens for answering the questions about seafood security.

Food availability is the amount of food produced or, in other words, the amount of food available through ecological conditions and governance (Ericksen, 2008). *Food access* describes sociocultural limits of food allocation, including the physical and spatial access to food and the affordability of purchasing food (economic access) (Ericksen 2008; FAO 2020; Porter et al., 2014). *Food utilization* describes the nutritional efficiency of food and individuals' capacity to use food (Bennett et al., 2018; Ericksen, 2008) and includes nutritional components such as protein and micronutrients, food safety, and nutritional absorption. *Stability* describes the short- and long-term abilities of food production and distribution systems to function throughout disruptions, such as ecological and economic shocks (Seekell et al., 2017), across multiple scales (Bene et al., 2016). I draw from the four pillars of food security to define and examine seafood security. Chapter 1 explains the four pillars of food security in greater detail and connects theory to methodology through my empirical research on the Pacific herring fishery.

Research Approach: A Pacific herring fishery value chain analysis.

I use a comprehensive commodity chain approach adapted from (Gereffi et al., (2005) value chain analysis and Friedland's (2001) commodity systems analysis. This method investigates the actors, activities, material and financial resources flow, and the linkages and feedback between each node constituting seafood production. It also empirically connects fisheries management to seafood systems and, more broadly, production to consumption. This method instructs data collection and analysis along with several critical data points, including the inputs and outputs of production, defining the geographic scope, describing industry organization and stakeholders, and the local institutional context. It uses descriptive analysis to investigate global and local commerce's social, spatial, and economic dimensions (socio-spatial) and to better characterize and understand the effects of globalization on (in)equitable divisions of labor and value (governance) and upgrading (Bair, 2005; Friedland, 2001; Gereffi et al., 2001). To accommodate the empirical vastness of this approach, I focus on one commodity: Pacific herring.

Methods and materials.

My methods are not intended to examine causation but rather to understand the multifaceted ways in which ecology shapes fisheries management and how fisheries management and the global economy shape seafood system activities and outcomes. I conducted multi-sited ethnography, including field and participant observations and semi-structured interviews using snowball sampling, to follow Pacific herring from the point of harvest in San Francisco, California, to consumption in California and various locations in Japan. To do this, I visited over 21 national and international sites where Pacific herring were harvested, bought, or sold, including a global seafood trade show and expo in Hong Kong. I conducted participant observations at public management meetings and during market transactions. I conducted over 39 semi-structured or informal interviews with various value chain actors in California and Japan. I cross-referenced interview data with institutional and industry reports, including but not limited to information about participation, harvesting, exports, and pricing. I detail data points and collection methods below.

Field and participant observations.

During the Pacific herring season in San Francisco, CA, I conducted field and participant observations from April 2017 to January 2019. I observed fishers leaving ports, recreational fishers, differences in fishing gear between the fleets, boat sizes, and unloading facilities. I also attended three Pacific herring fishery management meetings hosted by the California Department of Fish and Wildlife (CDFW) in January and February 2017. During field observations, I conducted informal interviews with fishers and wholesalers, which also initiated my snowball sampling.

Through these conversations, I learned how Pacific herring caught in California are often aggregated and stored with fish caught from Alaska in Washington. Then, the aggregated product is shipped overseas to Hokkaido, Japan, for processing. In the summer of 2018, I visited Hokkaido, Japan, to observe product forms and imports, manufacturing facilities and processing, relationships between distributors, consumers, physical space, and retail vendors selling products to end consumers. I also visited Tokyo, where the most prominent and highest number of fish markets exist. While in Japan, I collected information about end-pricing. In September 2018, I also attended a global seafood conference in Hong Kong to better understand end markets for herring globally by interviewing industry traders, intermediaries, and processors.

I also attended three public and stakeholder meetings from December 2018 to June 2019 regarding the 2019 Pacific herring Fishery Management Plan (FMP), which proposed several revisions to existing harvest control strategies used to regulate the commercial Pacific herring fishery in California. I observed and recorded concerns from commercial and recreational fishers, wholesalers (first receivers), conservation advocates, and fishery managers about proposed policy changes. This information was used to better understand the drivers of the decline in utilization and the cultural appropriateness of currently harvested Pacific herring seafood product forms. Chapter 2 reveals most of my findings gathered from participant observations and interviews.

Semi-structured interviews (with commodity chain actors and key informants).

Using snowball sampling, I completed 39 semi-structured interviews with commercial fishers, crew members, and dockside buyers in the United States, transnational seafood exporters and manufacturers in the U.S. and Japan, end-of-the-chain merchants in Japan, as well as midchain traders and wholesalers in

Hong Kong using Mandarin- and Japanese-speaking interpreters. I also spoke with key informants, expert scholars, conservation advocates, and fisheries managers in the U.S. and Japan. I asked interviewees questions about markets, price, relationships with other supply chain actors, and their concerns about management and the fishery.

Interviews ranged from 30 minutes to three hours and occurred at restaurants, on fishing vessels, at marketplaces and processing facilities, and over the phone. Content obtained from interviewees was transcribed and synthesized for thematic consistencies, including examining for outlining answers and identifying correlations, data similarities, and differences (Elliot 2006), as well as the frequency of recurring themes. In-depth interviews with various value chain actors helped me better understand how the fishery has changed over time, how social relationships influence economic behavior, and vice versa, and provided interpretations of how knowledge is transferred among actors. Findings from my interviews are seminal to understanding equity in seafood value chains and are presented in Chapter 2.

Landings (harvest) data.

I used descriptive analysis of quantitative biological and economic production data (i.e., landings) and national export data of the commercial Pacific herring fishery in California from 1981 to 2019 to understand how fisheries management shapes seafood security in the U.S. I chose 1981 to 2019 because it encompasses political, economic, and ecological changes to the fishery and was accessible through various state and federal databases described below.

Landings receipts are required for all California fisheries when fishers unload or physically move fish from boat to land. Landing receipts contain data about the fishing vessel and gear type, port(s), and date(s) of harvest. It also notes the volume or landed weight, sex, condition, use, and value of harvested fish by species. Landing data for the commercial Pacific herring fishery is submitted first to CDFW and then to the Pacific States Marine Fisheries Commission's Pacific Fisheries Information Network (PacFIN) program, which standardizes and stores data for use by fishery managers and the public.

I originally used confidential PacFIN data from 1981 to 2016 and filtered data for the species equaling or including "Pacific herring" to run several fishery totals, concentration equations, and other descriptive statistics analyses. Then, to ensure that all figures submitted for publishing adhere to the "rule of three" (that fishery totals did not include fewer than 3 participants), I also downloaded California herring landings data from the NOAA website (https://www.fisheries.noaa.gov/foss/). These data are pre-screened for confidentiality, so when "NA" appeared, I knew it was inappropriate to singularly present PacFIN data. I also used published CDFW landings data (https://wildlife.ca.gov/Fishing/Commercial/Landings) to complete the dataset for the years 2000 to 2020. I used R and Excel for data management, visualization, and analyses in Chapter 1.

NOAA Commercial Fisheries Statistics.

I used Pacific herring foreign trade information to couch California's industry in the greater U.S. and global context, better understand commodity pricing/value, and trace Pacific herring through the commodity chain. The

National Oceanic and Atmospheric Administration's (NOAA) Office of Science and Technology has information on commercial landings, foreign trade, and fishery products, including listing the volume and value of imports and exports by species and associated seafood by-products (e.g., frozen, fresh, roe, etc.). I created an export database from 1981 to 2020 of edible herring products using the public query tool (https://www.st.nmfs.noaa.gov/st1/trade/build_a_database/TradeSelectDateDistrict.html). Then, I filtered data from exporting districts in California, Washington, and Alaskan, and importing nations Japan and China. These data included the product type (e.g., roe, whole fish, dried, etc.), the amount (i.e., total kilos) of fish exported, and the value of the species. I summarized data annually for analyses. Then, I used R for data management, visualizations, and analyses.

I also examined NOAA's Fishery Market News Archives for information on Japanese exports, imports, and cold storage. Data on wholesale prices at the Tokyo wholesale market and the prices of Japanese fishery imports by species were available online at media.fisheries.noaa.gov for current years during my research (2017 – 2020). Archival data from 1977 through 2016 for Japanese Imports, Cold storage holdings, and wholesale pricing for herring are available from our website at: http://www.st.nmfs.noaa.gov/commercial-fisheries/market-news/related-links/market-news-archives/index. Archival data from 2005 through 2016 for US exports are also available from our website at: http://www.st.nmfs.noaa.gov/commercial-fisheries/market-news/related-links/market-news-archives/index. These data were used to determine various values and the value added from value chain node to the next using a proportional analysis and Microsoft Excel. The results were not highlighted in the dissertation manuscript, but they were briefly presented in the discussion section of Chapter 2.

California Fish and Wildlife CEQA Reports.

California Environmental Quality Act (CEQA) requires that policy changes' environmental and economic impact on fisheries be examined and documented. I used the CEQA documents from the Pacific herring fishery from 1998 to 2015, which are publicly available on the CDFW website. The Supplemental Environmental Documents for Pacific Herring Commercial Fishing Regulations reviews and evaluates proposed regulatory changes for the current fishing season, supplementing and replacing existing regulatory decisions" (CDFW website). Using these documents, I conducted a literature review to compile information on policy changes in the Pacific herring fishery over time, including the final and proposed alternative management decisions, and managers' motivations and justifications for changing management strategies and harvest control rules.

California Fish and Wildlife Annual Fishery Summaries.

CDFW's Pacific herring annual summaries include information about species population dynamics, including biomass estimates, catch-to-biomass ratios, spawning distribution, and species age structure and distribution. I used Pacific herring annual summaries for Humboldt Bay and Crescent City from 2003 to 2007, for Tomales Bay from 1990 to 2007, and San Francisco from 2002 to 2019, which are publicly available on CDFW's webpage (https://wildlife.ca.gov/Fishing/Commercial/Herring/Season-Summaries). I conducted a literature review of these documents to compile historical information on quotas, biomass estimates, landings, spawning locations, and market changes.

Dissertation Outline.

Chapter one investigates how changes in marine conditions influence access to fisheries and, in turn, create feedback on seafood system activities and security. Methodologically this chapter prescribes a framework for incorporating the four pillars of food security into fisheries conservation. Then, I apply this framework to California's Pacific herring fishery using landings data and state archives. My results explained the effects of commonly used harvest control mechanisms, such as quota, limited entry permits, and gear and spatial restrictions on seafood availability, accessibility, and system stability. I show that seafood's ecological conditions and policy decisions are intrinsically connected and influence seafood security. Quotas (annual harvest limits) are essential for reducing catch and seafood availability. However, utilization is a more appropriate determinant of seafood availability. Gear and spatial restrictions influence seafood access by restricting harvest locations, product form, participants' ability to respond to market changes, and narrowing market and income opportunities for fishers. The long-term effects of path-dependent, market-responsive harvest control tools used in California's commercial Pacific herring fishery ultimately created a rigid seafood system that inadvertently perpetuated economic instability in the fishery and constrained U.S. seafood security. This chapter concludes with examples of adaptive fisheries management that can successfully reduce catch and preserve participant flexibility, which is needed for ensuring seafood security.

Chapter two explores the socio-spatial, material, and economic linkages and feedback constituting the Pacific herring production network. I examine the various types and roles of functional and social go-betweens interconnecting domestic and international fish trade. I show the complexities of how the seafood trade unfolds and the implications of power asymmetry (governance) on distributional endpoints of commercial Pacific herring (*Clupea pallasii)* using various methods and materials obtained by following Pacific herring from the point of harvest in California and Alaska to manufacturing and consumption in Japan. I demonstrated that power asymmetry (referred to as governance in commodity chain studies) manifests through relationally bound actors who protect vital supply or demand information. Authority is also exerted– although not evenly– by intermediaries who create international sales agreements that reduce their interfirm risk and strengthen their market power. I found that this relationally confined governance, a value chain structure where actors' behavior is simultaneously influenced by relationships and economic dependence on a few buyers, in the commercial Pacific herring fishery results in product distribution outcomes that not only weave but also interlock local markets to the global economy. The domestic markets, and their associated environmental and social benefits, are simultaneously dependent upon and limited by the global fish trade.

Chapter three examines consumers' preferences for and perceptions of eating Pacific herring and theoretically connects sensory science and product upgrading. To better understand consumers' preferences for and perceptions of eating Pacific herring, I coupled ethnography with a quantitative hedonic survey at the Pacific Herring Festival in Sausalito, California, where voluntary consumers ranked their experiences with six sensory attributes across nine different preparations for two consecutive years. My results show that Pacific herring are "liked" as food with little preparation or upgrading beyond filleting. However, Californian consumers preferred filleted product forms, disliked bones in the fish, and indicated a relationship between texture and overall "liking." Understanding how consumer preferences for more sophisticated product forms are helpful for the commercial Pacific herring fishery can provide insights into the practical and socio-cultural needs for moving other underutilized forage fish species onto the plates of Americans.

I conclude my dissertation with a short monograph summarizing the multifaceted challenges facing the Pacific herring fishery and explaining how my research can help us understand the broader social, political, and environmental complexities underpinning the mismatch between forage fisheries production and seafood consumption in the U.S. I also highlight directions for future research, such as deepening understanding and explanations of fish being a central authoritative actor (using actor-network theory). Actor-network theory is both theory and a method first introduced by Bruno Latour's (1979) assessment of social constructivism in Laboratory Life. It recognizes and operationalizes the "mutual construction of nature, science, and society" (Mansfield, 2003 see also Demeritt 2001, 311) and recognizes nonhuman actors' agency in creating outcomes in human-nature systems (e.g., seafood value chains). In this way, my work on the Pacific herring value chain establishes the necessary foundations for bridging unproductive gaps between fisheries and food systems and deconstructing human-nature binaries.

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Chapter 1 Using the pillars of food security to assess fisheries management effects on seafood security: a political ecology assessment of California's commercial Pacific herring fishery.

Abstract.

Overexploitation of fishery resources can decrease the amount of seafood available for consumers, but fisheries management can create negative social and economic effects on fisheries and food security. The United States produces 7.5 billion pounds of wild-caught edible seafood annually, has hit an all-time low of overfished species, and is a global leader in the seafood economy. However, the U.S. fails to achieve national seafood security and produces a $17 billion trade deficit. In this paper, I investigate how changes in marine conditions influence access to fisheries and, in turn, create feedback on seafood system activities and security. Methodologically this chapter prescribes a framework for incorporating the four pillars of food security into fisheries conservation. Then, I apply this framework to California's Pacific herring fishery using landings data and state archives. My results explained the effects of commonly used harvest control mechanisms, such as quota, limited entry permits, and gear and spatial restrictions on seafood availability, accessibility, and stability. I show that seafood's ecological conditions and policy decisions are intrinsically connected and influence seafood security. Quotas (annual harvest limits) are essential for reducing catch and seafood availability. However, utilization is a more appropriate determinant of seafood availability. Gear and spatial restrictions influence seafood access by restricting harvest locations, product form, participants' ability to respond to market changes, and narrowing market and income opportunities for fishers. The long-term effects of path-dependent, market-responsive harvest control tools used in California's commercial Pacific herring fishery ultimately created a rigid seafood system that inadvertently perpetuated economic instability in the fishery and constrained U.S. seafood security. This paper concludes with examples of adaptive fisheries management that can successfully reduce catch and preserve participant flexibility, which is needed for ensuring seafood security.

Keywords: *seafood security, food access, fisheries management, forage fish*.

Introduction.

The U.S. harvested approximately 7.5 billion[2] pounds of wild-caught edible seafood in 2019 and consumed about 6 billion pounds of seafood (NMFS, 2021). Nevertheless, the U.S. fails to achieve seafood security. Seafood security is often used in the emerging fish as food literature (Kittinger et al., 2015; Mustafa et al., 2021; Pelletier et al., 2014) but rarely explicitly defines seafood security beyond seafood self-sufficiency (Helvey et al., 2017). Here, I define seafood security as a nation's ability to meet the minimal nutritional guidelines for seafood consumption (two times per week) for all people, at all times, with safe, nutritious, affordable seafood without relying on imports (Yıldırım, S., & Yıldırım, D. C., 2021). In this paper, I draw from the pillars of food security and historical fishery policy documents and production (landings) data in the California commercial

[2] The U.S. harvested a total of 9.3 billion pounds of fish and shellfish in 2019 and 19% was used for products other than human consumption (e.g.., bait, pet food, fish meal, etc). (NMFS, 2019).

Pacific herring fishery to conceptualize and investigate the linkages and feedback between fisheries and seafood security. Then, I applied this framework to the Pacific herring fishery in California. Pacific herring are emblematic of forage fisheries and the challenges facing fishery managers. They are edible, nutrient-rich, culturally important species harvested near urban areas of California but are rarely available as food in local or regional marketplaces. My results showed that as gear diversity decreased – a common mechanism used to reduce catch, participants were less able to respond to market changes, thereby reducing seafood availability and accessibility in the U.S. The long-term effects of harvest control tools used in California's commercial Pacific herring fishery ultimately created a rigid seafood system that inadvertently perpetuated economic instability in the fishery and constrained U.S. seafood security.

Background

The United States is the world's fourth-largest producer of wild-harvested seafood (FAO, 2020). Seafood can help eliminate hunger and meet dietary guidelines (J. Z. Koehn, Allison, Villeda, et al., 2022), yet, one in eight Americans are food insecure (Feeding America, 2022), totaling more than 38 million people, including 12 million children (USDA, 2022). Nearly half of the U.S. population lives in the coastal zone – 100km of the coastline – (Martínez et al., 2007), and of those living in the coastal zone, 40% are considered vulnerable populations[3] (U.S.

[3] Vulnerable populations include the economically disadvantaged, racial and ethnic minorities, the uninsured, low-income children, the elderly, the homeless, those with other chronic health conditions, including severe mental illness or hypertension, and those with limited access to transportation (Shi et al., 2008).

Census Bureau, 2019), where food insecurity is most prominent (Flores, H. L., & Amiri, A. (2019). Concentrations of macronutrients, including omega-3s and minerals such as zinc and iron, are available in only a fraction of the fish harvested in the U.S. and could meet the dietary requirements for residents living within 100km of the coast (Hicks et al., 2019).

Forage fish present great opportunities to reduce food insecurity and malnutrition in the U.S., especially among vulnerable populations. Recent scholarship in "blue food" emphasizes the importance of using small (forage) fish for meeting global food security and nutrition (Cashion et al., 2017; Golden et al., 2021; Love et al., 2017; Metian, 2009), reducing poverty and climate change effects (Koehn et al., 2022; Tigchelaar et al., 2021), supporting livelihoods (Alder et al., 2008; Koehn et al., 2017). However, this literature is often nutrition or fisheries-centric, empirically situated in developing or island nations (Brewer et al., 2009; Kittinger et al., 2015), and often fails to interpret the relationship between harvest control mechanisms (policy) and seafood security (post-harvest outcomes) (Basurto et al., 2020; Koehn et al., 2017). A deeper examination of conditions influencing opportunities to use (or not use) forage fish for improving seafood security is needed (Cashion et al., 2017; Love et al., 2017).

Forage fish, such as Pacific sardines (Sardina pilchardus), Pacific (Clupea pallasii) and Atlantic (Clupea harengus) herring, Anchovies (Engraulidae), and Menhadens (Brevoortia patronus), constitute over 30% of the U.S. wild harvest landings (NMFS, 2021), but only harness approximately 4% of the total value produced by American commercial fisheries (Love et al., 2017). These forage fish species are high in micronutrients, including omega-3s, iron, and calcium. They are also often lower in contaminants, such as mercury than higher trophic species (e.g., salmon and tuna) (Alder et al., 2008; Cashion et al., 2017; Love et al., 2017; Metian, 2009). Golden et al., (2021) demonstrate that forage fish (small pelagics) such as Pacific herring "can improve human health by reducing micronutrient deficiencies, particularly for calcium and vitamin B12, that can lead to subsequent disease. Small pelagics can also provide a dominant source of the omega-3 polyunsaturated fatty acids, which may reduce the risk of heart disease and promote brain health" (319). Nevertheless, eating forage fish has remained low in the U.S.– at approximately two pounds per capita– over the last 50 years (Love et al., 2017). The markets for forage fish are bait, feed, and/or fish meal rather than direct human consumption (Cashion et al., 2017; Isaacs, 2016; Love et al., 2017; Metian, 2009; R. L. Naylor et al., 2009). Using forage fish for low-value markets is often inefficient, wasteful, and harmful to the environment (Naylor et al., 2000; R. Naylor & Burke, 2005). Alder et al. (2008) state, "there is considerable scope for policymakers to change the current management of forage fisheries and to enhance their contribution to food security and economic development" (153).

Levin et al. (2016) call for more research on the human dimensions of the Pacific herring fishery. Pacific herring are emblematic of forage fisheries and the challenges facing fishery managers. California is home to one of the most productive Pacific herring spawning and fishing grounds on the U.S. Pacific coast (CDFW, 2019). California also has a higher average seafood consumption than the national average (Love et al., 2020). Yet, Pacific herring are rarely available as food in local or regional marketplaces in California or along the west coast. My research also builds upon Cashion et al. (2017), who state– but do not provide evidence for– “new or revived markets for human consumption are being found for Pacific herring” (5). Using the Pacific herring fishery in California as a case study (*Clupea pallasii*), I answer the following questions: In what ways do ecological conditions and harvest control mechanisms influence seafood security, namely food availability, accessibility, and system stability?

To answer my research questions, first, I explain how ecological conditions have shaped fisheries management in the Pacific herring fishery over the last 50 years by describing the temporal changes in fisheries policy over the last 50 years. I also describe the motivations and justifications for the Pacific herring fishery's four key harvest control strategies: quotas (annual harvest limits), limited entry permits, and gear and spatial restrictions. Next, using descriptive statistics, I analyze 35 years of landings data from NOAA’s non-confidential fisheries information systems from 1981 to 2009 and CDFW’s published landings reports from 2009 to 2019. Lastly, I explain the relationship between temporal trends in landings and food system outcomes, including seafood security, employment, and income. My methods largely draw from political ecology to examine the relationships between and consequences of intertwined ecology, policy, markets, and food security. In this way, I expand fish as food research by adopting food security approaches to investigate the natural and socio-political pathways constructing seafood security.

The four pillars of food security: a conceptual basis for connecting fisheries conservation and seafood security.

To better understand seafood security, fish as food scholars must engage a definition of seafood security rooted in food security (Koehn et al., 2017). According to the 1996 World Food Summit, food security is “when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their needs and food preferences for an active and healthy life” (43). The rise of the term food security emerged in response to the world food crisis in the 1970s. At that time, food security and food availability were synonymous. However, it was evident in agrifood systems that declines or rises in food availability did not singularly create nor eliminate hunger and famine (Maxwell & Smith 1992). Today, food availability, utilization, access, and stability are the four pillars of food security (Bennett et al., 2021; FAO, 2020; Love et al. 2017). These pillars provide a robust and fluid lens for answering the questions about seafood security. Below, I describe the four pillars of food security and connect each pillar to fisheries to foreground my empirical analysis. Table 1 summarizes my guiding frameworks used to connect the pillars of food security and fisheries.

Table 1– Fish as food research design using the four pillars of food security and existing or available fisheries data.

Food Security	**Questions/Definitions**	**Quantitative Data**[i]	**Qualitative Data**[i]
Food Availability	• How much and which types of food are available through ecological conditions and governance? • What is fishery utilization: the difference between what can be and what is harvested?	Pounds harvested and the condition and disposition of the harvest.	Fishery management plan, CEQA, and annual summaries: Annual changes to quotas, spatial zones, seasons, and gear types regulating harvest and wholesaling facilities. Biomass estimates and spawning locations.
Food Utilization	• What is the nutritional efficiency of food and individuals' capacity to use food?	FAO/INFOODS/ Global Food Composition Database[ii]	
Food Access	• How does food for consumption physically move, in what form, when, and to whom?[iii] • How much food is available to a unit: local vs. export? • Are the products available affordable? • Is the food available desirable and culturally appropriate?	Location, date, condition (grade), and disposition (headed, gutted, whole) of pounds harvested. The amount and locations of exports, the amount of and connections between fisher and dealer identification numbers.	Fishery management plan and annual summaries: descriptive narratives of the market and supply chain and quotas.

Stability	• What is the amount and variance in biomass of the species? • How strong, equitable, and stable are the relationships between actors constituting the supply chain? • What happens to the supply chain if one actor is removed?	The unit price and total revenue of the fish harvested. The amount and concentration of participants.	Fishery management plan and annual summaries: fisher demographics and narratives of the market and supply chain.

i. *Columns 3 and 4 describe data sources and specific information already available.*

ii. *FAO/INFOODS/ Global Food Composition Database is a global compendium of scrutinized analytical data (without any additional estimations, imputation, or calculation of missing values) for commonly consumed foods. Still, it has little information about the human body's ability to absorb nutrients.*

iii. *"To whom" refers to the next person in the supply chain instead of the end consumer. Arguably, middlemen in the supply chain influence end users who can physically access fish as food (Webb 2022). Existing fisheries datasets rarely have information regarding consumption beyond the initial exchange between fisher and first receiver.*

Food availability is the amount of food produced or, in other words, the amount of food available through ecological conditions and governance (Ericksen 2008; FAO 2020). Food availability is a common and easy focus of binding fisheries and food security. It can be measured through quotas and landings (Fabinyi et al., 2017). However, singularly focusing on production or food availability will not achieve food security (Barrett, C. B., 2013). Determining species abundance and distribution fluctuations is becoming more challenging due to climate change and unpredictable oceanic conditions such as harmful algae blooms and hypoxia. This, in turn, necessitates more conservative fisheries management, especially for forage fisheries. The effects of this are briefly described below using the Pacific herring case study.

Food utilization describes the individuals' capacity to use food – nutritional efficiency – (Ericksen 2008; FAO 2020; Maxwell and Smith 1992; Porter et al., 2014) and includes nutritional components such as protein and micronutrients, food safety, and nutritional absorption. Examining utilization– the nutritional efficiency of food and individuals' capacity to use food– is not within the scope of this paper. Notably, the term "utilization" is used differently between food and fisheries scholars and could be a point of misunderstanding. In fisheries, the term utilization is used to describe the difference between harvest ceilings (quotas) and the number of fishes harvested (landings) (Koehn et al., 2020). It will be used in this context for the remainder of the paper.

Food access describes sociocultural limits of food allocation, including the physical and spatial access to food and the affordability of purchasing food (economic access) (Ericksen 2008; FAO 2020; Porter et al., 2014). To determine the viability of obtaining food, one can examine the distance to markets or distance to food production sites (spatial access). In fisheries, landings by port location can be a useful tool for understanding spatial access. Physical access can be examined by asking how food for consumption physically moves, in what form, when, and to whom (Ericksen, 2008). Spatial access is often a determinant of production and physical access is a key outcome of market endpoints (exchange and distribution). For example, food could be produced near consumers, but whether that food produced is maintained domestically or destined for the export market (Ericksen 2008) determines physical access.

This paper does not evaluate affordability. However, it briefly summarizes the differences between desired seafood product forms (cultural appropriateness) for the U.S. and Japan. It examines the unit price paid to fishers (ex-vessel price), which are available through landing tickets, as a component of stability and fisher income. Although examinations of unit price can infer affordability, unit price does not represent the final price charged to or paid by consumers, nor does it provide insights about the consumer's willingness to pay. All of which are important considerations of food access.

Stability describes the short- and long-term abilities of food production and distribution systems to function throughout disruptions, such as ecological and economic shocks (Seekell et al., 2017), across multiple scales (Bene et al., 2016). Ludwig et al., (1997) define stability as a system's ability to return to a position of equilibrium when disturbed. The long- and short-term stability is influenced by risk,[4] diversity, economic growth, ecological sustainability, and political transparency (Barrett, C. B., 2013; HLPE 2019; Timmer 2000). Equitable distribution and labor (e.g., connectedness, reciprocity, and centrality) of the supply chain actors are also an important part of food system stability (Davis et al., 2021; Gephart et al., 2017; Hassini et al., 2012; Stoll et al., 2018), but are not within the scope of this paper.

The following research engages approaches from political ecology to examine the connection between environment, policy, and seafood availability and accessibility, namely spatial and physical access. My methods are not intended to examine causation but rather to understand the multifaceted ways in which ecology shapes fisheries management and how fisheries management shapes seafood system outcomes. In this way, I empirically expand political ecology and critical food studies literature, which has largely excluded examination of fisheries in the U.S., using California's Pacific herring fishery as my case study.

Materials and Methods.

I used descriptive analysis of quantitative biological and economic production data (i.e., landings) and national export data of the commercial Pacific herring fishery in California from 1981 to 2016 to understand how fisheries management shapes seafood security in the U.S. I chose 1981 to 2016 because it

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[4] The risk of food system instability may emerge as a result of any of the constant tensions between (environment, people, inputs, processes, infrastructure, institutions, etc.) and activities that relate to the pre-production, production, processing, distribution, preparation, and consumption of food and the outputs of these activities, including socio-economic and environmental outcomes (Jahn, et al., 2018).

encompasses political, economic, and ecological changes to the fishery, including the quotas falling from 15% to 5% of the biomass, fishery biomass volatility, and significantly reduced revenues ($15M in the mid-90s to now, less than $20,000) (CDFW, 2019).

Landings receipts are required for all California fisheries when fishers unload or physically move fish from boat to land. Landing receipts contain data about the fishing vessel and gear type, port(s), and date(s) of harvest. It also notes the volume or landed weight, sex, condition, use, and value of harvested fish by species. Landing data for the commercial Pacific herring fishery is submitted first to CDFW and then to the Pacific States Marine Fisheries Commission's Pacific Fisheries Information Network (PacFIN) program, which standardizes and stores data for use by fishery managers and the public.

Landings data from 1981 to 2009 are from NOAA Fisheries Commercial Fisheries Statistics (https://www.fisheries.noaa.gov/foss/). Landings from 2010 to 2020 are from CDFW's annual California Commercial Landings Reports (https://wildlife.ca.gov/Fishing/Commercial/Landings), "Poundage and value of landings of commercial fish in California." Unit price and participation are calculated from the PacFIN fish tickets. I used R and Excel for data management, visualization, and analyses.

I cross-referenced landings data analyses with reviews of the 2019 Pacific herring Fisheries Management Plan, California Environmental Quality Act Documents (CEQA), Supplemental Environmental Documents, and Annual Fishery Summaries from California's Department of Fish and Wildlife (CDFW) and additional state archives. These documents provided historical information on changes in the Pacific herring commercial fishery, such as policy changes and ecological and economic impacts assessments of proposed and adopted policy changes, including species population and biomass estimates, catch-to-biomass ratios, spawning distribution, age structure and distribution, and market changes in the fishery. This information is summarized throughout the paper and was used to construct biomass and quota tables and describe historical trends in management strategies.

I also attended three public and stakeholder meetings from December 2018 to June 2019 regarding the 2019 Pacific herring Fishery Management Plan (FMP), which proposed several revisions to existing harvest control strategies used to regulate the commercial Pacific herring fishery in California. I observed and recorded concerns from commercial and recreational fishers, wholesalers (first receivers), conservation advocates, and fishery managers about proposed policy changes. This information was used to better understand the drivers of the decline in utilization and cultural appropriateness, but my findings are not substantially discussed in this paper. Chapter 2 reveals most of my findings gathered from participant observations and interviews.

Results.

Biological and ecological conditions influence management strategies used to limit catch and shape the types, amount, and location of seafood. Year-to-year changes in abundance can necessitate more conservative harvest rates (5-10% of biomass) and reduce food availability beyond normally accepted catch limits (20% of biomass). Over the past century, several harvest control mechanisms accumulated and intensified to protect Pacific herring's abundance and functional importance in marine ecosystems. Several harvest control strategies, such as quotas, limited entry permits, and gear and spatial restrictions, were used in the Pacific herring commercial fishery to limit catch and retain a 5% (of biomass) harvest rate. However, tradeoffs between increasing seafood availability and protecting ecosystem health through harvest limits and gear restrictions exist.

Quotas are necessary to protect fishery resources and reasonably restrict seafood availability. Annual harvest limits may increase availability in the long run by reducing the risk of overexploitation and managing Pacific herring to ensure adequate forage for other species. However, limited entry permits, and spatial and gear restrictions negatively influence food access by concentrating the fleet towards one or few locations and harvesting techniques. Although these harvest control mechanisms are useful for reducing catch and ensuring adherence to annual catch limits, they also restrict participation, concentrate spatial food access, and constrain product innovation as markets change. As gear diversity decreases, opportunities for higher unit prices also decrease. There is a relationship between gear types and product form. When certain gear types are restricted, access to, possibly higher paying, and more sustainable markets are also restricted.

Biological and ecological conditions influence seafood security.

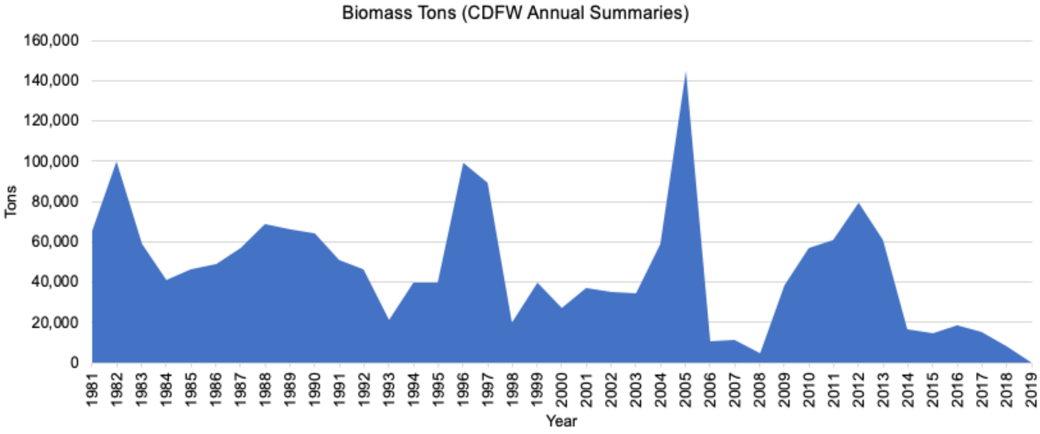
Biological and ecological conditions influence the types, amount, and location of where Pacific herring are available and accessible as food. Understanding how to better regulate Pacific herring for resource sustainability and seafood security is a fruitful exercise for the commercial Pacific herring industry. It can also provide insights into the tradeoffs between management motivation and food system outcomes in other underutilized, forage fish species.

Pacific herring migration and spawning dictate where and when Pacific herring are targeted for anthropogenic fishing and influence the types of Pacific herring available for food. Pacific herring migrate from Baja, California, to Alaska and the Bering Sea (CDFW, 2015). Pacific herring have relatively short life cycles (five to nine years, some, but few exceeding 15 years) and reach sexual maturity at a relatively young age (two or three). They quickly reproduce and are vital to marine ecosystems. Pacific herring transform plankton into digestible forms of energy for higher trophic species and are crucial food sources for marine birds, sea lions, and other fishes.

Pacific herring spend most of their life in the open ocean, but spawning occurs in shallow, intertidal areas, where eggs (i.e., roe) and sperm (i.e., milt) are found on vegetation (e.g., eelgrass), jetties, and other solid substrates (Lassuy 1989). Pacific herring are currently harvested during spawning, which dictates the approximate size of the fish– spawning occurs at three to four years of age– and the physical composition of the species. Interviewees claimed that as Pacific herring biologically prepare to release milt and eggs into the water column where they mix, their flesh becomes too “soft” or “too mushy” for certain food system activities, such as filleting or smoking, that are better suited for U.S. consumer preferences. (E. Koepf, 2017).

Additionally, Pacific herring, like other forage fish species, are sensitive to oceanic and environmental processes and naturally display boom and bust cycles of abundance (Figure 1) relative to changes in water temperature, rain abundance, and upwelling (Thompson et al., 2017). For example, less intertidal spawning occurs during warmer ocean periods such as El Niño (warmer waters, lower productivity). Spawning positively correlates with cooler waters of upwelling, such as La Niña (cooler waters, more productive). Therefore, more seafood is or could be available during cooler ocean regimes.

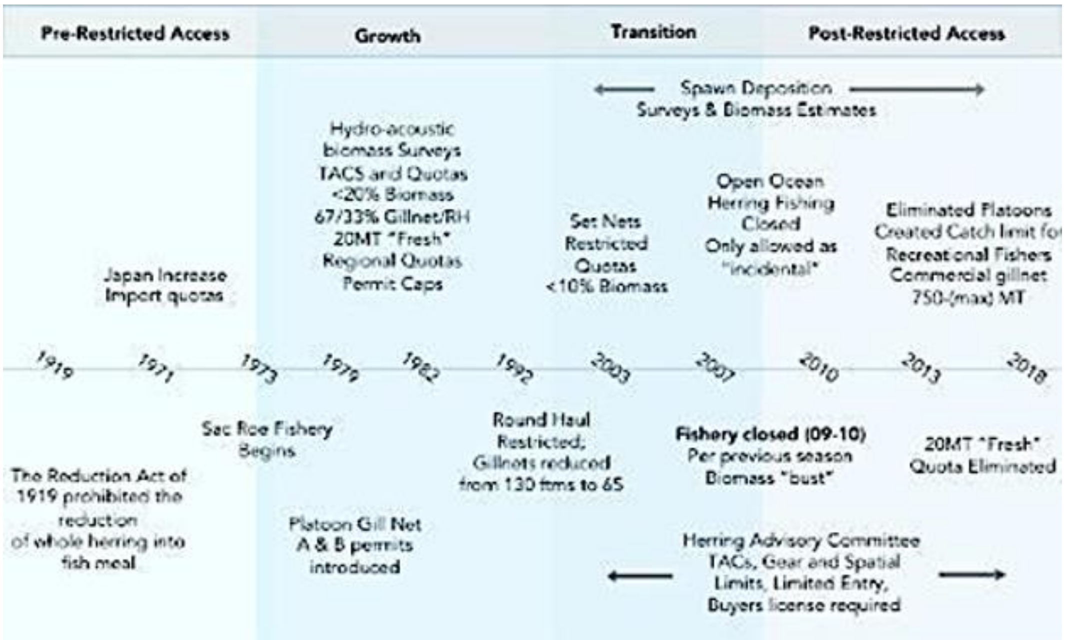
Figure 1– The changes in Pacific herring biomass in California between 1981 and 2019. Data source: CDFW.



Biological and ecological conditions influence management strategies.

In California's Pacific herring fishery, several harvest control mechanisms limit the total number of fish harvested and reach the desired optimal yield. Harvest controls ensure that Pacific herring are not overfished, and are (CDFW, 2019) used to protect their functional importance in marine ecosystems (CDFW, 2019) (Figure 2). Still, some harvest controls can create adverse social and economic effects on seafood security and system stability. The following seven sections describe the historical motivations and justifications of the management strategies: quotas, limited entry permits, platoon system, sector allocations, and spatial and gear restrictions.

Figure 2– The timeline of primary management mechanisms (e.g., quotas, spatial and temporal restrictions, limited entry permits, gear restrictions, etc.) used in the Pacific herring fishery in California between 1919 and 2016. Data source: CDFW



Fishing harvest controls used to meet annual projected catch limits in the commercial Pacific herring fishery must adhere to California's Marine Life Management Act (MLMA) and align with the principles and objectives of federal legislation (e.g., Marine Mammal Protection Act, Endangered Species Act), including the implementation of a Fishery Management Plans (FMP) (CDFW, 2019). The MLMA requires that management be based on the best available science and stakeholder input and directs FMPs to outline management measures to promote sustainable and productive fisheries (CDFW, 2019). The 2019 Pacific herring FMPs goals are: "to formalize a strategy for Pacific Herring management that is responsive to environmental and socioeconomic changes, using a decision-making process that preserves the sustainability of the fishery while considering the entire ecosystem" (CDFW website, 2022).

Before the 2019 Pacific herring FMP, the Pacific herring fishery historically used spawn surveys and hydroacoustic surveys to assess the stock size of Pacific herring in San Francisco Bay. These estimates were then used in statistical modeling techniques to assess the status of the population under various management strategies (MacCall et al., 2003). Annual catch limits were established relative to the stock size. Monitoring programs were implemented to ensure that the annual catch limits were appropriate and considered stock biomass fluctuations (CDFW, 2019). Historically and presently, annual catch limits (quotas) are the primary and necessary tool for ensuring fishery sustainability (CDFW, 2019).

Quotas are necessary and increase food availability in the long term.

Quotas are necessary to protect fishery resources and reasonably dictate how much seafood is or could be available without causing fishery resource overexploitation. In the Pacific herring fishery, quotas were established based on the prior years' biomass estimates, which included information from the monitoring programs, tracking in-year catches, and considerations for biomass fluctuations (CDFW, 2019). The Pacific Fishery Management Council (PFMC) recommends that the maximum harvest rate of herring should not exceed 20% of the available biomass (Pacific Fisheries Management Council, 1982 in CDFW 2019). Pacific herring quota in California has steadily declined and observed a <5% (of biomass) harvest rate since 2008 (Table 2).

Table 2 - The relationship between biomass and quota in California between 1981 and 2019. Data source: CDFW.

Year	Biomass Tons	Quota Tons	Quota as a % of biomass	Year	Biomass Tons	Quota Tons	Quota as a % of biomass
1981	52869	7500	14.19%	2001	27400	2499	9.12%
1982	65400	10000	15.29%	2002	37300	4128	11.07%
1983	99600	10399	10.44%	2003	35400	3262	9.21%
1984	59200	10399	17.57%	2004	34400	2020	5.87%
1985	40800	6500	15.93%	2005	58900	3169	5.38%
1986	46600	7530	16.16%	2006	145100	4328	2.98%
1987	49100	7470	15.21%	2007	10900	4328	39.71%
1988	56800	8432	14.85%	2008	11200	1057	9.44%
1989	68900	9238	13.41%	2009	4800	1019	21.23%
1990	66000	9057	13.72%	2010	38400	0	0.00%
1991	64500	8858	13.73%	2011	57100	1845	3.23%
1992	51000	7134	13.99%	2012	61000	1845	3.02%
1993	46600	5175	11.11%	2013	79500	2655	3.34%
1994	21000	1996	9.50%	2014	60600	3442	5.68%
1995	39900	4408	11.05%	2015	16700	2303	13.79%
1996	40000	5524	13.81%	2016	14900	751	5.04%
1997	99100	13543	13.67%	2017	18300	751	4.10%
1998	89600	9793	10.93%	2018	15300	834	5.45%
1999	20000	2739	13.70%	2019	8030	834	10.39%
2000	39500	5460	13.82%				

i. *Data are from annual fishery summaries*

Since 1973, annual Pacific herring quotas have been the primary harvest control mechanism for ensuring stock sustainability (CDFW, 2019). Originally, quotas were set at a 15% (of biomass) harvest rate from the late ’70s into the early 2000s, which was consistent with recommendations and presumably conservative.

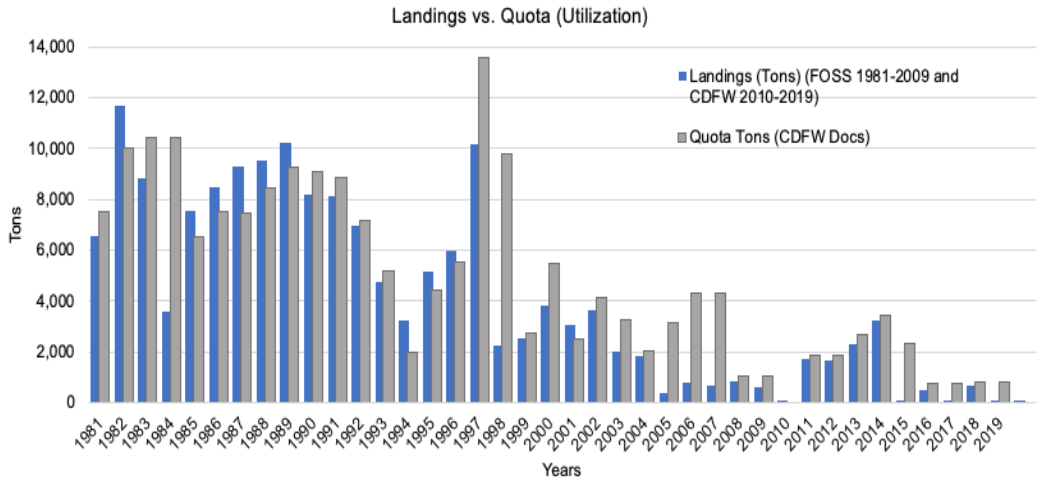
However, as biomass variations became more prevalent in the mid-90s, a peer review of the management strategies recommended a more conservative harvest rate (MacCall et al., 2003) to help safeguard Pacific herring from overexploitation amongst biomass abundance uncertainties.

In 2003, CDFW and peer scientists reviewed the fishery. They determined that a mixture of natural and anthropogenic factors, including climate change, shoreline development, and anthropogenic fishing, caused “variability in year-to-year abundance” (CDFW, 2019, p. 5-2). The 2003 evaluation of Pacific herring management measures resulted in a recommendation for a more conservative quota aim: 5-10%) (of biomass) harvest rate. The actual harvest rate ranged from 10-15% from 2000 to 2009. The fishery was closed in 2009 due to extremely low biomass in 2008.

Utilization is a key determinant of food availability.

Not all fish that are allowed to be harvested are harvested or come onshore and enter production or the seafood system. Landings – the amount (weight or number) of fish harvested – are more important than quota when examining food availability. Utilization is the difference between quotas (what is “allowed” to be harvested) and landings (what is harvested) and is an insightful determinant of seafood availability (Figure 3). It is the difference between what food could be available and what food is available.

Figure 3– Utilization trends in the Pacific herring fishery in California between 1981 and 2019. Data source: FOSS and CDFW.



Utilization was consistent from 1995 to 1997. Landings rarely exceeded more than 2000 tons since 1998, even in cases when quotas were significantly higher (from 2005 to 2006). In most recent years, from 2015 to 2019, approximately zero to 700 tons of Pacific herring were available for food even though quotas averaged approximately 2,400 tons from 2000 to 2015. Very few landings have occurred since 2015.

Changes in utilization could be caused by declining abundance trends, higher variability, more conservative harvest limits, higher costs associated with fishing, fewer markets, or price incentives, and/or a general "graying of the fleet[5]." Understanding why fishers are not harvesting available quota utilization is an opportunity for more research and could expand seafood security discussions deeper into understanding seafood access rather than seafood availability.

[5] the increase in the average age of commercial fishermen (Cramer et al., 2018).

Limited entry permits reduced employment in seafood systems.

The limited energy permit system in the herring fishery effectively reduced catch by way of reducing participation (employment) in seafood systems. Limited entry permits were one strategy that cemented the negative effects on seafood access from gear and spatial restrictions, which are discussed in more detail below. Limited energy permits were established in San Francisco, Tomales Bay, Bodega Bay, Humboldt Bay, and Crescent City Harbor (Table 3) (TRA, 2005).

Table 3– Number of permits in California (targeted) Pacific herring fishery between 1975 and 2019. CDFW.

<table>
<tr><th>Management Sector</th><th>1977</th><th>1983</th><th>1998</th><th>2005</th><th>2018</th><th>2019 FMP</th></tr>
<tr><td>San Francisco Bay (gillnet)</td><td>365</td><td>400</td><td>457</td><td>220</td><td>129</td><td>30 (cap)</td></tr>
<tr><td>San Francisco Bay (round-haul)</td><td>60</td><td>50</td><td>phased out converted to gill net</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Tomales Bay</td><td rowspan="2">Combined 69 permits</td><td rowspan="2">41</td><td>35</td><td>35</td><td>5</td><td>15 (cap)</td></tr>
<tr><td>Bodega Bay</td><td>n/a</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td>Humboldt Bay</td><td>6</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>Crescent City Harbor</td><td>4</td><td>3</td><td>3</td><td>3</td><td>0</td><td>0</td></tr>
</table>

i. *data collected from the 2019 CDFW Pacific herring FMP, including information in Figure 4-5.*

San Francisco, Tomales Bay, Bodega Bay, Humboldt Bay, and Crescent City Harbor are the four areas of Pacific herring fisheries management today. Commercial Pacific herring fishing in all other areas, including open ocean waters, is prohibited apart from Pacific herring as incidental catch[6] at a rate that does not exceed 10% of total landings (CDFW, 2019). Tomales Bay, Bodega Bay, Humboldt Bay, and Crescent City Harbor did not have the same levels of participation, competition, and conflict experienced in San Francisco Bay (CDFW, 2019). Tomales Bay and Bodega Bay permits were combined in 1977 and exchanged for San Francisco Bay permits in 1983. Humboldt Bay and Crescent City Harbor have had no changes in permit ownership since 1983 (CDFW, 2019).

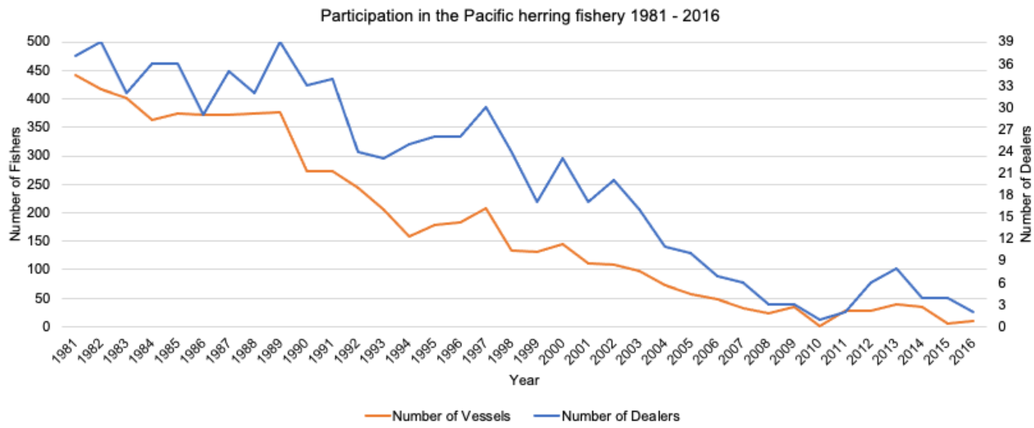
The platoon system was an effective mechanism for reducing fleet conflict

The platoon system in the herring fishery was effective at reducing fleet conflict and had an implicit effect on participation, but it had minimal negative effects on seafood security. In 1980, CDFW implemented a "platoon system" for Pacific herring to improve the "orderly conduct of the fishery" (CDFW, 2019; TRA 2005). The platoon system divided gillnet permit holders into two groups– "odd" and "even" -- and allocated a portion of the quota to permit holders that could be fished at alternating weeks of the season (CDFW, 2019). The platoon system was one of many efforts to reduce fishing effort, user and at-sea conflicts, ensure compliance, and encourage involvement in management processes (CDFW, 2019; TRA 2005). The platoon system maintained sector diversity between gillnet and round-haul until 1998. More recently, the platoon system has been eliminated because of the decline in participation in the fishery (CDFW, 2019). Participation (employment) of fishers and dealers (first receivers) has

[6] Incidental catch also known as "by-catch" refers to catching species other than the species (Gilman et al., 2014; Shester & Micheli, 2011)

declined from over 400 vessels and 35 dealers in 1981 to less than 50 vessels and two dealers in 2020 (Figure 4).

Figure 4– The number of fishers and dealers participating (employment) in the commercial Pacific herring fishery in California between 1981 and 2016. Data source: PacFIN.



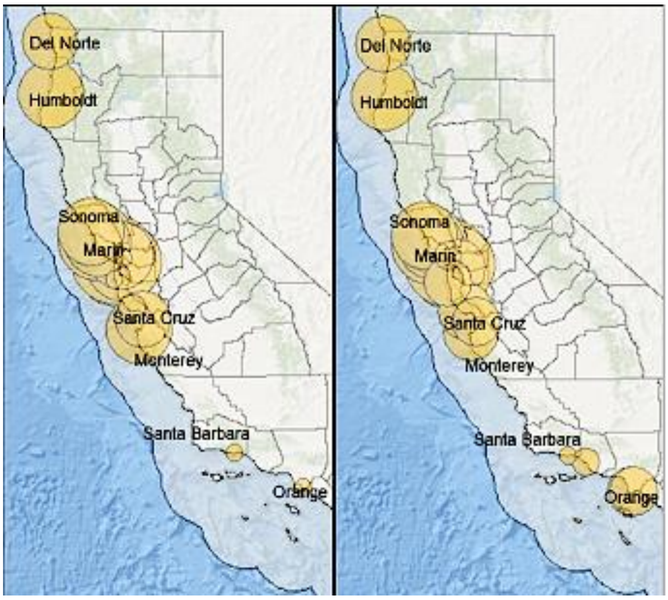
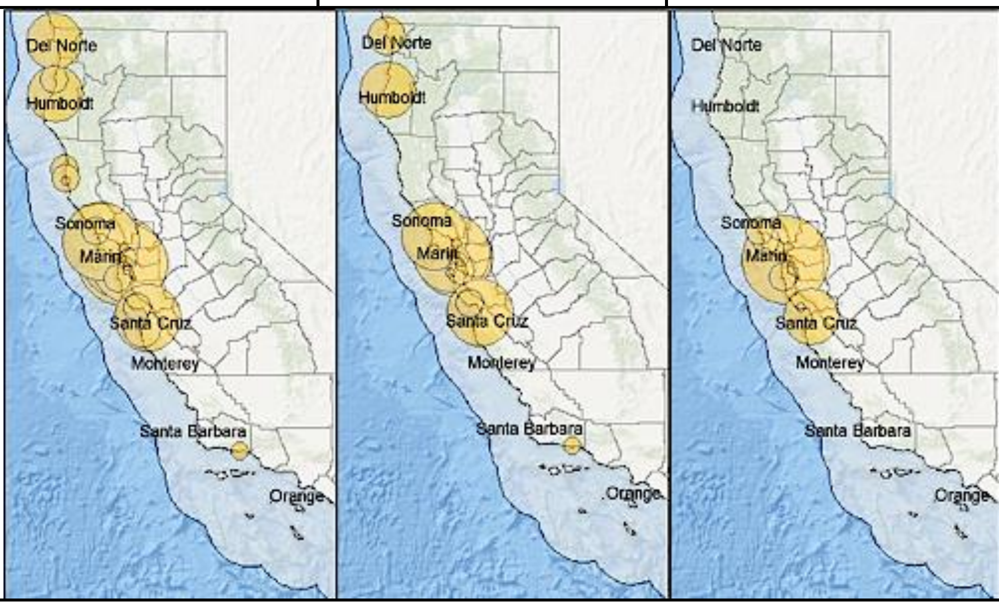
Sector allocations foster indirect effects on seafood access

Sector allocations in the herring fishery reduced fleet conflict and had an indirect effect on seafood security. Sector allocations limit seafood availability and influence seafood access, but the tradeoffs for reducing fleet conflict and protecting fisheries are seemingly balanced. From 1973 to 1992, a variety of gear, including gill nets, set nets (shore-side gill nets), round haul (vessel lampara and purse seine nets), cast nets (shoreside lampara nets), and hook and line gear were used to harvest Pacific herring commercially (Spratt, 1981). By 1980, quotas were allocated to the gillnet and round-haul, including purse seine and lampara nets sectors (CDFW, 2019). A “whole fish” or “fresh” fishery sector was allocated 20 tons from 1980 until 2013. Thereafter, the “fresh” quota was combined with the gillnet fishery “for the local whole fish market” (CDFW, 2019, p.5-4). Sector allocations were available for multiple regions in California, including several sites in San Francisco Bay and Tomales Bay. However, sector allocations were eliminated in Tomales Bay in the mid-80s for a general "single sector quota" (Spratt, 1992 in CDFW, 2019, p5-5). Quotas in Humboldt Bay and Crescent City were not historically assigned sector allocations but instead compiled a general quota.

Spatial restrictions concentrate geographical food access

Spatial restrictions in the herring fishery concentrated spatial seafood access. Historically, there was little interest and participation in the Pacific herring fishery outside San Francisco Bay, but landings still occurred all over the state until 2006 (Figure 5 a-e). From the early 1900s to the early 1970s, most landings occurred in Monterey and the San Francisco Bay. During the growth of the fishery, most landings occurred in San Francisco Area, then Tomales Bay and the least came from Humboldt Bay and Crescent City Harbor. In 2005, all landings ceased from any other region. Today, San Francisco Bay is the last remaining commercial fishery and (spatial) access point for Pacific herring as food.

Figure 5(a-e) – Historical changes in landings by harvesting sites (ports), resulting in a concentration of spatial seafood access, in California's Pacific herring fishery between 1981 and 2016. Data source: PacFIN, Esri, IUCN.

(a) 1981-1986	(b) 1987-1993	
		
(c) 1994-2000	(d) 2001-2006	(e) 2007-2016
		

i. Supplemental data and codes are available upon request: IUCN provided herring distribution grounds (the outer line), Esri had California state and county boundary data.

ii. PacFIN confidential landings data was used to create the bubble categories from 1981-2016.

iii. *Actual tonnage numbers have been removed for confidentiality, which ranged from <1 ton to 1,000 to 5000 tons of Pacific herring landed. Data is shown landings by port, but labeling each port degrades the visual interpretation of the map.*
iv. *The bubble size is relative to total landings.*

Gear restrictions constrain seafood product form

Gear restrictions used in the herring fishery had an interesting and overlooked relationship to seafood product form. Gear restrictions reduced fishing effort and streamlined fishery management resources. However, they also reduced physical seafood access in the long term by generating a product form that was singularly culturally appropriate for an export market rather than a domestic one.

From 1973 to 1992, a variety of gear, including gill nets, set nets (shore-side gill nets), round haul (vessel lampara and purse seine nets), cast nets (shoreside lampara nets), and hook and line gear was used to commercially harvest Pacific herring. In 1992, Regulators began phasing out and restricting gear types – set nets, round haul, seine gear, and lampara, and open ocean fishing– to protect fishery resources (CDFG, 1998; CDFW, 2019). In 1998, round-haul permits were converted into gillnet permits (CDFG, 1998; CDFW, 2019). By the late 2000s, only two types of gear were allowed in the Pacific herring fishery: gill nets and seine nets (CDFW, 2019).

Below, I discuss how fishing gear used in the commercial Pacific herring fishery historically changed, differed in structure, targeted different spatial zones and fish sizes, and had various effects on fish anesthetics. These findings are also summarized in Table 4.

Table 4- The relationship between gear type, structure targeted spatial zones and fish sizes, and effects on fish aesthetics used to harvest Pacific herring in California. Data source: CDFW.

Gear name	Period of Use in the commercial fishery	Structure	Targeted spatial fishing zone	Size of fish caught	Target life cycle harvest	Volume of fish	Effect on fish aesthetics
Hook and line (light tackle bait rigs or sabiki)	1990 – mid-80s.	Vertical hanging fishing gear catches fish using several small hooks on a line from a fishing pole.	In shallow waters such as bays and at the mouth of rivers or bays, and open ocean fishing.	Variety of sizes and a large diversity of fish grades and sizes.	Harvest spawning (ripe) and non spawning (non-ripe) fish.	Smallest volume of fish (a few pounds)	Minimal degradations to fish, including flesh, scales, and eyes.
Lampara (hoop net, cast net)	1981 – 1994	Net has the shape of a spoon or a dustpan with a short lead line under a longer float line. The net has a central bunt to contain the fish and two lateral wings. The nets are hauled in by hand and removed with a smaller net or a scoop.	In shallow waters such as bays and at the mouth of rivers or bays.	Variety of sizes.	Harvest spawning (ripe) fish.	Small volumes of fish.	Minimal degradation of fish appearance, including scales and flesh (Image 1)

Gillnet	1974 – Present	Fixed, vertical hanging fishing gear traps fish by blocking their swimming pathway. The mesh size, depth, and length of gillnets are tailored to the species fish that you want to catch.	In shallow waters such as bays and at the mouth of rivers or bays.	Very targeted fish size. Three to five years in age.	Harvest spawning (ripe) fish.	Larger volume of fish (~ 10 tons).	Degradation of scales and flesh. (Image 2)
Purse Seine (round-haul)	1976 – 1993	Nets hang vertically in the water with the bottom edge weighted down along the bottom and a float across the top. The net hangs upright in the water. Two boats draw the ends together to encircle and catch the fish.	Open ocean fishing.	Variety of sizes and a large diversity of fish grades and sizes.	Nonspawning (non-ripe) fish.	Most significant volumes of fish (~20 tons).	Smashing/ crowding of fish. Battered scales, but rarely degraded flesh– suitable for bait.

i. *The difference between a set net and a gill net is minimal in structure, but set nets are usually hung from the shoreside, and gillnets are hung at sea from a fishing vessel using buoys. Set nets were prohibited in the commercial fishery by the early 2000s (CDFW 2019).*

Hook and line (light tackle bait rigs) or sabiki rigs consist of six hooks attached along the line and are cast from shore (CDFW, 2019). They can be used to harvest spawning (ripe) and nonspawning fish but are often used from shore during spawning season. Hook and line gear can catch a variety of sizes and grades of fish. It rarely degrades fish aesthetics, including flesh, scales, and eyes. This method often harvests the smallest volume of fish (a few pounds) compared to the other gear methods. However, if a fisher is casting several poles for several hours, the poundage will increase relative to the fishing effort. Hook and line gear is only allowed in the recreational fishery.

Lampara nets (cast nets) are best used in shallow waters, accessible by smaller vessels, and can be used from the shore, pier, or dockside. The net has the shape of a spoon or a dustpan with a short lead line under a longer float line. It has a central bunt to contain the fish and two lateral wings and is hauled in by hand and removed with a smaller net or a scoop. It causes minimal degradation of fish appearance, including scales and flesh, and harvests small volumes of fish (relatively). Lampara nets are still used in the recreational fishery but were prohibited in the commercial fishery by the mid-1990s (CDFW 2019).

Gillnets are static, vertical hanging fishing gear that traps fish by blocking their swimming pathway. They can be used in shallow waters such as bays and at the mouth of rivers or bays. Gillnets effectively catch large amounts of fish (approximately 10 tons per boat per trip). Minimum and maximum mesh sizes can be manipulated to ensure fish have reached reproductive age and protect the population (Shester & Micheli, 2011). Gillnets used to harvest Pacific herring often damage the flesh of the fish, including the appearance and scales, and encompass and combine debris with the fish.

Gillnets used from shore (beach nets or set nets) were prohibited in the early2000ss (CDFW, 2019) because of their impact on nontargeted fisheries (by-catch) (Shester & Micheli, 2011). “Historically, most of San Francisco Bay has been closed to encircling nets (including purse seine, lampara, and beach nets) to prevent the take of salmon, Striped Bass, sturgeon, and American Shad” (CDFW, 2019, p.5-16). Today, vessel-only drift gillnets are the only gear types allowed in California’s commercial Pacific herring fishery.

Round haul gear or purse seine nets, often used for open-ocean fishing, are vertically hung in the water by two boats. The ends of the net are pulled together “like tightening the cords of a drawstring purse” (MSC.org, 2022). “Round-haul gear tended to catch smaller, younger, lower value fish, and possibly increased mortality in the fishery” (CDFW 2019 p 5-8). Round haul gear harvests considerably more fish [than gillnetting] per trip and it is more difficult to target a specific age group of fish using round-haul gear. All round-haul permits were phased out and converted to gill net permits by 1998.

In the context of seafood product form, round-haul (seine) does not necessarily protect nor degrade the physical appearance. The length, depth, and duration of the harvest have more consequences on fish aesthetics than the gear itself. Seine nets are often used in the open ocean; it isn't designed to harvest spawning fish in the shallows of bays. Pacific herring and other forage fish species, harvested using a seine net, can be sold as bait or in the fresh seafood market. California’s squid and anchovy fishery harvest Pacific herring as incidental or by-catch using seine gear, but all other open-ocean fishing for round-haul equipment was prohibited in 2010.

Mismatched seafood product forms and cultural appropriateness constrains physical food access

Restricting gear types is an effective way to reduce fishing effort, but it also eliminates opportunities for differentiated seafood product forms and a cultural approach for changing marketplaces from Japanese exports to more domestic markets. Historically, the primary market for Pacific herring has always been an export Japanese roe market and in fact, the reduction of Japanese tariffs in 1973 catalyzed growth in the fishery through economic incentives (CDFW, 2019; Spratt 1981). Gillnets used to harvest Pacific herring often damage the flesh of the fish, including the appearance and scales, and encompass and combine debris with the fish (Image 1). Damaged aesthetics or flesh does not disturb the roe, which is the primary sought product for Japanese export markets. However, Japanese demand for Pacific herring roe (kazunoko) has been significantly defined, which combined with decreasing unit prices and increasing management restrictions has exacerbated decreased interest, participation, and revenue in the fishery (CDFW, 2019).

Simultaneously, domestic demand for “sustainable, local, healthy” seafood has increased (Bronnmann & Asche, 2017; Love et al., 2017; Wessells, 1999), and the whole fresh products could be appropriate for U.S. consumers. American consumers prefer a seafood product with a pristine fish appearance, including intact scales and flesh, that can be filleted. Lampara nets and hook and line gear types cause very little degradation of fish appearance, including scales and flesh (Image 2), and (relatively) harvest very small volumes of fish.

Image 1 - P.herring caught with a gillnet.

Image 2 - P.herring caught with a castnet

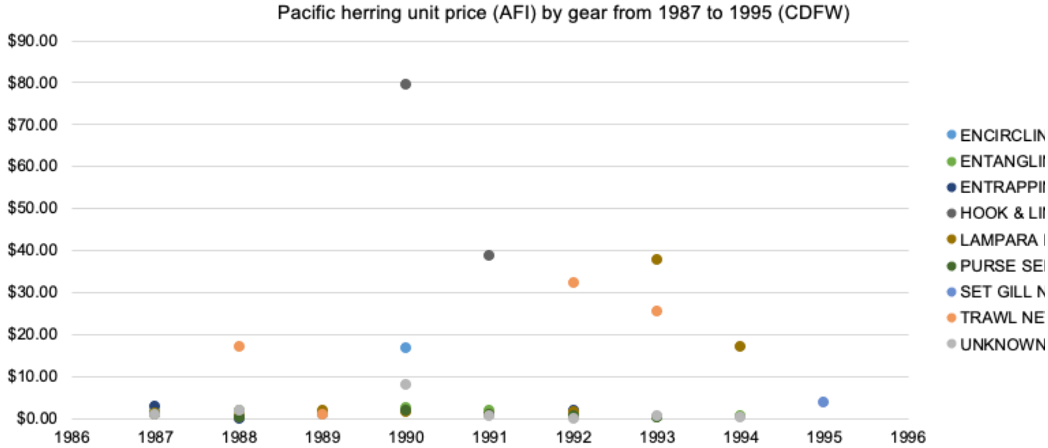
Furthermore, the 2019 Pacific herring FMP stated, “There are currently no local Herring buyers in California, so buyers travel from Washington or British Columbia during the Herring season” (CDFW 2019, 4-19). This isn't entirely true. Local demand for aesthetically pleasing, debris-free Pacific herring is a much smaller market (fewer pounds with higher prices) than the export roe market (large volume, lower prices). One interviewee, a fish buyer in San Francisco, 2019 explained that he as a first receiver “could only sell approximately 500 pounds of Pacific herring per week”, which made purchasing an additionally herring seller's permit[7] for $1000/annually an unnecessary hurdle and made it difficult for him to make selling herring locally economically viable (Bevol, K., 2019, January).

Gear diversity influences the unit price

The diversity of gear types used in the fishery declined from 10 types of gear in 1995 to only one gear type used in 2017. As gear diversity decreases, opportunities for higher unit prices also decrease as shown in Figure 6(a-d). Notably, unit price alone is not income – it's only one-half of revenue, including price, volume, and costs, but it is an important part of fishers' ability to diversify their income, innovate and improve resilience to market and possibility ecological shocks.

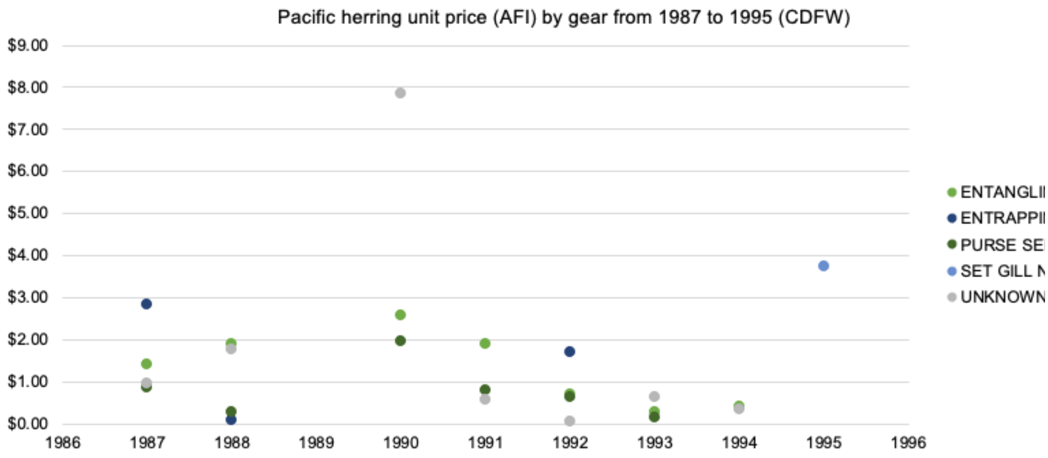
Figure 6 (a-d) – The relationship between gear type and unit price in California's commercial Pacific herring fishery from 1987 to 2017. Data source: CDFW.

(a) relationship between all gear types and unit price in the "Pacific herring" fishery from 1986 to 1995.

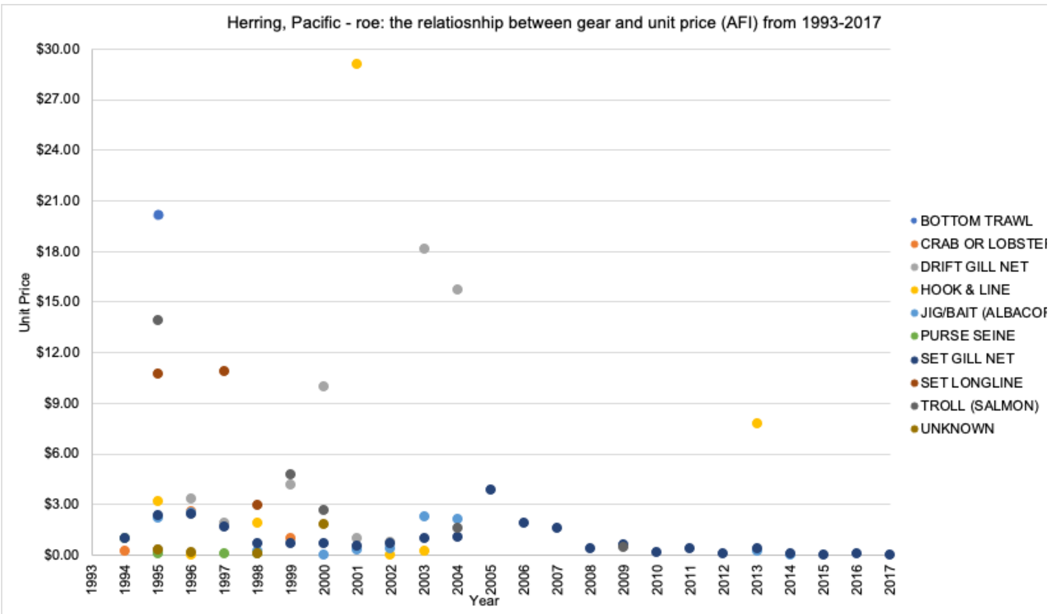


[7] the 2019 Pacific herring FMP states, "commercially landed Pacific herring may only be sold to an appropriately permitted buyer" (CDFW, 2019, p.4-20 and section 9.1).

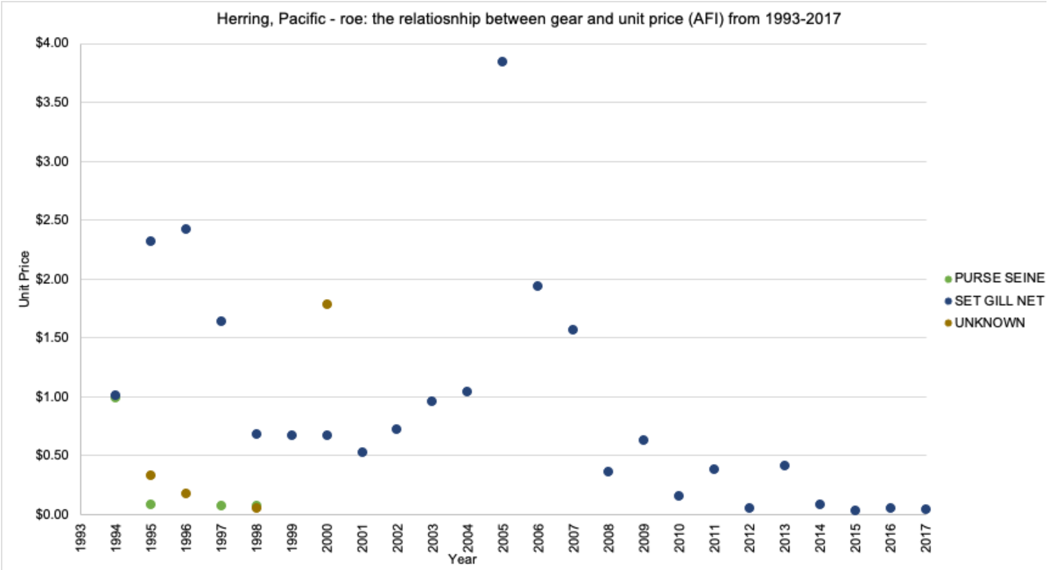
(b) relationship between most used gear types and unit price in the "Pacific herring" fishery from 1987 to 1995.



c) relationship between all gear types and unit price in the "Pacific herring – roe" fishery from 1994 to 2017.



(d) relationship between most used gear types and unit price in the "Pacific herring – roe" fishery from 1994 to 2017.



1. *CDFW changed data collection labeling between 1987 and 2019: From 1987 to 1992, Pacific herring was a single category. From 1992 to 2013, Pacific herring is split across three sectors: Pacific herring, Pacific herring - roe, and Pacific herring - round. From 2013 to 2019, landings were restricted to Pacific herring - roe. Pacific herring - round was recognized as "incidental" and therefore, excluded from this analysis, which focuses on the implications of a target fishery.*
2. *Full data, code, and analysis are available as supplementary material.*

From 1987 to 1995 when nine gear types were used in CDFWs previously labeled "Pacific herring" fishery: encircling nets, entangling nets, entrapping, hook and line, lampara, purse seine, set gill nets, and trawl nets, unit prices (price paid to the fisher per pound of seafood product) ranged from <$1.00 to approximately $80.00 per unit. However, unit price ranges from <$1.00 to approximately $8.00 per unit when I removed data from the encircling nets, hook and line, lampara, and trawl nets.

From 1993 to 2017 when ten gear types were used in CDFWs now labeled Pacific herring - roe fishery: bottom trawl, traps, drift gill set, hook and line, jig, purse seine, set gill net, set long line, troll, unit prices (price paid to the fisher per pound of seafood product) ranged from <$1.00 to approximately $30.00 per unit. However, unit price ranges from <$1.00 to approximately $4.00 per unit when I removed data from all gear types other than purse seine and gillnets (the primary allowed gear types in the commercial Pacific herring - roe fishery).

Interestingly, the highest unit prices in all years across both data sets were observed in catches with hook and line gear types, which are not currently legal in California's commercial Pacific herring fishery. Lampara and traps also had relatively higher prices than the other gear types. During my interviews with participants, hook and line gear types and lampara nets were frequently mentioned by fishers as a preferred method of fishing given the current political and economic climate.

Policy recommendations

Fisheries managers use various harvest control mechanisms to prevent overfishing, rebuild threatened fish species, and protect marine ecosystems, including marine mammals, endangered species, and essential habitats (Anderson et al., 2019; Cinner & Aswani, 2007). Still, some harvest controls can create adverse social and economic effects on the seafood system and seafood security.

In contrast to restricting all gear types, adaptive management policies can preserve fishers' investments in the fishery and maintain gear diversity, protect marine ecosystems, minimize conflict between sectors, and limit the downstream effects on seafood security using adaptation management strategies. For example, CDFW devised a phase-out protocol that eliminated the round-haul fleet in 1994 by adopting the following:

> *Regulations state that all round-haul permittees had five years to convert their permit to a gill net permit. Those who converted voluntarily were issued a CH permit, equivalent to two-gill net permits, to incentivize conversion. In 1998 all remaining round-haul permits were converted to gill net permits. (CDFW 2019, p. 5-7).*

An alternative to restricting gear types would be a "phase-in" protocol for vessel-only cast nets, hook and line gear, or sabiki hooks – all are allowed in the recreational fishery– to create product differentiation and improve market access to those who desire that the aesthetics of the fish be retained, namely U.S. markets. Another potential management measure to reduce barriers to new entry and increase the number of participants is to eliminate the additional "herring buyers permit." The inspiration for permit implementation in the 80s was related to the high number of participants and potential post-harvest fraud. However, current levels of participation no longer pose pricing and illegal unloading threats to the fishery.

Discussion

In this paper, I investigated how changes in marine conditions influenced access to fisheries and, in turn, created feedback on seafood system activities and security. Methodologically this chapter prescribed a framework for incorporating the four pillars of food security into fisheries conservation. Then, I applied this framework to California's Pacific herring fishery using landings data and state archives. My results explained that commonly used harvest control mechanisms, such as quota, limited entry permits, and gear and spatial restrictions, have varying effects on seafood availability, accessibility, and system stability. I show that seafood's ecological conditions and policy decisions are intrinsically connected and influence seafood security. Quotas (annual harvest limits) are essential for reducing catch and seafood availability. However, gear and spatial restrictions decrease seafood access by restricting harvest locations, constraining product form, reducing participants' ability to respond to market changes, and narrowing marketing channels and income opportunities for fishers.

Seafood security is often used in the emerging fish as food literature (Kittinger et al., 2015; Mustafa et al., 2021; Pelletier et al., 2014) but rarely explicitly defines seafood security beyond seafood self-sufficiency (Helvey et al., 2017). In this paper, I draw from the pillars of food security and historical fishery policy documents and production (landings) data in the California commercial Pacific herring fishery to conceptualize and investigate the linkages and feedback between fisheries and seafood security. This framework supports defining seafood security as a nation’s ability to meet the minimal nutritional guidelines for seafood consumption (two times per week) for all people, at all times, with safe, nutritious, affordable seafood without relying on imports (Yıldırım, S., & Yıldırım, D. C., 2021). “Fish as food” scholars have unanimously agreed that forage (small) fish are essential for global food security (Alder et al., 2008; Cashion et al., 2017; Love et al., 2017), but fish as food research rarely renders actionable political reform (Bennett et al., 2021). This paper concluded with examples of adaptive fisheries management, such as gear switching, that can successfully reduce catch and preserve participant flexibility, which is needed for ensuring seafood security.

The primary hypothesis that emerged from this research was that gear restrictions used in the commercial Pacific herring fishery were an effective tool at reducing catch by way of reducing participation, but it also eliminated opportunities for differentiated seafood product forms. The ability to use different gear types provides fishers the ability to access diverse markets, experiment with different fishing methods, maximize profits, and reduce risk through flexibility. Furthermore, gear restrictions and sector concentrations reduced seafood access by restricting fishers' ability to harvest a seafood product form that is culturally appropriate for U.S. consumers. Arguably, gear restrictions imposed further codified changes already occurring in the fishery– a fishery geared towards Japanese export markets for roe. Still, this path-dependent decision underestimated the relationship between gear, seafood product form, and physical seafood access: to whom, in what form, and when food for consumption physically moves. This, in turn, has constrained fishers' ability to access diverse markets and experiment with different fishing methods resulting in socio-economic instability.

One limitation of this analysis is that it does not explore how food for consumption physically moves and to whom. It does not explore the social relationships between seafood industry actors or dig deeper into explaining the connection between food harvested in California and the poundage of fish exported from California. Preliminary analysis, not shown in this paper, showed that it is almost impossible to track and connect individual landings to exports.

Seafood trade involves complex interactions between wild captured fisheries, aquaculture, domestic aggregation, imports, exports, and re-imports (Gephart et al., 2019; Gephart & Pace, 2015). Collecting data on complex trade relationships, product aggregation, and market trends are rarely accessible (Crona et al., 2016) and often presents hurdles to understanding the conditions underpinning seafood insecurity. A better understanding of how global supply chains are structured, organized, and governed to aggregate and transport seafood products is needed for greater insights into how seafood security can be achieved in the U.S. (Webb, 2022).

Unpredictable changes in oceanic conditions that influenced Pacific herring distribution and fecundity, extreme variations in Pacific herring biomass, and the propensity to target Pacific herring during a vulnerable life cycle process necessitates conservative fisheries management, including stricter quotas and reduced participation (employment) in the fishery. As such, quotas have historically decreased from 15% of biomass to less than 5% of the biomass. Conservative quotas restrict food availability in the short term but protect resources and ensure food availability over the long term.

Quotas are not an adequate measurement of seafood availability. Quotas define how much food *could* be available rather than how much *is* available. Landings are a more appropriate metric and determinant of seafood availability. Utilization (Figure 3) is the difference between quotas (what is "allowed" to be harvested) and landings (what is harvested). Understanding why fishers are not harvesting available quota or understanding the drivers of utilization changes are opportunities for more research and could expand seafood security discussions deeper into understanding seafood access rather than seafood availability.

The motivations of managers are not designed, by state or federal legislation, to incorporate future seafood security tradeoffs. The long-term effects of consequences of path-dependent harvest control tools used in California's commercial Pacific herring fishery ultimately created a rigid seafood system that inadvertently perpetuated economic instability in the fishery and constrained U.S. seafood security. Fisheries managers follow state and federal guidance aimed at protecting fishery and marine resources. They are not focused on understanding the implications of harvest control mechanisms on dimensions of seafood access: seafood product form, cultural appropriateness, and market flexibility. Alternatively, the 2019 Pacific herring FMP could use a gear switching clause, which could have allowed existing permit holders to sell or maintain the value of their permits and the flexibility to change harvesting gear. Adopting gear-switching amendments in the Pacific herring fishery could also prevent fishers needing to purchase different gear for various fisheries. Being able to participate in multiple fisheries with fewer inputs and investments could foster more diverse fishing portfolios for California fishers, which are important for resilient fisheries (Baldursson & Magnusson, 1997; Finkbeiner, 2015; Stoll et al., 2015).

Conclusion

There is an opportunity to use forage fish for improving seafood security in the United States. Pacific herring, Pacific sardines, Atlantic herring, Anchovies, and Menhadens (forage fish) constitute over 30% of the U.S. wild harvest landings and are a potential solution for improving seafood security, especially for vulnerable populations. These forage fish species are high in micronutrients and often lower in marine contaminants. Nevertheless, consumption of forage fish in the U.S. rarely exceeds two pounds per capita annually. My research shows that limited access to culturally appropriate product forms resulting from gear restrictions in fisheries management could be a contributing factor inhibiting forage fish seafood security, namely in terms of seafood access.

Alternatively, fishery management could reorient itself towards preserving the flexibility of fishers' harvesting techniques and maintaining diverse fishery sectors while maintaining quotas to protect marine ecosystems and limit downstream effects on seafood security and simultaneously. Although revised approaches to fisheries management strategies are necessary to improve seafood security, this alone will not ensure seafood security. Product diversity, sector diversity, and diverse fishing portfolios are key attributes of maintaining stability, improving seafood security, and more resilient fisheries (Short et al., 2021).

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Chapter 2 A value chain and governance analysis of the U.S. commercial Pacific herring fishery: how secrecy, reciprocity, and economic leverage affect spatial and economic distributions in multiscalar seafood commerce.

Abstract.

Recent studies have contrasted the challenges and opportunities associated with domestic and internationally traded seafood commodities, specifically from the lens of environmental sustainability and fisher livelihoods. However, few studies have focused on the essential roles of intermediaries and the power dynamics constituting the fish trade. Here, I draw on insights from global value chain (GVC) and production network (GPN) theories, renowned approaches in economic geography and political economy, to examine the functional intermediaries within and between domestic and international fish trade. This paper contributes substantially to GVC and GPN studies by using the commercial Pacific herring (*Clupea pallasii)* fishing industry, a non-core-periphery case study, to describe the socio-spatial dimensions of the fish trade. By following Pacific herring from the point of harvest in California and Alaska to manufacturing and consumption in Japan, I found that authority is exerted by intermediaries, but not evenly. Knowledge underpinning the value chain is often kept secret to protect supply or demand information that can be used as leverage when needed. At the same time, dockside buyers (early chain intermediaries) are held captive by a few buyers (exporters). Exporters and international seafood traders establish sales agreements that minimize their risk (either capital investment or product liability) and increase their market power, resulting in economic leverage over dockside buyers and manufacturers. The governance structure in multiscalar seafood commerce is both relationally connected and economically confined by a few actors. This "relationally confined" governance structure in the Pacific herring value chain fosters a U.S. domestic market that is dependent upon and limited by the global seafood economy. My analysis of a non-core- periphery case study concludes that the global market's ability to catalyze regional seafood systems is an illusion and encompasses unevenness. Therefore, I suggest that for more sustainable and equitable blue food systems, a better understanding of power dynamics and their effects on the fish trade is more important than focusing on the appropriateness of geographic distributions in seafood systems.

Keywords: *global commodity chains; global production network; sustainable seafood; socio-economic drivers of fishing behavior; governance*

Introduction

Seafood is one of the world's most traded food commodities (Smith et al., 2010; Stoll et al., 2018), valued at levels greater than coffee, cocoa, and sugar combined (Watson et al., 2017). It is an essential food source for the world's growing population (Béné et al., 2015). It is more nutritious and less environmentally destructive than other forms of protein (i.e., chicken, pork, beef) (Koehn et al., 2022). Globalized seafood commerce can also reduce unemployment and poverty in low-income countries by providing consistent access to buyers (Béné et al., 2016; Naylor et al., 2021; Tigchelaar et al., 2022).

However, the global fish trade can also facilitate negative social and environmental externalities, such as overfishing, slave labor, consumer fraud, seafood waste, and maritime transshipment-related greenhouse gas emissions (Costello et al., 2020; Finkbeiner et al., 2017; Love et al., 2015; Purcell et al., (2016). Teh et al. (2019) explained that environmental and social issues such as overfishing and forced labor in commercial fishing often co-occurred in Southeast Asia. The global fish trade also interacts with and acts upon domestic fisheries with complex consequences. For example, Helvey et al. (2017) suggest that "leakage," or the consumption of primarily imported seafood over U.S. harvested seafood, perpetuates negative social and environmental externalities. In response, they argue that the U.S. should undertake efforts to reduce the ecosystem impacts of foreign fisheries and move toward greater self-sufficiency to protect its seafood security and minimize leakage.

In contrast to these characteristics of the global seafood trade, seafood localism consists of social and entrepreneurial movements that shorten and straighten seafood supply chains. Alternative seafood networks, such as community-supported fisheries, dockside markets, fishermen's markets, and *boat-to-tray,* aim to reduce leakage and build social and political capital by connecting U.S. consumers to U.S. harvested seafood (McClenachan et al., 2014; Stoll et al., 2020). These movements aim to improve traceability, decrease overfishing and waste, provide higher wages to fishers and reduce the seafood miles driving greenhouse gas emissions from global seafood imports (Brinson et al., 2011; Campbell et al., 2014; Olson et al., 2014). Despite their promises of social and environmental benefits, alternative seafood networks have struggled to gain a significant portion of the market share (Hennig, 2017; Stoll et al., 2021). They are valued at approximately $8.2 million of the projected market potential valued at $3 billion (Hennig, 2017).

Recent studies have contrasted the challenges and opportunities associated with globally traded fish commodities from the lenses of food security (Bennett et al., 2021; Fabinyi et al., 2017; HLPE, 2014), fisher livelihoods (Fabinyi et al., 2016; Wamukota, A. W., & McClanahan, T. R., 2017) and environmental sustainability (Crona et al., 2015, 2016; Gephart & Pace, 2015). However, a major missing piece in these emerging works of literature is an understanding of the numerous roles of intermediaries in the fish trade and their effects on the spatial and economic distributions of seafood. This paper examines the various types and roles of functional and social intermediaries within and between domestic and international fish trade using the commercial Pacific herring (*Clupea pallasii*) fishery and transnational trade. Pacific herring is an underutilized fishery, globally traded and harvested in California and Alaska (CDFW 2019; Thompson et al., 2017). Although Alaska and California have higher than national averages of seafood consumption (Love et al., 2020) and strong historical and cultural ties to the fishery (CDFW 1998, 2016, 2018; Okamoto et al., 2020), Pacific herring is rarely available as food in the U.S. marketplace or along the west coast. Additionally, Pacific herring are primarily exported from the U.S. to Japan or from the U.S. to Canada (NMFS 2022); thereby representing transnational trade patterns of several species harvested from the U.S.[8]

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[8] The U.S. exported 2.2 billion pounds of seafood, approximately one-fourth of the total U.S. commercial fisheries harvested in 2020 (NMFS 2022). Most U.S.

Using the Pacific herring as a case study, I highlight the intermediaries' role in shaping spatial and economic (socio-spatial) distributions in seafood. Understanding the socio-spatial complexities of the Pacific herring value chain is helpful for the Pacific herring industry and can also help explain the socio-spatial effects of power on producer nations and the economic geography of seafood distribution in other underutilized species harvested but not readily available at food in the U.S. Lastly, my analysis of the Pacific herring value chain builds upon recent works calling for more attention to the broad social, political, and economic forces influencing socio-ecological systems, including "how global market forces influence the commercial fishery and motivations in the fishery" (Levin et al., 2016).

This paper seeks to answer the following questions: what is the configuration of the Pacific herring value chain (actors, activities, linkages)? How does the value chain configuration elicit power asymmetry (how do power relations play out) and what are the implications of power asymmetry on the spatial and economic distributions of seafood (e.g., seafood localism versus globalization)? Using the Pacific herring as a case study, I highlight intermediaries' role in shaping spatial and economic distributions of seafood by mapping the "nodes" of activities and actors and the "links" connecting nodes in the value chain. Then, I explain how power operationalizes through information exchange (or the lack thereof), social relationships, and economic leverage. Next,

fish exports are concentrated in a few key markets, including the European Union, China, Canada, and Japan, which were the top four export destinations of American seafood (USDA 2015).

I introduce “relationally confined” governance where actors are concurrently relationally connected and captive by a few buyers with a great deal of financial influence. I also argued that this relationally confined governance arrangement hinders distinctions between domestic and international fish trade and that blue food systems undoubtedly occur concurrently at multiple scales in various locations (multiscalar). Ultimately, the global fish trade is necessary for and prevents the growth of seafood localism.

Literature review – Insights from global commodity chain studies.

The study of global commodity chains offers an insightful analysis of the limitations and complexities of shifting seafood distributional outcomes in a global economy (Bair, 2005; Gereffi and Fernandez-Stark, 2016). Friedland (2001) suggests the most significant contribution of global commodity chain studies is the ability to examine the multidimensional effects of globalization. Global commodity chain research builds upon Adam Smith’s and Karl Marx’s definitions of commodity – any good or service produced by human labor bought, sold or exchanged in the marketplace (Friedland 2005). It suggests a “follow the commodity” approach for descriptive analysis that explains the inputs, outputs, geographic scope (spatial scale), industry stakeholders, and the linkages between them (the configuration) that change a raw material into a consumable commodity (Friedland 2005; Teneva et al., 2018).

Global commodity chain research provides theoretical frameworks and empirical approaches for defining power by investigating nodes (actors or activities) in commodity chains that exercise control over others, in what ways, and helps explain the effects and implications for industry and producers (Raikes et al., 2000). Gereffi (1994, p. 97) defined governance as “authority and power relationships that determine how financial, material and human resources are allocated within a chain.” They state that by defining to whom, at what value, and to what location financial, material, and human resources flow (governance analysis) provides valuable insights for defining critical characteristics of control (Gereffi, G., & Fernandez-Stark, K. 2016). Gereffi (1994) suggests that global commodity chain (GCC) governance is either producer-driven (bottom-up) or buyer-driven (top-down) governance. In producer-driven commodity chains, administrative headquarters control investment and manufacturing, dictate barriers to entry, and control production (Gereffi 1994, Raikes et al. 2000). In contrast, buyer-driven commodity chains occur when buyers in developed nations (often in the U.S. or Europe) play an influential role in determining product specifications and excerpt authority or economic leverage over manufacturers in developing countries (often in Asia, Africa, or India). Original GCC theories of governance highlighted the role of “lead firms[9].” They revealed how value chain configurations could create power asymmetry. Still, they were limited in being implicitly linear (either bottom-up or top-down) and failed to recognize the fluidity of actors and knowledge sharing among socio-spatial production networks (Raikes et al., 2000).

[9] Firms in the value chain that “structurally organize their business transactions to exercise control and coordination, determine locational choices, and strategically manage their firm-specific activities to enhance knowledge accumulation, or create better performance outcomes” (Kano et al., 2020, 582).

Gereffi et al. (2005) later expanded this dualist representation of governance in global value chain governance theory (GVC), suggesting that the crucial variables in determining governance are (a) the complexity of the information shared between actors in the chain, (b) how the information for production could be duplicated (or codified) to improve one's positionality or authority in the commodity chain and (c) the level of supplier competence (Bair & Gereffi, 2001). Applying these variables, they described five categories of governance resulting from value chain configurations, which range from lower to higher levels of power asymmetry: (1) market, (2) modular, (3) relational, (4) captive, and (5) hierarchical (Frederick & Gereffi, 2009). Market systems are relatively simple, with equal power between sellers and buyers and minimal or no centralized intermediaries. Modular systems use complex production processes, but the information is easily codified using generic machinery. In relational production systems, buyers and sellers rely on complex information that is not easily transmitted. Lead firms exert some control, but the information exchange processes result in mutual dependence (reciprocity). Captive production describes a configuration where several small suppliers depend on one or a few buyers who often wield incredible power. Finally, hierarchical governance describes vertical integration and managerial control chains within which lead firms develop and manufacture products in-house. The power asymmetries in hierarchical and captive networks compel suppliers to link to their buyers under conditions set by, and often specific to, a particular buyer. Although GVC expanded the characterizations of power and emphasized the importance of information in creating barriers to entry, GCC and GVC theories have to date, ignored extractive industries[10] almost entirely (Coe et al., 2008).

Rather than focusing on governance, global production networks (GPN)– the most recent contributions to global commodity studies—best explains the relationship between regional development and global commerce (Coe et al., 2004; Henderson et al., 2002). GPN recognized the complexity of transactions in value chains, namely between developing and developed countries (core-peripheral case studies) in global production. It further explored the economic reverberations and feedbacks between global and local economies (Raikes et al. 2000), including risk (either in the form of capital investment or product liability), market power, and control over resources (Yang & Coe, 2009). GPN asserts that certain configurations of power asymmetry– horizontal yet hierarchical relationships linking production nodes– can "unleash regional [economic] potential" (Coe et al. 2004, 470). It provides a framework for capturing dynamic, asymmetrical relationships across geographies that produce divergent environmental, social, and economic outcomes. However, understanding the breadth and depth of social and economic relationships constituting spatially distant global production networks poses immense conceptual and empirical difficulties (Coe et al. 2008). Nevertheless, harnessing the descriptive qualities– material, relational, functional, and structural– of global production networks is increasingly important considering currently unprecedented global ecological

[10] Extractive industries such as fishing, hunting, oil, mining, and water process extract raw materials or natural resources (non-renewables) from nature and used them in production and exchange (Bridge, 2008).

change and seafood globalization (Coe et al., 2008; Hamilton-Hart, N., & Stringer, C., 2016; Fabinyi 2016a, 2016b; Fabinyi et al., 2012).

This paper builds on the GVC and GPN bodies of work to examine the functional and social intermediaries connecting domestic and international fish trade. In addition, this paper contributes methodologically to GVC and GPN studies by using the commercial Pacific herring (*Clupea pallasii)* fishing industry, which is representative of extractive industries and a non-core-peripheral case study. It also contributes substantially to these bodies of work by introducing a "relationally confined" governance structure, where power is rooted in relational connections and a few lead firms' economic leverages. This proposed governance –relationally confined– structure encompasses the concepts of relational and captive governance as described in GVC. It also results in a U.S. Pacific herring fishery and domestic market dependent upon and limited by the global seafood economy.

Follow the fish methodology and materials.

To understand the value chain structure, configurations of power, and the socio-spatial catalyst shaping the economic geography of seafood distribution in the commercial Pacific herring (*Clupea pallasii)* fishery, I combined multi-sited ethnography, semi-structured interviews using snowball sampling, and archival research. I followed Pacific herring from the point of harvest in San Francisco, California, to consumption in California and various locations in Japan. To do this, I visited over 21 national and international sites where Pacific herring was harvested, bought or sold, including a global seafood trade show and expo in

Hong Kong. I conducted participant observations at public management meetings and during market transactions. I conducted over 39 semi-structured or informal interviews with various value chain actors in California and Japan. I cross referenced interview data with institutional and industry reports, including but not limited to information about participation, harvesting, exports, and pricing. I detail data points and collection methods below.

Field and participant observations.

During the Pacific herring season in San Francisco, CA, I conducted field and participant observations from April 2017 to January 2019. I observed fishers leaving ports, recreational fishers, differences in fishing gear between the fleets, boat sizes, and unloading facilities. I also attended three Pacific herring fishery management meetings hosted by the California Department of Fish and Wildlife (CDFW) in January and February 2017. I conducted informal interviews with fishers and wholesalers during field observations, which also initiated my snowball sampling. Through these conversations, I learned how Pacific herring caught in California are often aggregated and stored with fish caught from Alaska in Washington. Then, the aggregated product is shipped overseas to Hokkaido, Japan, for processing.

In the summer of 2018, I visited Hokkaido, Japan, to understand various product forms (commodity communities), manufacturing facilities and processing, and transnational relationships. I also visited Tokyo to collect information about end-pricing, where the most prominent and highest number of fish markets exist. In September 2018, I attended a global seafood conference in Hong Kong to better understand herring's global and Asian seafood market.

Semi-structured Interviews.

Using snowball sampling, I completed 39 semi-structured interviews with commercial fishers, crew members, and dockside buyers in the United States, transnational seafood exporters and manufacturers in the U.S. and Japan. I also interviewed midchain traders and wholesalers and end-of-the-chain merchants in Hong Kong using Mandarin- and Japanese-speaking interrupters. I spoke with key informants, expert scholars, conservation advocates, and fisheries managers in the U.S. and Japan. Table 5 discusses the roles of actors in the Pacific herring industry interviewed and the number of interviews with each group.

Table 5 – Types of actors involved in the Pacific herring industry and the number of interviews with each group.

Stakeholder category	Number of interviews	Role in the Pacific herring industry
Regulator (R)	5	Set and enforce governmental rules around the industry (one in Japan, four in the U.S).
Fishers (F)	8	Catch Pacific herring (eight in the U.S.).
Dockside buyers (DB)	5	Buy and sell Pacific herring and often provide a suite of services to fishermen, including but not limited to fuel, dockage, and housing. They also maintain the facilities and equipment required for initial transformation, including fish pumps, tote, ice, etc. (five in the U.S.).
Transnational Exporter (E)	2	Create sales contracts, connect docksider buyers to manufacturers, and can be or act as an early-chain distributor. (one in Japan, one in the U.S.).
Manufacturer (M)	5	Transform Pacific herring into value-added seafood (one in Japan, three in the U.S., one in Hong Kong)

Seafood traders (T)	4	Create sales contracts, connect manufacturers to distributors and retail markets, can be or act as the distributor (one in Hokkaido, Japan, three in Hong Kong, China).
Retailer (RT)	32	Sell Pacific herring products to end-users (four in the U.S., twenty in Japan, eight in Hong Kong, China).
Nonprofit or Conservation groups (NGO)	4	Provide non-profit support to other actors (one in the U.S., three in Japan).
Scientist (S)	2	Conduct research to gather data about the Pacific herring fishery (one in the US, one in Japan)

i. *The number of interviews (n = 67) is more than the number of interviewed individuals because several people held more than one role in the Pacific herring value chain, including those who work for or own an alternative seafood network.*
ii. *Several fishers and buyers worked in both Alaska and California. I also spoke with regulators from California in person and those in Alaska over the phone.*
iii. *Due to the limited risk of interviewees, this research satisfied UCSC's protocols exempting an extensive IRB review.*
iv. *Supplemental data, such as transcriptions and interviewee lists, are available upon request but have been summarized to protect confidentiality.*

Interviews ranged from 30 minutes to three hours and occurred at restaurants, fishing vessels, marketplaces, processing facilities, and over the phone. I asked interviewees questions about markets, price, relationships with other supply chain actors, and their concerns about management and the fishery. Content obtained from interviewees was transcribed and synthesized for thematic consistencies, including examining for outlining answers and identifying correlations, data similarities, and differences (Elliot 2006), as well as the frequency of recurring themes. In-depth interviews with various value chain actors helped me better understand how the fishery has changed over time, how social relationships influence economic behavior, and vice versa, and provided interpretations of how knowledge was transferred among actors.

California Fish and Wildlife CEQA Reports.

California Environmental Quality Act (CEQA) requires that policy changes that have an environmental and economic impact on fisheries be examined and documented. I used the CEQA documents from the Pacific herring fishery from 1998 to 2015, which are publicly available on the CDFW website. The Supplemental Environmental Documents for Pacific Herring Commercial Fishing Regulations reviews and evaluates proposed regulatory changes for the current fishing season, supplementing and replacing existing regulatory decisions" (CDFW website). Using these documents, I conducted a literature review to compile information on policy changes in the Pacific herring fishery over time, including the final and proposed alternative management decisions and managers' motivations and justifications for changing management strategies and harvest control rules.

California Fish and Wildlife Annual Fishery Summaries.

CDFW's Pacific herring annual summaries include information about species population dynamics, including biomass estimates, catch-to-biomass ratios, spawning distribution, and species age structure and distribution. I used Pacific herring annual summaries for Humboldt Bay and Crescent City from 2003 to 2007, for Tomales Bay from 1990 to 2007, and for San Francisco from 2002 to 2019, which are publicly available on CDFW's webpage (https://wildlife.ca.gov/Fishing/Commercial/Herring/Season-Summaries). I conducted a literature review of these documents to compile historical information on quotas, biomass estimates, landings, spawning locations, and market changes.

NOAA Commercial Fisheries Statistics.

I used Pacific herring foreign trade information to couch California's industry in the greater U.S. and global context, better understand commodity pricing/value, and trace Pacific herring through the commodity chain. The National Oceanic and Atmospheric Administration's (NOAA) Office of Science and Technology has information on commercial landings, foreign trade, and fishery products, including listing the volume and value of imports and exports by species and associated seafood by-products (e.g., frozen, fresh, roe, etc.).

I created an export database from 1981 to 2020 of edible herring products using the public query tool (https://www.st.nmfs.noaa.gov/st1/trade/build_a_database/TradeSelectDateDistrict.html). Then, I filtered data from exporting districts in California, Washington, and Alaskan and receiving exports nations Japan and China. These data included the product type (e.g., roe, whole fish, dried, etc.), the amount (i.e., total kilos) of fish exported, and the value of the species. I summarized data annually for analyses. Then, I used R for data management, visualizations, and analyses.

I also examined NOAA's Fishery Market News Archives for information on Japanese exports, imports, and cold storage. Data on wholesale prices at the Tokyo wholesale market and the prices of Japanese fishery imports by species were available online for current years during my research (2017 – 2020). Japanese imports, cold storage holdings, and wholesale pricing for herring are available from 1977 through 2016 on the NMFS website at: http://www.st.nmfs.noaa.gov/commercial-fisheries/market-news/related-links/market-news-archives/index. Data on US exports by species and district are available from 2005 through 2016 on the NMFS website at: http://www.st.nmfs.noaa.gov/commercial-fisheries/market-news/related-links/market-news-archives/index. Using a proportional analysis and Microsoft Excel, I used these data to determine values and the value added from one value chain node to the next. I briefly present the results of the proportional analysis in the discussion section.

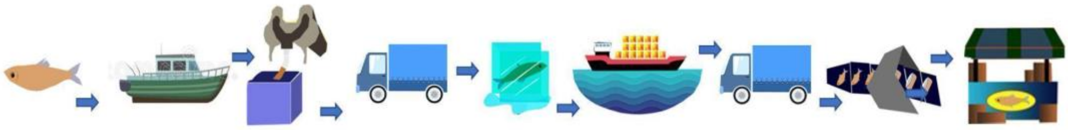
Results.

Pacific herring value chain typology.

Fishery regulators (R), who often work closely with scientists (S), fishers (F), docksider buyers (DB), international exporters (E), seafood traders (T), manufacturers (M), and seafood retailers (RT) are the actors constituting the Pacific herring value chain (Figure 7).[11] All actors can influence production, but Regulators and Conservation groups (NGOs) rarely participate directly in the production or distribution of Pacific herring commodities and do not contribute necessary functions for moving fish from California to end markets in the U.S. and Japan.

[11] Indigenous people, advocacy groups, recreational fishers, and subsistence users are also crucial actors in the Pacific herring fishing. However, this paper focuses on the commercial Pacific herring industry and the global commodity communities and value chain. If this paper's aim centered on management decisions and outcomes of the aforementioned actors would necessitate a greater proportion of the analysis.

Figure 7 – Pacific herring value chain (from left to right) including fish, fisher, dockside buyer, transportation, cold storage, exporters, transportation, manufacturer, and retail markets.



Production inputs can be material, labor, or knowledge. Outputs typically fall into two categories: seafood products or sales contracts. Sales contracts are instruments used to control resources and can define economic and geographic seafood outcomes. Material and functional inputs and outputs (Table 4) are frequently Pacific herring value chain actors. However, their roles are not mutually exclusive or bound to a specific node in the value chain.

Table 6 – The Pacific herring value chain typology: the relationship between actors, geographic scope, and inputs and outputs.

Actors	Geography	Inputs	Outputs
Regulator/Scientists (R/S)	California and Alaska	Sampling vessels, lab, equipment, staff scientists, and committee coordination	Harvest controls: the number of fish to be harvested, when (the time of year), how (what gear is allowed), and where (what spatial zones)
Fishers (F)	California and Alaska	Permits, boat, gear, fuel, boat storage, crew, fishing permits, at-sea time.	Fish (catching fish)
Dockside buyers (DB)	California and Alaska	Permits, unloading infrastructure (e.g., the fish pump, ice, forklifts), waterfront access, cell phone.	Fish move into the food system: physically move fish from boat to land, and enough processing (e.g., ice, water, tote, freezer) for transportation.

Transnational Exporters (E)	Washington, Alaska, USA, Tokyo, Japan, Hong Kong, China	Permits, freezer facilities, shipping boxes or containers, sales staff, desks, phone, internet.	Sales contracts.
Manufacturers (M)	California, New York, USA, Hokkaido, Japan, Hong Kong, China	Processing facility and equipment, the labor force (possible housing for migrant workers), occupy the facility, and store unsold products.	Usable, market-ready seafood product.
International Seafood Traders (T)	International (locations unknown)	Sales labor force, business equipment (e.g., desks, phone, internet, etc.)	Sales contracts
Retailers (RT)	California, USA, Hokkaido and Tokyo, Japan	Market stands or sales facility, sales staff, product, and product display	Cash for processed and packaged fish.

NGOs do not participate in the trade functions, but they often advocate for lower harvest ceilings or improved conditions for fishers. In the case of Pacific herring, NGOs were instrumental in California for funding the revision of the state's Pacific herring FMP, and in Japan, for closely working with traders to improve sustainable sourcing.

Fishery regulators, with the help of scientific expertise, in the Pacific herring fishery are state departments: California Department of Fish and Wildlife and Alaska's Department of Fish and Game. They create and implement harvest controls (e.g., harvest ceiling, limited entry permits, and gear and spatial restrictions). They do not participate in the exchange or distribution of seafood but influence production through harvest controls. One interviewee in California in January 2018 noted, "The authorities have all the power to tell someone to stop fishing." They establish harvest ceilings—the number of fish that can be harvested without degrading natural resources—to protect the species and marine ecosystems. They also determine various harvest control strategies to prescribe when (the time of year), how (what gear is allowed), and where (what spatial zones) Pacific herring can be harvested.

Fishery regulators' inputs are tools, equipment such as sampling vessels, lab equipment, and staffing for gathering and analyzing data, calculating harvest ceilings, implementation, and enforcement. Their activities are almost exclusively situated in the place of extraction (harvest). For example, Alaska's Department of Fish and Game determines harvest ceilings (quota) and harvest control strategies for Alaskan fishers and California's Fish and Game Commission, with the strong influence and guidance from California's Department of Fish and Wildlife (CDFW), determines harvest ceilings and control strategies for Californian fishers.

Fishers harvest fish; their material inputs include, but are not limited to, anything required to harvest fish from the sea, such as fishing permits, boats, fishing gear, and at-sea time. Their emphasis is on catching fish and often disregards the following steps in the Pacific herring value chain. One fisherman interviewee said, "It's not my job to find the market" (Interviewee, 2018). Fishers often specialize in a fishery and a geographic area. Currently, San Francisco, California (CDFW 2019) and Alaska, from the southern boundary at Dixon Entrance (55° N) to Norton Sound (64° N) (Spies 2006, Woodby et al. 2005) are the primary locations for the Pacific herring commercial fishery in the U.S.

Dockside buyers are crucial to the Pacific herring value chain, as they move fish into the food system from the boat. They move fish into the food system, physically transporting fish from boat to land, and provide enough processing so the fish will not spoil during delivery. This activity requires ownership or access to waterfronts, fish pumps[12], ice machines, storage containers (i.e., insulated plastic containers), trucks, and cold storage. They frequently communicate with regulators, fishers, and exporters, often conducted via cell phone or in-person communication to match supply with demand.

Exporters establish sales contracts with dockside buyers, manufacturers, and seafood traders. The exporter's primary function is matching the supply and demand of a pre-processed, frozen product. Their activities rely on their ability to transfer fish but don't necessarily mean that they physically move Pacific herring. Negotiating sales contracts require business operations and equipment such as trade permits and reporting, office space, desks, and communication tools. They may purchase or own cold storage equipment, including storage containers (i.e., waxed dipped cardboard boxes) to help dockside buyers physically move fish from boat to land. Exporters often work across several species and can leverage the profits in one fishery to reduce economic loss in another fishery. One U.S. exporter based in Alaska explained, "I'm not making any money on herring, but [by participating] I can keep my tenders working all year round, so they don't go

[12] Fish pumps are similar to a large wet dry vacuum and are necessary for moving Pacific herring, and other forage fish, from boat to land. It is a normative practice in the commercial fishery that requires capital investment for owning and moving the pump or paying a per pound rent fee to another intermediary who already owns one.

elsewhere during the salmon season" (interviewee, 2018). Exporters work across a few species and specialize in geographies of production, which is illustrated by one interviewee's response to questions about market diversification, "50 to 60% of our business is salmon roe, 20% is headed and gutted sockeye salmon, and 20% is herring and herring roe."

Manufacturers create market-ready seafood products, including thawing, filleting, canning, brining, packaging, and refreezing fish. They are responsible for packaging and storing product until it moves into multiple retail markets and locations. Processing activities require access to (via rental) or ownership of processing facilities and equipment and an adequate or skilled labor force (possible housing for migrant workers). After final processing, various Pacific herring products are shipped to multiple retail markets and locations throughout Japan for consumption. Manufacturers rely on seafood traders to do most of the sales post-processing. One interviewee illustrated this in August 2019 and stated, "I process salmon and mackerel, but mostly, 95% of the business is herring processing…I work closely with trading companies to acquire markets. My customers are mostly Japanese supermarkets and some restaurants. I mostly sell to various markets in Tokyo but do very little, if any, direct sales."

Seafood traders establish sales contracts with exporters, manufacturers, and distributors (e.g., retail outlets). Their activities rely on their ability to transfer fish, but that doesn't necessarily mean they encounter or physically possess Pacific herring. Their actions require "white collar" equipment such as a sales labor force, desks, phones, internet, etc.

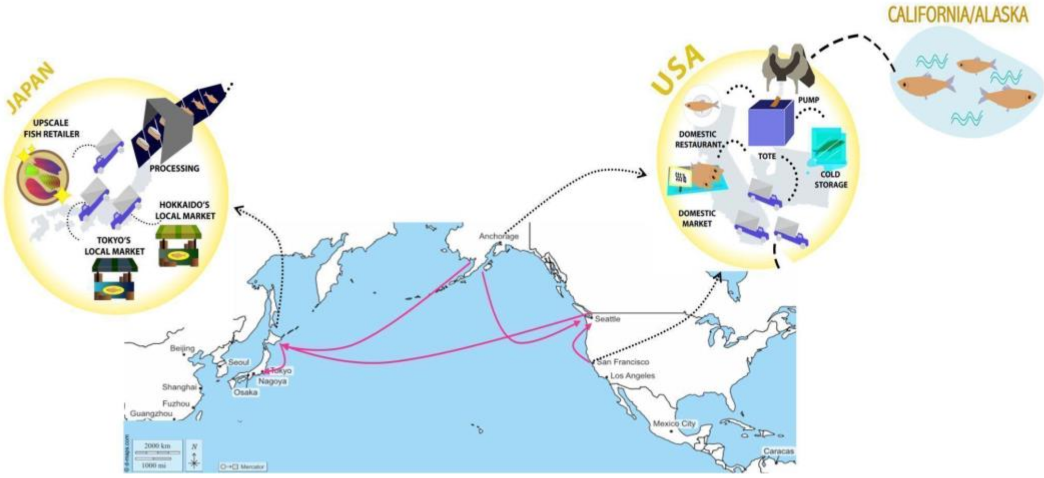
In contrast to exporters, seafood traders rarely need cold storage equipment because the product is delivered directly to manufacturers and, from there, to distributors or retailers. Their primary function is to match the supply and demand of final product forms.

Retail markets sell ready-made seafood products to end-users, which could be a very complex or simple arrangement. For example, a simple format resembles a farmer's market, whereas a complex structure looks more like a grocery store. Inputs vary depending on the final layout, but, in its simplest form, a sales facility, sales staff, product, and product display are key material inputs. Also, knowing the highest price that end consumers are willing to pay.

The commercial Pacific herring value chain organization.

The Pacific herring value chain is complex and requires various functional and socio-political relationships at multiple scales. Fish and money move linearly. Material and functional inputs and outputs and the final product forms change with geography (commodity communities) (Figure 8). Processing techniques and distribution channels also frequently shift in relation to commodity communities.

Figure 8 – Pacific herring global production network: geographic scope, economic distributions, and commodity communities.



i. *Ecologically, Pacific herring range from Baja California to Alaska and across the North Pacific to Japan. Economically, commercial fishing occurs during spawning (from December to June) in the bays of California and Alaska (Hay et al., 2009). Although many fish are harvested in California and Alaska, they are almost entirely frozen in the U.S. and shipped to Japan for manufacturing and consumption (CDFW 2019; Interviewee, 2018).*

Regulation and fishing activities are almost exclusively situated where the Pacific herring congregate for spawning and where extraction (harvest) is allowed.

California harvested Pacific herring move from boats to large square plastic totes filled with ice and water dockside via fish pumps (large wet dry vacuums). Then, they are shipped via truck to Washington for freezing and long-term cold storage. In one interview, a dock sider buyer said, "Freezer space in California is more expensive and harder to access than freezer storage in Washington or Alaska. Cold storage in California is used for fruits and vegetables rather than fish, and no one wants their strawberries to smell like fish" (Interviewee, 2019). Alaskan dockside buyers have similar processes but may also use at-sea freezing processors (i.e., tenders) rather than bringing the fish on land. Dockside buyers rarely specialize in one fishery but are often place-based or reside in a particular geographic area. One interviewee in December 2018 explained that a Pacific herring dockside buyer from Alaska "would not come" to California because it was not economically lucrative.

Pacific herring manufacturers are primarily based in Hokkaido, Japan, and specialize in processing one or two products for a particular buyer. Exporters are not bound to one species or geography, but most are based in Alaska or Washington. Seafood traders work across all species and product forms, but they seemingly specialize in geographical markets rather than geographies of production. Retail locations in Tokyo often specialize in dried roe products. In contrast, retail locations in Hokkaido offer a more comprehensive range of Pacific herring products, including dried and pickled carcasses and brined roe.

Pacific herring value chain structure.

Fishers are functional suppliers to dockside buyers and the primary actors subjected to the authorities of fishing regulations. Fishers are also linked to one another, seem to create sub-clans, frequently communicate, and make decisions to support the "fleet" rather than the individual. For example, one fisherman explained in a phone interview that he would not be going fishing because "there were not enough pounds to catch to make it lucrative for everyone." So rather than taking tonnage from other fishermen, and lowering profit across all fishers, he opted not to fish (Interviewee, 2018).

Dockside buyers are a pass-through of knowledge between regulator and exporter, and functional linchpins, connecting fishers to exporters. They participate in price negotiations with cold storage facility owners, trucking companies, and other dockside buyers who have waterfront access or fishing pumps. They talk with exporters about their costs and needs for profit but rarely have the authority to increase the price. Dockside buyers often try to collaborate, equipment cost-share, or aggregate products from various U.S. locations during freezing and storage phases to reduce production costs.

Two dockside buyers in California shared a fish pump and worked from the same unloading space during the Pacific herring season. However, the dockside buyers stored "their" product in different locations –one in Salinas, California, and one outside Seattle, Washington– presumably for varying distributional channels. In this case, the reciprocities reduced unloading costs while keeping cold storage contacts separate and marketing channels secret. Dockside buyers discuss product quantity with exporters and advocate for a better price depending on "quality." In the commercial Pacific herring fishery, where products are destined primarily for a roe market (CDFW, 2019; Woodby, 2005), the "ripeness" or the size and color of the roe determines quality (Interviewee, 2018).

Exporters connect with dockside buyers, several unidentified seafood traders, and manufacturers. The knowledge breadth and exchange between exporters and seafood traders is hard to describe beyond the ability to match supply and demand. Lead firms seemingly have one branch in the U.S. and one in Japan with the same business name. One interviewee described the functional relationship between lead firms and traders but did not describe the information discussed other than pricing determinants such as taxes, ocean freight, and exchange rates:

> *Japanese trading companies make purchase orders directly with Seattle [U.S. lead firm branch]. Japan [lead firm branch] gets a commission. There are a total of three people and their office. Japan [lead firm branch] agrees with the trading company for the whole herring. Then the whole herring is sent to the manufacturer to be "popped."*[13] *The roe has a contract to go back to the Japanese trading company. The manufacturer keeps the carcasses for his markets. The trading company sells the roe to multiple people, which also depends on the exchange rate.*
>
> *(Interviewee, 2019)*

[13] A common industry term for breaking open the Pacific herring and "popping" out the roe as one piece.

Manufacturers are the functional intermediaries between exporters and traders. Currently, there are only three manufacturers in Hokkaido. They work independently with several exporters and traders. However, they collectively work to make labor arrangements, such as travel and lodging for fish processors. They communicate primarily with traders to sell their products, with exporters to obtain products, and with each other to reduce production costs and streamline workforce logistics.

Retailers communicate with seafood traders and, less frequently, some manufacturers. Their role is to connect with end-users and sell the finished product, regardless of product form. They have discretionary authority about what product form they desire and at what price they want to sell it.

Power manifests through secrecy and reciprocity.

The Pacific herring value chain has several centralized intermediaries that move supply, conduct various levels of manufacturing, and maintain complex sales information. The conversations, negotiations, and knowledge of supply and demand occur vertically and horizontally across all players. Geography and direct linkages (one up and one down) seemingly influence or couch the boundaries of exchange. However, regardless of place, information-sharing is reserved for tightly knitted, “quid pro quo” (reciprocal) relationships. Power and authority are operationalized through each actor's information, which provides some real or perceived economic opportunity if exchanged (Table 7).

Table 7– The relationship between value chain actors, the information each possesses, the complexity of the information, and how easily the information can be transferred (or codified) to improve one's authority.

Actors	**Information possessed**	**The complexity of the information**	**How easily informatio n codified**
Regulator/ Scientists (R/S)	Information of biological and environmental conditions of the fish, Information of biomass estimating economics and policies determining harvest controls	High	Easily
Fishers (F)	Knowledge of fishing regulations, fishing locations, species behavior, methods for harvesting, dockside buyers, quality standards	Moderate	Easily
Dockside buyers (DB)	Knowledge of fishers, fishing regulations, market quality standards, exporters, locations, and logistics for freezing, transporting, and storing fish.	High	Moderate
Transnational Exporters (E)	Knowledge of international market conditions, number, and value of contracts, global tariffs, and taxes, overseas freight, manufacturers, international market pricing, overseas shipping rates, and the information for storage in the country of destination.	High	Hard
Manufacturers (M)	Knowledge of quality and grading standards, preservation techniques, and transformation details (e.g., brine ratios, duration of smoking, packaging standards). They are also experts at knowing conditions for maintaining a labor force.	High	Moderate

International Seafood Traders (T)	Knowledge of market prices, knowledge of manufacturers, and knowledge of the volume of products that can be distributed, including timing and price variance.	High	Hard
Retailers (RT)	Information to contact distributors and knowledge of end-user preferences and price acceptance.	Low	Easily

With scientists' help, fishing regulators create harvest limits (quotas). The processes of creating harvest limits include stakeholder engagement via state and federal regulations such as the Magnuson–Stevens Fishery Conservation and Management Act, California’s Marine Life Management Act, and Alaska’s Fishery Management Plans (FMP) per fishing unit (species by region). In the recent revisions to California’s Pacific herring FMP, fishers and dockside buyers attended meetings to discuss the minimum quota necessary to keep “the market open” and fishers advocated for a change in permit structure and gear type. Fishers and dockside buyers participate in quota negotiation as a means of advocating for their individual and shared economic opportunities.

Regulators information on the biological and environmental conditions. Regulators create, implement, and understand guiding legislation governing fisheries and the sustainability of the resource. They hold the regulatory authority and responsibility to determine harvest controls. It is imperative that this knowledge is accessible to value chain actors. Their knowledge requires a high level of complexity and is publicly transferred and easily codified.

Fishers know when, how, where, and under what terms Pacific herring can be harvested. They frequently share this knowledge among their peers and use that knowledge as leverage over one another. However, their fishing activity is reported to regulators and visible from the land; the Pacific herring fishery occurs within the first three miles of the shoreline. Therefore, understanding fishing regulations, species behavior, and the best fishing place is moderately complex but easily transferred via public forums, visibility, and governmental reports.

Dockside buyers have knowledge of quotas, fishers (suppliers), fishing regulations, market quality standards, exporters, locations, and logistics for freezing, transporting, and storing fish. They also know one or a few international exporters but have very little knowledge of manufacturers and distribution channels beyond that of exporters. Their ability to match supply and demand and move fish from the boat into the food system is complex, requires a high level of competency, and is not easily transferred. However, county health departments require several handling licenses, which increases codification.

Exporters know tariffs, taxes, overseas freight, and quality standards, but only to the degree that traders have defined "quality." Their expertise resides in knowing where to access Pacific herring and to whom to sell it (seafood traders). They are vital transnational go-betweens for moving Pacific herring from the U.S. to Japan. This invaluable information is seemingly positioned within one or few individuals who have built connections between intermediaries over decades. It is complex and almost impossible to codify. One interviewee explained that he: "went to college in Seattle and worked with my uncle at [Exporter Firm]. I came back to Japan afterward and have worked with the company for 17 years" (Interviewee, 2019).

Manufacturers possess knowledge of logistical and manufacturing processes for transformation. They must create uniform products for end markets, which encompasses a high level of competency and often include "specializing" in a particular product form (e.g., dried carcass or brined roe). They are also responsible for organizing and coordinating a labor force skilled in fish processing, including working with the Ministry of Health and Labor Welfare guidelines, finding housing for migrant workers, and speaking multiple languages. Their knowledge is complex, requires a high level of competency, and is not easily transferred. However, the art of processing can be substituted with technology and informed by marketing research and product development. One interviewee illustrated the complexity and competency required for manufacturing in August 2018:

> *Fish shipments have a lot of mixed sizes; this is unusual and difficult to work with. It's best to have similar sizes, same-sex, and individually quick-frozen fish. The block freezing changes the quality of the fish. He buys from several companies … some are [delivered] sexed and individually quick frozen, and some [of the fish] are block frozen*[14]*. Block freezing is cheaper and changes the quality of the fish. First, they are thawed. Then, they are rinsed, and the carcasses are put on a machine to remove the spine and fillet them. Small fish are removed. All fish are hung to dry in a drying machine for 24 hours. Heat and humidity are controlled. The smaller fish are hung to dry for 3-4 days in a separate chamber because they need more attention. The drying chamber for the large fish is 5 x 6 meters.*

[14] Block frozen means that the fish is frozen with water and ice rather than the fish being individually frozen (e.g., individual quick frozen).

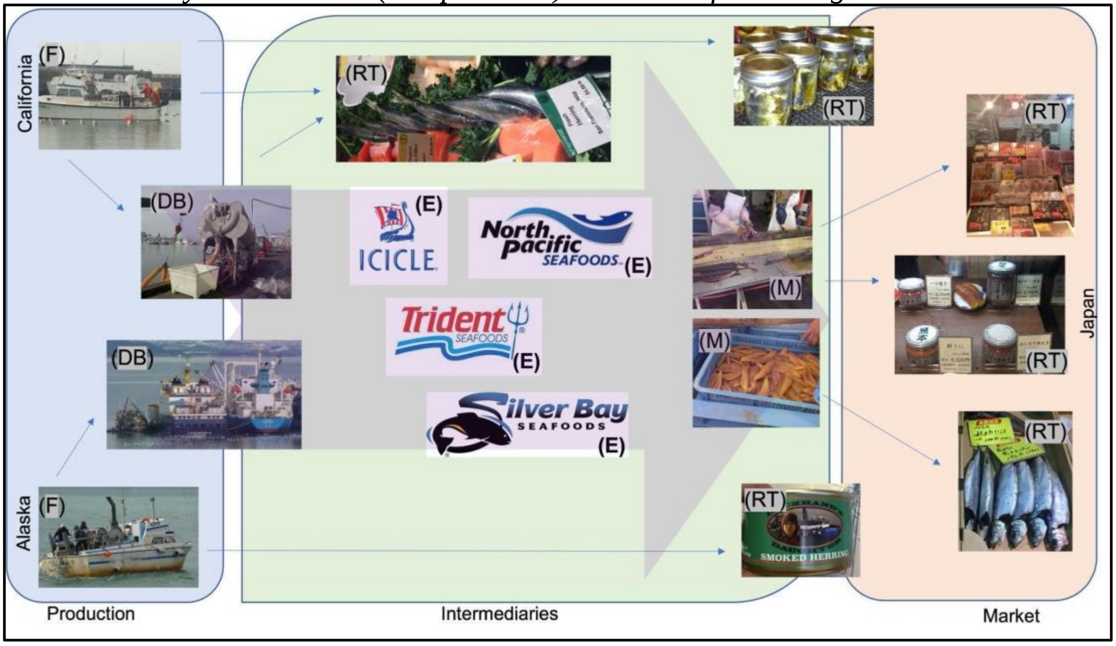
Seafood traders' knowledge and ability to match supply and demand for thousands of tons of Pacific herring is not easily transmitted and is used to exhibit leverage over the other actors in the supply chain. They possess knowledge of market prices, manufacturers, and the volume of products that can be distributed, including timing and price variance.

Retailers have information about traders (who, in this case, often act as distributors) and knowledge of end-user preferences and price acceptance. Their knowledge is, on its face, simple and easily transferred. In Japan, Pacific herring retailers were plentiful and rarely had differentiated products regardless of geography.

Uneven distributions of risk and market power transform horizontal relationships into hierarchical ones.

Uneven risk and market power distributions transform horizontal relationships into hierarchical ones (Figure 9). The relationships among intermediary groups such as dockside buyers, exporters, manufacturers, and seafood traders are seemingly horizontal, but they are hierarchical, with one or two exporters controlling the market. Although intermediaries demonstrate greater authority than fishers or retailers, their power or authority is not evenly distributed.

Figure 9– Vertical and horizontal linkages between actors, activities, geography, and commodity communities (end products) in the Pacific herring value chain.



i. *Raw commodity production occurs in Alaska and California. Dockside buyers in the U.S. connect to and are also defined by the activities of exporters in the U.S. and Japan. Most manufacturing occurs in Japan, but some (less than 10%) final products are created in the U.S. for niched end users by vertically integrated seafood businesses.*
ii. *Commodity communities include fresh whole and canned or jarred fillets in Alaska and California, as well as brined or jarred roe and dried or pickled carcasses in Japan.*
iii. *Dockside buyers, exporters, and manufacturers are seemingly horizontal, functional intermediaries in the Pacific herring value chain; Notably, it is difficult to decipher the exact nature or amounts of product flows in the large purple arrow.*
iv. *See Tables 3 & 4 for letter legend.*

Uneven risk and market power are created through sales agreements that control supply. Risk occurs primarily in processing infrastructure, including physical equipment, human labor, and product liability[15]. Market power is the

[15] Product liability refers to a manufacturer or seller being held liable for placing a defective product into the hands of a consumer. Responsibility for a product defect that causes injury lies with all sellers of the product who are in the distribution chain.

ability of a firm (or group of firms) to set prices or implement pricing strategies that wield individual profitability, increase competitiveness, and decrease economic welfare for similar firms (Perloff, J. M. et al., 2007). Risk and market power are unevenly distributed among supply chain actors in the Pacific herring value chain.

Regulators and scientists control production through harvest ceilings and fishing regulations, but they have no market power or distribution risk.

Fishers have relatively high levels of risk because they must purchase fishing permits and equipment, including fishing vessels, fuel, gear, boat storage, etc., which is further complicated. After all, the costs of such items fluctuate depending on the attractiveness of the fishery. For example, in 1990, the cost of Pacific herring permits was approximately $60,000; now, the permits are worth roughly $500 (Interviewee, 2018; CDFW, 2019). However, fishers have little to no market power and often are referred to as "price takers" even though they are crucial suppliers and food producers.

Dockside buyers, manufacturers, and retailers transport, store, and change Pacific herring into various products through domestic processing and transportation. They maintain product liability (e.g., spoilage) and processing infrastructure, including physical equipment and human labor.

Notably, product perishability declines as processing intensifies, which leaves the most product liability in the hands of the dockside buyer or until the Pacific herring is frozen. Furthermore, dockside buyers are responsible for owning, accessing, and maintaining capital-intensive necessities such as forklifts, fish pumps, and ice machines. These capital investments can make it challenging to meet profit margins. For example, a dockside buyer in California stated, “I can sell Pacific herring for $700 to $800 a ton, but it costs me approximately $1500 a ton to ship it to Washington. Very few cold storage facilities in California will hold fish” (Interviewee, 2018).

Pacific herring manufacturers in Japan have a lot of risks but very little market power. They also create product forms based on their buyer's quality conditions, often established by a particular buyer's needs. A manufacturer in Japan in August 2018 explained, “I work very closely with trading companies to acquire markets. I make 95% of my income from the roe, already contracted with traders.” They must purchase and maintain processing equipment and coordinate - often Migrant - labor. Manufacturers must find housing for laborers and help laborers travel between their home country and the processing facility. This is further complicated because the processing occurs for only a couple of months of the year. Packaging is a considerable cost, one interviewee in Japan in August 2018 stated, “We do our own packaging. We have 120 types of packaging. There are different packages for small fish versus large fish. The packaging is a cost for the manufacturer.” Manufacturers must also assume high levels of product liability and are functionally responsible for changing fish from a frozen product into a sellable end-use product. For example, if a fish dryer breaks or humidity is faulty, the entire “lot” of products could spoil.

Exporters and seafood traders have very little product liability because they can use “free on board” (FOB) in sales contracts. FOB transfers liability and risk from a seller (exporter) to a buyer (manufacturer). It shifts the burden of insurance costs, freight costs, and product liability (CIF) to the buyer (in this case, often the manufacturer). The buyer must then pay for the Exporters' and seafood traders' authority grows due to minimizing risk and freight once received (Zhang & Sexton, 2003). Additionally, relationships among intermediary groups are seemingly horizontal, but one or two exporters control the market. “Exporter B is a newcomer in the market. They sell faster, earlier, and at a fixed price. No one will get into a [sales] contract until Exporter B has established a price” (Interviewee, 2018). These “lead firms,” usually just one or two, tend to purchase the most considerable portion of supply and create sales contracts with international traders, setting the price for all other trade agreements. Lead firms economically capture the Pacific herring value chain.

Discussion.

This paper examines the roles intermediaries play in the global and domestic fish trade. It provides theoretical and methodological approaches for assessing the fish trade's functional, material, and social flows and how those flows influence power dynamics. Using the commercial Pacific herring fishery and global roe trade as my case study, I show the complexities of how the multiscalar fish trade unfolds, and the implications of power asymmetry on geographical distributional endpoints. My approach is mainly descriptive, which is arguably a necessary and valuable first step in identifying and understanding seafood’s economic and geographical distributional outcomes for producers and consumers in the U.S.

Seminal theories from global commodity chain studies: buyer versus production-driven governance, the five modes of value chain governance, and global product network theories, help us think about, define, and identify power asymmetry in seafood systems. Although different, each theory denotes similar initial practices for uncovering control, including defining the following activities: inputs, outputs, geographic scope (spatial scale), industry stakeholders, and the linkages between them (industry organization and governance structure). The patterns of control outlined in global commodity chains are helpful when trying to define and explain the effects and implications of the global economy on seafood localism. However, I demonstrate that global seafood commodity chains do not align with previously described governance categories. My analysis of the Pacific herring value chain – an extractive, non-core periphery case study – builds upon and expands these seminal theories by introducing a "relationally confided" governance structure.

My analysis of the Pacific herring seafood trade showed that fish trade is complex, requires a multitude of functionally and socio-politically dependent relationships at various scales, and occurs domestically and globally concurrently. Each actor's information and knowledge provide some stronghold at each functional node. The knowledge underpinning the value chain (e.g., knowledge of suppliers, buyers, cold storage, etc.) is often kept secret from one actor to the next in hopes of maintaining leverage or loyalty. The relationships between regulator and fisher are more clearly grounded in professional or economic activity. However, it is more difficult to determine the nature of the relationships among fishers and between fishers and dockside buyers. Through my interviews, dockside buyers are more likely to combine forces with fishers for reasons other than economics. One interviewee in California in January 2018 stated, "They [fishers] begged me to come down and buy their fish…we are staying in an Airbnb together around the corner."

Authority is exerted– although not evenly– by intermediaries. Lastly, intermediaries rely on complex information that is not easily transmitted, are deeply relational, and are, concurrently, captive by a few buyers with a great deal of economic leverage (relationally confided governance). The complexity of power asymmetry is complicated because intermediaries are not always differentiated and, in some cases, take more than one or all functions in the commodity chain. For example, seafood traders were mentioned several times during my fieldwork but are difficult to materially and visually map. Furthermore, relationships among intermediary groups are seemingly horizontal but are, in fact, hierarchical. The system is based on "relational processes of exploitation and exclusion that presupposes the continually reproduced poverty" (Arrighi, 1990, 16 in Havice & Campling, 2017).

The role of a lead firm manifests through international trade sales agreements that can reshape the distribution of risk and market power along the value chain and constraints fishers' and dockside buyers in the U.S. economic opportunities in the commercial Pacific herring industry. One or a few buyers assumed the roles of lead firms and exhibited a great deal of economic leverage. Fishers, dockside buyers, manufacturers, and retailers succumb to pricing established by exporters and seafood traders because they don't know market conditions or marketing channels, especially for large volumes of Pacific herring. Two interviewees in California in January 2018 illustrated the commercial Pacific herring fisheries' dependence on international ties, "I have to go through Japanese markets to get to other markets" and "Japanese control the market."

My second hypothesis is that local production is ubiquitously coupled with the global economy by territory, agency, and value dispersal. In the global trade of Pacific herring, relationally confined governance necessitates global trade for domestic fish trade. Without financial incentives from globalized markets, fishers and dockside buyers have little to no economic incentives to participate in the fishery, thereby stifling supply for local markets. However, the global fish trade also prevents the growth of the domestic fish trade by controlling supply through international sales contracts. Despite the environmental and social benefits of increasing seafood localism in the U.S., the domestic fish trade depends on transnational exporters who control the supply. My analysis–of a non-core-periphery case study– concludes that the global market's ability to catalyze regional development is an illusion. A relationally confided value chain governance structure reproduces "uneven geographies of capitalism as they create processes of exclusion from global commodity circuits" (Bair and Werner, 2011, 1000).

One limitation of this paper is the lack of analysis of consumer demand and changes in consumer demand in Japan and the U.S. The ability to build, seize, and match supply and demand is one of the most vital aspects of value chains and was explicitly expressed several times in my fieldwork. I've demonstrated that knowledge of and the ability to match supply and demand is a crucial determinant of power. Many studies have projected the growing demand for seafood (Béné et al., 2015; Naylor et al., 2021), the geographical differences in consumption

(Naylor et al., 2021), and how income trends relate to purchasing domestically (Witter, A. et al., 2021), but none have centered on understanding how various cultures and consumer preferences influence the value of seafood–outside of environmental exploitation for export markets– and the distribution of that value along the chain. Further research is needed to define and understand the relationship between demand, governance, scale, and sustainability in the fish trade.

Economic evaluations, and comparisons of buying and selling prices along the commercial Pacific herring value chain could improve the understanding of how financial leverage plays out in the multiscalar fish trade. I used ethnographic photos of the end products in Japan and the U.S., including pricing labels, and state and national quantitative archives such as harvest and national export data to estimate value distribution along the Pacific herring value chain. I conducted a preliminary analysis of pricing at the point of harvest, wholesale prices quoted during interviews, and final retail prices to perform a proportionality test (Purcell et al., 2017) of gross earnings for fishers, and dockside buyers, exporters, and retailers. My findings showed that exporters have the most significant proportion of value from end-product pricing ($0.50 per pound or 4.27%), then dockside buyers ($0.35 per pound or 2.99%), and lastly, fishers ($0.20 per pound or 1.71%). These preliminary findings support my hypothesis that exporters have more economic leverage than dockside buyers and fishers. Still, it does not understand the relationship between retail and intermediary pricing. Although understanding the positionality and stronghold of retailers was not the focus of this paper, more research on the international retail segment, namely in Asia, is needed to better understand their level of risk and authority and how that reverberates into varying economic geographical outcomes for blue food systems in the U.S.

My hypotheses build upon recent attention on Equity and sustainability in the fish trade as a function of scale or geography and alternative seafood networks. Alternative seafood networks have emerged as a practice of resistance to the globalized food economy and its associated adverse impacts on the environment, practitioners, food workers, and consumers' health (Witter & Stoll, 2017). Stoll et al. (2017) explained restructuring the geographic distribution of seafood is not easy. Neoliberal production paradigms perpetuate reciprocal relationships, financial leverage, and fishers' unwillingness to jeopardize their relationship with traditional buyers and stifle seafood system sustainability and equity (Bolton et al., 2016; Stoll et al., 2017). This paper's research helps explain why alternative seafood markets struggle to cut out intermediaries, maintain consistent supply, and harness reliable and profitable distribution channels.

Most importantly, this research highlights that knowledge exchange and social relationships play a vital role in fish trade across scales. They prop up lead firms' authority and influence material and financial flows. Maintaining an ignorant eye towards the importance of relationships between fishers and dockside buyers and, mutually exclusively, dockside buyers and exporters will likely perpetuate alternative seafood markets' –by way of dockside buyers –reliance on international markets.

Conclusion

Harnessing the descriptive qualities–material, relational, functional, and structural– of global production networks is essential in a time of unprecedented global ecological change and seafood globalization. In this paper, acquiring capital for processing infrastructure, whether human labor or equipment, created barriers to entry in the fish trade. Carefully protected knowledge and relationships, controlling supply, and establishing sales contracts that decreased risk increased market power for late chain intermediaries. Changes in waterfront land-use zoning, subsidized lease rates, or publicly maintained (municipal or harbor districts) communal processing equipment (e.g., ice machines, fish pumps, storage containers) could help reduce barriers to entry and exploitation (of actors) and increase the competitiveness within fish trade. Nevertheless, monitoring the breadth, reach, and disparities between intermediaries in the fish trade will require attention from and collaboration between fish as food scholars, economic geographers, and fishery managers.

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Chapter 3 Tasty small fish: a mixed-method sensory examination of California consumers' likeness and preferences for Pacific herring products.

Abstract.

Pacific herring have mismatched supply and demand and symbolize an underutilized trash fish in California. Underutilized fisheries generally have healthy levels of fish abundance but low fishing pressure, economic value, and visibility in the market. Pacific herring are high in micronutrients such as omega-3 fatty acids and low in mercury. The San Francisco Bay Area has higher than the national average seafood consumption. It has one of the most productive spawning and fishing grounds for Pacific herring along the West Coast. However, Pacific herring are rarely available as food in the Bay Area. My research examines the drivers of this mismatch from the consumer's perspective. For two consecutive years, I coupled ethnography with a quantitative hedonic survey at the Pacific Herring Festival in Sausalito, California, where volunteer consumers ranked their experiences to six sensory attributes across nine different preparations. My results show that Pacific herring are "liked" as food. Still, Californian consumers preferred filleted product forms, disliked bones in the fish, and indicated a relationship between preference for texture and their overall "liking." Understanding consumer preferences for more Pacific herring product form can help the commercial Pacific herring fishery and, in an effort to, move other underutilized forage fish species onto the plates of Americans, can provide insights into the practical and socio-cultural needs of consumers more broadly.

Keywords: *forage fish, seafood, sensory science, consumer preferences, upgrading*

Introduction.

California has approximately 40 million residents and higher-than-average per-capita seafood consumption (Fong et al., 2022; Love et al., 2022). California is the single largest market in the U.S., worth $3 billion, and is known for its trendsetting eaters who appreciate the nutritional benefits of seafood (Jain and Henning 2018). Hicks et al. (2019) determined that nutrients available in even a fraction of the fish harvested could meet the dietary requirements of coastal residents who live within 100km of the coast. More than half of all California residents live near the coast, and in all coastal counties north of San Francisco, 15 to 19 % of residents experience food insecurity (Feeding America, 2022). California also has great ethnic and culinary diversity (U.S. Census Bureau, 2020), including large Hispanic (39%) and Asian American (15%) populations who are more accustomed to eating less luxurious or less-known seafood items and often have a wider range of acceptance towards less processed seafood product forms (e.g., whole fish).

In 2020, California's wild fisheries landed 106,289 million pounds of seafood (NFMS, 2020) and several high-volume fisheries, including various forage fish species such as sardines and mackerel. Fishery regulations in California allow the (minimum) harvest of 700 tons of Pacific herring (*Clupea pallasii)* annually, and the San Francisco Bay Area has one of the most productive spawnings and fishing grounds for Pacific herring along the west coast (CDFW

2019). Pacific herring spawning and commercial fishing can be seen from California's shorelines. Their harvest locations are close to several urban centers in the San Francisco Bay Area (e.g., Point Richmond) (CDFW, 2007, 2018). Furthermore, Pacific herring are edible, rich in micronutrients, low in toxicity, and rated “best choice” by U.S. dietary guidelines. There seems to be an opportunity for Pacific herring consumer markets in California but seizing this opportunity has yet to occur. The following research aims to understand the practical and sociocultural options and limitations of moving Pacific herring onto the plates of American consumers, particularly in California, by coupling sensory science research and product upgrading–moving into higher valued production activities.

Understanding Californians’ sensory responses to eating Pacific herring is helpful for the commercial Pacific herring industry, including fishers and seafood workers. It can also provide insights into how consumption of other U.S. harvested underutilized forage fish species could be increased in the U.S. The following paper defines and explains the importance of using a convenience sample of testing subjects (also lead consumers) in my research design. I also demonstrate that taste, enjoyability, or “likeness” are not necessarily driving the mismatched trend of forage fish production and consumption. My results also show that variations in product forms (i.e., preparations or treatments) influence consumer likeness, though differences were not statistically significant. Small sample sizes likely limited the ability to detect statistically significant differences. I conclude my research with recommendations for future research, including investigating U.S. consumers' seafood purchasing motivations beyond taste and examining institutional and industry limitations to product upgrading.

Background.

U.S. consumers seemingly have an affinity for sustainable seafood (Bronnmann & Asche, 2017; Logan et al., 2008; Wessells, 1999). However, U.S. seafood purchasing behaviors do not necessarily align with sustainability parameters, such as lower trophic level species, locally or regionally produced seafood options with few food miles, or aquaculture species produced with minimal inputs (Carlucci et al., 2015; Hallstein & Villas-Boas, 2013; Nesheim et al., 2007.; Witkin et al., 2015; Yaktine, 2007, & Nesheim, 2007). Seafood consumption in the U.S. consists of both domestic and imported sources of wild-caught and aquaculture species (Love et al., 2020; Shamshak et al., 2019; Stoll et al., 2021). In 2014, U.S. per capita consumption increased by 0.9 pounds from 2012, for a total of 15.5 pounds of seafood consumed per capita annually (NMFS, 2020). In 2019, American consumption increased to 19.2 pounds of seafood per capita, totaling approximately 6.3 billion pounds of seafood consumed 2019 (NMFS, 2019, 2020). Most of the increase in consumption is from imported aquaculture (Gephart et al., 2019; Pramod et al., 2014). Imported seafood, either farmed or captured fish, often comes from places with less rigid environmental policies and/or enforcement, such as China, India, Thailand, Vietnam, and Indonesia (Gephart et al., 2019; Gephart & Pace, 2015; Helvey et al., 2017). In contrast, U.S. federal and state fisheries management, including data collection, harvest controls, cumbersome paperwork and licensing, and enforcement (Helvey et al., 2017; Stoll et al., 2015), govern exported U.S. harvested seafood.

Furthermore, the U.S. is one of the world's top fishing nations (FAO, 2020), but the U.S. imports about twice as much as it exports[16] and has a $14 billion seafood trade deficit (NMFS, 2020). Beyond the economic consequences of the trade deficit, U.S. consumption of primarily imported seafood rather than U.S. harvested seafood also creates "leakages" or negative social and environmental externalities. Helvey et al. (2017) argue that the U.S. should increase awareness of U.S. fisheries, develop U.S. domestic aquaculture, support sustainable fishing practices internationally, and practice multilateral cooperation to move the U.S. towards greater self-sufficiency, minimize leakage, and increase seafood security.

Beyond concerns about seafood security, the trade deficit, and leakage is the growing homogeneous consumption patterns of a small number of fish and shellfish species (Witter et al., 2021). Whitefish (e.g., pangasius, domestic catfish, cod, pollock, tilapia), shrimp, farmed salmon, and canned tuna are the most consumed seafood products in the U.S. (Love et al., 2022). Alternatively, eating underutilized or forage fish, such as herrings, anchovies, and sardines, could reduce the ecological pressure on higher trophic, overfished species, such as salmon and tuna, and create jobs in coastal communities in the U.S. (Zhou et al., 2015). It could also reduce the trade deficit, increase seafood security, and

[16] Estimating how much U.S. harvested seafood is consumed by Americans is difficult –because of the significant role re-imports play in the seafood system (Gephart et al., 2019; Teneva et al., 2018)

improve nutritional outcomes for consumers (Love et al., 2017). Currently, forage fish represent over 31% of the total volume of fish harvested in the United States but only represent approximately four percent of the total value of all species harvested in the United States (Gephart et al.,2016, Msangi, S. et al., 2013; NMFS 2020).

Additionally, forage fishes are foundational ecological species vital to marine food webs, reproduce quickly, are high in micronutrients such as polyunsaturated fatty acids, and low in contaminants (e.g., mercury, BPAs from microplastics) (Pikitch et al., 2012). However, they are rarely accessible for human consumption, rarely appear on nutrition assistance program lists, and have decreased in popularity among American consumers over the last 50 years. (Love et al., 2019). Cashion et al. (2017) demonstrated that "ninety percent of fish destined for fishmeal are food-grade fish" and are suitable for direct human consumption. Still, they do not provide practical, institutional, or socio-cultural recommendations for moving more food-grade forage fish into direct human markets.

A rich body of literature examines seafood purchasing patterns, explores network analysis and mathematical modeling of imports and exports, and criticizes or supports the adoption of eco-certification (Overdevest, 2010; Stoll & Johnson, 2015). However, this literature often fails to address the role of consumer preference in determining product innovation or outline the necessary steps for increasing consumption of U.S. harvested (or farmed) species, including product upgrading or identifying the demographics of target consumers. This study contributes to emerging sustainable seafood consumption literature by examining the assertion that taste drives (or is a crucial factor in) consumers' seafood purchasing (Carlucci et al., 2015; Lamy & Szejda, 2020; Love et al., 2017).

This paper also contributes to sensory science research methodologically by coupling hedonic surveys and qualitative assessments at a public venue and tasting event to understand consumer preferences for seafood with multiple treatments (preparations). I present the results of consumers' hedonic scaling of "liking" and preferences–comparing one treatment to another– for eating Pacific herring (*Clupea pallasii*) in California, a state that produces the most significant sales, income, and value-added impacts generated by the U.S. Seafood Industry (NMFS 2020) and has "a consumer market not to be ignored" (Hennig and Jain, 2018). Beyond showing statistical summaries of the survey results, I also explain how preferences for various treatments influence product upgrading, which and often requires more labor or manufacturing inputs from the industry.

Research Design.

Sensory science provides an approach to understanding human behavior in response to the physiology of the senses through knowledge of consumer preferences, experimental design, and statistics (Lahne, 2016; Martens, 1999). It evokes, measures, analyzes, and interprets human responses to characteristics of foods or materials perceived by sight, smell, touch, taste, and hearing (Lahne, 2016; Martens, 1999). Sensory science experiments often use trained taste testers that can better identify and quantify observable characteristics of food traditionally using quantitative and statistical methods, such as a 9-point hedonic scale survey and analysis of variances (Kos Skubic et al., 2018; Meiselman, 2013; Sveinsdóttir et al., 2009).

The more commonly known "Coca-Cola test" asks consumers to compare and rank two or more blindly (not labeled) tasted products. The Coca-Cola test is a simpler, less costly, and more natural way of understanding consumer preferences (Paulsen et al., 2012). However, the "Coca-Cola test" fails to compare various treatments or experiments to one another (e.g., preparation or processing differences). Knowing consumers' sensory acceptance of different food preparations or taste profiles is helpful for successful marketing (Kos Skubic et al., 2018), including identifying the practical opportunities and limitations for moving into new product lines (Meiselman, 2013).

Alternatively, Varela et al. (2014) combined hedonic testing and allowances for open comments to find how much consumers like various flavors and taste profiles of coffee and carefully study consumers' opinions. This technique revealed the main factors underlying the consumers' liking and allowed for customer segmentation or "clustering" to design marketing strategies and create new products. Additionally, to measure consumer reactions to several varieties of apples, Galmarini and Mehinagic (2012) used untrained consumers, a hedonic survey and allowed for qualitative assessments of consumers' ''likes'' or ''dislikes.''

The convenience of the Coca-Cola test, harnessing qualitative assessments, using untrained consumers inspired my unique methodology. I wanted a research design that would be more representative of real-world consumer-food interactions (nonblind), more inclusive of mixed methods, and less costly than using trained taste testers in a formal experiment tasting room. As such, my research design is directional and practical. Industry, including research and development teams, can easily replicate my research design and swiftly analyze the results with minimal statistical expertise. Additionally, my approach presents a low-cost way of assessing consumer likeness and preferences for one product over another and can guide future product upgrading and marketing strategies.

Methods.

I investigated consumers' experience eating Pacific herring and whether preparation styles influenced the “liking” of Pacific herring at a public venue and tasting event – the Bay Model Visitor Center in Sausalito, California, and the Pacific Herring Festival – for two consecutive years. I used a survey tool with a 6-point hedonic scale (1=dislike very much; 2=dislike; 3=dislike a little; 4=like a little; 5=like; 6= like very much) and a comments box that measured six sensory variables: appearance, color, aroma, taste, texture, and overall liking a convenience (Appendix B). I also used a convenience sample of taste testing subjects and nonblind (labeled) herring products treated (prepared) in nine different ways.

Once surveys were collected, I entered responses into Excel and R to summarize the social characteristics and demographics of the taste-tasting subjects. Then, I created histograms to understand the distribution of sensory responses for all Pacific herring products to answer the question: do consumers like Pacific herring? Next, I calculated the sample means, standard errors, and standard deviations[17] to compare treatments and answer the question: do different preparations (treatments) influence likeness? To further examine this question, I created histograms of the distribution of sensory responses for each treatment of the Pacific herring product. I also categorized qualitative consumer comments into "Like" or "Dislike." After binary categorization, I determined the number of mentions per category and calculated the total remarks per treatment and the proportions of positive and negative comments. My analysis of qualitative responses helped me better understand consumers' sensory acceptance of various food preparations or taste profiles for Pacific herring.

Lastly, I conducted paired sample t-tests using a 95% significance level to compare tasting subjects' responses to various treatments (preparations) across six sensory variables. Results from the paired sample t-test were not significant and are not presented in this paper. Supplemental data is available upon request.

Testing location.

I surveyed consumers over two years, January 2018 and January 2019, at the Pacific Herring Festival at the Bay Model Visitor Center, Sausalito, California (historically one of the largest commercial fishing ports for Pacific herring in the 20th Century). The Pacific Herring Festival brings together several chefs and restaurateurs who prepare Pacific herring in various ways for consumers and visitors to taste, mostly in celebration of the Pacific herring's cultural and historical significance to the San Francisco Bay Area. Tasting sessions occurred from 10 am to 2 pm during the Pacific herring festival in mid-January 2018 and

[17] Treatments 8 and 9 were left out of the statistical analysis because of the small number of survey responses (see Table 6).

2019. Image 3 shows a photo of the venue, climate, setting, and festival participants in 2019.

Image 3– Testing Location: Bay Model Visitor Center, Sausalito, California.

Survey instrument.

The surveys measured consumers' sensory experience to six attributes: appearance, color, aroma, taste, texture, and "overall linking" of eating herring products with nine treatments. I used untrained tasting subjects and distributed the survey upon initial contact.

Rather than using a 9-point hedonic scale, I measured sensory responses and consumer likeness to Pacific herring prepared in nine different ways (nine treatments) using a 6-point hedonic survey instrument (1=dislike very much; 2=dislike; 3=dislike a little; 4=like a little; 5=like; 6= like very much)[18]. I narrowed the respondents' choice to analyzed food products with greater certainty. I excluded a neutral evaluation selection to eliminate respondents' opportunities for "dumping ground " answering (Chyung et al., 2017). This "forced-choice"

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[18] A copy of the survey instrument is available as supplemental material in Appendix B at the conclusion of the dissertation manuscript. My survey is considered a hedonic scale as opposed to Likert scale because it asks subject to provide scoring for individual sensory variables and an overall liking.

scale removes the temptation of respondents' to select a midpoint if their actual evaluation is not neutral.

My surveys also encouraged qualitative responses, such as written comments or informal interviews, from taste testing subjects and participants at the Pacific Herring Festival in Sausalito, California. For example, the subjects least preferred Treatment 6, but one commented that her "7-month-old baby loved it." A target consumer for Treatment 6 could be mothers of young eaters rather than those demographically like most taste-testing subjects.

Taste Testing Subjects

Without incentives, a convenience sample of taste testing subjects agreed to complete my surveys upon initial contact (Image 4). Taste testing subjects self-selected herring products with various treatments that appealed to them, influencing the sample size of survey responses per treatment. Although tasting subjects self-selecting products in a nonblind experiment are atypical in sensory science, they are arguably more representative of purchasing conditions.

Before starting the survey, I gave participants a verbal explanation of the study, including the purpose, methods, implications, and instructions for the testing protocol. Participants evaluated self-selected herring products with various treatments (Image 5), which may account for the variation in sample size (n) or responses per treatment type. I administered surveys while or right after the taste testing subjects ate their plate of herring products to reduce recall errors.

Image 4 – Taste testing subjects and survey administration.

Image 5– Typical dish of herring products with various treatments surveyed.

Treatments and preparation.

Testing subjects had the opportunity to taste test Pacific herring prepared in nine different ways: (1) Herring Bahn (*hb*); (2) Herring Escabeche (*he*); (3) Crostini di Aringhe Sotto (*ca*); (3) Herring tacos (*ht*); (5) Paella (*p*); (6) Sidesalat Tea Sandwich (*ss*); (7) Smoked Herring (*sh*); (8) Fish on a stick; and (9) Fried Milt. Pacific herring products were processed and prepared by the chefs who served them (Imagines 6 – 14). The same vendor provided unprocessed herring products to all participating chefs. Herring products were taste tested on the same day of preparation and immediately after consumption. Table 8 describes and depicts all treatments and number of survey responses.

Table 8– The relationship between herring product name and number, food description and preparation (treatment), number of survey responses (n), and images of the products surveyed.

Product	Treat ment#	Food Description	n=	Image of the herring product (Imagines 6-14)

Herring Bahn Mi (hb)	1	Vietnamese Sandwich	26	 *Image 6 - Herring Bahn Mi (hb).*
Herring Escabache (he)	2	Marinating fried fish with herbs, lemon, and olive oil	8	 *Image 7- Herring Escabeche (he).*
Crostini di aringhe sotto (ca)	3	Pickled herring and onions on a crostini	8	 *Image 8- Crostini di aringhe sotto (ca).*
Herring tacos (ht)	4	Grilled herring fillets served in a corn tortilla with cabbage slaw	12	 *Image 9 - Herring tacos (ht).*
Paella (p)	5	Rice with veggies, fish and roe	14	 *Image 10 - Paella (p).*

Sidesalat tea Sandwich (ss)	6	(Red paste) herring + potatoes + beets	27	 Image 11 - Sidesalat tea sandwich (ss).
Smoked Herring (sh)	7	Applewood hot smoked	25	 Image 12 - Smoked Herring (sh).
Fish on a stick	8	Whole fish smoked, bbq outside on a stick	1	 Image 13 - Fish on a stick.
Fried Milt	9	Roes of male herring, often known as 'soft herring roe.'	3	 Image 14 - Fried Milt (male roe).

i. *Treatment 8 (Fish on a stick) and 9 (fried milt – male roe or caviar) were not included in the analyses because of the small sample size.*
ii. *The author took all images except for Treatments 3, 4, and 9; in these cases, photographs were taken from various internet sources: the herring taco was sourced from recipetineats.com, crostini di aringa was sourced*

from gustissimo.it/, and the fried soft roe imagine from prawncocktailyears.com.

Results.

Sample testing subjects were equally male and female, frequently cooked and prepared meals at home, and ate seafood at least two times a week, which is also the minimum suggested dietary guidelines.

Nearly all products tasted and surveyed, regardless of preparation, received mean scores of above five (1=dislike very much; 2=dislike; 3=dislike a little; 4=like a little; 5=like; 6= like very much, indicating that subjects generally "liked" Pacific herring. Preparation was not a significant factor in determining likeness, but the distribution of responses showed that Treatments 3 (escabeche) and 4 (tacos) were the most liked by tasting subjects, and Treatment 6 (tea sandwiches) were the least liked.

The means and differences of means of the various treatments were nominal. Still, the assessment of tasting subjects' qualitative comments (Table 9) showed that Treatments 1 and 7 had the most positive comments, including "good flavor," "good or great," and "tasty." Treatments 2 and 5 had the second most positive comments, including "enjoyable." Treatments 2 and 7 were the only Treatments that received a "favorite" comment. Most negative comments were about ingredients other than the Pacific herring in the product dishes, such as the sauces, bread, or spiciness. However, the taste testing subjects disliked bones approximately 16% of the time.

Participation in the survey and description of taste testing subjects

Critical information about target markets and lead consumers was revealed in their social characteristics. Although using a convenience sample of taste testing subjects can be unrepresentative of the population, it can also represent a potential target market, “early adopters,” or lead consumers. Lead consumers are users whose needs or preferences often become general in a marketplace in the future (Herstatt & Von Hippel, E., 1992; Hialager et al., 2015; Morrison et al., 2000).

In this case, subjects knowingly attended a festival where a lot of one product, Pacific herring, would be served and showed an affinity for and interest in eating and celebrating seafood and the working waterfront of Sausalito. Their preferences can be indicative of a potentially untapped market. By tracking the social characteristics of the taste testing subjects at the Pacific Herring Festival, we can better understand how to define lead consumers or possibly identify early adopters interested in eating forage fish. Understanding the tasting subject’s demographics can also lead to improved success ratings of new product concepts (Herstatt & Von Hippel, E., 1992; Hialager et al., 2015; Morrison et al., 2000), improve product success, and provide innovations for target marketing.

Furthermore, suppose tasting subjects showed a greater propensity towards eating atypical seafood options and did not like a particular item or preparation. In that case, there is a high likelihood that the “average” consumer will also dislike that product. For example, my results showed that tasting subjects rarely self-selected whole fish (Treatment 8) or roe (Treatment 9). Suppose lead seafood eaters rarely selected whole fish or roe products. In that case, it will be very difficult or almost impossible for average consumers to like, select or purchase whole fish or roe products.

As part of the 2018 and 2019 surveys, tasting subjects were asked demographic questions, including their gender, age, and patterns of engaging with food (e.g., cooking, shopping, eating). Statistical results for comparisons of taste testing subjects' demographics across both survey years are reported in Table 9.

Table 9 – Summary statistics of taste testing subjects.

		2018 (n=16)	2019 (n=30)
Sex Distribution			
	Male	40.00%	46.67%
	Female	40.00%	53.33%
	Not Specified	20.00%	0.00%
Age Distribution			
	25-32	26.67%	4.26%
	33-39	0.00%	15.96%
	40-49	6.67%	31.91%
	50-65	53.33%	22.34%
	65+	13.33%	25.53%
Purchasing Groceries (frequency)			
	1x/month	0.00%	0.93%
	2x/month	13.33%	1.85%
	1x/week	46.67%	30.56%
	2x/week	26.67%	48.15%
	4x/week	13.33%	18.52%
Preparing Meals (frequency)			
	1x/month	6.67%	0.00%
	2x/month	0.00%	0.00%
	1x/week	6.67%	4.35%
	2x/week	13.33%	8.70%
	4x/week	73.33%	86.96%
Eat Seafood (frequency)			
	1x/month	6.67%	0.96%
	2x/month	33.33%	96.20%
	1x/week	13.33%	17.31%
	2x/week	26.67%	57.69%
	4x/week	20.00%	14.42%

Californian lead consumers "like" Pacific herring

Nearly all herring products tasted and surveyed, regardless of preparation, received mean scores of above five (1=dislike very much; 2=dislike; 3=dislike a little; 4=like a little; 5=like; 6= like very much). Statistical results for sample means, standard deviation, and standard error are reported in Table 10.

Table 10– Statistic summary for all treatments across response variables.

		Response Variables					
Treatments		*Appearance*	*Color*	*Aroma*	*Taste*	*Texture*	*Overall Liking*
1	mean	5.308	5.538	5.500	5.538	5.385	5.440
	SD	0.736	0.508	0.583	0.582	0.697	0.583
	Std Error	0.144	0.100	0.114	0.114	0.137	0.117
	n =	26	26	26	26	26	25
2	mean	5.250	5.500	5.500	5.750	5.625	5.750
	SD	1.035	0.756	0.535	0.463	0.518	0.463
	Std Error	0.366	0.267	0.189	0.164	0.183	0.164
	n =	8	8	8	8	8	8
3	mean	5.375	5.250	5.000	5.375	5.125	5.250
	SD	0.744	0.707	0.756	0.744	0.835	1.035
	Std Error	0.263	0.250	0.267	0.263	0.295	0.366
	n =	8	8	8	8	8	8
4	mean	5.364	5.455	4.909	5.667	5.750	5.667
	SD	0.674	0.820	1.814	0.492	0.452	0.492
	Std Error	0.203	0.247	0.547	0.142	0.131	0.142
	n =	11	11	11	12	12	12
5	mean	5.286	5.214	5.357	4.929	5.214	5.231
	SD	0.611	0.802	0.633	1.592	0.893	0.927
	Std Error	0.163	0.214	0.169	0.425	0.239	0.257
	n =	14	14	14	14	14	13
6	mean	5.037	5.259	4.923	4.778	4.667	4.778
	SD	0.759	0.526	0.977	1.450	1.359	0.934
	Std Error	0.146	0.101	0.192	0.279	0.261	0.180
	n =	27	27	26	27	27	27

7	mean	5.360	5.292	5.417	5.520	5.360	5.417
	SD	0.700	0.859	0.654	0.872	0.810	0.776
	Std Error	0.140	0.175	0.133	0.174	0.162	0.158
	n =	25	24	24	25	25	24

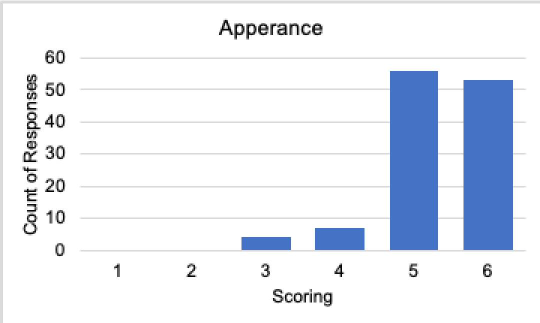
Although there was no significance between the sample means of sensory attributes across treatments, the standard deviation (variance in answers) was most for Treatments 3, 5, and 6, and the standard error was the most for Treatment 4 with sensory attributes color and aroma. Color, taste, and texture showed higher response variances across all treatments than the other sensory attributes.

Preparations had differences in sample sizes, which could be partly influenced by the subject's self-selecting herring products (nonblind experiment) because some preparations (treatments) were more enticing than others. For example, Treatment 8 (whole fish) was evaluated once, and Treatment 9 (roe product) was evaluated thrice; this could also imply that Californian consumers are apprehensive about selecting whole fish and caviar products. In contrast, Treatments 1 and 6 (both sandwiches) and Treatment 7 (smoked fish) – arguably more familiar products to Americans – were most selected and evaluated.

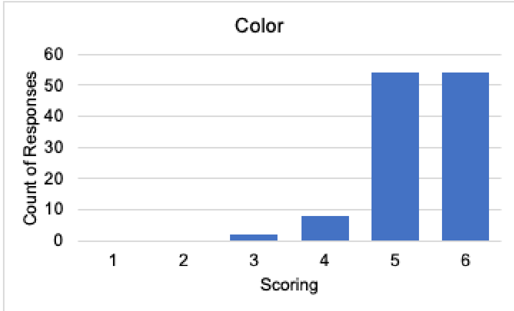
The distribution of survey responses showed that most responses were equal to or higher than a five for all treatments across sensory variables, indicating an overall “likeness” or positive sensory experiences across all variables and treatments. Responses showed the most negative responses towards aroma and texture variables. The distribution of survey responses for all treatments across sensory variables for *(a) appearance, (b) color, (c) aroma, (d) taste, (e) texture, and (f) overall liking* are reported in Figure 10.

Figure 10 – Distribution of survey responses for all treatments across sensory variables for (a) appearance, (b) color, (c) aroma, (d) taste, (e) texture, and (f) overall liking.

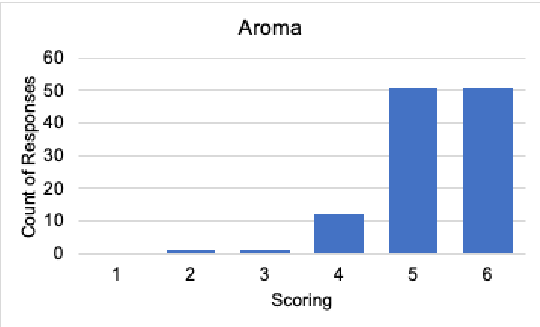
(a) Distribution of survey responses for all treatments for appearance



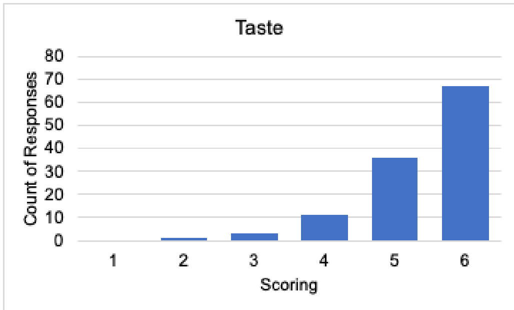
(b) Distribution of survey responses for all treatments for color



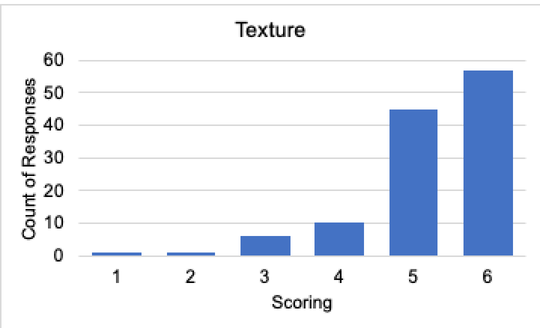
(c) Distribution of survey responses for all treatments for aroma



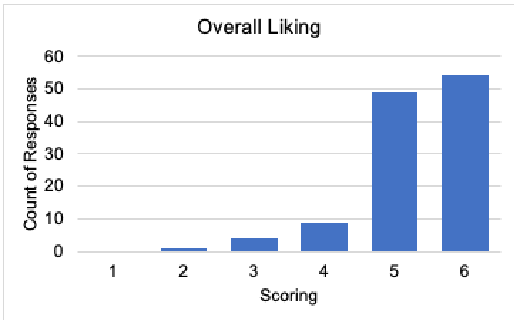
(d) Distribution of survey responses for all treatments for taste



(e) Distribution of survey responses for all treatments for texture



(f) Distribution of survey responses for all treatments for overall liking

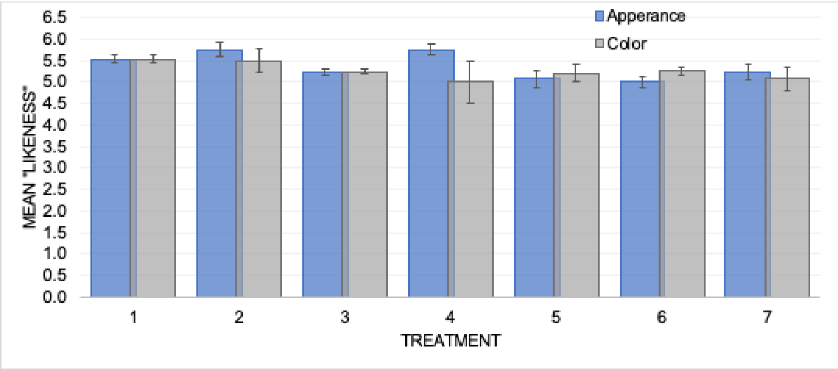


Treatments are not significantly different but influenced likeness.

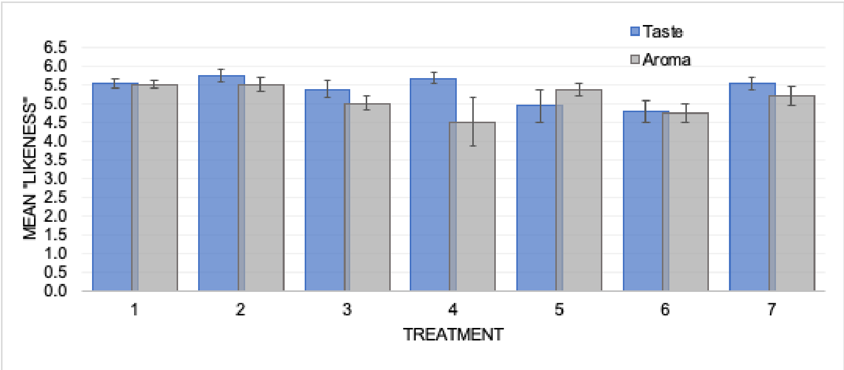
Although the differences between means are not statistically significant, treatments influenced consumer likeness. They showed preferences for one treatment over the other. Statistical results for the sample mean and standard error are reported in Figure 11 below.

Figure 11- Differences of likeness for six sensory attributes across various treatments for the following paired attributes: (a) appearance and color, (b) aroma and taste, and (c) texture and overall liking. Error bars denote how far the mean value of a sample set of data is likely to be from the overall mean value.

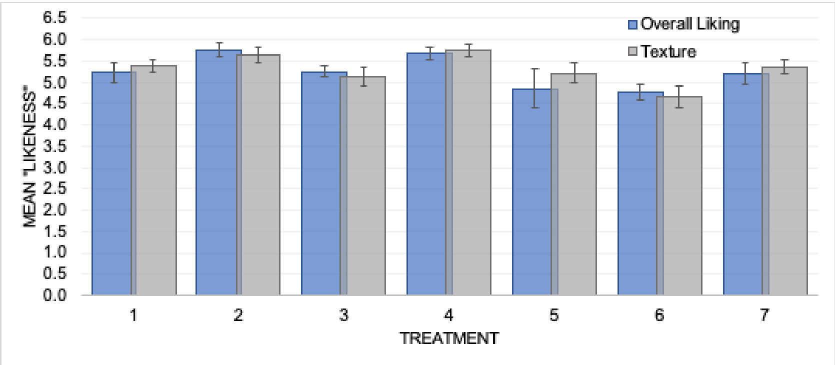
(a) Comparison of likeness for the paired attributes' appearance and color



(b) Comparison of likeness for the paired attributes' aroma and taste



(c) Comparison of likeness for the paired attributes' texture and overall liking



Interestingly, the analysis above showed little difference between means for all treatments across the following paired sensory features: appearance and color, aroma and taste, and texture and overall liking (Figure 11a-c). The similarities of means across paired responses variables point toward the idea that consumers may have difficulty distinguishing between the sensory response to appearance and color, aroma and taste, and texture and overall liking. If consumers don't like the aroma, they too may not like the taste and vice versa. Also, if consumers like or prefer a particular texture, that could influence their overall "liking." More research is needed to substantiate this hypothesis.

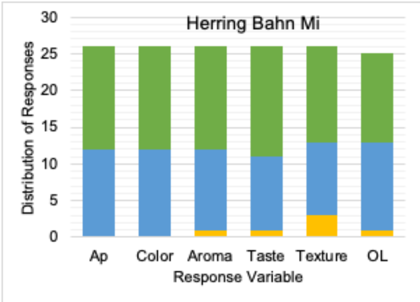
Treatments 1 (Bahn sandwich) and 2 (escabeche) received minor negative responses across all variables and were the most liked. Treatment 6 (pickled herring salad sandwiches) received the most negative responses across all variables and was the least liked. For response variables taste and overall liking, Treatments 2 and 4 (taco) were the most desired and had no negative responses. Statistical results for the distribution of survey responses by the sensory variables for each various treatment are reported in Figure 12.

Figure 12 – Distribution of survey responses by the sensory variables for (a) legend; (b) treatment 1; (c) treatment 2; (d) treatment 3; (e) treatment 4; (f) treatment 5; (g) treatment 6; and (h) treatment 7. ("Ap" means appearance and "OL" means overall liking)

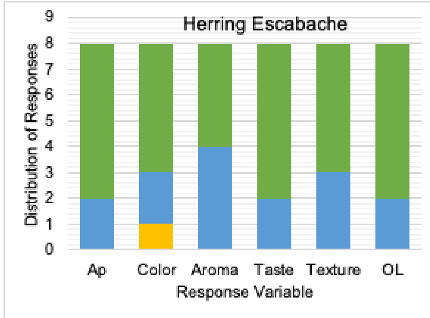
(a) Legend for all subsequent figures

- Like very much
- Like
- Like a little
- Dislike a little
- Dislike
- Dislike very much

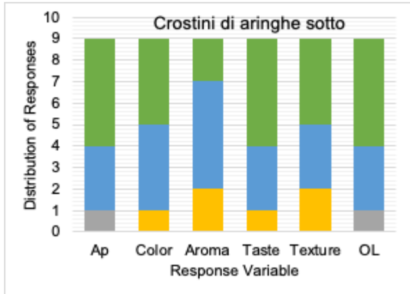
(b) Distribution of survey responses by sensory variable for Treatment 1



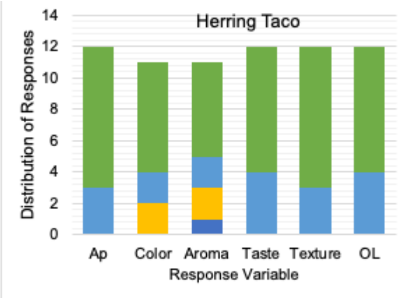
(c) Distribution of survey responses by sensory variable Treatment 2



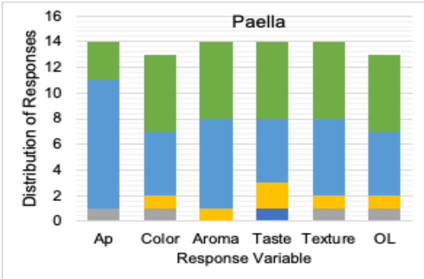
(d) Distribution of survey responses by sensory variable for Treatment 3



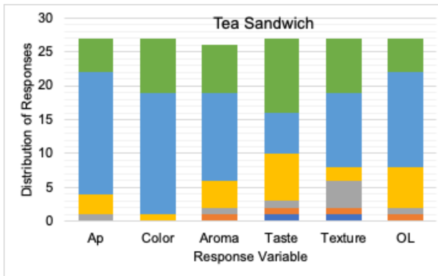
(e) Distribution of survey responses by sensory variable for Treatment 4



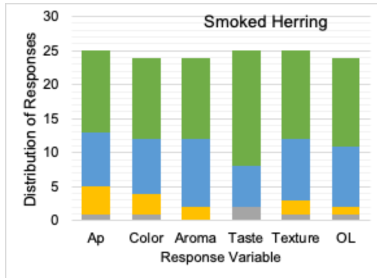
(f) Distribution of survey responses by sensory variable for Treatment 5



(g) Distribution of survey responses by sensory variable for Treatment 6



(h) Distribution of survey responses by sensory variable for Treatment 7



Qualitative assessments showed more positive comments (48%) than negative comments (22.5%) by lead consumers (or tasting subjects). The qualitative assessment showed that Treatments 1 and 7 had the most positive comments, including "good flavor," "good or great," and "tasty." Treatments 2 and 5 had the second most positive comments, including "enjoyable." Treatments 2 and 7 were the only Treatments that received a "favorite" comment. Treatment 4 received no negative comments, and Treatment 6 received the most negative comments. Most of the negative comments were not about the Pacific herring but rather about the other ingredients used in the sampling dishes (e.g., bread, sauce) or explained that other ingredients hid the fish flavor (i.e., "too mild"). Table 11 summarizes tasting subjects' qualitative comments.

Table 11 – Like and dislike comments mentioned by the consumers for each Treatment. The number of mentions, the total mentions per treatment, and the proportion of each.

Treatments	1	2	3	4	5	6	7	%*
Like comments								
Delicious	2							5.13%
Flavor	2						1	7.69%
Good/Great	2			1	3	2	1	23.08%
Liked	2	2						10.26%
Enjoyed		1			1			5.13%
Favorite		1					2	7.69%
Excellent		1						2.56%
Easy to eat			1					2.56%
Presentation		1	1					5.13%
Herring focused				1			1	5.13%
Fresh				1				2.56%
Loved			1	1	1	1	1	12.82%

Rich					1			2.56%
Tasty						1	2	7.69%
TOTAL	8	6	3	4	6	4	8	39
								48.75%
Dislike Comments								
Too spicy	1							5.56%
Bones	1	1					1	16.67%
Too fishy	1						2	16.67%
So-so			1			1		11.11%
Texture					1	1		11.11%
Too mild in fish flavor						3		16.67%
Wasn't satisfying						1		5.56%
Raw (undercooked)						1		5.56%
Too tough							2	11.11%
TOTAL	3	1	1	0	1	7	5	18
								22.50%
Unrelated to the fish	6	2	1	4	2	5	3	23
TOTAL								28.75%

i. *Percentage of mentions concerning the total number of like or dislike comments.*

Discussion

My research answers the following two research questions: do consumers like Pacific herring, and does preparation affect or influence likeness? I used sensory science surveys, interviews, and analysis of the resulting data to answer these questions. This paper builds upon years of analysis of the Pacific herring value chain for this dissertation, where ethnographic research and interviews with transnational value chain actors conveyed a pessimistic view of the economic success of the Pacific herring industry. One science advisor claimed, “the fishery is dying. The permits are rendered worthless” (Valencia. S., 2018). Another interviewee explained, “No one is going to spend $17M on a fish smoking facility for herring” (Billik. B., 2017). Understanding their interpretations of the Pacific herring industry motivated me to connect measurable consumers' preferences and practical understandings for upgrading[19].

My results show that, regardless of preparation (treatment), nearly all Pacific herring products received mean scores of five or better and that treatment was not a significant factor in determining likeness. Overall, lead consumers’ qualitative assessments were more positive than negative across all treatments. However, when examining histograms across treatments and qualitative evaluations, treatments did influence “likeness:” Treatment 6 (tea sandwiches) was the least liked, whereas Treatments 2 (escabeche) and 4 (tacos) were the most liked.

My findings showed that consumers did not prefer smoked herring over other options, so a smoking facility is unnecessary. Still, tasting testing subjects showed preferences for filleted products, a dislike of having bones in the fish, and that texture influences overall liking. My results showed that to create a product that Californian lead consumers want to eat, whole fish should be filleted– with or without skin– and jarred or preserved with olive oil and lemon juice in the case of

[19] Upgrading, a central theme of commodity chain studies, provides a theoretical approach for investigating firms, countries, or regions moving into higher-value production activities to increase the benefits of participating chain actors (Gereffi, G., & Fernandez-Stark, K., 2016).

escabeche. However, Pacific herring are currently harvested as whole fish in gillnets in San Francisco Bay, California. fish are pumped from the boat onto land using a large pump (similar to a wet dry vacuum). The large pump moves the fish from the boat onto a conveyer belt and into large plastic totes for icing. The totes are then moved to Washington or other locations for cold storage. There is currently no stateside processing other than icing and freezing.

Limitations of this study are that it does not explore consumers' motivations for purchasing other than taste, nor does it ask questions about race and culture, which seem to influence seafood purchasing. Terry et al. (2018) showed that 20% of adults consumed seafood at least two times a week, and those non-Hispanic Asian adults (41.2%) consumed seafood at least twice as much as non-Hispanic white (18.7%), non-Hispanic blacks (22.6%), and Hispanic (14.5%) adults. Love et al., 2022 noted regional differences influence seafood purchasing patterns and that fresh seafood makes up the largest percentage (43%) of sales revenue. Shamshak et al., (2019) reinforced that seafood consumption in the U.S. is becoming more, not less, homogeneous. Understanding the social psychology driving seafood purchasing rather than demographics and taste-related motivation would improve understanding of the limitations and opportunities for moving underutilized forage fish into mainstream American consumption.

Product upgrading is undoubtedly necessary for moving underutilized forage fish into U.S. consumer markets, but it is challenging to do it profitably and sustainably. For the industry to move into more sophisticated product lines, value chain participants will likely need to invest in a new or more skilled labor force or production system (e.g., filleting machine) that can efficiently and effectively fillet small, bony fish (product upgrading[20]). Value chain actors might also need to pursue processing[21] or functional upgrading[22]. Regardless, investing in additional labor or physical processing infrastructure could, in turn, require larger markets that take advantage of economies of scale, thereby altering the ecological and economic tradeoffs throughout the industry.

Conclusions

My results show that Pacific herring are "liked" as food with little statistical significance to preparation beyond a preference for filleted product forms. My research defined crucial characteristics of possible early adopters. It can be used to improve socio-cultural and practical strategies to increase forage fish consumption and marketing in California or America more broadly.

My research suggests that taste or enjoyability are not crucial factors limiting the consumption of underutilized forage fish in the U.S. However, industries' current product forms of Pacific herring in California (i.e., whole frozen) do not align with consumer preferences. My results showed that moving Pacific herring from boat to plate requires the industry to move herring products into a form that early adopter consumers (lead users) prefer and/or are familiar with, such as filleting or jarring.

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[20] Product upgrading is when industry moves into more sophisticated product lines (Gereffi, G., & Fernandez-Stark, K., 2016).

[21] Processing upgrading transforms inputs into outputs more efficiently by reorganizing the production system or introducing superior technology (Gereffi, G., & Fernandez-Stark, K., 2016).

[22] Functional upgrading acquires new functions (or abandons existing functions) to increase the overall skill content of the activities (Gereffi, G., & Fernandez-Stark, K., 2016).

Moving into more sophisticated product forms could require or incentivize value chain actors to “move up” into new or improved end-marketing strategies (Havice & Campling, 2013), such as community-supported fisheries or fishers trying to sell off their boats. More research on the motivations driving consumer seafood purchasing beyond that of taste, including evaluations of seafood literacy, is needed to move the U.S. towards increasing direct human consumption of forage fish.

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Conclusion

As I step away from the dissertation process, I feel that seafood system sustainability, seafood security, and equity in seafood value chains are unproductively torn between two worlds: one of fisheries and one of food systems. Fisheries research often lacks the critical analysis of political ecology and human geography used to understand systemic effects and feedback related to the food system and natural resource management. Global commodity chain and food studies lack epistemological explorations into fisheries. To bridge the gaps between fisheries conservation and sustainable food systems literature, I engaged several bodies of literature: fisheries, aquaculture, political ecology, the political economy of food, commodity chain studies, geographies of consumption, and sensory science. Together, these bodies of literature helped frame my research design, including my research questions and data collection methods.

My research's primary aim was to understand the environmental, political, socioeconomic, and spatial complexities fostering a present-day mismatch of supply and demand for forage fish – an underutilized, ecologically abundant, nutritious seafood option. I investigated food availability and accessibility issues, power asymmetry in the global seafood economy, and consumer preferences for underutilized forage fish by conducting a value chain assessment and examining the historical political and economic trends in the Pacific herring fishery in California. My frameworks laid theoretical and methodological pathways that (1) contributed to debates deconstructing human-nature binaries in political ecology, (2) expanded global value chain studies conceptions of governance, and (3) presented methodological alternatives for understanding consumers' preferences.

My multidisciplinary dissertation uncovered a deep understanding of multiscalar forage fish commerce, built bridges between fisheries and food studies, and introduced several hypotheses for future research within political ecology and global commodity chain studies.

First, I established a framework that combined the four pillars of food security and fisheries data. Then, I applied this framework and reviewed over fifty years of fisheries policy to assess the linkages between access to natural resources, food system activities (e.g., production, exchange, etc.), and food system outcomes (e.g., wages, employment, food security). My research explored fisheries management, socio-economic drivers of fishing, and possibly reversing declining utilization trends in fisheries. Some fisheries management strategies used in the Pacific herring fishery constrained seafood products form, narrowed marketing channels, and inadvertently limited seafood availability and access. Fisheries management often focuses on pre-harvest conditions to determine quotas, but the mechanisms used in fisheries management undoubtedly have downstream implications on the seafood system; they choose how much, in what ways, when, and where fish can be harvested. Reversing the negative ecological, economic, and social trends in seafood systems requires a reorientation of fisheries management that focuses more on food systems activities and outcomes. Still, little research has proposed a way to do so. My research barely scratched the surface of understanding how fisheries management connects to fisheries access but proposes a route for a better understanding of how the two influence one another. Critical food study scholars and programs could undoubtedly expand upon my findings.

Next, I introduced a new governance structure – relationally confined– into the global value chain and production network theories, which previously ignored fisheries (apart from Elizabeth Havice and Micheal Fabinyi). The Pacific herring seafood trade transnational exporters and international seafood traders captured Pacific herring supply through international sales contracts, which provided cash incentives to early midchain actors – who consequently have high levels of production risk – based on neoliberal production paradigms. Meanwhile, the relationships between Pacific herring value chain actors centered on secrecy and reciprocity. Early midchain actors kept knowledge of fishers (suppliers) secret from exporters and of exporters (markets) secret from fishers. Together, this relational and captive governance structure –relationally confined– created an uneven power dynamic. Value chain actors were simultaneously incentivized to create social relationships in the hopes of knowledge sharing. Gaining knowledge of supply or available buyers could reduce one's economic dependence upon a few anonymous transnational exporters. Keeping knowledge secret perpetuated captive value chain structures.

This relationally confined governance structure influenced seafood's spatial and economic distributional outcomes. Global sales contracts with transnational exporters create control supply and limit opportunities for seafood localism. Fish harvested in the U.S. were contractually destined to end up elsewhere. This thesis could be further explored in other fisheries or industries, namely those that center on commodities globally traded in high volumes for low values and also sought out for consumption in producing states, such as corn and soy. It would also be interesting to understand how this governance structure interplays with global environmental change and geopolitics. These fruitful explorations can build upon my critique and expansion of global value chain governance and the application of global production theory to a multiscalar seafood value chain.

I suggested that rather than focusing on the appropriateness of geographic outcomes of seafood systems (local versus global), scholars should focus on the power dynamics that affect the fish trade, paying special attention to "power in the middle" (e.g., concentrations and consolidation of intermediaries) as a central component of the fish trade. Applying this thinking to the rapid growth of marine aquaculture and the newly approved use of red algae as an additive to feed for dairy cattle in California to reduce methane emissions could illuminate an inevitable and or dramatically destructive political-economic climates where Monsanto becomes one of the largest owners of marine spaces. My definitions of power explained in Chapter 2 (e.g., secrecy, reciprocity, economic leverage through trade agreements) and proposed relationally confined governance are useful theoretical tools. My interventions can be used to examine the concentration and consolidation of intermediaries in emerging industries, such as aquaculture or plant-based meats. It can also help us understand the socio-pathways fostering or stifling socio-ecological and food system consequences.

Furthermore, I implicitly suggested that fish are authoritative yet unpredictable actors orchestrating human-nature outcomes in seafood commerce. Forage fish are a highly variable and vital ecological link in marine food webs: they are rich in nutrients, short-lived, and come and go with ocean currents. Additionally, they swim in big schools to protect their fitness and, by nature, are highly perishable and occur in supply gluts. Biological and ecological forage fish attributes present a set of obstacles that human value chain actors must confront to circumvent biophysical properties that require intensive, expensive, seasonal processing inputs. There are many research opportunities to deepen our understanding and explanations of fish as a central persuasive actor influencing global seafood commerce and the mismatch between forage fish production and consumption.

Finally, I drew from sensory science to measure consumers' sensory responses to or enjoyment of eating forage fish. I adapted sensory science experimental designs to be more inclusive of actual purchasing experiences, such as using nonblind samples, and outlined strategies that can be replicated swiftly and practically for product innovation. I surveyed consumers at a public venue and event who taste-tested several Pacific herring product forms with various treatments. I demonstrated that consumers “like" eating Pacific herring but prefer more sophisticated product forms (e.g., fileted product forms and dislike bones in the fish). I concluded my consumer research with a call for more attention to the institutional and industry limitations to moving forage fish into higher-valued activities (upgrading). More investigations of consumers' seafood purchasing motivations beyond taste, such as understanding the connections between culture, and race, are needed. More work defining and exploring the effects of seafood literacy on consumer decision-making would also be a worthwhile contribution to pieces of literature on alternative food networks, geographies of consumption, and fish as food research.

Beyond scholarly advancements, my research also suggested several practical socio-political pathways needed for a lasting positive impact on fisheries and food security. Gear switching allowances in fisheries policy, subsidized land use or zoning preferences, and communal or cooperatively owned, publicly maintained waterfront processing infrastructure could reduce the barriers to entry for vital seafood value chain actors. Exploring the successes and failures of how such socio-political pathways were previously used would be interesting: how they manifested or operationalized and to what extent they improved socio-economic outcomes. For example, have gear switching clauses preserved participant flexibility and insulated seafood systems from market shocks? What regions have used subsidized land use or zoning preferences for working waterfronts, and what were the impacts of such policies on the industry? Moreover, how were the benefits allocated? Was it equitable and inclusive?

Personally, my subsequent interests are twofold: to become more engaged in research on the connections between marine pollution, seafood consumption, and public health. For example, I am interested in exploring the comparisons and connections between high and low trophic species, environmental toxicity, and human health. This examination could analyze comparisons and effects of microplastics and mercury in Pacific herring, salmon, and tuna. I am also very interested in understanding policy action opportunities that engage more deeply with climate change. Understanding the pre- and post-harvest effects of spatial migration shifts of marine species, including equitable transfers of fishing rights and working waterfronts, is timely and essential. I would also like to investigate consumers' perceptions of pollution in seafood.

Regardless of the direction, this dissertation takes me or the academic research enterprise, I feel confident that I've achieved my aim. I answered several deeply misunderstood questions about the opportunities and limitations of using forage fish for direct human consumption in the United States, namely California– a leader in seafood consumption and value-added seafood production – and created several avenues for meaningful work across fisheries and food systems.

Appendix A – Semi-structured Interview Tool

Pacific Herring Commodity Chain Assessment in North Central California

Interview Guide

Introduction to the Project

Thank you for agreeing to participate in this interview. I'm doing this as part of a research project (which is part of my dissertation work at the University of California, Santa Cruz funded through the University of California through working as a professor's assistant. My project is titled *Give small fish a chance: a food systems framework for understanding sustainable fisheries, fishing communities, and seafood systems.* I'd like to better understand how the San Francisco Pacific herring fishery in North Central, CA works, and the connections between fishermen, markets, fisheries management, and the ecology of the fishery.

Informed Consent

Before we begin, I need to remind you of your rights as a participant in the study. First, your participation is voluntary. You can decline to participate or to answer questions without consequence, but please know that the more and better information I can collect, the more accurate the results of the study will be. Second, your identity will be confidential. While I will keep your name in case, I need to ask follow-up questions or to clarify a response, notes that I take from this interview will be labeled with a code rather than your name; only I will have access to the file that associates you with that code number. In reporting my results, I will present information in a way that does not enable you to be identified, unless I have your consent to do otherwise. Finally, if there is any information you would like to share with me that you would like to keep out of the study analysis, please say so, and I will be sure to treat it that way. **[Use the form below for consent].**

One thing on this sheet that I haven't mentioned is that I'd like to audiotape the interview so that I completely and accurately capture everything that we discuss. Once I make a transcript of the audio recording, the recording will be erased. If this is OK, go ahead and check that box.

Getting permission for data to be retained and used in future studies

Through this process, I'm trying to build my understanding of fisheries. Would it be OK for me to draw on your input for future studies or research that I might work on?

Pre-interview Questions

Before we begin the interview, do you have any questions about me, the project, or the interview?

If you have questions as we're talking, feel free to ask.

CONSENT TO PARTICIPATE IN RESEARCH

Introduction: You are invited to take part in a research study conducted by Stephanie Webb from the Department of Environmental Studies at the University of California, Santa Cruz. Before you decide whether or not to participate in the study, please read this form and ask questions if there is anything that you do not understand.

Description of the project: The purpose of the study is to gain a better understanding of the connections among San Francisco Pacific herring fishery activity, market forces, fishery management, species patterns, and abundance.

I would like to collect information that describes the factors that influence fishermen's decisions about when, where, and what they fish for, and where they sell their catch. I'm also interested in whether San Francisco Pacific herring fishermen fish in multiple locations, switch among species, and between markets, and how this ability or inability to shift influences their livelihood and income.

I'd like to better understand how the San Francisco Pacific herring fishery in North Central, CA works and better understand the connections between fishermen, markets, fisheries management, and the ecology of the fishery. My research is not being done to directly inform management or any regulatory changes in the fishery, but rather to understand the opportunities and limitations of expanding new markets for Pacific herring.

As part of the academic process, my research also intends to further scientific knowledge about the connections among people, communities, fisheries, and food systems and determine whether that knowledge can be used to enhance the fleet and ecological sustainability of the fishery.

What you will do in the study: If you decide to take part in this study, you will participate in a semi-structured interview at a time and place convenient for you. You will be asked questions about your knowledge and experience related to the San Francisco Pacific herring fishery. These may include questions about your fishing experience, general locations and times when you fish, your fishing gear, your fish sales, how your fishing activity has changed over time, and what influences your fishing decisions.

Time required: The interview will take approximately 1 hour with the potential for follow-up meetings if you are willing and able.

Risks or discomfort: I don't anticipate any risks associated with the study, but I will be asking you about your fishing operation, experience, and insights.

Benefits of this study: Although there will be no direct benefit to you for taking part in this study, your participation will contribute to increasing our knowledge about the connections among physical, biological, institutional, and socioeconomic factors that influence the San Francisco Pacific herring fishery to enhance the effectiveness of resource management.

Confidentiality: Your identity will be kept separate from the information that you provide and will not be used in any project products.

With your permission, I would like to record this interview so that I can make an accurate transcript. Once I have made the transcript, I will erase the recording.

I would like your permission to keep the data you provide for possible use in future research related to this study. If you agree, I will keep that information secure, and only use it for those specific purposes.

The decision to end participation at any time: Your decision to take part in this study is completely voluntary. Even if you decide at first to take part, you are free to change your mind at any time and quit the study without consequence to you. In addition, you are free to not answer any interview questions.

Rights and Complaints: If you have questions, please contact me, Stephanie Webb, UCSC, High Street, Santa Cruz, CA 95060; swebb1@ucsc.edu; (636) 577-4694. You may also contact the researcher supervising this work: Deborah Letourneau, UCSC, High Street, Santa Cruz, CA 95060; dletour@ucsc.edu, If you have any questions regarding your rights as a research participant, please contact the Office of Research Compliance or Administration at the UCSC at 831-459-1473 or orca@ucsc.edu.

Signature: Signing this document means that you understand the information given to you and that you voluntarily agree to participate in the research described above.

___ I agree to be interviewed.

___ I agree to have my interview audio-recorded.

___ I give my permission for my data to be retained and used in future studies.

____

Signature of Participant Date

____

Printed Name

Please sign both consent forms, keeping one for you.

Questions:

Institutional

1. How are you involved in the Pacific herring fishery? (Check all that apply)
    a. Fishermen
    b. Buyer
    c. Intermediary
    d. Broker
    e. Wholesaler
    f. Distributor
    g. Retailer
    h. Direct sales
    i. Fishery Manager
    j. Science
2. How would you describe the San Francisco Pacific herring fishery?
3. How do you feel that the Pacific herring industry has changed over time?
4. What motivates you to (not) participate in the fishery?
    a. In the '80s?
    b. In the last 10 years?
    c. Presently?
    d. Would you categorize this as social, economic, or political?

Markets

1. Once you land your catch, can you walk me through the process of getting it to a buyer?
2. Can you tell me what you know about what ultimately happens to your catch? Who uses (buys?) your catch? Where does your catch end up? For what?
3. Do you know what happens to male fish and the rest of the fish?
4. What other fish species can you catch while you're fishing for herring?

5. What other fish species can you catch using your herring gear?
6. Can you use your herring vessel for other fisheries?
7. Do you always sell to the same buyer? Why? Do most fishermen in this area sell to the same buyer? Why or why not?
    a. How do you price your buying/selling price?
    b. How has the price changed over time?
    c. How often does the price fluctuate in one season?
    d. How do you communicate with your buyer?
8. Have you changed your location or method of fishing/marketing for Pacific herring?
    a. How close are your markets?
    b. Where are they located?
    c. Do you process your product?
        i. How? Where?
9. Are you catching the full amount of quota?
    a. Why or why not?
10. What market forces most affect your business?
    a. Positive or negative?
    b. Recent or overtime? Year?
11. What do you think are the biggest challenges facing the herring industry?

Economic

1. Why do you think there are changes in market prices?
2. How do you think the market can be improved?
3. How much does it cost to participate in the fishery for one year?
    a. Fuel?
    b. Gear?
    c. Permits?
    d. Groceries?
4. How much would you need per ton to go fishing again?

5. Holding regulations constant, as quotas are now, how much would you need per ton to go fishing?
6. If someone wanted to get into the fishery, how much does a permit cost?
7. What are the challenges of having export markets?
    a. Do you need special licenses?
8. Silver Bay Seafood is selling 5oz cans of brined Atlantic herring at the new leaf. Do you think that is possible with Pacific herring?
9. Do you think there is an opportunity for new markets?
10. Have you heard of community-supported fisheries?
11. Do management decisions create obstacles for new markets?
    a. If so, how and which ones?

Quality and Value-added

1. Do you keep some fish for personal use? How often? Are there particular sizes you keep? Or particular conditions when you keep fish?
2. How do you define quality or "good fish" or "food roe"?
    a. Who sets/determines how quality is determined?
    b. How has this definition changed over time?
3. What does value-added mean to you?
4. Would you be interested in changing your handling methods, if you were paid a higher price for whole fish or fresh fish markets (e.g., sardines)?
5. Are there unspoken rules or norms that determine who you sell to?

Technology

1. What equipment is most important to your business?

    Observations

☐ ice machine ☐ boat/FV ☐ pump station ☐ cell phone

☐ smartphone ☐ totes ☐ retail counter ☐ transportation corridor

☐ warehouse ☐ fish finder ☐ hoist ☐ other

Intensification and Diversity

1. Do you participate in other fisheries?
2. What makes you want to switch from one fishery to another?
3. If so, what % of your total fishing portfolio is represented by Pacific herring?

Spatial and Temporal distribution of fishing effort

1. Can you help me to understand where and when you fish? now and in the past?
2. What type of changes, if any, have you seen in the Pacific herring fishery? Can you tell me about variability in the fishery within a season, between seasons, from year to year?
3. How do you decide where to fish? Do you fish in certain depths? Do you generally fish in kelp beds or outside?
4. Have the places that you fish changed since you started commercially fishing? How and why?
5. How do ocean conditions play a role in determining if you fish and where you fish? Do they influence what you target or catch?
6. How do distances (at sea and proximity to markets/buyers) play a role in determining if you fish and where you fish?
7. What are some of the things that influence your decision of whether or not to commercially fish in the Pacific herring fishery on a given day? What things influence your decision to move to another fishery?

Fishery management

1. Have you ever been involved in state or federal fisheries management? Can you tell me about that experience?
2. Did you know CDFW is redoing the FMP? Did you participate in the survey?

    a. In what capacity were you involved?
    b. What limits your involvement in management?
2. What permits/licensing is necessary for you to fish/sell/buy fish?
    a. What is most/least important?
3. What political action(s) have the biggest impact on your business?
4. What things do you wish managers or others had a better understanding of? Is there anything you would like them to know about the fishery?

<u>Closing Questions/Comments</u>

I think we've covered almost everything I wanted to ask you, and you've given me a lot of information to think about. Before we finish, are there any questions you have for me, or *is there anything else you think I should know about the fishery, your role in it, or any of the other things we've discussed?*

Are there other people knowledgeable about the fishery that you'd suggest that I talk to for this research?

[STOP AUDIO RECORDER]

<u>Next Steps and Follow-up</u>

I want to quickly share my plans with you. I hope to complete the interviews by July 2018. As I work with the information that I've collected, I may have follow-up questions. Would it be all right for me to contact you? If so, what's the best way – email, phone, mail? [record this info on a separate sheet – not with interview notes]

It’s been great talking with you, I really appreciate your time and input. Feel free to contact me at any time with questions or comments: 636-577-4694

Appendix B – Hedonic Survey Tool

CONSENT TO PARTICIPATE IN RESEARCH

Introduction: You are invited to take part in a research study conducted by **Stephanie Webb from the Department of Environmental Studies at the University of California, Santa Cruz**. Before you decide whether or not to participate in the study, please read this form and ask questions if there is anything that you do not understand.

Description of the project: The purpose of the study is to gain a better understanding of the connections among San Francisco Pacific herring fishery activity, market forces, fishery management, species patterns, and abundance. I would like to collect information that describes the factors that influence the Pacific herring commodity chain, specifically, consumption. I am interested in how consumers engage with various herring projects using their senses.

I'm doing this as part of a research project (which is part of my dissertation work at the University of California funded by the University of California, titled *The Political Ecology of Small Fish: a food systems approach to understanding sustainable fisheries and fishing communities*. In doing this project, I'd like to better understand how the San Francisco Pacific herring fishery in North Central, CA works, the connections between human aspects of the fishery (fishermen, markets, and fisheries management), and the ecology of the fishery

My research is not being done to directly inform management, regulatory changes in the fishery, or seafood company. Major goals are instead to further scientific knowledge about the connections among people, communities, fisheries, and food systems and determine whether that knowledge can be used to enhance the sustainability of fishing communities, fisheries, and seafood systems.

Time required: The interview will take approximately 5 minutes per herring sample.

Risks or discomfort: I don't anticipate any risks associated with the study, but I will be asking you about your experience while eating samples at the Herring festival.

Confidentiality: The survey is anonymous; however, I have asked for basic demographic information as well as three purchasing behavior questions. Please answer these to the best of your ability. I would like your permission to keep the data you provide for possible use in future research related to this study. If you agree, I will keep that information secure, and only use it for those specific purposes.

The decision to end participation at any time: Your decision to take part in this study is completely voluntary. Even if you decide at first to take part, you are free to change your mind at any time and quit the study without consequence to you.

Rights and Complaints: If you have questions, please contact me, **Stephanie Webb, UCSC, High Street, Santa Cruz, CA 95060; swebb1@ucsc.edu; (636) 577-4694.** You may also contact the researcher supervising this work: Deborah Letourneau, UCSC, High Street, Santa Cruz, CA 95060; dletour@ucsc.edu, If you have any questions regarding your rights as a research participant, please contact the Office of Research Compliance Administration at the UCSC at 831-459-1473 or orca@ucsc.edu.

___ I agree to take the survey

___ I give my permission for my data to be retained and used in future studies.

(Side 1)

TASTER DEMOGRAPHICS:

SEX (circle one): M F R(ather not disclose or identify)

AGE RANGE (circle one): <11 11 – 17 18 – 25 25 – 32

33-39

40 – 49 50 – 65 65+

TASTER BEHAVIOR:

1. How often do you purchase groceries? 1x/month

   2x/month 1x/week

   2x/week 4x/week

2. How often do you prepare meals? 1x/month

   2x/month 1x/week

   2x/week 4x/week

3. How frequently do you eat seafood? 1x/month

   2x/month 1x/week

   2x/week 4x/week

(Side 2)

PRODUCT ATTRIBUTES AND PREPARATION:

PLATE: *[write sample]*

CHEF OR RESTAURANT:

INSTRUCTIONS: Taste a given sample and place an "X" in the BELOW scale that best describes your feeling.

	Dislike Very Much	Dislike	Dislike A Little	Like a Little	Like	Like Very Much
APPEARANCE						
SIZE						
COLOR						
AROMA						
TASTE						
TEXTURE						
OVERALL LIKING						

What did you like or dislike about the sample?

____

____

____

Appendix C – Paired sample t-test

Paired-sample t-tests at a 95% confidence interval, most suitable for statistical inquiry for a within-subjects survey design, rarely indicated statistical significance or failed to reject the null hypothesis across treatments. The null hypothesis was *the sample means across treatments are equal*. I used a cluster comparison of subjects from 2018 and 2019, whereas responses were analyzed "with-in" subjects or when subjects completed surveys for all treatments respectively. In 2018, the t-test showed that Treatments 4 (tacos) and 6 (tea sandwich) under the response variable "overall liking," rejected the null hypothesis, $t(4) = -3.16$, $p = 0.03$ (Table 10j). This was the only significant difference: the least liked and the most liked.

Notably, in 2018, the t-test for Treatments 4 (tacos) and Treatments 6 (tea sandwich) under the response variable "appearance," failed to reject the null hypothesis, but the scoring was very close to being significant at a 95% confidence interval, $t(4) = -2.44$, $p = 0.070$ (Table 10f). Similarly, although the paired t-test for Treatments 2 (escabeche) and Treatments 4 (tea sandwich) under the response variable "overall liking," failed to reject the null hypothesis, it too was very close to showing significance, $t(4) = -2.13$, $p = 0.09$.

There were no significant differences between treatments or response variables in 2019. Statistical results for paired sample t-tests are reported in Table 12.

Table 12 – Paired-sample t-tests at a 95% confidence interval cluster comparison between 2019 (a-e) and 2018 (f-j), *whereas completed responses were analyzed for subjects that completed evaluations for all treatments across all response variables, respectively.*

2019 (df) = 7	**Appearance**		**Aroma**		**Texture**		**Taste**		**Overall Liking**	
Paired-sample	t	p-value	t	p-value	t	p-value	t	p-value	t	p-value
hb/p	1.835	0.104	0	1	0	1	0	1	0.313	0.762
hb/ss	1.511	0.169	0.894	0.3972	0.816	0.437	0	1	0.356	0.731
hb/sh	1.154	0.282	1.414	0.195	0.426	0.681	0	1	0.283	0.784
p/ss	0	1	1.155	0.2815	1.414	0.195	0	1	0	1
p/sh	-0.426	0.681	1.155	0.2815	0.286	0.782	0	1	0	1
ss/sh	-0.316	0.760	0	1	-0.478	0.645	0	1	0	1
	(a) t-tests at a 95% confidence interval results for all paired treatments from 2019 cluster for response variable "Appearance"		(b) t-tests at a 95% confidence interval results for all paired treatments from 2019 cluster for response variable "Aroma"		(c) t-tests at a 95% confidence interval results for all paired treatments from 2019 cluster for response variable "Texture"		(d) t-tests at a 95% confidence interval results for all paired treatments from 2019 cluster for response variable "Taste"		(e) t-tests at a 95% confidence interval results for all paired treatments from 2019 cluster for response variable "Overall Liking"	

2018 (df) = 4	Appearance		Aroma		Texture		Taste		Overall Liking	
Paired-sample	t	p-value	t	p-value	t	p-value	t	p-value	t	p-value
ca/p	0	1	1	0.373	0.272	0.799	0	1	-0.206	0.847
ca/ss	-0.408	0.704	1.291	0.266	0.25	0.815	2.058	0.108	0.301	0.778
ca/ht	-1.372	0.242	-1.5	0.208	-1.5	0.208	-1.5	0.208	-1.372	0.242
ca/he	-1	0.373	-0.784	0.476	-1	0.374	-1	0.374	-1	0.374
p/ss	-0.408	0.704	0.929	0.405	0	1	1.5	0.208	1	0.374
p/ht	-1.372	0.242	-1.372	0.242	-1.372	0.242	-1.5	0.208	-1	0.374
p/he	-0.884	0.426	0.884	0.426	-0.884	0.426	-0.784	0.477	-0.589	0.587
ss/ht	-2.44	0.070	-1.725	0.159	-1.372	0.242	-1.964	0.121	-3.162	0.034
ss/he	-1.633	0.177	-1.428	0.226	-1	0.373	1	0.374	-2.138	0.099
ht/he	1	0.373	1	0.373	1	0.374	-1.725	0.159	1	0.373
	(f) t-tests at a 95% confidence interval results for all paired treatments from 2018 cluster for response variable “Appearance.”		(g) t-tests at a 95% confidence interval results for all paired treatments from 2018 cluster for response variable “Aroma.”		(h) t-tests at a 95% confidence interval results for all paired treatments from 2018 cluster for response variable “Texture.”		(i) t-tests at a 95% confidence interval results for all paired treatments from 2018 cluster for response variable “Taste.”		(j) t-tests at a 95% confidence interval results for all paired treatments from 2018 cluster for response variable “Overall Liking.”	