Health Impact Review of SHB 1010
SHB 1010, Concerning the sanitary control of shellfish (2023 Legislative Session)

November 17, 2023

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WASHINGTON STATE BOARD OF HEALTH

HEALTH EQUITY
Governor's Interagency Council on Health Disparities

Full review
The full Health Impact Review report is available at:
https://www.sboh.wa.gov/sites/default/files/2023-11/HIR-2024-03-SHB%201010_0.pdf

Acknowledgements
We would like to thank the key informants who provided consultation and technical support during this Health Impact Review.

Disclosure
The Washington State Board of Health (SBOH) conducts Health Impact Reviews in collaboration with the Governor's Interagency Council on Health Disparities. SHB 1010 would impact SBOH authority, allowing SBOH to adopt rules regulating commercial crab harvesting, tracking, and recalls.

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Evidence indicates that SHB 1010 may lead to Washington State Board of Health conducting rulemaking and Department of Health implementing a program to regulate commercially harvested crab for biotoxin contamination, which may increase monitoring, flexibility of management actions, coordination, and compliance related to biotoxin contamination in commercially harvested crab.

SHB 1010 may also increase opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events, which would likely improve economic, social, cultural, mental, and emotional outcomes and reduce inequities for commercial crabbers and fishing communities.

SHB 1010 would also likely improve public health safeguards related to biotoxin contamination in commercially harvested Dungeness crab, which would likely prevent negative health outcomes and reduce inequities for people who consume Dungeness crab commercially harvested in Washington State.

BILL INFORMATION

Sponsors: House Agriculture & Natural Resources Committee

Summary of Bill:
- Allows Washington State Board of Health (SBOH) to adopt rules regulating commercial crab harvesting, tracking, and recalls by June 30, 2025.
- Grants Washington State Department of Health (DOH) authority to regulate commercially harvested crab for biotoxin contamination.

HEALTH IMPACT REVIEW

Summary of Findings:
This Health Impact Review found the following evidence for provisions in SHB 1010:

- **Informed assumption** that allowing SBOH to adopt rules regulating commercial crab harvesting, tracking, and recalls and granting DOH authority to regulate commercially harvested crab for biotoxin contamination may lead to SBOH conducting rulemaking and DOH implementing a program to regulate commercially harvested crab for biotoxin contamination. This assumption is based on public health regulatory structure and information from key informants.
- **Informed assumption** that SBOH conducting rulemaking and DOH implementing a program to regulate commercially harvested crab for biotoxin contamination may increase monitoring, flexibility of management actions, coordination, and compliance related to

biotoxin contamination in commercially harvested Dungeness crab.[a] This informed assumption is based on proposed changes to the law and information from key informants.

Pathway 1: Commercial crabbers and fishing communities

- **Informed assumption** that increased monitoring, flexibility of management actions, coordination, and compliance related to biotoxin contamination in commercially harvested Dungeness crab may increase opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events. This assumption is based on information from published literature and key informants.
- **A fair amount of evidence** that increased opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events would likely improve economic outcomes for commercial crabbers and fishing communities.
- **Strong evidence** that improved economic outcomes for commercial crabbers and fishing communities would likely improve social, cultural, mental, and emotional outcomes for commercial crabbers and fishing communities.
- **Strong evidence** that improved health outcomes for commercial crabbers and fishing communities may reduce inequities.

Pathway 2: Food safety

- **Strong evidence** that increased monitoring, flexibility of management actions, compliance, and coordination related to biotoxin contamination in commercially harvested Dungeness crab would likely improve public health safeguards.
- **Strong evidence** that improved public health safeguards related to biotoxin contamination in commercially harvested Dungeness crab would likely prevent negative health outcomes for people who consume Dungeness crab commercially harvested in Washington State.
- **A fair amount of evidence** that improving health outcomes for people who consume Dungeness crab commercially harvested in Washington State would likely reduce inequities.

"Additional considerations" includes potential impacts for the Puget Sound state commercial Dungeness crab fishery; Tribal commercial Dungeness crab fisheries; and Dungeness crab processors.

[a] SHB 1010 pertains to commercially harvested crab. Since state commercial crab fisheries only allow harvest and retention of Dungeness crab (personal communication, Washington Department of Fish and Wildlife [WDFW], November 2023), provisions of SHB 1010 would only apply to Dungeness crab. This review retains "crab" in discussion of bill provisions and otherwise uses "crab" and "Dungeness crab" interchangeably.

Introduction and Methods

A Health Impact Review is an analysis of how a proposed legislative or budgetary change will likely impact health and health disparities in Washington State (RCW 43.20.285). For the purpose of this review "health disparities" have been defined as differences in disease, death, and other adverse health conditions that exist between populations (RCW 43.20.270). Differences in health conditions are not intrinsic to a population; rather, inequities are related to social determinants (access to healthcare, economic stability, racism, etc.). This document provides summaries of the evidence analyzed by State Board of Health staff during the Health Impact Review of Substitute House Bill 1010 (SHB 1010).

Staff analyzed the content of SHB 1010 and created a logic model visually depicting the pathways between bill provisions, social determinants, and health outcomes and equity. The logic model reflects the pathways with the greatest amount and strongest quality of evidence. The logic model is presented both in text and through a flowchart (Figure 1).

We conducted an objective review of published literature for each step in the logic model pathways using databases including PubMed, Google Scholar, and University of Washington Libraries. The annotated references are only a representation of the evidence and provide examples of current research. In some cases, only a few review articles or meta-analyses are referenced. One article may cite or provide analysis of dozens of other articles. Therefore, the number of references included in the bibliography does not necessarily reflect the strength-of-evidence. In addition, some articles provide evidence for more than one research question and are referenced multiple times.

We consulted with people who have content and context expertise about the provisions and potential impacts of the bill. The primary intent of key informant interviews is to ensure staff interpret the bill correctly, accurately portray the pathway to health and equity, and understand different viewpoints, challenges, and impacts of the bill. We spoke with 14 key informant interviewees, including: 6 Washington State agency staff working on commercial Dungeness crab or related policy; 4 researchers with experience evaluating Dungeness crab, biotoxin contamination, and fishery management responses; 3 Tribal staff with knowledge of Tribal commercial Dungeness crab fisheries; and 1 person with experience commercially harvesting Dungeness crab in Washington State.

We evaluated evidence using set criteria and determined a strength-of-evidence for each step in the pathway. The logic model includes information on the strength-of-evidence. The strength-of-evidence is summarized as:

- **Very strong evidence:** There is a very large body of robust, published evidence and some qualitative primary research with all or almost all evidence supporting the association. There is consensus between all data sources and types, indicating that the premise is well accepted by the scientific community.
- **Strong evidence:** There is a large body of published evidence and some qualitative primary research with the majority of evidence supporting the association, though some sources may

have less robust study design or execution. There is consensus between data sources and types.

- **A fair amount of evidence:** There is some published evidence and some qualitative primary research with the majority of evidence supporting the association. The body of evidence may include sources with less robust design and execution and there may be some level of disagreement between data sources and types.
- **Expert opinion:** There is limited or no published evidence; however, rigorous qualitative primary research is available supporting the association, with an attempt to include viewpoints from multiple types of informants. There is consensus among the majority of informants.
- **Informed assumption:** There is limited or no published evidence; however, some qualitative primary research is available. Rigorous qualitative primary research was not possible due to time or other constraints. There is consensus among the majority of informants.
- **No association:** There is some published evidence and some qualitative primary research with the majority of evidence supporting no association or no relationship. The body of evidence may include sources with less robust design and execution and there may be some level of disagreement between data sources and types.
- **Not well researched:** There is limited or no published evidence and limited or no qualitative primary research and the body of evidence was primarily descriptive in nature and unable to assess association or has inconsistent or mixed findings, with some supporting the association, some disagreeing, and some finding no connection. There is a lack of consensus between data sources and types.
- **Unclear:** There is a lack of consensus between data sources and types, and the directionality of the association is ambiguous due to potential unintended consequences or other variables.

This review was completed during the interim and was not subject to the 10-day turnaround required by law. More information and detailed methods for this review are available upon request.

Analysis of SHB 1010 and the Scientific Evidence

Summary of relevant background information

- Dungeness crab (*Cancer magister*) got its name from Dungeness, Washington, on the Strait of Juan de Fuca.[1]
- Dungeness crab are opportunistic feeders and feed on bivalves (e.g., razor clams), fish, and other crab.[2] In coastal waters, Dungeness crab primarily feed on razor clams (personal communication, Washington State Department of Health [DOH], September 2023).
- Dungeness crab exist in commercial quantities along the Pacific Coast from Alaska to south of San Francisco, California.[3]
    - Of West Coast states (i.e., Washington, Oregon, and California), Washington State is the largest producer of commercial Dungeness crab.[4]
- Dungeness crab is the only commercially important crab within Washington State's territorial waters.[1]
- Commercial Dungeness crab fisheries include Tribal and state fisheries on the coast and in Puget Sound.[1]
    - Tribes participate in commercial, ceremonial, and subsistence harvesting for finfish and shellfish, including Dungeness crab.[5] Commercial harvests "allow [T]ribal members the opportunity to sell the shellfish products they harvest."[5] Tribal commercial crabbers harvest in Tribal usual and accustomed fishing grounds, which include areas in Puget Sound and "encompass approximately 50[%] of the Washington [State] coastline."[3] Some Tribal commercial crab fisheries also permit harvest and retention of Red Rock crab (personal communication, Washington Department of Fish and Wildlife [WDFW], November 2023).
    - State commercial crab fisheries only permit harvest and retention of Dungeness crab (personal communication, WDFW, November 2023).[b]
    - State recreational harvesting of Dungeness crab, Red Rock crab, and Tanner crab is permitted on the coast and in Puget Sound.[6] An average of over 220,000 recreational crabbing licenses are sold annually in Washington State.[2] The majority of recreational crabbing occurs in Puget Sound (personal communications, September-October 2023).
- Commercial Dungeness crab fisheries are economically important for Tribes and for the state (personal communications, October 2023).[2,7,8]
    - From February 2023 through September 15, 2023 (the most current data available), the coastal state commercial Dungeness crab fishery landings[c] (initial

[b] SHB 1010 pertains to commercially harvested crab. Since state commercial crab fisheries only allow harvest and retention of Dungeness crab (personal communication, Washington Department of Fish and Wildlife [WDFW], November 2023), provisions of SHB 1010 would only apply to Dungeness crab. This review retains "crab" in discussion of bill provisions and otherwise uses "crab" and "Dungeness crab" interchangeably.

[c] Landing data are reported by WDFW and only include information from state commercial crab fisheries. Information from Tribal commercial crab fisheries is shared with WDFW but is not reported.

delivery of crab for commercial purposes) totaled 24,062,301 pounds of crab, with a total state fishery ex-vessel value[d] of $64,632,247.[7]

Regulatory structure

- The National Shellfish Sanitation Program (NSSP) is a cooperative program between states and the U.S. government, including the U.S. Food and Drug Administration (FDA).[9] The intent of NSSP is "to promote and improve the sanitation of shellfish (oysters, clams, mussels and scallops [i.e., bivalves]) moving in interstate commerce through federal/state cooperation and uniformity of [s]tate shellfish programs."[9] NSSP regulations apply to molluscan shellfish and do not specifically apply to crab (personal communications, September 2023).[10]
- Tribal commercial Dungeness crab fisheries are regulated by Tribes (personal communications, September-October 2023).
- In 1994, the federal district court adopted a court order known as the "Consent Decree Regarding Shellfish Sanitation Issues."[11] The order was "based on a […T]ribal and state agreement which established a program to protect the public from contaminated shellfish...[T]ribal shellfish biologists and technicians [work] with their counterparts in [DOH] and [FDA] to ensure protection of public health. Only those growing areas that meet federal standards as approved harvest areas are open to [T]ribal commercial harvesting."[5]
    - Tribes monitor for algae that cause paralytic shellfish poisoning, domoic acid, and fecal coliform bacteria.[5]
    - The Consent Decree Regarding Shellfish Sanitation Issues does not reference crab.
- In 1995, the federal 9th Circuit Court issued the Rafeedie Decision, requiring that the "harvestable surplus of shellfish in Washington [State] be allocated equally (50/50) between the Treaty Tribes and State fisheries"[1] in Tribal usual and accustomed fishing grounds.
    - In 2007, 17 treaty Tribes and Puget Sound state commercial shellfish growers reached a landmark settlement related to implementation of the Rafeedie Decision addressing how Tribes would harvest naturally-occurring shellfish on privately-owned commercial tidelands.[12]
    - Four treaty Tribes (Quinault Indian Nation, Quileute Indian Tribe, Hoh Tribe, and Makah Tribe)[13] and WDFW co-manage the coastal commercial Dungeness crab fisheries between Point Chehalis, Washington, and the U.S.-Canada border.[14]
    - Tribes and WDFW have agreements about how to co-manage Tribal and state coastal and Puget Sound commercial crab fisheries to ensure the opportunity to harvest 50% of the harvestable resource (personal communication, WDFW, September 2023).
- In 1997, U.S. Congress granted Washington, Oregon, and California authority to manage Dungeness crab fisheries outside state waters (extending 3 to 200 miles offshore).[3]
- Washington State commercial Dungeness crab fisheries are regulated by WDFW. Chapter 220-340 WAC outlines WDFW's rules for commercial shellfish harvesting in

[d] The ex-vessel value is a "measure of the dollar value of commercial landings, usually calculated as the price per pound at first purchase of commercial landings multiplied by the total pounds landed."[48]

Washington State, including regulations related to licensing, gear, seasons and areas, and harvesting limits.[15]
    - "Commercial crab fishing" means any taking, fishing, use, or operation of gear to fish for crab for commercial purposes and includes the possession of crab on the water for commercial purposes and the landing or initial delivery of crab for commercial purposes.[15]
    - Dungeness crab management is "based on a minimum size limit of 6 ¼ inches, prohibition of harvest of female crab, and a season closure during the primary male molt period [i.e., approximately mid-September to early December]. The minimum size limit assumes that male crab that are harvested have been sexually mature and have mated at least once before reaching legal size. Male crabs 6 ¼ inches or larger are assumed to be harvestable surplus; it is assumed that as much as 95[%] of the legal sized males are harvested annually."[3]
- Chapter 69.30 RCW allows Washington State Board of Health (SBOH) to adopt rules governing the sanitation of shellfish, shellfish growing areas, and shellfish plant facilities and operations and provides authority for DOH to regulate commercially harvested shellfish for health and safety in Washington State.[16]
    - "Shellfish" is defined as all varieties of fresh and frozen oysters, mussels, clams, and scallops (i.e., bivalve mollusks).[16] This definition does not include crab.
    - SBOH rules and DOH's program regulate a number of aspects of shellfish harvesting, including the quality of shellfish growing waters and areas, boat and barge sanitation, sewage and wastewater disposal, and the handling, storage, and refrigeration of shellfish.[10]
- WDFW and DOH also have authority and responsibility to regulate recreational crabbing in Washington State.[17,18]
    - RCW 77.32.555 allows WDFW to include a surcharge on recreational shellfish and seaweed licenses to fund biotoxin testing and monitoring.[19] DOH has responsibility for administering the Biotoxin Account, which provides funding for DOH to monitor beaches used for recreational shellfishing, and the Olympic Region Harmful Algal Blooms Program (ORHAB) to monitor seawater for phytoplankton that can produce biotoxins.[19]
        - ORHAB is part of University of Washington's Olympic Natural Resources Center and works with Tribes and additional partners to monitor seawater for phytoplankton that can produce biotoxins as an early warning system to detect harmful algal blooms in Washington State's coastal waters (personal communication, ORHAB, September 2023).
- SoundToxins is a cooperative partnership led by Washington Sea Grant to provide biotoxin testing and monitoring of seawater in the Puget Sound.[20] The program is a voluntary effort and does not receive funding through RCW 77.32.555 (personal communication, ORHAB, September 2023).
- Washington, Oregon, and California have entered into the Tri-State Dungeness Crab Memorandum of Understanding that provides for "interstate cooperation in management of the Pacific Coast Dungeness crab fishery and in dealing with adjustments to the fishing season […]"[21] The Tri-State process includes discussion of fishery delays, closures, and management actions (personal communications, October 2023).[21]

Biotoxin contamination and management

- There are 5 forms of naturally-occurring poisoning biotoxins associated with consumption of shellfish.[22] All are harmful to humans if ingested and may cause serious illness or death.[22]
    - Biotoxins may temporarily accumulate in crab tissue.[2] Two poisoning biotoxins have been detected in the viscera (internal organs) of crustaceans, including Dungeness crab.[22] Dungeness crab viscera "consists of all soft matter (including available entrapped liquid) in the crab visceral cavity, excluding the gills […] shell or meat."[23]
        - Amnesic shellfish poisoning (ASP) biotoxin from domoic acid[e] has been detected in Dungeness crab.[22] FDA has noted, "levels of domoic acid in Dungeness crab on the [W]est [C]oast have exceeded guidance levels for this toxin and required harvesting closures."[22] Crab may retain domoic acid for several weeks or longer.[24]
            - The FDA safety levels for domoic acid in Dungeness crab are 20 parts per million (ppm) in the meat and 30 ppm in the viscera.[22]
        - Paralytic shellfish poisoning (PSP) biotoxin has also been detected in Dungeness crab.[22] Shellfish species retain PSP for different lengths of time, ranging from weeks to more than 5 years, which can impact the time they may pose a risk to human health from consumption.[22]
            - The FDA safety level for PSP is 800 ppm.[25]
- In 1992, FDA adopted a policy to prevent consumer exposure to domoic acid from commercially harvested Dungeness crab.[13,23] FDA stated that they would "take regulatory action on any Dungeness crab in interstate commerce which is found to be contaminated with greater than 30 ppm domoic acid in the cooked crab viscera."[23] They recommended states adopt monitoring plans for domoic acid and take actions to prevent consumer exposure if domoic acid levels exceed 30 ppm in the viscera.[23] FDA stated preventive actions should include closure of harvest areas and evisceration.[23]
    - The act of removing and discarding the crab viscera, including the entire intestinal tract, hepatopancreas (digestive gland), and all associated abdominal organs is known as evisceration.[26]
    - DOH, Tribes, WDFW, and Washington State Department of Agriculture (WSDA) develop and follow a strategy to prevent consumer exposure to domoic acid from coastal Dungeness crab.[13]
- Biotoxins cannot be eliminated through cooking, freezing, drying, or smoking[22,27] and can persist in shellfish for long periods of time.[27] Therefore, "[w]here [domoic acid] and PSP is a potential hazard in finfish or crustaceans, states have generally closed or restricted fishing areas [...] In addition, removal and destruction of the viscera [i.e., evisceration] may eliminate the hazard […]"[22]
- The geographic distribution and occurrence of biotoxins vary and change by "locations because the distribution of the source algae may vary over time."[22]
    - Biotoxins enter "the food web through filter feeders such as mussels, clams, and anchovies [that feed on algae] and [are] then transferred to predators such as crabs, lobsters, and fish. Bivalves [e.g., mussels] and crustaceans [e.g., crabs] generally exhibit the highest risk of contamination […]"[28]

[e] ASP is commonly referred to as domoic acid. This HIR uses domoic acid to describe this biotoxin.

- Harmful algal blooms (HABs) are increasing in size, frequency, and duration due in part to climate change.[4,8,28-32] Along the West Coast, HABs include algae that produce domoic acid.[28]
    - In 2015, a large marine heatwave generated a HAB that extended from Alaska to southern California and "the only [fishery] management action available to West Coast states was to employ area closures."[28] As a result, there were "expansive and prolonged closures of commercial and recreational fisheries. The Dungeness crab fishery […] was hit especially hard."[28]
        - Under federal law, disaster assistance may be considered for fishery failures if revenue losses are between 35% and 80% of average revenues in the previous 5 years and is allowed if revenue losses are above 80%.[8] The 2015 HAB event, "generat[ed] an economic shock for fishing communities and result[ed] in fisheries resource disaster declarations for the California Dungeness crab fishery and the Quileute Tribe […] Dungeness crab fishery."[33]
    - Washington State experienced fishery closures due to domoic acid during the 2014-2015, 2015-2016, 2016-2017, and 2020-2021 commercial Dungeness crab fishing seasons.[28]
    - In 2021, WDFW adopted an emergency rule temporarily requiring evisceration in response to prolonged closures due to domoic acid.[28,34] The emergency rulemaking stated, "the viscera from crab caught between the [Washington and Oregon] border and Point Chehalis, including Willapa Bay are unsafe for human consumption and [DOH has] issued a recommendation requiring evisceration of crab caught in this area. To strengthen the enforcement of an evisceration requirement needed to protect public health, all crab landed into [Washington State] from any [W]est [C]oast area south of Point Chehalis, Washington, must be eviscerated."[34] Emergency rules expire after 120 days (RCW 34.05.350).[35]
- As a result of prolonged closures, states have acted to increase domoic acid monitoring and management:
    - California passed legislation in 2021 allowing evisceration orders, increasing testing sites, and outlining domoic acid management boundaries.[28] California law (Article 15. Eviscerated Crab [111224-111224.6]) provides authority for the California State Department of Health Services to issue an evisceration order if: 1) the Director of Fish and Wildlife has closed the commercial Dungeness crab fishery due to domoic acid levels; 2) Domoic acid levels of the crab viscera exceed allowable levels; and 3) Domoic acid levels of the crab meat do not exceed allowable levels.[26]
    - The Oregon State legislature also passed legislation in 2021 allowing evisceration orders rather than fishery closures and doubled the number of biotoxin monitoring sites for Dungeness crab.[28] Oregon law (OAR 635-005-0466) allows for evisceration if domoic acid levels in crab viscera exceed allowable levels.[36]

Summary of SHB 1010

- Allows SBOH to adopt rules regulating commercial crab harvesting, tracking, and recalls by June 30, 2025.
- Grants DOH authority to regulate commercially harvested crab for biotoxin contamination.

Health impact of SHB 1010
Evidence indicates that SHB 1010 may lead to SBOH conducting rulemaking and DOH implementing a program to regulate commercially harvested crab for biotoxin contamination, which may increase monitoring, flexibility of management actions, coordination, and compliance related to biotoxin contamination in commercially harvested crab.

SHB 1010 may also increase opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events, which would likely improve economic, social, cultural, mental, and emotional outcomes and reduce inequities for commercial crabbers and fishing communities.

SHB 1010 would also likely improve public health safeguards related to biotoxin contamination in commercially harvested Dungeness crab, which would likely prevent negative health outcomes and reduce inequities for people who consume Dungeness crab commercially harvested in Washington State.

Pathway to health impacts
The potential pathways leading from the provisions of SHB 1010 to health and equity are depicted in Figure 1.

We have made informed assumptions that allowing SBOH to adopt rules regulating commercial crab harvesting, tracking, and recalls and granting DOH authority to regulate commercially harvested crab for biotoxin contamination may lead to SBOH conducting rulemaking and DOH implementing a program to regulate commercially harvested crab for biotoxin contamination, which may increase monitoring, flexibility of management actions, coordination, and compliance related to biotoxin contamination in commercially harvested Dungeness crab. These assumptions are based on public health regulatory structure, proposed changes to the law, and information from key informants.

Pathway 1: Commercial crabbers and fishing communities
We have also made the informed assumption that increased monitoring, flexibility of management actions, coordination, and compliance related to biotoxin contamination in commercially harvested Dungeness crab may increase opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events. This assumption is based on information from published literature and key informants.

There is a fair amount of evidence that increased opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events would likely improve economic outcomes[4,8,30,32,33,37] and social, cultural, mental, and emotional outcomes[4,32,33,37-40] for commercial crabbers and fishing communities. There is strong evidence that improved health outcomes for commercial crabbers and fishing communities may reduce inequities.[30-33,37-39]

Pathway 2: Food safety
There is strong evidence that increased monitoring, flexibility of management actions, compliance, and coordination related to biotoxin contamination in commercially harvested

Dungeness crab would likely improve public health safeguards,[8,24,25,27,28,37,41] which would likely prevent negative health outcomes for people who consume Dungeness crab commercially harvested in Washington State.[22,24,25,27,42] There is a fair amount of evidence that improving health outcomes for people who consume Dungeness crab commercially harvested in Washington State would likely reduce inequities.[27,42]

Scope

Due to time limitations, we only researched the most linear connections between provisions of the bill and health and equity and did not explore the evidence for all possible pathways. For example, we did not evaluate potential impacts related to:

- DOH fees for commercial crabbing. RCW 43.70.250 states that the cost of professional, occupational, or business licensing programs administered by DOH must be self-supporting.[29,43] Therefore, DOH must collect sufficient revenue through fees to fund the cost of administering a program, including a program to regulate commercially harvested crab for biotoxin contamination.[29] Using an estimate of 220 commercial Dungeness crab license holders (which only includes active crab license holders in the coastal state commercial Dungeness crab fishery), DOH anticipates SHB 1010 would likely require the addition of a fee for commercial crab license holders with a proposed cost ranging from $1,940 to $2,040 annually.[29] DOH anticipates this would likely provide about $427,000 annually to operate the program.[29] Key informants stated that the actual fee amount would be determined through rulemaking as the process would clarify who the rule may apply to (coastal and/or Puget Sound state commercial crabbers, processors, etc.) and how much funding would be needed to operate the program (personal communications, WDFW, September 2023). Staff from WDFW stated that commercial crabbers were concerned about the proposed cost (personal communication, WDFW, September 2023). This Health Impact Review did not evaluate how this fee may impact commercial crabbers or whether funding generated from the fee would be sufficient for DOH program implementation, maintenance, or sustainability.
- DOH's Public Health Laboratories. Researchers have discussed potential challenges with increasing biotoxin monitoring, including staff capacity, sample processing time, and lab backlogs.[28] If SHB 1010 were to pass, DOH's Public Health Laboratories would be responsible for assessing levels of biotoxin in crab.[29] In order for the Public Health Laboratories to comply with federal testing requirements and methodological protocols for testing biotoxin in crab, the Public Health Laboratories would need to hire additional staff, purchase specialized equipment, initiate instrument service contracts, and purchase supplies.[29] This Health Impact Review did not evaluate how SHB 1010 would impact the Public Health Laboratories' work or capacity to test for biotoxin in crab or to respond to increased testing demands during biotoxin contamination events. This Health Impact Review also did not consider whether sufficient funding would be available to test for biotoxin in crab at the Public Health Laboratories.
- WDFW rulemaking. If SHB 1010 were to pass, WDFW anticipates new rulemaking may be required to add clarity and enforceability to the general WDFW fishing regulations.[29] For example, WDFW works with DOH on regulation and enforcement of Chapter 69.30 RCW. Based on SHB 1010, WDFW anticipates SBOH's adoption of rules and DOH's

implementation of a program to regulate commercial Dungeness crab for biotoxin contamination would likely also require WDFW enforcement.[29] This may require WDFW to increase patrols (e.g., to ensure evisceration of crab during biotoxin events) and to complete inspections of processing facilities, marketplaces, and airport cargo to ensure contaminated crab are not distributed or sold.[29] In a fiscal note for SHB 1010, WDFW also stated that, "[i]n order to respond to a biotoxin [contamination] event […] and make changes to an existing fishery, rulemaking by WDFW will be necessary for harvest reporting, tracking, and recalls."[29] Since SHB 1010 does not directly require WDFW to implement additional enforcement activities or require WDFW to initiate rulemaking, this Health Impact Review did not evaluate impacts of potential additional WDFW enforcement actions or rulemaking related to commercial crabbing. This review also did not consider whether sufficient funding would be available to support WDFW enforcement or rulemaking.

- Media coverage. Misinformation and perception of seafood safety impact consumer demand for seafood.[4] Key informants suggested that media coverage of a public health outbreak could have harmful impacts for the commercial Dungeness crab fishery (personal communications, September 2023). Researchers have noted that media coverage "from a public health outbreak could have even larger negative impacts on consumer perceptions of and demand for crab. Thus, protecting public health is also crucial to maintaining a viable fishery […]."[28] For example, following media coverage of the 2015 HAB event, one researcher stated: "if consumers were avoiding California crabs due to safety concerns, the demand for Oregon and Washington crabs could also increase. Another possibility is that […] extended media attention […] led to consumer avoidance of Dungeness crab from all [3] states."[4] Key informants also suggested these dynamics could occur within Washington State. For example, coastal fishery closures may either increase or decrease demand for crab harvested from Puget Sound (personal communications, October 2023). Coastal fishery closures that impact only some areas of the coast may impact perception, price, and demand for crab harvested from coastal areas that remain open (personal communications, October 2023). State commercial crab fishery closures may also impact demand for crab harvested from Tribal commercial crab fisheries that remain open (personal communication, November 2023). Lastly, interviews with people living in fishing communities also suggested that public perception could impact ex-vessel and market prices of crab.[32] This Health Impact Review did not evaluate how potential media coverage of public health outbreaks or fishery closures may impact consumer demand for Dungeness crab, the commercial Dungeness crab industry, commercial crabbers, fishing communities, or the price of crab.
- People who consume commercial Dungeness crab and live outside of Washington State. Dungeness crab is a commercially important crab within Washington State's territorial waters[1] and a main state export (personal communications, September-October 2023). Key informants suggested that as much as 90% of Dungeness crab commercially harvested in Washington State may be exported to China (personal communication, DOH, September 2023). Key informants stated that Dungeness crab harvested in Washington State may also be exported domestically (e.g., to West Coast states during

fishery closures, to East Coast states) (personal communications, October 2023). For example, during the 2015 HAB event, "closure of the California [Dungeness] crab fishery led to a shortage of Dungeness crab during the holiday season, which may have driven up demand for crabs from Oregon and Washington."[4] People who consume Dungeness crab commercially harvested in Washington State who live outside the state may also be impacted by changes to Washington State's regulation of commercial crab. Since Health Impact Reviews focus on how proposed legislation may impact health and equity in Washington State (RCW 43.20.285), this review focused on potential impacts for Washingtonians.

- People who harvest Dungeness crab recreationally. Recreational harvesting of Dungeness crab is permitted on the coast and in Puget Sound.[6] People recreationally harvest more than 1.5 million pounds of Dungeness crab annually, and crabbing is one of the most popular recreational fisheries in Puget Sound.[17] Some people, including Tribal people, harvest Dungeness crab for subsistence (personal communications, September 2023). In Washington State, closure of the state commercial Dungeness crab fishery also causes a closure of the recreational Dungeness crab fishery (personal communication, DOH, September 2023). Therefore, SHB 1010 may impact the ability of recreational crabbers to harvest Dungeness crab. Since the impact on people who recreationally harvest Dungeness crab is less directly tied to provisions in SHB 1010, we did not explore this potential pathway in the Health Impact Review.
- Additional reasons for fishery delays or closures. Commercial Dungeness crab fisheries may be delayed or closed for additional reasons, not only due to a biotoxin event (personal communications, October 2023).[4] Delays may result from price negotiations or weather,[4] and closures may occur if the market is saturated and consumer demand for crab does not match supply (personal communications, October 2023). Commercial Dungeness crab fisheries may also close for migrating whales to avoid entanglement with crabbing gear (personal communications, September-October 2023). For example, due to delayed openings during 2014-2016 HAB events, California experienced an increase in whale entanglements with Dungeness crab fishing gear.[30] As a result, California restricted the 2018 "summer harvest of Dungeness crab for the first time due to ecosystem considerations, further compressing the fishing season."[30] Fishery closures for any reason may limit the length of the commercial Dungeness crab fishing season.[30] This Health Impact Review did not consider how closures due to biotoxin events may interact with additional reasons for fishery closures or how compounding closures may impact commercial crabbers.
- Crab health. Dungeness crab populations face threats from ocean warming and acidification, hypoxia (low oxygen), sedimentation (e.g., due to dredging or the removal of sediments from the waterbody), disease, pesticides, and other pollutants (e.g., heavy metals).[2] Key informants stated that HABs and biotoxins have the potential to impact the health of crab and large numbers of crab have been lost due to biotoxin contamination events (personal communications, ORHAB, September 2023). However, "it is unclear how vulnerable the species and fishery are to changing climate and ocean conditions."[2] In 2020, the Pacific Northwest Crab Research Group noted that climate change and

warming ocean waters "may impact molting patterns and growth trajectories which could impede the current [fishery] management scheme and potentially reduce protection to vulnerable [crab] life stages."[2] Other researchers have noted that climate change has already impacted production, food-web and disease dynamics, and species distribution.[31] This Health Impact Review did not evaluate how climate change, HABs, or biotoxins may impact the health of crab, the future viability of the Dungeness crab population, or additional ecosystem interactions.

Magnitude of impact

SHB 1010 would impact state commercial Dungeness crab fisheries in Washington State, which includes commercial crabbers on the coast and in Puget Sound. The bill may also impact fishing communities and people who consume Dungeness crab commercially harvested in Washington State. The bill may also have impacts for Tribal commercial Dungeness crab fisheries; see "Additional Considerations" for further discussion.

In Puget Sound, there are Tribal and state fleets of commercial crab vessels.[1] In 1980, the Washington State Legislature limited the Puget Sound state commercial crab fishery to 250 licenses.[1] No new licenses have been issued since 1980, though current license holders may transfer an existing license to a new holder.[1] In 2019, there were 132 commercial crabbers holding 250 licenses.[1] Each license holder may employ additional workers. Each license is allowed 100 crab pots, allowing for a total of 2,500 crab pots in the Puget Sound state commercial crab fishery.[1] Commercial crabbing in Puget Sound primarily occurs from Everett, Washington, northward, with the majority of harvesting occurring near Blaine/Point Roberts.[1] Commercial harvesting also occurs near Bellingham, Samish, Padilla, Skagit, and Dungeness Bays, Port Gardner, and Port Susan.[1] Landings (initial delivery of crab for commercial purposes) for the state Puget Sound commercial crab fishery averaged 2.75 million pounds of Dungeness crab annually from 2002 through 2018.[1f]

On the coast, there are 228 coastal state commercial crab license holders, with approximately 200 active commercial crab license holders.[14] Each license holder may employ additional workers. This "fishery operates under limited entry rules which require new participants to purchase an existing license directly from the current owner."[14] Four coastal Tribes also "have fishing rights within their federally adjudicated usual and accustomed fishing area."[14] The primary ports for commercial crabbing on the coast are Ilwaco, Chinook, Westport, Tokeland, and La Push.[14] While landings for the coastal state commercial crab fishery fluctuate due to water temperature, food availability, and ocean currents, the fishery averages 9.5 million pounds of Dungeness crab annually.[3] For the 2021-2022 season, coastal state commercial crab fishery landings totaled 15,277,788 pounds of crab.[7] From February 2023 through September 15, 2023 (the most current data available), the coastal state commercial Dungeness crab fishery landings totaled 24,062,301 pounds of crab, with a total state fishery ex-vessel value[g] of $64,632,247.[7]

[f] Landing data are reported by Washington Department of Fish and Wildlife (WDFW) and only include information from state commercial crab fisheries. Information from Tribal commercial crab fisheries is shared with WDFW but is not reported.

[g] The ex-vessel value is a "measure of the dollar value of commercial landings, usually calculated as the price per pound at first purchase of commercial landings multiplied by the total pounds landed."[48]

Dungeness crab are retained in Washington State, shipped domestically, and exported internationally (personal communication, Washington State Department of Agriculture (WSDA), October 2023). Key informants stated that the majority of Dungeness crab commercially harvested in Washington State are exported to China and Canada (personal communications, October 2023). Researchers have stated that most Dungeness crab are sold to restaurants, directly to consumers, or to the export market.[4] The total annual volume of Dungeness crab sales through grocery stores are a small percentage of the consumer market, comprising 5.53% to 7.11% of total West Coast landings for the 2013-2014 through 2015-2016 seasons.[4] Washington State may also import, export, and process crab commercially harvested in another state (personal communication, WSDA, October 2023).

Washington State experienced fishery closures due to domoic acid during the 2014-2015, 2015-2016, 2016-2017, and 2020-2021 commercial Dungeness crab fishing seasons.[28] During these events, coastal commercial Dungeness crab fisheries were closed due to biotoxin contamination. However, the Puget Sound commercial Dungeness crab fishery has not experienced closures due to biotoxin contamination (personal communication, WDFW, October 2023). While the coastal commercial Dungeness crab fishery may be impacted more directly by biotoxin contamination than the Puget Sound commercial Dungeness crab fishery, key informants shared that climate change may impact the future potential for biotoxin events in Puget Sound (personal communications, September-October 2023). Therefore, the provisions of SHB 1010 may apply to and impact commercial crabbers on the coast and in Puget Sound (personal communications, September 2023).

Logic Model

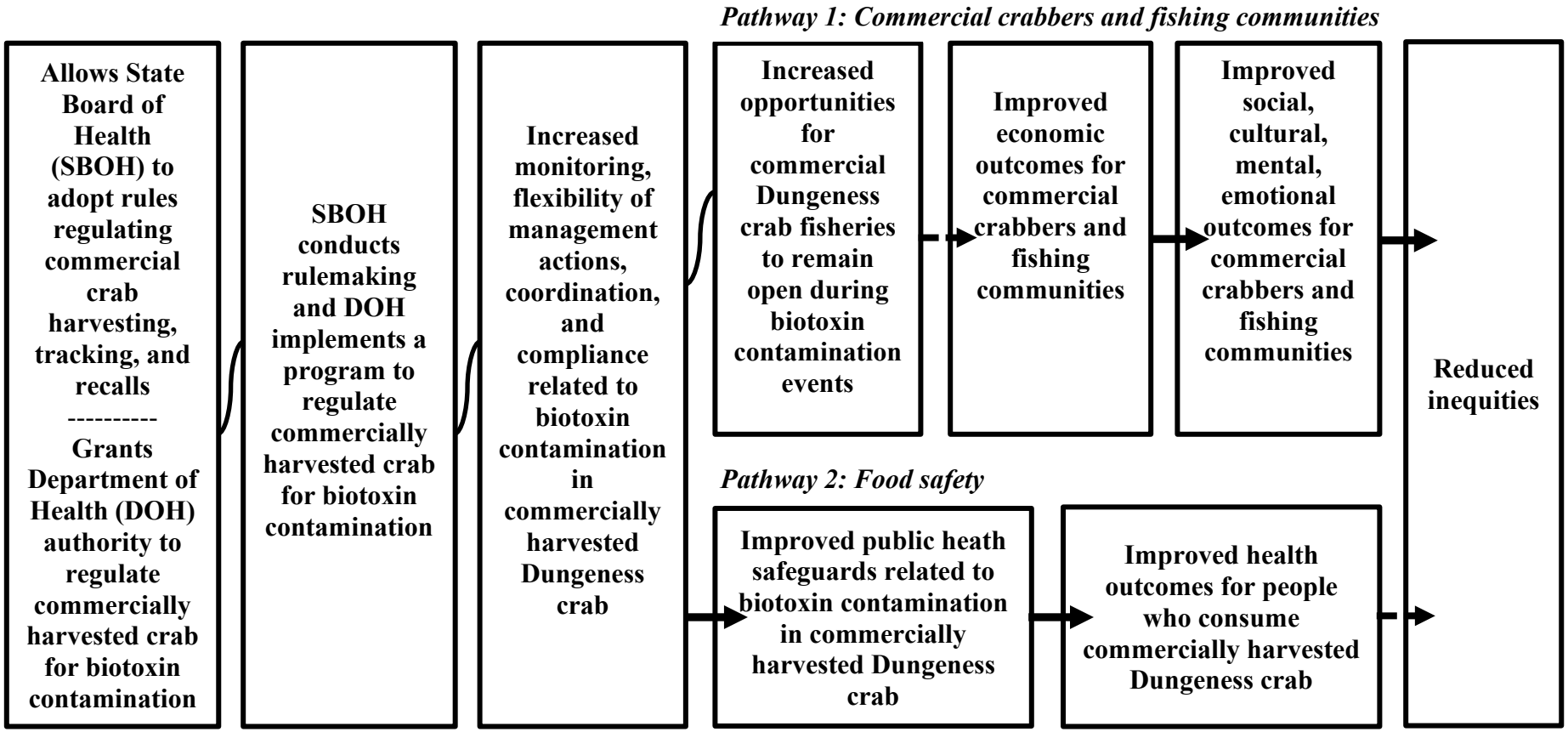

Figure 1:

Concerning the sanitary control of shellfish

SHB 1010

Summaries of Findings

Would allowing State Board of Health (SBOH) to adopt rules regulating commercial crab harvesting, tracking, and recalls and granting Department of Health (DOH) authority to regulate commercially harvested crab for biotoxin contamination result in SBOH conducting rulemaking and DOH implementing a program to regulate commercially harvested crab for biotoxin contamination?

We have made the informed assumption that allowing SBOH to adopt rules regulating commercial crab harvesting, tracking, and recalls and granting DOH authority to regulate commercially harvested crab for biotoxin contamination may lead to SBOH conducting rulemaking and DOH implementing a program to regulate commercially harvested crab for biotoxin contamination. This informed assumption is based on public health regulatory structure and information from key informants representing SBOH and DOH.

Under state law, SBOH has broad authority to develop public health rules to protect and improve the health of people in Washington State,[44,45] including rules related to the sanitary control of shellfish. Public health rules adopted by SBOH are implemented and enforced by DOH and local heath jurisdictions.[44,45]

Chapter 69.30 RCW relates to the sanitation of shellfish, shellfish growing areas, and shellfish plant facilities and operations to protect public health and provides authority for DOH to regulate commercially harvested shellfish for health and safety in Washington State.[16] Under current law, Chapter 69.30 RCW defines "shellfish" as all varieties of fresh and frozen oysters, mussels, clams, and scallops (i.e., bivalve mollusks).[16] This definition does not include crab. Therefore, current law regulating the sanitary control of shellfish only applies to bivalve mollusks and does not extend to crab or additional crustaceans.[10] Since crab are not subject to Chapter 69.30 RCW, if SHB 1010 were to pass, SBOH would likely adopt new rules specifically focused on commercial crab fisheries (personal communication, SBOH, September 2023).[29]

For some public health rules, SBOH works closely with DOH to develop rules, especially in cases where DOH has a program responsible for implementing SBOH's rules (personal communication, SBOH, September 2023). If SHB 1010 were to pass, staff representing SBOH stated they would engage DOH in rulemaking to develop rules regulating commercial crab harvesting, tracking, and recalls related to biotoxin contamination (personal communication, SBOH, 2023). SBOH staff stated they would also work with additional partners, such as Washington Department of Fish and Wildlife (WDFW) which works with DOH on regulation and enforcement of Chapter 69.30 RCW (personal communication, SBOH, September 2023).[29] SBOH would also seek to work with Tribes, Washington State Department of Agriculture (WSDA), local health jurisdictions, state commercial Dungeness crabbers, subject matter experts, interested parties, and communities most likely to be impacted by the rules.[29]

Key informants stated that rulemaking should address unique situations for the coast and Puget Sound fisheries (personal communications, September 2023). For example, while the coastal commercial Dungeness crab fishery[h] has been closed due to biotoxin contamination, Puget

[h] SHB 1010 pertains to commercially harvested crab. Since the state commercial crab fisheries only allow harvest and retention of Dungeness crab (personal communication, Washington Department of Fish and Wildlife [WDFW],

Sound has not experienced harmful algal blooms (HABs) that have required the Puget Sound commercial Dungeness crab fishery to close due to biotoxin contamination (personal communication, WDFW, October 2023). The commercial crabbing season and management agreements between Tribes and WDFW are also different in Puget Sound compared to the coast, which may create unique regulatory circumstances that should be addressed in rulemaking (personal communication, WDFW, October 2023). Therefore, key informants stated that the rulemaking process should seek to engage Puget Sound Tribal and state commercial crabbers and should include elements that account for the uniqueness of the Puget Sound commercial crab fishery (personal communication, WDFW, October 2023). See "Additional Considerations" for further discussion of the Puget Sound state commercial Dungeness crab fishery and Tribal commercial Dungeness crab fisheries.

A key informant with experience commercially crabbing in Washington State mentioned additional factors that should be considered as part of the rulemaking process, including the timing of management actions (e.g., when closures and evisceration orders should be recommended), who should communicate management actions (e.g., some commercial crabbers have a trusted relationship with WDFW), locations for eviscerating crab (on vessel, on dock, in transit, etc.), and fees for commercial crabbers (personal communication, October 2023). They also stated that commercial crabbers generally have a trusted relationship with WDFW but would need to build trust and relationships with public health agencies (personal communication, October 2023).

Similar factors have also been discussed in the literature. Following the 2015 HAB event, interviews with people living in 2 fishing-dependent communities, including Long Beach, Washington, found that "distrust in government decisions about closure boundaries was especially prevalent among fishers."[32] Interviewees stated they needed more information about how crab were tested to determine if they were safe to consume and how test results impacted fishery management decisions, including geographic closure boundaries.[32] Interviewees also stated the importance of clearly and quickly communicating with crabbers about closures to protect public health in order to build trust.[32] Interviewees as well as key informants mentioned the importance of engaging with and communicating with commercial crabbers in a variety of ways (e.g., email, phone, mail) to accommodate challenges accessing technology, especially with varying work conditions, schedules, and time on boat (personal communications, October 2023).[32]

Key informants representing SBOH and DOH stated rulemaking must occur before DOH could implement a program (personal communications, September 2023). Key informants representing SBOH and DOH stated that, once rules are adopted by SBOH, DOH would implement a program to regulate commercially harvested crab for biotoxin contamination (personal communications, September 2023).

SHB 1010 would grant DOH authority to develop and implement a new program regulating biotoxin contamination for commercial crab. Since SHB 1010 allows rulemaking, aspects of a program to regulate commercially harvested Dungeness crab for biotoxin contamination would

November 2023), provisions of SHB 1010 would only apply to Dungeness crab. This review retains "crab" in discussion of bill provisions and otherwise uses "crab" and "Dungeness crab" interchangeably.

be determined during rulemaking and program development would follow rulemaking. It is not possible to fully predict what may be included in a new program. Staff representing SBOH stated that developing rules and a program to regulate commercial crab would have unique issues that would need to be explored, researched, and developed through rulemaking (personal communication, SBOH, September 2023). However, key informants stated that existing programs like the National Shellfish Sanitation Program (NSSP) and state Shellfish Sanitation Program could serve as models for a new commercial crab regulatory program (personal communications, September 2023). For example, Chapter 69.30 RCW includes regulations addressing monitoring, management actions, compliance, and coordination for bivalve mollusks. Staff representing SBOH as well as additional key informants also stated that a new program may consider the framework and components of the existing state Shellfish Sanitation Program (personal communications, September 2023).

More specifically, a new program would likely build on and expand elements of the existing state "Strategy for Preventing Consumer Exposure to Domoic Acid from Coastal Dungeness Crab," which is developed and followed by DOH, Tribes, WDFW, and WSDA (personal communication, DOH, September 2023).[13] As part of a fiscal note for SHB 1010, DOH indicated that work to develop and implement a program to regulate commercially harvested crab for biotoxin contamination would likely include: monitoring biotoxins; sampling crab; processing samples; analyzing data; communicating results; issuing advisories and/or closures; coordinating with regulatory agencies (e.g., WDFW, WSDA); engaging with the commercial crab industry; managing complaints; and overseeing crab licenses.[29]

Lastly, Washington, Oregon, and California have entered into the Tri-State Dungeness Crab Memorandum of Understanding that provides for the "interstate cooperation in management of the Pacific Coast Dungeness crab fishery and in dealing with adjustments to the fishing season […]."[21] The Tri-State process includes discussion of fishery delays, closures, and management actions (personal communications, October 2023).[21] Both California and Oregon have passed legislation allowing for evisceration orders if domoic acid levels in crab viscera exceed allowable levels.[26,36] Researchers have noted that commercial crabbers may have distrust of or confusion about differences in state fishery management actions, especially along state borders.[28,32] Key informants have suggested that SHB 1010 may provide an opportunity to align rules and available management options across all 3 states (personal communications, October 2023).

Therefore, based on public health regulatory structure and information from key informants representing SBOH and DOH, we have made the informed assumption that SHB 1010 may lead to SBOH conducting rulemaking and DOH implementing a program to regulate commercially harvested crab for biotoxin contamination.

Would SBOH conducting rulemaking and DOH implementing a program to regulate commercially harvested crab for biotoxin contamination increase monitoring, flexibility of management actions, coordination, and compliance related to biotoxin contamination in commercially harvested Dungeness crab?

We have made the informed assumption that SBOH conducting rulemaking and DOH implementing a program to regulate commercially harvested crab for biotoxin contamination

may increase monitoring, flexibility of management actions, coordination, and compliance related to biotoxin contamination in commercially harvested Dungeness crab. This informed assumption is based on proposed changes to the law and information from key informants.

While it is not possible to fully predict what may be included in a new program, there are existing programs and processes that may serve as models for the regulation of commercial Dungeness crab in Washington State. DOH, Tribes, WDFW, and WSDA develop and follow a state "Strategy for Preventing Consumer Exposure to Domoic Acid from Coastal Dungeness Crab."[13] If SHB 1010 were to pass, elements of this plan would likely be expanded, including changes to monitoring, management actions, coordination, and compliance (personal communication, DOH, September 2023).

Monitoring

There are current ongoing and seasonal monitoring efforts to understand potential biotoxin contamination in Dungeness crab. DOH partners with University of Washington's Olympic Region Harmful Algal Blooms (ORHAB) program and Washington Sea Grant's SoundToxins program, which monitor seawater from Washington State's coastal beaches and bays and Puget Sound (respectively) for phytoplankton that can produce biotoxins as an early warning system to detect HABs (personal communication, ORHAB, September 2023).[19,20] ORHAB and SoundToxins work closely with DOH, Tribes, and WDFW and communicate to DOH if phytoplankton that can produce biotoxins is present in the waterbodies (personal communications September-November 2023). This can allow DOH to increase monitoring frequency and take preventive action (personal communications, September-November 2023). For example, if high levels of phytoplankton that can produce biotoxins are found by ORHAB, DOH may request additional crab sampling in an area based on elevated HAB risk.[13] These monitoring programs are ongoing and may provide an early indication of potential HABs (personal communication, ORHAB, September 2023).

DOH monitors for biotoxins in bivalve mollusks (e.g., razor clams) on the coast.[13] Since coastal Dungeness crab feed on razor clams, DOH uses data from bivalve monitoring to help predict potential levels of biotoxins in Dungeness crab (personal communication, DOH, September 2023). In the event "there is an increase in domoic acid in razor clams, more frequent sampling of Dungeness crab may be required" by DOH.[13] Additionally, DOH monitors for biotoxins in bivalve mollusks in Puget Sound. If shellfish samples suggest that levels of biotoxins may be elevated in Puget Sound, "DOH will notify […] WSDA, WDFW, and any […] Tribe in the impacted area and request crab samples for testing."[13]

As part of the state strategy, DOH receives crab samples from coastal Tribes and WDFW (personal communications, October-November 2023). WDFW contracts with coastal commercial crabbing vessels to collect Dungeness crab samples to test for biotoxin contamination (personal communication, DOH, November 2023).[29] DOH receives 1 set of 6 Dungeness crab from 5 sampling areas (3 coastal areas and 2 coastal bays [i.e., Willapa Bay and Grays Harbor]) to test for biotoxin contamination before the start of each commercial crabbing season (personal communication, DOH, September 2023).[13] Crab samples are not currently collected from the Puget Sound,[13] and DOH does not currently conduct any coordinated sampling with WDFW for crab in Puget Sound (personal communication, WDFW, October 2023).

DOH tests the crab viscera from each sample (i.e., from 6 individual whole cooked Dungeness crab per area).[13] In order for the commercial crabbing season to open, domoic acid levels in the crab viscera must be below 30 ppm (personal communications, September 2023). DOH may also test crab meat samples separately if domoic acid in the crab viscera is over 30 ppm (personal communication, DOH, September 2023). During the commercial crab season, DOH may continue to test crab samples on a monthly basis during elevated HAB risk (personal communication, DOH, November 2023).[13] DOH may ask WDFW for additional crab samples if biotoxin levels are elevated.[13]

SHB 1010 would allow DOH to test more continually and to increase the amount of monitoring and testing for biotoxin in Dungeness crab (personal communication, DOH, October 2023). If SHB 1010 were to pass, DOH would likely increase the number of crab sampled, the number and types of locations monitored (e.g., coast, coastal bays, Puget Sound), and the frequency of monitoring for biotoxin contamination in crab (personal communication, DOH, October 2023). SHB 1010 may also allow DOH to monitor for additional biotoxins in Dungeness crab. If the bill were to pass, DOH would plan to test for Amnesic Shellfish Poisoning (ASP) biotoxin (i.e., domoic acid), Paralytic Shellfish Poisoning (PSP) biotoxin, and Diarrhetic Shellfish Poisoning (DSP) biotoxin (personal communication, DOH, October 2023).

Management actions

Under current law, DOH does not have authority to alter practices of the commercial crab fisheries due to biotoxin contamination (personal communications, September 2023). Using general public health authority, DOH is able to close state commercial Dungeness crab fisheries in case of a public health threat, including when levels of marine biotoxins are detected above the action level in crab samples (personal communication, DOH, October 2023). Specifically, if the results of monitoring show that "toxin levels in the viscera of [1] or more crabs in a single sample set of [6] crabs is equal to or exceeds 30 ppm, DOH will issue a closure announcement of the commercial crab fishery" for that sample area.[29] DOH may also close the commercial crab fishery if "any single crab sample of meat shows domoic acid levels of 20 ppm or higher […]"[13] The intent of sampling from different geographic areas is to "protect consumers from high levels of biotoxin in crab while minimizing disruption to commercial and recreational harvest opportunities. Such a plan allows for closures of defined areas if necessary, rather than the entire fishery."[13] If DOH determines a closure of an area or the entire coast is recommended, DOH notifies the U.S. Food and Drug Administration (FDA) and "guides and recommends" the 4 coastal Tribes, WDFW, and WSDA regarding whether the fishery should open, close, require evisceration, or issue a recall based on biotoxin levels (personal communication, DOH, October 2023).[13] WDFW then issues an official closure order and communicates the closures with Tribal and state commercial crabbers.[13] Tribes make decisions to open, close, or recall based on DOH recommendations (personal communication, DOH, October 2023). See "Additional Considerations" for further discussion of Tribal commercial Dungeness crab fisheries.

However, DOH does not currently have the authority to issue an evisceration order if monitoring indicates that domoic acid levels are elevated in the crab viscera but not in crab meat (personal communications, September 2023). When this occurs, DOH may "guide or recommend" WDFW and Tribes regarding whether the fishery should require evisceration (personal communication,

DOH, September 2023). In 2021, based on guidance from DOH that domoic acid levels were elevated in crab viscera but not meat, WDFW adopted an emergency rule temporarily requiring that crab harvested from an area affected by domoic acid be delivered only to a processor authorized to eviscerate Dungeness crab and prohibiting deliveries of live crab from the area (personal communication, WDFW, November 2023).[28,34] Key informants representing WDFW stated that the agency was able to adopt an emergency rule requiring evisceration through their general authority to regulate the time, place, and manner of fishing (personal communication, WDFW, September 2023). However, emergency rules expire after 120 days (RCW 34.05.350).[35] The state strategy to prevent consumer exposure to domoic acid from coastal commercial Dungeness crab states that, "[t]ight controls on harvest, landing and processing of crab from [sample areas] would be necessary before evisceration would be approved as a method of biotoxin control. WDFW or WSDA would have the lead role(s) in implementing such controls […]"[13] However, the authority to issue an evisceration order and the authority to enforce an evisceration order is currently unclear (personal communication, WDFW, September 2023).

Key informants stated that SHB 1010 may allow DOH to develop, establish, and implement additional options to respond to biotoxin contamination events to protect public health, including issuing evisceration orders (personal communications, September-October 2023). While WDFW was previously able to issue an evisceration order using emergency rulemaking, key informants stated that SHB 1010 would clarify the authority to issue and enforce evisceration orders (personal communications, September-October 2023). Overall, key informants representing state agencies stated that SHB 1010 would provide DOH clearer authority and greater flexibility to take actions to protect public health during biotoxin contamination events (personal communications, September 2023).

Coordination

Under current law, DOH has authority to tag bivalve mollusks for tracing and recalls to protect public health, but does not have authority to tag, trace, or recall crab (personal communication, SBOH, September 2023). Therefore, there is not currently a system for tagging, tracing, or recalling crab that goes to markets, grocery stores, restaurants, etc. (personal communication, SBOH, September 2023). Key informants stated that tagging may be especially important during events requiring a closure on the coast but no closure in Puget Sound, as retailers and consumers would then be able to verify crab were harvested from the Sound and are safe to eat (personal communication, WDFW, October 2023).

SHB 1010 may allow coordination between DOH, WDFW, and WSDA around tagging, tracing, recalls, and communication with commercial crabbers (personal communication, DOH, October 2023). This may also provide DOH with clearer authority and greater flexibility to take action to protect public health during biotoxin contamination events.

Compliance

DOH and WDFW maintain a Memorandum of Understanding (MOU) that allows WDFW to enforce SBOH's rules related to sanitary control of bivalve mollusks (personal communications, September 2023). The MOU allows WDFW to work with commercial shellfish operations to ensure compliance as well as authority to enforce recalls (personal communication, WDFW, September 2023). Since the current shellfish sanitation law does not extend to crab, the MOU

and enforcement agreements do not extend to crab (personal communication, WDFW, September 2023). Key informants representing WDFW stated that this creates challenges for enforcing public health actions related to crab (personal communication, WDFW, September 2023). For example, when WDFW adopted an emergency rule temporarily requiring evisceration in 2021, authority to enforce the evisceration order was unclear (personal communications, September 2023).

SHB 1010 would help clarify authority for enforcement of evisceration and allow WDFW to provide support to commercial crabbers for compliance (personal communications, WDFW, September 2023). SHB 1010 would also help clarify authority to assist with public health tracking and recalls (personal communication, WDFW, September 2023).

Since SHB 1010 would allow SBOH to conduct rulemaking and grant authority for DOH to regulate commercial crab for biotoxin contamination, it is not possible to predict exact regulations SBOH may require in rule or exact programming DOH may adopt as part of implementation. However, since DOH does not currently have the authority to regulate commercially harvested Dungeness crab and since key informants have indicated that DOH would likely build on and expand elements of the state strategy, we have made the informed assumption that SHB 1010 may increase monitoring, flexibility of management actions, coordination, and compliance related to biotoxin contamination in commercially harvested Dungeness crab.

Pathway 1: Commercial crabbers and fishing communities

Would increased monitoring, flexibility of management actions, coordination, and compliance related to biotoxin contamination in commercially harvested Dungeness crab increase opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events?

We have made the informed assumption that increased monitoring, flexibility of management actions, coordination, and compliance related to biotoxin contamination in commercially harvested Dungeness crab may increase opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events. This assumption is based on information from published literature and key informants. Key informants stated that increased monitoring and flexibility of management actions would have the potential to limit areas impacted by a closure, shorten the duration of time a fishery may need to remain closed, or reduce full closures of the commercial Dungeness crab fishery (i.e., by taking alternative action to allow fishing to continue [e.g., evisceration]) (personal communications, September-October 2023).

Temporal and spatial specificity of actions

Washington State experienced fishery closures due to domoic acid during the 2014-2015, 2015-2016, 2016-2017, and 2020-2021 commercial Dungeness crab fishing seasons.[28] During these events, the coastal commercial Dungeness crab fishery was closed due to biotoxin contamination. One researcher noted that early warnings of HABs and domoic acid contamination could "allow more timely and spatially-refined [i.e., geographically limited] identification of areas of high and low toxin risk and smaller [focused] closures" which "could potentially reduce [economic] losses from future closures […]"[8]

Increased monitoring of crab may also allow for greater temporal and spatial specificity of closures (i.e., time or geographically limited closures). Following the 2015 HAB event, Oregon expanded the number of testing sites from 5 to 12 locations which allowed more close monitoring during biotoxin contamination events and resulted in more specific closures and evisceration orders.[28] In addition, DOH stated that, if SHB 1010 were to pass, DOH would plan to analyze crab from both the coast/coastal bays and Puget Sound (personal communication, DOH, October 2023). This would allow DOH to better understand biotoxin levels in crab in different waterbodies and Marine Areas and to understand where levels are elevated (personal communications, September-October 2023). Key informants stated that increased monitoring could provide greater refinement of fishing areas and specific closure directives (personal communications, September 2023). For example, increased monitoring of all areas could allow more area-specific closures, limit whole fishery closures, and specifically recommend which geographic areas to remain open and which geographic areas to close (personal communications, September 2023).

Increased monitoring may also limit the timing of closures. For example, crab may retain domoic acid for several weeks or longer[24] and shellfish species have been shown to retain PSP for weeks to more than 5 years, which can impact the time they may pose a risk to human health from consumption.[22] By monitoring more frequently or continuously, DOH may better understand when levels of biotoxins return below action levels in Dungeness crab, which may limit the timing or duration of closures. Following the 2015 HAB event, Oregon increased testing frequency to monthly, which has helped identify and respond to mid-season contamination risks.[28] This "monthly monitoring has [initiated] mid-season management (both closures and evisceration orders), but continued monitoring has been relatively quick […] to lift restrictions",[28] suggesting that increased monitoring may also impact the duration of closures.

Lastly, a modeling study found that increasing monitoring of West Coast Dungeness crab for domoic acid contamination "resulted in a reduction in the proportion of undetected public health risk by 16% […] and increase in the proportion of unnecessary fishery closures of only 2% […]"[28] The study authors concluded that these results suggest that, "investments in expanded biotoxin monitoring limit unnecessary closures to the fishery."[28]

Evisceration orders

Increased monitoring of Dungeness crab for biotoxins may also allow for greater understanding of biotoxin levels in parts of the crab. DOH currently tests for biotoxin levels in Dungeness crab viscera and, as indicated, in crab meat separately (personal communication, DOH, September 2023), which could provide information needed for evisceration. Both California and Oregon have passed legislation allowing for evisceration orders if domoic acid levels in crab viscera exceed allowable levels.[26,36] Researchers have noted that requiring evisceration of Dungeness crab is an example of "regulatory approaches that are flexible and can increase opportunities for the industry amid HAB events, while ensuring food safety for consumers."[46] Researchers also suggested that evisceration orders, "may be more effective if combined with finer scale spatial management informed by HAB monitoring and forecasting data [...] it may be possible to continue harvest and sale of whole crab from areas without high concentrations [of domoic acid] and limit the need to eviscerate or hold crab to areas with high concentrations."[46]

In 2021, WDFW adopted an emergency rule temporarily requiring evisceration in response to prolonged closures due to domoic acid.[28,34] The emergency rulemaking stated, "the viscera from crab caught between the [Washington and Oregon] border and Point Chehalis, including Willapa Bay are unsafe for human consumption and [DOH has] issued a recommendation requiring evisceration of crab caught in this area. To strengthen the enforcement of an evisceration requirement needed to protect public health, all crab landed into [Washington State] from any [W]est [C]oast area south of Point Chehalis, Washington, must be eviscerated."[34] Key informants stated that allowing DOH to issue evisceration orders could create more options and opportunities for fishing to occur (personal communications, September-October 2023).

While SHB 1010 may increase opportunities for the commercial Dungeness crab fisheries to remain open during biotoxin contamination events, events will likely continue to occur with greater frequency and intensity due to climate change (personal communications, September 2023).[4,8,28-32] As a result, there may be an increase in events that require fishery closures to protect public health (personal communications, September 2023) and closures may be longer, more frequent, and more widespread.[30,31] Commercial fishers and fishing communities are likely to experience many impacts due to climate change, including shifts in the geographic distribution of fish species, changes in fishery productivity, frequency and magnitude of HABs, and seafood safety.[30] Moreover, "[f]isheries are inherently variable and prone to unexpected shocks and natural cycles with climate change creating even more uncertainty. The Dungeness crab fishery is no exception, experiencing fluctuations in harvest from season-to-season and spatial and temporal changes in the population."[2]

However, key informants representing Washington State agencies stated that additional testing and real-time data of biotoxin levels in crab, additional options to respond to high levels of biotoxins, and clearer authority to respond to biotoxin events have the potential to limit areas impacted by closures, shorten fishery closures, or reduce full closures (personal communications, September 2023), even as closures to protect public health continue or increase in the future. Key informants stated that SHB 1010 would provide "more tools in the toolbox" to respond to climate change, HABs, and biotoxin contamination events (personal communications, September-October 2023). Therefore, we have made the informed assumption that SHB 1010 may increase opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events.

Would increased opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events improve economic outcomes for commercial crabbers and fishing communities?

There is a fair amount of evidence that increased opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events would likely improve economic outcomes for commercial crabbers and fishing communities.

Commercial crabbers

Generally, research has demonstrated that fishery closures have negative economic impacts for commercial fishers and fishing communities. For example, following the 1992 cod fishery closure (which was not due to a HAB event) in Newfoundland (Canada), surveys were

conducted with 681 people from randomly selected households in 23 communities.[47] Survey results showed that 71% of people who experienced unemployment and 35% of people who were employed after the fishery closure reported that "they and their family were financially worse off than they were before the fishery closure."[47]

It has also been well-documented that fishery closures due to the 2015 HAB event on the West Coast had negative economic consequences. Following the 2015 HAB event that resulted in prolonged fishery closures in Washington, Oregon, and California, revenue from the West Coast commercial Dungeness crab fishery was $97.5 million lower compared to the previous season.[33] More than half of commercial fishers reported experiencing high income losses greater than $9,999.[33] People who experienced "greater absolute income losses were exposed to longer fisheries closures, more dependent on shellfish as a source of income, employed in the fishing industry, and owned their business […]"[33]

WDFW's 2021 Emergency Rule stated, "[f]urther delaying the opening of the coastal commercial Dungeness crab fishery until domoic acid in crab viscera is below federal action levels, which could take several months, would cause significant economic harm to the coastal crab industry and to the coastal communities depending on this highly valuable fishery."[34] Key informants stated that there are immediate economic consequences to commercial crabbers and fishing communities when there are seasonal delays due to biotoxin contamination (personal communications, October 2023). A key informant with experience commercially crabbing in Washington State stated that closures result in "no income and this makes it hard to pay bills […] [C]rew members cannot stick around all winter without getting paid making harvest impossible if the season opens after extended closures" (personal communication, October 2023).

Results from a survey with people living in 16 fishing-dependent communities on the West Coast, including 2 communities in Washington State, found that prolonging the commercial Dungeness crab fishery closure by a quarter of the season was significantly "associated with an 8-11% increase in the probability of experiencing high income losses."[33] In Washington State, the fishery was closed for about 13% of the 2015 season and the typical fishing license owner had a high probably of experiencing income losses over $10,000.[33] Survey respondents employed in the fishing industry reported an annual income of $50,000 to $74,000,[37] suggesting losses over $10,000 may represent a significant portion of annual income. Based on survey results, 87% of respondents employed in the fishing industry reported that the 2015 HAB event negatively impacted finances and 80.7% reported a loss of money.[37] A separate study modelling economic losses in California after the 2015 HAB event estimated that the harvester sector lost $18.12 million in direct income losses and 492 harvester jobs and that processors lost $3.29 million in direct income losses and 111 processor jobs.[8]

About 26% of commercial fishers were able to offset income losses due to the 2015 HAB event by taking adaptive actions (e.g., alternate jobs, alternate fishing, advertising, trading or bartering, discounts) or coping actions (e.g., borrowing money, governmental assistance, default).[33] The majority of West Coast commercial crabbers maintain a diverse fishing portfolio (personal communications, October 2023), meaning they harvest crab and also participate in additional fisheries (e.g., sablefish, salmon, sardines, tuna).[33] Portfolio diversity can help commercial fishers reduce yearly fluctuations in revenue and financial risk.[8] However, previous research has

shown that many Dungeness crab fishers receive the majority of their income from Dungeness crab,[30,33] suggesting portfolio "diversification may not offset losses from a delay or closure unless [Dungeness crab] fishers have access to a good substitute fishery during the closure."[8] Evidence from California after the 2015 HAB event suggested that some crabbers did not fish at all and lost revenue from both crab and additional fisheries; some crabbers fished for crab and lost revenue from additional fisheries they would have participated in during the delay; and most fishers did not have access to an alternative fishery due to fishery restrictions or lack of permits, licenses, gear, etc.[8] The authors found that "over half of the estimated loss in total revenues for the California Dungeness crab fleet is attributable to reduced revenues in [additional] fisheries – from vessels that either dropped out of fishing in 2016 all together or reduced their fishing in [additional] fisheries in order to participate in the delayed crab fishery."[8]

The price of Dungeness crab may further impact economic outcomes for commercial crabbers. The price of Dungeness crab is negotiated between crabbers and processors, with starting prices negotiated before the opening of the commercial Dungeness crab season and continuing throughout the season.[4] Many factors impact the price of Dungeness crab (personal communications, September-October 2023), and the ex-vessel price of crab varies throughout the season depending on volume harvested and product type.[4] Research suggests that, among other factors, the price of crab may be impacted by biotoxin contamination events. Using economic modelling, researchers found that the 2015 HAB event reduced California commercial Dungeness crab ex-vessel prices by 9.6% but did not impact consumer prices.[4] While further research is needed to fully understand market impacts of biotoxin contamination events, lower prices of Dungeness crab could contribute to economic losses for commercial crabbers.

Key informants also noted that closures may have negative economic impacts if customers choose to purchase crab from other states or choose to avoid crab due to concerns about biotoxin contamination (personal communications, October 2023).

We did not find any research evaluating the economic impacts of evisceration for commercial crabbers. Overall, information from key informants suggests that the economic impacts of evisceration orders are complicated. Key informants shared that crabbers receive lower prices for eviscerated crab, compared to live or whole cooked crab (personal communications, October 2023). A key informant with experience commercially harvesting crab in Washington State stated that evisceration "takes away considerable value from the crab resource" (personal communication, October 2023). It is generally accepted that the live and whole cooked crab markets are more economically lucrative and receive a higher price than eviscerated crab (personal communications, September-October 2023). Generally, a key informant with experience commercially crabbing stated that "evisceration is not the action the [commercial crab fishery] wants to take immediately because [eviscerating] the crab reduces the overall income available from the crab resource, […] but the [commercial crab fishery] will want to eviscerate if the closure is prolonged" and starts to experience pressure from other potential sources of closure (e.g., due to whale migration) (personal communication, October 2023).

Oregon State University, in collaboration with researchers from Washington, California, and the National Oceanic and Atmospheric Administration (NOAA), is completing a research project to examine the economic impacts of fishery management decisions and mitigation strategies,

including evisceration orders.[46] The projected completion date for this research is August 2024.[46] While research is ongoing, researchers shared that even if crabbers receive a lower price for eviscerated crab, crabbing under an evisceration order would likely be more economically beneficial to crabbers than a full fishery closure which may halt all income for crabbers (personal communication, Oregon State University, October 2023). Researchers identified a need for additional research, including a need for a cost-benefit analysis to fully understand the costs of evisceration and impacts on market value.[46]

Fishing communities

It is well accepted that, "[t]he commercial Dungeness crab fishery is vital to the health of coastal fishing communities […] because it generates the highest revenues and has a high rate of vessel participation."[33] One researcher stated that, "[w]hile fishery closures prevent disease, they can cause severe social, cultural, and economic disruption to fishing communities that can persist long after the bloom has dissipated, resulting in profound hardship."[37] Key informants and researchers noted that fishery closures may impact households, communities, and the hospitality industry, including stores, restaurants, and hotels (personal communications, October 2023).[33]

In addition to direct impacts on commercial crabbers, fishery closures may have additional adverse impacts on household income. Data have suggested that the majority of commercial fishers are men.[33] One study found that, "the burden of providing a reliable income to counter the variability of fishing revenue often falls disproportionately on women."[33] Additional research has also shown that women may become primary income-earners after prolonged fishery closures.[47] A survey with 262 people living in fishing communities found that "respondents not[ed] that their household was able to cope with HAB-related income losses because a female member of the household earned a non-fishing income. The extent to which a non-fishing income can buffer household losses will depend on the degree to which the income source is associated with the fishing industry and the pervasiveness of economic effects within a community."[33]

Stores, restaurants, and hotels may also experience negative economic impacts from fishery closures since "the recreational harvest and consumption of shellfish are activities that motivate tourist visits to the coast. When these activities are unavailable due to HAB-induced closures, tourist visits to hotels and restaurants in coastal fishing towns decrease […] even in coastal towns where shellfishing is uncommon."[33] Following the 2015 HAB event, most respondents employed in the hospitality industry reported income losses less than $3,000.[33] Researchers have also noted that job losses due to fishery closures may also have a ripple effect in communities due to changes in household spending.[8,47]

Lastly, fishery closures due to biotoxin contamination "may be the most immediate threat from changing ocean conditions to the Dungeness crab industry and associated coastal communities."[31] Evidence indicates that climate change is likely to increase the intensity and frequency of future HAB events,[4,8,29-32] and researchers and key informants noted that additional research is needed to understand the economic impact HABs, biotoxin contamination events, fishery closures, and alternatives like evisceration for commercial crabbers and fishing communities (personal communications, September-October 2023).[2,8] One researcher explained these possible connections:

> [A] complete cost benefit analysis should compare […] potentially avoided [economic] losses to the total cost of monitoring and forecasting programs needed to implement finer

> scale management and support decisions of when and where to open and close areas of fishing under different rules, the cost of mitigation actions (including increased regulatory costs), and how various mitigation measures may affect product value (e.g., if eviscerating crab reduces the value of the crab). To understand the value of mitigation strategies and the investments that enable them, the probable frequency, size and duration of future HAB events that lead to large scale contamination must also be estimated.[8]

Similarly, in 2020, the Pacific Northwest Crab Research Group also identified a number of research priorities needed to fill gaps in knowledge and understanding of the Dungeness crab population.[2] Among other research questions, the group noted a need to better understand how various management strategies impact socioeconomic factors for crabbers, how biotoxins impact the crab fishery, how climate change impacts socioeconomic factors for crabbers, and how climate change, HABs, and the Dungeness crab fishery may interact.[2]

Interviewees from 2 fishing-dependent communities specified that more frequent HAB events would likely result in "the loss of homes, boats, jobs, and the inability to pay monthly bills" or result in a cultural shift away from commercial fishing.[32] Therefore, climate change and HAB events are likely to continue to introduce uncertainty and unpredictability for commercial crabbers and climate change may further impact and exacerbate economic impacts to the commercial Dungeness crab fishery.

While there is strong evidence that prolonged fishery closures due to HAB events have negative economic impacts for commercial crabbers and fishing communities, we have downgraded the body of evidence to a fair amount of evidence for three reasons. First, the majority of research on the economic impacts of Dungeness crab fishery closures has focused on impacts of the 2015 HAB event and has been limited to the state coastal commercial crab fishery. The state Puget Sound commercial crab fishery and Tribal commercial crab fisheries may experience unique impacts from fishery closures. See "Additional Considerations" for further discussion about the state Puget Sound commercial Dungeness crab fishery and Tribal commercial Dungeness crab fisheries. Second, we did not find any research evaluating the potential impact of evisceration orders (which may be an alternative management action if SHB 1010 were to pass) on economic outcomes for commercial crabbers and fishing communities. Third, researchers have identified a need for additional research related to the interaction of climate change, HABs, and fishery management decisions, including evisceration orders.[2,8,46]

Therefore, there is a fair amount of evidence that increased opportunities for commercial Dungeness crab fisheries to remain open during biotoxin contamination events would likely improve economic outcomes for commercial crabbers and fishing communities.

Would improved economic outcomes for commercial crabbers and fishing communities improve health outcomes for commercial crabbers and fishing communities?
There is strong evidence that prolonged fishery closures due to biotoxin contamination events have negative social, cultural, mental, and emotional impacts for commercial crabbers and fishing communities, which impact health.

Research on the social, cultural, mental, and emotional impacts of HABs is limited and emerging.[32,33,37] Researchers have noted that, "[s]ocial impact assessments of HABs and HAB

management strategies are almost nonexistent",[37] are even more limited for coastal communities,[32] and lack "standardized tools […] to describe the social, cultural, and economic impacts of severe HAB events."[32] However, "[t]he societal impacts of [HABs] can be severe and include adverse health outcomes, economic loss, disruption to social and cultural practices, and losses to both individual and community wellbeing."[37] We did not find any research evaluating the potential impact of evisceration orders on social, cultural, mental, and emotional outcomes for commercial crabbers. Since SHB 1010 may increase opportunities for the commercial Dungeness crab fishery to remain open during biotoxin events and may improve economic outcomes, evidence indicates some negative social, cultural, mental, and emotional impacts may be lessened.

A general body of evidence suggests that employment stability may impact mental and emotional outcomes and "[p]ublished literature has provided ample evidence of detrimental effects of unemployment on mental, physical, and social well-being of individuals, family and community."[47] The World Health Organization (WHO) stated, "health effects start when people first feel their jobs are threatened, even before they actually become unemployed. This shows that anxiety about insecurity is also detrimental to health."[38] Results from an analysis of longitudinal studies demonstrated a relationship between losing a job and negative changes in mental health including indicators such as depression, anxiety, distress, and general well-being.[40] Data also suggested that returning to employment after a period of being unemployed is associated with an improvement in mental health indicators.[40]

Commercial crabbers

Commercial fishers experience high levels of mental and emotional stress, depression, anxiety, feelings of hopelessness, sleep disturbances, domestic unrest, substance use, social withdrawal, anger management issues, shaking, hair loss and discoloration, self-harm, risk-taking, and death by suicide.[38] Commercial fishers are also less likely to use healthcare services due to irregular work schedules and hours, self-employment status, and community culture.[38]

In 2015, researchers in Australia conducted qualitative interviews with 34 commercial fishers to examine the health and well-being of fishers.[38] All commercial fishers identified mental health as a key challenge to health and wellbeing.[38] Commercial fishers discussed two causes of stress: 1) Traditional risks and 2) Modern uncertainties.[38] Traditional risks included dangerous working conditions, fluctuating markets, variable catches, odd hours, being self-employed, anxiety about physical risks, and economic stressors.[38] The authors explained that, "[t]raditional risks within fishing were about calculated risks over which fishers had some control, and which they could approach using their accumulated skill and knowledge."[38] For example, "economic stressors that fishers have traditionally faced are manageable in part because there is an expectation that businesses will be able to bounce back in the coming months or years to make up for poor catches or markets."[38] Traditional risks were viewed as less stressful than modern uncertainties and as "part of the job."

Modern uncertainties included government fishery management decisions (e.g., fishery closures)[38] as well as increasing regulatory surveillance; oversight and compliance; changes to access rights; negative representation in the media; and conflict with other stakeholders.[39] The authors explained that fishery closures or fear of closures "cause fishers distress both due to the

restrictions themselves but also in terms of their perplexing and uncontrollable nature […] Fishers emphasized the perceived rapidity; the unexpected nature; and the inability to anticipate, and prepare for, such closures, as being particularly worrying."[38]

In a 2017 national follow-up study with 872 commercial fishers in Australia, fishers reported that 22% of stressors were related to traditional risks (e.g., financial burdens, harvesting), 22% were related to modern uncertainties (e.g., regulation change, quota and license requirements), and 13% were related to future uncertainties (e.g., climate change, seafood stocks).[39] The most common perceived stressors were those relating to changes in government regulation and uncertainty about future regulatory changes.[39]

Following the 2015 HAB event, a survey with people living in 16 fishing-dependent communities on the West Coast, including 2 communities in Washington State, found that 87.5% of respondents employed in the fishing industry reported that the 2015 HAB event caused stress.[37] About 38% of respondents employed in the commercial crab fishery "strongly agreed" that they experienced stress as a result of the 2015 HAB event.[33] For commercial fishers, "high income loss increased the predicted probability of strongly agreeing to experiencing stress […]"[33] Interviews suggested that stress was often due to financial insecurity and resulting strain in social and familial relationships.[32,33] Prior research on fishery closures has also found that finances and money were main sources of stress.[47] Following the cod fishery closure (which was not due to a HAB event) in Newfoundland (Canada), 59% of people experiencing unemployment and 49% of people who were employed stated that their life was more stressful or much more stressful after the closure.[47] People who experienced unemployment following the fishery closure were also more likely to experience worse mental health and less likely to report satisfaction with tasks, making decisions, and day-to-day activities compared to people who were employed.[47]

The survey following the 2015 HAB event on the West Coast also found that 39% of respondents employed in the commercial crab fishery "strongly agreed" that "their family gatherings, holidays, or traditions were negatively impacted […] by the HAB event due to a lack of shellfish to eat. Examples of these cultural impacts include an inability to partake in traditional gift-giving of shellfish, a lack of crab for holiday meals, and disruption to social activities – notably razor clam harvests – that are integral to community identity."[33] Researchers and key informants also mentioned the importance of crab for certain holidays (e.g., Thanksgiving, Christmas, New Year, Chinese New Year) and the potential impact closures may have for some communities (personal communications, October 2023).[4]

No studies have evaluated the impact of evisceration orders on the social, cultural, mental, or emotional health of commercial crabbers. Key informants stated that evisceration orders are challenging for commercial crabbers, requiring them to change processes and procedures (personal communications, October 2023). The survey following the 2015 HAB event found that commercial fishers who engaged in alternate fishing did not report increased stress and "being able to engage in [alternate] fishing activities [may] not trigger stress because occupational identity and cultural norms are sufficiently maintained."[33] If being able to crab under an evisceration order also maintains occupational identity and cultural norms, commercial crabbers may experience less stress than engaging in non-fishing alternative actions or coping actions as a

result of a biotoxin contamination event. However, no research has been conducted to test this hypothesis.

Fishing communities
Research has also shown that fishery disruptions may also impact sociocultural, physical, and mental health for people living in fishing communities, including impacts related to mental health concerns, life expectancy, substance use, and loss of cultural identity.[32] About 29% of respondents employed in hospitality "strongly agreed" that they experienced stress as a result of the 2015 HAB event on the West Coast.[33] Livelihood insecurity and lost cultural opportunities impact the physical and emotional health of people living in fishing communities.[33] The 2015 HAB event impacted opportunities for spiritual enrichment and traditional activities which "are important to human wellbeing, providing a sense of place and identity in coastal communities."[33] About 29% of respondents employed in hospitality "strongly agreed" that the HAB event had negative cultural impacts.[33]

Overall, there is strong evidence that prolonged fishery closures due to biotoxin contamination events have negative social, cultural, mental, and emotional impacts for commercial crabbers and fishing communities, in part due to economic impacts. Therefore, improved economic outcomes for commercial crabbers and fishing communities would likely improve social, cultural, mental, and emotional impacts for commercial crabbers and fishing communities.

Would improved health outcomes for commercial crabbers and fishing communities reduce inequities?
There is strong evidence that improved health outcomes for commercial crabbers and fishing communities may reduce inequities by occupation and community.

Inequities by occupation
Commercial fishers are more directly impacted and experience larger economic losses as a result of HAB events and fishery delays and closures compared to other occupations (e.g., workers in the hospitality industry).[33,37] Researchers have stated that commercial fishers may experience greater income losses "because their incomes are directly tied to closed fisheries."[33]

In addition, commercial crab fishing license owners or vessel operators may experience greater losses than other occupations in the fishing industry. For example, surveys with 16 fishing communities on the West Coast after the 2015 HAB event, including communities in Washington State, found that people "employed in fishing-related occupations experienced greater financial, emotional, and sociocultural impacts than those employed in [different] sectors."[37] Commercial crab fishing license owners or vessel operators had a greater probability of experiencing income losses compared to deckhands, fish processors, and fish retailers.[33] However, the authors hypothesized that employees and deckhands may be first to lose their jobs if employers suffer losses.[33] Interviews with people living in 2 fishing-dependent communities also suggested that deckhands may experience more severe economic impacts from closures.[32] Additionally, a key informant with experience commercially crabbing in Washington State suggested that younger members of the commercial crabbing fleet may have higher debts and may be more likely to experience challenges due to closures and evisceration orders (personal communication, October 2023).

Commercial fishers also experience worse mental health outcomes compared to people employed in different occupations. Prior research in Australia found that commercial fishers experience unique stressors as an occupation, including unstable access to fisheries, financial insecurity under management arrangements, and "relentless financial uncertainty."[38] These uncertainties are, "a key driver of chronic livelihood insecurity, resulting in reports of stress, depression, and [death by suicide]."[38] Research has also found "[p]eople in the fishing industry were least likely to present a positive attitude to health as an underlying health belief, when compared with [different] industry groups […]"[38]

In a 2017 national study with 872 commercial fishers in Australia, 22.9% of fishers reported experiencing high or very high levels of psychological distress, compared to 11.7% of the Australian general population.[39] Across all fishers, greater perception of traditional risks and modern uncertainties was associated with greater psychological distress; however, stressors varied by fishing location and by occupation within the fishing industry.[39] For example, commercial fishers who fished offshore were significantly more likely to report greater perception of traditional risks than fishers who fished inshore.[39] Fishers involved in the management of the operation had stronger perceptions of modern uncertainties and crew members reported higher perceptions of future concerns.[39] The authors stated that fishers engaged in management of the operation may experience greater perception of and psychological distress related to modern uncertainties as they may have "greater responsibility for decision-making, meeting regulatory and reporting obligations, and […] greater financial investment compared to the crew."[39]

Inequities by community

Researchers have stated that fishery management practices in response to climate change and biotoxin contamination events should account for "communities-of-place, such as individual ports, and communities-of-practice, such as groups of vessels with similar characteristics and constraints […to] meet equity objectives in the face of climate shock."[30]

Communities-of-place

Key informants stated that some of the most economically vulnerable communities in Washington State are located on the coast (personal communication, WDFW, September 2023). In the literature, coastal communities include those with cultural, social, or economic dependence on coastal resources and fishing-dependent communities are those that are highly dependent on and engaged in the harvest or processing of fishery resources.[37,48] The geographic isolation of many coastal and fishing-dependent communities may also compound socioeconomic impacts of fishery closures due to HAB events.[32] Some coastal or fishing communities may rely on income from the Dungeness crab industry more than others, especially where income from Dungeness crab landings are a significant proportion of the community economy.[31]

Researchers have stated that some fishing communities may be more resilient to HABs, while "some fishing communities may have limited capacity to cope and adapt to HABs because of other chronic or co-occurring socioeconomic and environmental health challenges such as competing ocean uses, a lack of young people entering the [fishing] workforce […], and climate

change effects."[37] A study with 18 coastal, fishing-dependent communities in Washington, Oregon, and California, including Chinook, Ilwaco, Tokeland, and Westport, Washington, "used social vulnerability to assess the level of disruption that would occur in a community given an interference in the lucrative Dungeness crab fishery."[31] The authors included measures of personal disruption, population composition, poverty, labor force, household characteristics, housing disruption, and retiree migration.[31] The authors then combined fishery-reliance and social vulnerability to determine a susceptibility score to indicate the degree to which a community would be impacted by a change in Dungeness crab harvest.[31] The authors concluded that Washington State coastal communities had a high social vulnerability score and had the highest reliance on the Dungeness crab fishery of all 18 communities in their analysis.[31] Overall, Washington State had the highest regional susceptibility score which "indicates higher overall risk that Washington coastal communities would be negatively impacted by a decrease in Dungeness crab [harvest] from changing ocean conditions."[31]

Income from commercial fishing may also have additional community impacts. Interviews with 2 fishing-dependent communities found that harbor districts experienced reduced revenue following the 2015 HAB event since they derive revenue from landings.[32] Key informants suggested that revenue from landings may impact whether or not a port can be dredged (sediments removed from the waterbody), which may impact whether commercial fishing vessels can get in and out of a particular port (personal communication, WDFW, September 2023). This can be especially important for smaller ports along the Washington State coastline (personal communication, WDFW, September 2023).

Communities-of-practice

Evidence also shows that impacts may differ by vessel size. An economic analysis of the 2014-2015 and 2015-2016 HAB events in California found that both small and large Dungeness crabbing vessels shifted their landing locations to areas not impacted by closures and increased their distance travelled in response to fishery delays and closures.[30] However, the shifts and distance travelled were greater for larger vessels than smaller vessels.[30] In addition, the authors found that smaller vessels experienced a significantly lower proportion of revenue and participation in the Dungeness crab fishery compared to previous years.[30] The study authors concluded that larger vessels had a greater ability to mitigate losses due to HAB events and fishery delays and closures than smaller vessels.[30]

Economic and additional measures of social vulnerability measures contribute to health. There is a large body of robust evidence that supports the association between income, or socioeconomic status, and health. A report by the U.S. Agency for Healthcare Research and Quality stated, "more than half of measures show that [low-income] households have worse [health]care than high-income households" and "significant [inequities] continue for people [with low-incomes] compared with high-income people who report they were unable to get or were delayed in getting needed medical care due to financial or insurance reasons."[49] Significant correlations exist between lower income and a number of health indicators including worse overall self-reported health, depression, asthma, arthritis, stroke, oral health, tobacco use, women's health indicators, health screening rates, physical activity, and diabetes.[50] Further, 2015 data indicate that age-adjusted death rates were higher in Washington State census tracks with higher poverty

rates.[51] Household income was the strongest predictor of self-reported health status in Washington in 2016, even after accounting for age, education, and race/ethnicity.[52]

Moreover, many Washington State coastal communities are considered Medically Underserved Areas with limited access to primary care services, including the majority of communities in Clallam, Grays Harbor, and Pacific Counties.[53] It is well-established that access to healthcare services impacts health, and there is a large body of evidence supporting the positive association between use of health services for the early detection and treatment of physical and mental health disorders and improved health outcomes.

Inequities experienced by commercial fishers and fishing communities may also be exacerbated by climate change. One researcher explained that "inequities in the distribution of climate impacts across a population […] are potentially compounded for vulnerable populations [like fishing communities] due to a greater dependence on natural resources and a lack of social, financial, and other resources to cope with and adapt to environmental change."[30]

Overall, there is strong evidence that improved health outcomes for commercial crabbers and fishing communities may reduce inequities by occupation and community.

Pathway 2: Food safety

Would increased monitoring, flexibility of management actions, compliance, and coordination related to biotoxin contamination in commercially harvested Dungeness crab improve public health safeguards?

There is strong evidence that increased monitoring, flexibility of management actions, compliance, and coordination related to biotoxin contamination in commercially harvested Dungeness crab would likely improve public health safeguards. Generally, researchers have noted that "[p]revention is the best way to manage the risk of potentially serious seafood poisonings."[27] Prevention of potential illness from HABs and biotoxin contamination events requires routine monitoring of coastal waters, seafood, and shellfish as well as fishery closures as needed.[25,27,37]

Monitoring

There is research suggesting that increased monitoring of marine biotoxins may protect public health. A review of literature examining public health outbreaks stated that improvements to monitoring programs are needed as illnesses from consuming seafood contaminated with marine biotoxins continue to occur and toxins continue to be found in coastal waters.[25] The authors recommended intensifying shellfish monitoring programs in HAB-prone areas to determine if toxin levels are above regulatory limits and increasing the frequency of surveillance when marine biotoxins are more likely to be present in the food chain.[25] Specifically, they recommended using 2 monitoring approaches to help prevent public health outbreaks: "1) monitoring of plankton species and of favorable conditions for growth […] and 2) screening of marine biotoxins in seafood harvested at specific locations."[25]

A modeling study found that increased monitoring of West Coast Dungeness crab for domoic acid contamination "resulted in a reduction in the proportion of undetected public health risk by

16% […] and increase in the proportion of unnecessary fishery closures of only 2% […]"[28] Researchers found that a 6 crab per survey protocol correctly diagnosed the safety of opening the Dungeness crab fishery 89% of the time.[28] They also found that public health benefits increased with more sampling sites, and the "incremental benefits to public health outcomes were considerably larger than the incremental losses to fishery outcomes."[28]

Evisceration

Domoic acid preferentially accumulates (i.e., builds up) in the viscera of shellfish and finfish.[24,41] Previous research has found that, when Dungeness crab fed on razor clams contaminated with domoic acid, 68% of the estimated dose of domoic acid is concentrated in the crab hepatopancreas (digestive gland).[24] In a dose-response study with Dungeness crab harvested from Sequim Bay and the Strait of Juan de Fuca in Washington State, researchers found that domoic acid accumulates in the hepatopancreas of crab until it reaches a "break-through" concentration and begins to accumulate in other tissues.[24] In 2018, Oregon Department of Agriculture and California Department of Public Health conducted research comparing domoic acid levels in Dungeness crab meat to levels in Dungeness crab viscera.[41] Dungeness crab with detectable levels of domoic acid had an average level of 51.8 ppm in the viscera and an average level of 8 ppm in the meat.[41] Based on testing of paired meat and viscera from each crab, levels of domoic acid in Dungeness crab meat exceeded 20 ppm when levels in the crab viscera were 46 ppm.[41] Together, these studies suggest that domoic acid levels in crab viscera exceed action levels before domoic acid levels in crab meat. Overall, evisceration may reduce exposure to harmful levels of domoic acid, "since [domoic acid] tends to be concentrated in the viscera, eviscerating crab before they are cooked and consumed can make contaminated crab safe to eat as long as toxin levels in the crab meat are safe" (below 20ppm).[8]

Coordination

One researcher noted that, to be effective, efforts like increased monitoring and evisceration "require investments in monitoring, testing, and chain of custody infrastructure to ensure contaminated crab are not sold to the public."[8] Moreover, illness reporting and investigations are important so that closures can occur and "the risk of secondary cases in cluster outbreaks can be reduced."[27]

Key informants stated that, taken together, increased monitoring, flexibility of management actions, compliance, and coordination are necessary to protect public health and reduce public health risk for people who consume Dungeness crab commercially harvested in Washington State (personal communications, September-October 2023). Researchers have also stated that any HAB mitigation strategy "requires a system of monitoring, regulation, and tracking of harvested crab to ensure crab from areas of high [domoic acid] concentrations" are safe for consumption.[46] Overall, there is strong evidence that increased monitoring, flexibility of management actions (e.g., evisceration), compliance, and coordination related to biotoxin contamination in commercially harvested Dungeness crab would likely improve public health safeguards.

Would improved public health safeguards related to biotoxin contamination in commercially harvested Dungeness crab prevent negative health outcomes for people who consume Dungeness crab commercially harvested in Washington State?
There is strong evidence that improved public health safeguards related to biotoxin contamination in commercially harvested Dungeness crab would likely prevent negative health outcomes for people who consume Dungeness crab commercially harvested in Washington State.

According to WDFW, Dungeness crab is one of the most popular items on Washington State seafood menus.[1] Since there have been instances of biotoxin levels that exceed allowable levels for domoic acid in Dungeness crab in Washington State's territorial waters, improved public health safeguards related to biotoxin contamination may prevent negative health outcomes for people who consume Dungeness crab commercially harvested in Washington State. Moreover, "[c]limate change is predicted to impact seafood safety through increased incidence of […] biological contamination events, e.g., [HABs]."[4] Researchers have noted that seafood-related illnesses are likely to increase in the future, including due to increased frequency of HABs.[27]

Eating contaminated seafood may have negative health outcomes. Consuming contaminated seafood "is the leading cause of foodborne illness with known [cause]. It is responsible for 10-20% of outbreaks among all food types and about 5% of all individual illnesses."[27] From 2001 through 2015, there were thousands of cases of human illness from consuming seafood contaminated with marine biotoxins.[25] These numbers are likely underestimates of seafood-related illnesses since cases are underreported and difficult to diagnose (e.g., symptoms may be similar to allergic reactions or viral or bacterial infections); since contaminated food is often not available for analysis to confirm the presence of marine biotoxins; and since there are preventive efforts to avoid contaminated seafood entering the market.[25,27] As an example of underestimating, previous research in Alaska found that the incidence of paralytic shellfish poisoning (PSP) was 100 times higher based on survey results than the incidence calculated based on public health surveillance data.[25]

Amnesic shellfish poisoning (ASP) from domoic acid[i] has been detected in Dungeness crab.[22] Crab may retain domoic acid for several weeks or longer.[24] When consumed at high levels, domoic acid may cause nausea, vomiting, abdominal cramps, and diarrhea.[22] More serious symptoms may occur after 48 hours, including dizziness, headache, seizures, disorientation, short-term memory loss, difficulty breathing, coma, and death.[22] The only public health outbreak related to the consumption of seafood contaminated with domoic acid occurred in 1987 in Canada among people who consumed contaminated mussels.[25] Over 150 people experienced symptoms of domoic acid and 4 people died as a result of eating contaminated mussels.[42] There have been no incidents of acute illness from consuming domoic acid since 1987 (including in Washington State) due to the adoption of a 20 ppm regulatory level for domoic acid and shellfish sanitation monitoring programs.[25,42]

There is emerging evidence that chronic, low-level exposure to domoic acid at levels below the current regulatory level of 20 ppm may impact health for people who live in coastal communities.[42] Researchers have noted that, "[w]ith the intensification of [HABs] due to climate change and recent consumption surveys identifying that many shellfish harvesters may be

[i] ASP is commonly referred to as domoic acid. This HIR uses domoic acid to describe this biotoxin.

regularly exposed to low levels of [domoic acid], there is an urgent need to comprehensively understand the health impacts associated with chronic, low-level exposure to [domoic acid]."[42]

PSP has also been detected in Dungeness crab.[22] Shellfish species retain PSP for different lengths of time, ranging from weeks to more than 5 years, which can impact the time they may pose a risk to human health from consumption.[22] PSP may cause gastrointestinal symptoms as well as numbness, burning, or tingling in the face and extremities; incoherent speech; loss of coordination; muscle paralysis; shortness of breath; respiratory paralysis; and death.[22] FDA notes, "PSP is an extremely potent toxin with a high mortality rate in cases where medical support is not available."[22] There were more than 100 confirmed cases of PSP in South and North America from 2001 through 2015.[25]

Researchers have noted that "[p]revention is the best way to manage the risk of potentially serious seafood poisonings."[27] Measures to prevent the consumption of marine biotoxins are important as "diagnostic tests are not yet available to detect the presence of these toxins in people, and there are no available antidotes."[27] Prevention of potential illness from HABs requires routine monitoring of coastal waters, seafood, and shellfish as well as fishery closures as needed.[25,27] Moreover, illness reporting and investigations are important so that closures can occur and "the risk of secondary cases in cluster outbreaks can be reduced."[27]

Therefore, there is strong evidence that improved public health safeguards related to biotoxin contamination in commercially harvested Dungeness crab would likely prevent negative health outcomes for people who consume Dungeness crab commercially harvested in Washington State.

Would improving health outcomes for people who consume Dungeness crab commercially harvested in Washington State reduce inequities?
There is a fair amount of evidence that improving health outcomes for people who consume Dungeness crab commercially harvested in Washington State may reduce inequities.

Researchers have noted that additional research is needed to identify who may be most at risk from consuming seafood contaminated with marine biotoxins.[42] There are no data available about who consumes Dungeness crab commercially harvested in Washington State. Available evidence and information from key informants suggests that older people, people who eat crab viscera, people who consume high volumes of crab, and people with certain health conditions may be at greatest risk for shellfish biotoxin poisoning (personal communication, DOH, September 2023).[42] However, no studies have quantitatively examined how consuming shellfish contaminated with domoic acid may impact people by age or by health condition.[42]

Inequities by age
Results from previous biotoxin contamination events have suggested that the most severe neurological symptoms may occur in males over 60 years of age who consume seafood contaminated with domoic acid.[27] Following the 1987 public health outbreak related to the consumption of seafood contaminated with domoic acid, older men were more likely to experience severe symptoms of ASP.[42] Researchers hypothesized "that sex-based differences in seafood consumption and age-related changes in kidney function may have contributed to variations in […] responses."[42]

Inequities by crab consumption habits
People who consume crab viscera may be at greater risk of exposure to harmful levels of poisoning biotoxins. Key informants stated that some people and certain communities eat crab viscera (referred to as "crab butter") and may be at greater risk of exposure to biotoxins (personal communication, DOH, September 2023).

Some evidence also suggests that people who consume high volumes of crab may be at greater risk of experiencing severe symptoms. There is limited data about who may consume higher volumes of Dungeness crab commercially harvested in Washington State. Key informants suggested that Tribal people and certain ethnic communities may consume higher volumes of Dungeness crab (personal communications, September-October 2023). Researchers have noted that the onset of symptoms of PSP appear to be dose-dependent and accelerate more quickly after consumption of higher volumes of contaminated seafood.[27] Therefore, "symptoms may rapidly progress to respiratory arrest in someone who otherwise exhibited no evidence of respiratory distress and death may result."[27]

There is also emerging, though limited research about the impacts of chronic, low level exposure to domoic acid.[27] Researchers have noted that some coastal areas experience persistent, low levels of domoic acid and people living in these communities who eat shellfish may experience negative health outcomes due to chronic exposure.[27,42] Low-level exposure to domoic acid has been shown to impact: 1) learning and memory in humans and animals; 2) emotionality (e.g., anxiety-related behaviors) and motor responses in animals; 3) neurological function in animals; and 4) prenatal and neonatal development in animals.[42] Generally, more research is needed to understand how chronic, low-level exposure to domoic acid may impact human populations.[42]

Inequities by health status
Results from previous biotoxin contamination events showed that, among younger age groups, people most vulnerable to biotoxins also experienced pre-existing health conditions, including renal disease, hypertension, and diabetes.[27] Additionally, there are some studies that suggest low-levels of domoic acid may impact cardiac, renal, and immune functions in animals.[42] Researchers have noted a need for more research to "help reveal the human subpopulations with pre-existing conditions who may be more vulnerable" to domoic acid exposure.[42]

Overall, there is a fair amount evidence that improving health outcomes for people who consume Dungeness crab commercially harvested in Washington State may reduce inequities by age, consumption habits, and health status.

Additional considerations
The majority of research related to impacts of HABs, fishery closures, and management decisions has focused on the coastal state commercial Dungeness crab fishery. However, increased opportunities for commercial Dungeness crab fisheries to remain open during biotoxin events may also have economic, social, cultural, emotional, and mental impacts for: Puget Sound state commercial Dungeness crab fishery; Tribal commercial Dungeness crab fisheries; and Dungeness crab processors. Since there is less research evaluating how these sectors of the

commercial crab industry may be impacted by opportunities for the fishery to remain open, discussion of these pathways was not included in the logic model.

Puget Sound state commercial Dungeness crab fishery
Research related to HABs and fishery closures has been largely limited to the coastal state commercial Dungeness crab fishery. The Pacific Northwest Crab Research Group has noted, "Dungeness crab management in Washington's inland waters [i.e., the Puget Sound] is spatially and temporally complex, with many small discrete spatial management units and a protracted fishing season."[2] Key informants emphasized that the Puget Sound state commercial Dungeness crab fishery may experience additional or unique circumstances and impacts from management actions compared to the coastal fishery (personal communications, October 2023).

While the Puget Sound state commercial Dungeness crab fishery has not experienced closures due to HABs and biotoxin contamination, key informants stated that commercial Dungeness crab fishery closures on the coast may also impact the Puget Sound commercial Dungeness crab fishery. For example, there are impacts to the Puget Sound crab market when the coastal commercial Dungeness crab fishery closes (personal communication, WDFW, October 2023). While it is difficult to anticipate market impacts, key informants shared that closures may positively or negatively impact demand for Puget Sound crab (personal communication, WDFW, October 2023). For example, coastal Dungeness crab fishery closures due to biotoxin contamination could increase demand for crab harvested in Puget Sound or could decrease demand for crab generally due to public perception of health risks (personal communications, October 2023).

Staff representing Washington State agencies also stated that climate change may introduce the potential for HABs and biotoxin contamination events in Puget Sound (personal communications, September-October 2023). With warming oceanic waters, climate change, and the unpredictability of biotoxins, there is the potential the Puget Sound may experience HABs and biotoxin contamination events in the future (personal communications, DOH, October 2023). SHB 1010 may increase monitoring of Dungeness crab in Puget Sound (personal communication, DOH, October 2023). Increased monitoring could help to understand baseline levels of domoic acid, PSP, and DSP; act as an early warning sign; or anticipate biotoxin events in Puget Sound in the future due to climate change and warming waters. If biotoxins are not detected above action levels in Puget Sound crab, SHB 1010 may not directly impact the Puget Sound commercial crab fishery (personal communication, DOH, October 2023). However, increased monitoring, flexibility of management actions, coordination, and compliance may help to protect public health if Puget Sound were to experience a biotoxin contamination event in the future (personal communications, September-October 2023). Since there is less research about how HABs and biotoxin contamination events may impact commercially harvested crab from Puget Sound, it is not possible to determine the full impacts of SHB 1010 on the Puget Sound Dungeness crab fishery and this pathway was not included in the logic model.

Tribal commercial Dungeness crab fisheries and Tribal communities
Tribal commercial Dungeness crab fisheries are regulated by Tribes (personal communications, September-October 2023). The "Consent Decree Regarding Shellfish Sanitation Issues," in which treaty Tribes agreed to conduct shellfishing activities in accordance with public health requirements identified in the NSSP,[11] does not reference crab. However, Tribal staff with

knowledge of Tribal commercial crab fisheries said they believe that, if SHB 1010 were to pass, Tribes would likely continue to follow any actions DOH recommended to protect public health in the case of a biotoxin contamination event (personal communications, October 2023). For example, one Tribal staff stated that if evisceration was allowed in their co-managed harvest area instead of a closure, their Tribe may decide to eviscerate as well (personal communication, November 2023). DOH also stated that, in keeping with the Consent Decree, if SHB 1010 were to pass, they would continue to "guide and recommend" actions to Tribes and work with them during a biotoxin contamination event (personal communication, DOH, September 2023).

Most research on the impacts of Dungeness crab fishery closures has been limited to the state commercial Dungeness crab fishery. Tribal commercial crabbers and Tribal communities may experience economic, social, cultural, mental, and emotional impacts of HABs similarly to state commercial crabbers (personal communications, October-November 2023). However, key informants stated that Tribal commercial Dungeness crab fisheries operates differently than state commercial crab fisheries and may experience additional or unique circumstances and impacts from HABs and fishery closures (personal communications, October 2023). Researchers have also noted a need to specifically understand impacts of HABs and fishery closures for Tribal communities.[32] For example, following the 2015 HAB event, the Quileute Tribe Dungeness crab fishery received a fishery resource disaster declaration and received financial disaster assistance.[33] Under federal law, disaster assistance may be considered for fishery failures if revenue losses are between 35% and 80% of average revenues in the previous 5 years and is allowed if revenue losses are above 80%.[8] The California Dungeness crab fishery was the only additional fishery to receive a disaster declaration following the 2015 HAB event,[33] suggesting the HAB event may have disproportionately impacted coastal Tribes.

Researchers have also stated that HABs and management strategies can "cause severe social and cultural disruptions", including for Tribal communities.[37] In addition to commercial crabbing, Tribal communities participate in ceremonial and subsistence harvesting for Dungeness crab,[5] and may experience unique sociocultural impacts from fishery closures, HABs, and biotoxin contamination events. For example, in interviews with people who lived in Long Beach, Washington, following the 2015 HAB event, one respondent stated that access to crab resources "is traditionally important for gift-giving among Pacific Northwest Native American coastal communities."[32] Researchers noted that an inability to continue traditions may negatively impact sociocultural and emotional wellbeing.[32]

Overall, Tribes, Tribal commercial crabbers, and Tribal communities will likely be impacted if SHB 1010 were to pass. However, since Tribal commercial crab fisheries operate differently than state fisheries and since Tribes, Tribal commercial crabbers, and Tribal communities may experience additional and unique impacts from HABs and fishery closures that require further understanding, it is not possible to determine the full impacts SHB 1010 may have on Tribes, Tribal commercial crabbers, and Tribal communities. Therefore, this pathway was not included in the logic model.

Dungeness crab processors

There has been little research on the economic impacts of fishery closures, delays, and additional fishery management actions (e.g., evisceration) for Dungeness crab processors (personal

communications, October 2023). Key informants noted that market dynamics are complicated for processors, and it is difficult to determine how fishery management actions may impact processors (personal communications, October 2023). For example, it is possible that evisceration may have a positive economic impact for processors, especially if the market shifts from live or whole cooked crab markets to crab part markets (personal communications, October 2023). However, since there has been no published literature evaluating the economic impacts of fishery management actions for processors, it is not possible to determine the impacts SHB 1010 may have for Dungeness crab processors and this pathway was not included in the logic model.

Annotated References

1. **Puget Sound Commercial Crab Fishery: History, management, and regulations. 2023; Available at: https://wdfw.wa.gov/fishing/commercial/crab/pugetsound/about. Accessed 9/18/2023.**
This Washington Department of Fish & Wildlife (WDFW) webpage provides information about the history, management, and regulation of the Puget Sound state commercial crab fishery. The webpage also provides general information about Dungeness crab.

2. **Buckner E., Cruz, A. 2020-2025 Pacific Northwest Dungeness Crab Research Guide. Pacific Northwest Crab Research Group;2022.**
The Pacific Northwest Crab Research Group includes scientific research partners, resource managers, and community members, including the Puget Sound Restoration Fund, Washington Sea Grant, Swinomish Indian Tribal Community, Washington Department of Fish and Wildlife (WDFW), Jamestown S'Klallam Tribe, and Suquamish Tribe. In 2020, the Research Group published the 2020-2025 Pacific Northwest Dungeness Crab Research Guide. The Dungeness crab fishery is one of the highest valued along the West Coast. Based on 2021 unpublished data from WDFW, the authors estimated an annual ex-vessel value of $70 million for the Puget Sound and coastal Dungeness crab fisheries combined. In addition, there is an average of 220,434 recreational crabbing licenses sold each year. The authors noted, "it is unclear how vulnerable the species and fishery are to changing climate and ocean conditions." In 2020, research group outlined four research themes for the Puget Sound Dungeness crab fisheries: 1) Dungeness crab population status, structure, and dynamics; 2) land use and climate change impacts; 3) fishery and industry impacts; and 4) ecology and food web dynamics. In this report, the authors identify the top 10 research questions regarding Dungeness crab biology and management. Management questions were related to Dungeness crab population assessment; spatial and temporal management; adaptive management; habitat conservation and mitigation; disease, pests, and pollution; and fishery impacts. Spatial management refers to geographical and/or political boundaries outlined for harvesting. The authors noted, "Dungeness crab management in Washington's inland waters [i.e., Puget Sound] is spatially and temporally complex, with many small discrete spatial management units and a protracted fishing season." Climate change and warming ocean waters "may impact molting patterns and growth trajectories which could impede the current [fishery] management scheme and potentially reduce protection to vulnerable life stages." Moreover, "[f]isheries are inherently variable and prone to unexpected shocks and natural cycles with climate change creating even more uncertainty. The Dungeness crab fishery is no exception, experiencing fluctuations in harvest from season-to-season and spatial and temporal changes in the population. Recent investigations into potential climate change impacts show deleterious effects to larval development when exposed to increasing acidic ocean conditions."

3. **About the coastal commercial crab fishery. 2023; Available at: https://wdfw.wa.gov/fishing/commercial/crab/coastal/about. Accessed 9/18/2023.**
This Washington Department of Fish & Wildlife (WDFW) webpage provides an overview of the coastal state commercial Dungeness crab fishery.

4. **Mao Junwei, Jardine Sunny L. Market Impacts of a Toxic Algae Event: The Case of California Dungeness Crab. *Marine Resource Economics.* 2020;35(1):1-20.**
Mao and Jardine stated that, "[c]limate change is predicted to impact seafood safety through increased incidence of […] biological contamination events, e.g., Harmful Algal Blooms (HAB)." They stated that misinformation and perceptions of seafood safety are drivers of consumer demand for seafood and "avoidance costs can occur when consumers respond to imperfect information about a contamination event, perceiving a health risk from seafood consumption where one does not exist." They presented previous research showing that biotoxin "contamination events may negatively impact demand even after the product is no longer contaminated and a decline in consumer demand can occur for similar products from uncontaminated areas." Mao and Jardine estimated ex-vessel and consumer prices for Dungeness crab after the 2015 HAB event-related fishery closures were lifted and crab was declared safe to eat. They compared prices before and after the event in California, using Oregon and Washington as controls since those fisheries opened before the California fishery. California received state and national media attention during the 2015 HAB event. Using economic modelling, Mao and Jardine found that the 2015 HAB event reduced ex-vessel prices by 9.6%, but did not impact consumer prices. The authors stated that there was "no evidence of avoidance cost in the California consumer market" after the 2015 HAB event. They presented three possible explanations, including 1) there was an impact on consumer demand, but data do not accurately represent consumer response; 2) there was no impact on consumer demand, but processors lowered prices in anticipation of decreased consumer demand; or 3) there was no impact on consumer demand, but price negotiations between fishers and processors was impacted by the HAB event, with crabbers "more sensitive to the delay and direct economic losses associated with foregone harvest" and more willing to accept a lower price. Mao and Jardine also presented background data showing that, "California, Oregon, and Washington, respectively, landed an average of roughly 36%, 25%, and 40% of the coast-wide volume of Dungeness crab" for the 2012-2013 through 2015-2016 seasons.

5. **Shellfish Treaty Rights FAQ. 2016; Available at: https://nwifc.org/about-us/shellfish/treaty-rights-faq/#gsc.tab=0. Accessed.**
This Northwest Indian Fisheries Commission webpage provides answers to frequently asked questions about Shellfish Treaty Rights, including information about biotoxin monitoring.

6. **Dungeness crab (Cancer magister). 2023; Available at: https://wdfw.wa.gov/species-habitats/species/cancer-magister#locations. Accessed 9/18/2023.**
This Washington Department of Fish & Wildlife (WDFW) webpage provides information about Dungeness crab, including a brief description of recreational crabbing.

7. **Coastal commercial Dungeness crab fishery. 2023; Available at: https://wdfw.wa.gov/fishing/commercial/crab/coastal. Accessed 9/18/2023.**
This Washington Department of Fish & Wildlife (WDFW) webpage provides information about the coastal state commercial Dungeness crab fishery. The webpage includes links to additional information about the coastal state commercial Dungeness crab fishery rules, regulations, and licensing and data about landings. At the publication of this Health Impact Review, the most recent crab landing data were updated 9/15/2023.

8. **Holland D. S., Leonard J. Is a delay a disaster? Economic impacts of the delay of the California Dungeness crab fishery due to a harmful algal bloom. *Harmful Algae.* 2020;98:101904.**
Holland and Leonard used modelling to estimate statewide revenue losses and losses for commercial Dungeness crab fishers in California following the 2015 harmful algal bloom (HAB) event. Overall, they found that commercial crabbers experienced a loss in revenue from the Dungeness crab fishery as well as a loss in revenue for additional fisheries. The authors included a number of explanatory variables in their model, including mean 5-year vessel revenue, number of years fished in the past 5 years, latitude of landings, portfolio diversification, and vessel length. The authors hypothesized that vessels with a less diverse portfolio (i.e., a higher dependence on crab) would experience greater revenue impacts. They also hypothesized that larger vessels would experience lower revenue impacts since they can travel further, longer, and at a greater distance from land. The authors found that many of their variables significantly predicted crab and total revenue, including mean 5-year vessel revenue, number of years fished in the past 5 years, latitude of landings, and vessel length. Greater diversification resulted in higher predicted revenues. Overall, the authors estimated that if the Dungeness crab season had not been delayed, the total revenue for commercial fishers who harvest Dungeness crab would have been $26.1 million higher. Of this, $13.6 million would have been revenue specifically from Dungeness crab. The authors stated, “fishers lost out on revenue from [additional] fisheries equal in magnitude to the reduction in crab revenues” because “the delayed opening forced many [crabbers] to choose between participation in the lucrative crab fishery when it opened and [additional] fisheries they would normally have participated in at that time of year.” Overall, “over half of the estimate loss in total revenues for the California Dungeness crab fleet is attributable to reduced revenues in [additional] fisheries – from vessels that either dropped out of fishing in 2016 all together or reduced their fishing in [additional] fisheries in order to participate in the delayed crab fishery.” The authors also estimated that the harvester sector lost $18.12 million in direct income and 492 harvester jobs, with about half of losses due to Dungeness crab and half to additional fisheries. Processors lost $3.29 million in direct income and 111 processor jobs.

9. **National Shellfish Sanitation Program (NSSP). 2020; Available at: https://www.fda.gov/food/federalstate-food-programs/national-shellfish-sanitation-program-nssp. Accessed 9/18/2023.**
The National Shellfish Sanitation Program (NSSP) is administered by the U.S. Food and Drug Administration (FDA). The intent of NSSP is "to promote and improve the sanitation of shellfish (oysters, clams, mussels and scallops) moving in interstate commerce through federal/state cooperation and uniformity of State shellfish programs." The FDA, U.S. Environmental Protection Agency (EPA), National Oceanic and Atmospheric Association (NOAA), states, and the shellfish industry participate in NSSP. Additionally, foreign governments also participate under international agreements with the FDA.

10. **Washington State Legislature House Agriculture & Natural Resources Committee and House Appropriations Committee. House Bill Report: HB 1010. 2023.**
Staff for the House Agriculture & Natural Resources Committee and the House Appropriations Committee prepared the House Bill Report for HB 1010. The Bill Report for HB 1010 is relevant to the Substitute version of the bill.

11. ***U.S. v. Washington*, (United States District Court, W.D. Washington 1994).**
In 1994, the federal district court adopted a court order known as the "Consent Decree Regarding Shellfish Sanitation Issues." The decree was entered into by and between the U.S., 18 federally-recognized Tribes, and the State of Washington. The purpose of the Consent Decree was to outline processes for protecting the public from foodborne illness associated with the consumption of contaminated shellfish.

12. **Commercial Shellfish Growers Settlement. 2016; Available at: https://nwifc.org/about-us/shellfish/commercial-shellfish-growers-settlement/#gsc.tab=0. Accessed 9/18/2023.**
This Northwest Indian Fisheries Commission webpage provides an overview of the Commercial Shellfish Growers Settlement, which was an agreement reached in 2007 between the Puget Sound state commercial shellfish growers and 17 treaty Tribes in Western Washington. The settlement addressed implementation challenges of the 1994 Rafeedie Decision.

13. **Health Washington State Department of. Strategy for Preventing Consumer Exposure to Domoic Acid from Coastal Dungeness Crab. 2018.**
The Washington State Department of Health (DOH), Washington State Shellfish Treaty Tribes, Washington Department of Fish and Wildlife (WDFW), and Washington State Department of Agriculture (WSDA) develop and follow a state strategy to prevent consumer exposure to domoic acid from coastal Dungeness crab. This document outlines the specific elements of the state strategy, including monitoring, closure criteria, opening-reopening criteria, crab in the market, alternatives to closure, and communication.

14. **Commercial Dungeness crab fishery. 2023; Available at: https://wdfw.wa.gov/fishing/commercial/crab. Accessed 9/18/2023.**
This Washington Department of Fish & Wildlife (WDFW) webpage provides a high-level overview of the commercial Dungeness crab fishery, including information about the Puget Sound and coastal fisheries. The webpage also provides context about the Tribal commercial Dungeness crab fisheries.

15. **Chapter 220-340 WAC: Commercial Shellfish.**
Chapter 220-340 WAC outlines Washington Department of Fish & Wildlife (WDFS) rules for commercial shellfish harvesting in Washington State, including regulations related to licensing, gear requirements, seasons and areas, and harvesting limits.

16. **Chapter 69.30 RCW: Sanitary Control of Shellfish.**
Chapter 69.30 RCW concerns the sanitary control of shellfish. In the intent section, RCW 69.30.005 states, "[p]rotection of the public health requires assurances that commercial shellfish are harvested only from approved growing areas and that processing of shellfish is conducted in a safe and sanitary manner." Shellfish is defined as: "all varieties of fresh and frozen oysters, mussels, clams, and scallops, either shucked or in the shell, and any fresh or frozen edible products thereof."

17. **Recreational crabbing in Puget Sound. 2023; Available at: https://wdfw.wa.gov/fishing/basics/recreational-crabbing-puget-sound. Accessed 9/28/2023.**
This Washington Department of Fish and Wildlife (WDFW) webpage provides information about recreational crabbing in Puget Sound.

18. **Recreational Shellfish Program. 2023; Available at: https://doh.wa.gov/about-us/programs-and-services/environmental-public-health/environmental-health-and-safety/about-shellfish-program/about-recreational-shellfish-program. Accessed 10/26/2023.**
This webpage provides information about the Washington State Department of Health's Recreational Shellfish Program. The program is responsible for evaluating marine water quality; monitoring shellfish and beaches for biotoxins, vibrio, and pollution; closing a recreational beach if shellfish are unsafe for consumption; and conducting outreach and education.

19. **RCW 77.32.555, Surcharge to fund biotoxin testing and monitoring--Algal bloom program--Biotoxin account, (2015).**
RCW 77.32.555 allows Washington Department of Fish and Wildlife (WDFW) to include a surcharge on recreational shellfish and seaweed licenses to fund biotoxin testing and monitoring by the Washington State Department of Health (DOH) of beaches used for recreational shellfish harvesting, and by University of Washington's Olympic Region Harmful Algal Bloom Program (ORHAB) of seawater. DOH has responsibility for administering the Biotoxin Account.

20. **Sound Toxins: About. 2023; Available at: https://soundtoxins.org/about.html. Accessed 10/2/2023.**
Sound Toxins is a cooperative partnership led by Washington Sea Grant to provide biotoxin testing and monitoring of seawater in the Puget Sound.

21. **Tri-State Dungeness Crab. 2012; Available at: https://www.psmfc.org/program/tri-state-dungeness-crab-tsdc. Accessed 10/26/2023.**
Washington, Oregon, and California have entered into the Tri-State Dungeness Crab Memorandum of Understanding that provides for "interstate cooperation in management of the Pacific Coast Dungeness crab fishery and in dealing with adjustments to the fishing season […] the [3] state Fish and Wildlife agencies consult on issues affecting the commercial Dungeness crab fishery."

22. **(FDA) U.S. Food and Drug Administration. Fish and Fishery Products Hazards and Controls Guidance. 2022.**
The U.S. Food and Drug Administration (FDA) maintains "Fish and Fishery Products Hazards and Controls Guidance." The most recent update was in June 2022. As part of this guidance, FDA provides background information, geographic occurrence, and health outcomes associated with naturally-occurring shellfish poisoning biotoxins. It also includes specific guidance for Dungeness crab.

23. **Marine biotoxin in Dungeness crab [press release]. 1993.**
In 1993, the U.S. Food and Drug Administration (FDA) and the U.S. Department of Health & Human Services released a statement to state health officials addressing marine biotoxins in Dungeness crab. The FDA's Center for Food Safety and Applied Nutrition, Health Hazard

Evaluation Board assessed data to determine "the tolerable level of domoic acid in Dungeness crab." FDA stated that they would "take regulatory action on any Dungeness crab in interstate commerce which is found to be contaminated with greater than 30 ppm [parts per million] domoic acid in the cooked crab viscera." They recommended that states adopt monitoring plans for domoic acid and take actions to prevent consumer exposure if domoic acid levels exceed 30ppm in the viscera. FDA stated preventive actions should include closure of harvest areas and evisceration. This level was an adjustment from a 1992 level of 20 ppm domoic acid in crab viscera.

24. **Shultz I.R., Skillman A., Sloan-Evans S., Woodruff D. Domoic acid toxicokinetics in Dungeness crabs: New insights into mechanisms that regulate bioaccumulation.** ***Aquatic Toxicology.*** **2013;140-141:77-88.**
Shultz et al. conducted a dose-response experiment to understand the absorption, distribution, and excretion of domoic acid in Dungeness crab. The authors cited previous research showing that, when razor clams contaminated with domoic acid were fed to Dungeness crab, 68% of the estimated dose of domoic acid was concentrated in the crab hepatopancreas. For this study, Shultz et al. used adult, male Dungeness crab harvested from Sequim Bay and the Strait of Juan de Fuca in Washington State from December to April. Using oral and intravascular dosing of domoic acid, the study authors evaluated domoic acid levels in various tissue samples from Dungeness crab. The authors found that, "[a]fter oral administration, essentially the entire dose [of domoic acid] is absorbed from the foregut within 2 [hours] and deposited in the hepatopancreas." The authors found "extraordinarily low [domoic acid] levels observed in [additional] tissues after [low doses]", suggesting "the large capacity of the hepatopancreas to sequester and retain [domoic acid]." However, the authors found that "the oral bioavailability of [domoic acid] is highly dose dependent, approaching zero at the lower doses" and approaching higher levels at higher doses. They stated that their "results suggest a diffusional barrier exists that reduces or limits [domoic acid] transport between the hemolymph and hepatopancreas." However, at higher domoic acid levels, there can be saturation and breakthrough can occur into additional tissues. Overall, they found that "[u]nder natural circumstances, crabs feeding on contaminated shellfish would be expected to readily absorb [domoic acid], which is then stored in the hepatopancreas […] and slowly eliminated in urine. If the [domoic acid] exposure level exceeds storage capacity of the tissue, breakthrough occurs resulting in much higher systemic exposure and potential for [domoic acid] toxicity." Assuming a hepatopancreas of 3.45% of the crab's body weight, the authors estimate the storage capacity of the hepatopancreas for domoic acid as 145-290 ppm of hepatopancreas tissue.

25. **Nicolas Jonathan, Hoogenboom Ron L. A. P., Hendriksen Peter J. M., et al. Marine biotoxins and associated outbreaks following seafood consumption: Prevention and surveillance in the 21st century.** ***Global Food Security.*** **2017;15:11-21.**
Nicolas et al. conducted a review of literature about human illness from consuming contaminated seafood following marine biotoxin contamination events. The review also provided a summary of literature related to the prevention of seafood contamination outbreaks, including opportunities to reduce the impact of harmful algal blooms (HABs) on human health. Based on available evidence, the authors "concluded that marine biotoxins represent a threat to human health as thousands of poisonings following consumption of seafood contaminated with marine biotoxins were reported [from 2001 through 2015], emphasizing the need for carrying

on/developing surveillance programs to detect the presence of HABs, and for development, validation and implementation of sensitive high-throughput methods for detecting these biotoxins in seafood to protect consumers." The authors noted that "the literature currently available provides an underestimate of the real incidence of fish/shellfish poisoning due to marine biotoxins, especially because symptoms of poisonings are similar to allergic reactions and viral or bacterial infections" and since contaminated food is often not available for analysis to confirm the presence of marine biotoxins. As an example of underestimating, the authors stated that a previous survey in Alaska found that the incidence of Paralytic Shellfish Poisoning (PSP) was 100 times higher based on survey results than the incidence calculated based on surveillance data. The only public health outbreak related to the consumption of seafood contaminated with domoic acid occurred in 1987 in Canada among 107 people who consumed contaminated mussels. Since that time, "the toxin is well monitored in shellfish sanitary monitoring programs resulting in a significant reduction of toxic shellfish entering the market. Globally, certain shellfish production sites are still frequently closed due to the presence of high [domoic acid] in various types of shellfish." There were more than 100 confirmed cases of PSP in South and North America from 2001 through 2015. The authors stated that improvements to monitoring programs are needed as illnesses from consuming seafood contaminated with marine biotoxins "are still frequently occurring and more toxins (in terms of diversity) are found in worldwide coastal waters and seafood products." The authors recommended intensifying shellfish monitoring programs in HAB-prone areas to determine if toxin levels are above regulatory limits and increasing the frequency of surveillance when marine biotoxins are more likely to be present in the food chain. Specifically, the authors stated that 2 monitoring approaches should be implemented "at the same time for the prevention of outbreaks: 1) monitoring of plankton species and of favorable conditions for growth […] and 2) screening of marine biotoxins in seafood harvested at specific locations."

26. **Health and Safety Code. Article 15. Eviscerated crab [111224.111224.6]. In: Legislature CS, ed2021.**

This California law relates to the evisceration of Dungeness crab. The law includes a definition of evisceration. It also provides authority for the California State Department of Health Services "to issue an order authorizing the evisceration of Dungeness crab [...] if the domoic acid for Dungeness crab [...] exceeds the allowable levels for viscera in a specified area." The Department of Health Services may only issue an evisceration order if: 1) the Director of Fish and Wildlife has closed the commercial Dungeness crab fishery due to domoic acid levels; 2) Domoic acid levels of the viscera exceed allowable levels; and 3) Domoic acid levels of the crab meat do not exceed allowable levels.

27. **Grattan L., Holobaugh S., Morris J.G. *Foodborne Infections and Intoxications. Chapter 31: Seafood Intoxications.* 2013.**

In this book chapter, Grattan et al. provide background information about seafood consumption-related illnesses. The authors stated that consuming seafood "is the leading cause of foodborne illness with known etiology. It is responsible for 10-20% of outbreaks among all food types and about 5% of all individual illnesses […] These are conservative estimates as there is considerable diagnostic uncertainty and under-reporting with respect to seafood-related illnesses." In addition, seafood-related illnesses are likely to increase in the future, including due to increased frequency of harmful algal blooms (HABs). The authors presented diagnosis, clinical symptoms, and

treatment information for Paralytic Shellfish Poisoning (PSP) and Amnesic Shellfish Poisoning (ASP or domoic acid). The authors also discussed potential measures for the prevention of seafood consumption-related illnesses.

28. **Free C. M., Moore S. K., Trainer V. L. The value of monitoring in efficiently and adaptively managing biotoxin contamination in marine fisheries. *Harmful Algae.* 2022;114:102226.**

Free et al. provide background information about harmful algal blooms (HABs) and their impact on the West Coast Dungeness crab fishery. HABs "are increasing in size, frequency, and duration due in part to the combined effects of eutrophication and climate change." HABs may be "harmful because they produce toxins that accumulate in species harvested by fisheries and aquaculture and can cause human illness or mortality when consumed in high doses." Along the West Coast, HABs include algae that produce domoic acid. When consumed at high levels, domoic acid can cause Amnesic Shellfish Poisoning (ASP i.e., domoic acid), with symptoms ranging from gastrointestinal concerns (e.g., stomach pain, vomiting, diarrhea) to neurological concerns (e.g., headache, dizziness, confusion, memory loss, seizure) or death. Domoic acid "enters the food web through filter feeders such as mussels, clams, and anchovies and is then transferred to predators such as crabs, lobsters, and fish. Bivalves [e.g., mussels] and crustaceans [e.g., crab] generally exhibit the highest risk of contamination […]" The authors noted that, in 2015, a large marine heatwave generated a HAB that extended from Alaska to southern California and "the only management action available to West Coast states was to employ area closures." As a result, there were "expansive and prolonged closures of commercial and recreational fisheries. The Dungeness crab fishery […] was hit especially hard." People living and working in fishing communities experienced financial losses and impacts to emotional health and sense of place. Additionally, fishers expressed confusion and skepticism about the fishery closure. The authors stated that there is a "dual need to demonstrate the credibility of the science supporting toxin monitoring and management and to standardize best practices across fisheries and management boundaries." Currently, Washington, Oregon, and California have monitoring sites and "a fishing area will open if each of [6] crabs collected from the area test below the action level [of 30 ppm (parts per million) in the viscera]." Each state defines the "spatial-temporal frequency of monitoring and size and arrangement of the associated management zone" differently. All three states passed legislation to modify their biotoxin monitoring and management plans. For example, in 2021, Washington Department of Fish and Wildlife (WDFW) adopted an emergency rule temporarily requiring evisceration. The Oregon State legislature passed legislation allowing evisceration orders rather than fishery closures and doubled the number of biotoxin monitoring sites for Dungeness crab. Similarly, California passed legislation allowing evisceration orders, increasing testing sites, and delineating domoic acid management boundaries. The authors stated that "although eviscerated crabs often receive lower market prices, this option presents the fishing industry with some flexibility during extended closures." In this study, Free et al. evaluated the value of biotoxin monitoring in protecting human health and minimizing the impact on fishing communities. Focusing on the West Coast Dungeness crab fishery and domoic acid contamination, they developed a simulation model and power analysis to "quantitatively measure the benefits of expanded monitoring for jointing achieving public health and fisheries objectives." Washington State experienced fishery closures due to domoic acid during the 2014-2015, 2015-2016, 2016-2017, and 2020-2021 commercial Dungeness crab fishing seasons. As a result of these closures, "Washington's

domoic acid monitoring and management has remained largely unchanged, with the exception of adopting an emergency rule temporarily allowing evisceration orders in [February] 2021, which were used in the southern portion of the state from [February to April] 2021." Moreover, "Washington's regular monitoring program is sparser than Oregon and California with only two sites regularly monitored coastwide and the lowest number of samples per landings and latitude. However, Washington adjusts its crab sampling requirements in response to test results from razor clams, sentinel mussels, and to [algal] and particulate domoic acid data. This policy aims to efficiently use lab resources and has proved responsive to risk in the past." The authors presented information about the current effectiveness of the number of crabs sampled and spatial and temporal frequency of monitoring (i.e., number of monitoring sites). The authors found that the 6 crabs per survey protocol correctly diagnosed the safety of opening the Dungeness crab fishery 89% of the time. They also found that public health benefits increased with more sampling sites, and the "incremental benefits to public health outcomes were considerably larger than the incremental losses to fishery outcomes." For example, "in the large contamination and 12-site monitoring program scenario, transitioning from no follow up sampling to weekly follow up sampling resulted in a reduction in the proportion of undetected public health risk by 16% […] and increase in the proportion of unnecessary fishery closures of only 2% […]" These results show that, "investments in expanded biotoxin monitoring limit unnecessary closures to the fishery." The authors discuss potential disproportionate impacts to small versus large vessels. They also noted that, despite impacts to fishers, "bad press from a public health outbreak could have even larger negative impacts on consumer perceptions of and demand for crab. Thus, protecting public health is also crucial to maintaining a viable fishery, especially as the threat of [harmful algal blooms] and toxin contamination increase under climate change." The authors also discussed potential challenges with increasing biotoxin monitoring (e.g., staff capacity, processing time, lab backlogs, product recalls).

29. **Management Washington State Office of Financial. Multiple Agency Fiscal Note Summary: SHB 1010 (Shellfish sanitary control). 2022.**

Fiscal notes for SHB 1010 were submitted by the Washington Department of Fish and Wildlife (WDFW) and the Washington State Department of Health (DOH).

30. **Jardine Sunny L., Fisher Mary C., Moore Stephanie K., Samhouri Jameal F. Inequality in the Economic Impacts from Climate Shocks in Fisheries: The Case of Harmful Algal Blooms. *Ecological Economics.* 2020;176.**

Jardine et al. stated that "inequities in the distribution of climate impacts across a population […] are potentially compounded for vulnerable populations due to a greater dependence on natural resources and a lack of social, financial, and additional resources to cope with and adapt to environmental change." The authors noted that most research on the distributional impacts of climate change on fisheries has focused on developing nations and little research has examined the impact of climate change on fisheries in developed nations. Commercial fishers and fishing communities "are closely connected to the environment and are expected to be impacted by climate change in numerous ways", including shifts in the geographic distribution of fish species, changes in fishery productivity, frequency and magnitude of harmful algal blooms (HABs), and seafood safety. The authors stated that the economic impacts for commercial fishers of climate change "depend on the ability of individual fishers to adjust spatial harvest patterns, change gear types, and/or target new species." Jardine et al. examined impacts of the 2014-2016 HAB events

in California on small and large vessels in the commercial Dungeness crab fishery. Since previous research has suggested that smaller vessels receive lower profits, receive lower returns for labor, and experience limited mobility compared to larger vessels, the authors hypothesized that "small vessel operators and communities dominated by small fishing vessels may also be less resilient to climate shocks." The authors found that, even during baseline (i.e., without a HAB event), large vessels were more mobile and generally fished in multiple port areas. As a result of HAB events, both small and large vessels shifted their landings to areas that were not impacted by a fishery closure and increased their distance travelled. However, large vessels experienced a greater magnitude in shifts and distance travelled. After controlling for multiple port and time trends, the authors found that the proportions of small vessel revenue and participation were significantly impacted by the HAB event. Overall, "the estimated reduction in the proportion of revenue to small vessels during the [2015-2016] season represents a 30% reduction from the before-period […]" The authors found that larger vessels had a greater ability to mitigate losses from the HAB events than smaller vessels. The authors stated that this study demonstrates "empirical evidence that climate impacts of fishing communities are not uniform." The authors state that future management practices should account for "communities-of-place, such as individual ports, and communities-of-practice, such as groups of vessels with similar characteristics and constraints [… to] meet equity objectives in the face of climate shocks."

31. **Magel Caitlin L., Lee Elizabeth M. J., Strawn Astrea M., et al. Connecting Crabs, Currents, and Coastal Communities: Examining the Impacts of Changing Ocean Conditions on the Distribution of U.S. West Coast Dungeness Crab Commercial Catch.** ***Frontiers in Marine Science.*** **2020;7.**

Magel et al. state that fishery systems have "complex relationships between coastal socioeconomics, resource management, and environmental factors." This study examined the impact of changing oceanic conditions on commercial Dungeness crab harvest and on fishing communities in Washington, Oregon, and California. Among additional study objectives, the authors examined how changes in Dungeness crab catch may impact 18 coastal, fishery-reliant communities. Study communities included Chinook, Ilwaco, Tokeland, and Westport, Washington. To measure fishery-reliance, Magel et al. used indices developed by NOAA that account for crab catch per capita, crab revenue per capital, and crab processors per capita. The authors "used social vulnerability to assess the level of disruption that would occur in a community given an interference in the lucrative Dungeness crab fishery", and included measures of personal disruption, population composition, poverty, labor force, household characteristics, housing disruption, and retiree migration. The authors then combined fishery-reliance and social vulnerability to determine a susceptibility score to indicate the degree to which a community would be impacted by a change in Dungeness crab harvest. Susceptibility scores may indicate: "[c]ommunities that are both heavily reliant on Dungeness crab and socially vulnerable would have high susceptibility scores […] In contrast, communities with either high vulnerability and low reliance on Dungeness crab, or low vulnerability and high reliance on crab would have similar susceptibility scores. Finally, a community with both low reliance and vulnerability, would be the least susceptible because they are generally resilient to change, and a change in the Dungeness crab fishery would not have a large impact on the community." Based on their analysis, the authors found that "Westport, Washington was an outlier with a very high Dungeness crab reliance index […]" Overall, "Washington port communities had the highest reliance on the Dungeness crab fishery, followed by Oregon, Central California, and Northern

California." Washington State also had a high social vulnerability score. The authors stated that Washington State had the highest regional susceptibility score which "indicates higher overall risk that Washington coastal communities would be negatively impacted by a decrease in Dungeness crab [harvest] from changing ocean conditions."

32. **Ritzman J., Brodbeck A., Brostrom S., et al. Economic and sociocultural impacts of fisheries closures in two fishing-dependent communities following the massive 2015 U.S. West Coast harmful algal bloom. *Harmful Algae.* 2018;80:35-45.**
Ritzman et al. conducted 36 in-person, semi-structured interviews with people living in two fishing-dependent communities, including Long Beach, Washington and Crescent City, California, to examine the economic and sociocultural impacts of commercial Dungeness crab fishery closures due to the 2015 harmful algal bloom (HAB). For purposes of this study, the authors considered Long Beach, Washington to include the communities of Long Beach, Illwaco, and Chinook, Washington. In 2014, Dungeness crab accounted for 45% of landings in the Long Beach area. Nineteen interviews with conducted in the Long Beach area. The authors used inductive coding to identify themes and presented results by theme.

33. **Moore Kathleen M., Allison Edward H., Dreyer Stacia J., et al. Harmful Algal Blooms: Identifying Effective Adaptive Actions Used in Fishery-Dependent Communities in Response to a Protracted Event. *Frontiers in Marine Science.* 2020;6.**
Moore, K.M. et al. conducted surveys with 16 fishing communities on the West Coast after the 2015 harmful algal bloom (HAB) event. The authors published a number of articles based on this study; this article reports on adaptive actions taken by commercial Dungeness crab fishers in response to the 2015 HAB event. As a result of the 2015 HAB event, "[c]ommercial Dungeness crab fishers lost over 10% of the 2015-2016 fishing season in Washington [State…] The commercial Dungeness crab fishery is vital to the health of coastal fishing communities […] because it generates the highest revenues and has a high rate of vessel participation." Across the entire West Coast, revenue from the commercial Dungeness crab industry was $97.5 million lower compared to the previous season. The event "generat[ed] an economic shock for fishing communities and result[ed] in fisheries resource disaster declarations for the California Dungeness crab fishery and the Quileute Tribe (Washington) Dungeness crab fishery." The majority of research to date has focused on the economic impacts of HABs. Research on the social and cultural impacts of HABs is limited and emerging. The authors stated that HABs can have negative impacts on human health, "recreational and commercial fishery closures due to seafood contamination, associated revenue losses in business, a loss in seafood provisioning, and beach cleanup costs." Additionally, HABs can impact opportunities for spiritual enrichment and traditional activities which "are important to human wellbeing, providing a sense of place and identity in coastal communities. Livelihood insecurity and lost cultural opportunities can impact the physical and emotional health of [people] […]". The authors stated that, "predictable and unpredictable [fisheries] closures have different psychological impacts [compared to different community disruptions] and require different adaptive responses […] HAB-induced closures are […] more like the disruptions that occur following extreme climate events, geological hazards or oil spills." The authors also noted that, in addition to direct impacts on the shellfish industry, closures also impact hospitality businesses since "the recreational harvest and consumption of shellfish are activities that motivate tourist visits to the coast. When these activities are unavailable due to HAB-induced closures, tourist visits to hotels and restaurants in coastal

fishing towns decrease […] even in coastal towns where shellfishing is uncommon." In 2017, Moore et al. conducted surveys with 262 people working in the shellfish industry or in a hospitality-related business in 16 fishing communities to understand economic, social, and cultural impacts of the 2015 HAB event. The majority of respondents were commercial fishers (64%), white (70%), and male (75%). Of commercial fishers, about 52% were fishing license owners or vessel operators, 25% were employed in fish-related retail, 15% were fish processors, and 8% were deckhands. Of the hospitality industry, 55% were managers and 44% were owners of a store, restaurant, or hotel. Overall, about 33% of respondents relied on shellfish for 75% or more of their annual income and the median income was in the medium income bracket ($50,000-$99,999). Forty percent (102) of respondents were from Washington. Questions focused on income loss; income loss recovery; emotional stress; effect on family gatherings, holidays, or traditions; coping strategies; adaptive actions; and sociodemographic factors. More than half of commercial fishers reported experiencing high income losses (>$9,999) due to the HAB event. Most respondents employed in the hospitality industry reported income losses <$3,000. The authors hypothesized that fishers experienced greater income losses compared to different occupations "because their incomes are directly tied to closed fisheries." More than 80% of respondents took adaptive actions (e.g., alternate job, alternate fishing, advertising, trading or bartering, discounts) or coping actions (e.g., borrowing money, governmental assistance, default) to offset income losses. From these actions, about 26% of respondents employed in the commercial crab fishery and 50% of respondents employed in hospitality were able to offset income losses. Alternate fisheries included sablefish, salmon, sardines, and tuna. About 38% of respondents employed in the commercial crab fishery and 29% of respondents employed in hospitality "strongly agreed" that they experienced stress as a result of the 2015 HAB event. Additional interviews with 2 fishing communities suggested that stress was often due to financial insecurity and associated increases in relational strain. Additionally, 39% of respondents employed in the commercial crab fishery and 29% of respondents employed in hospitality "strongly agreed" that "their family gatherings, holidays, or traditions were negatively impacted […] by the HAB event due to a lack of shellfish to eat. Examples of these cultural impacts include an inability to partake in traditional gift-giving of shellfish, a lack of crab for holiday meals, and disruption to social activities – notably razor clam harvests – that are integral to community identity." Based on survey data, the study authors developed models to further understand factors impacting magnitude of income loss, likelihood of income recovery, and emotional stress. Based on modeling, the authors concluded that, increasing the commercial Dungeness crab fishing season HAB closure by a quarter of the season was statistically significantly "associated with an 8-11% increase in the probability of experiencing high income losses." In Washington State, the fishery was closed for about 13% of the season. Commercial crab fishing license owners or vessel operators had a greater probability of experiencing income losses compared to deckhands, fish processors, and fish retailers. For fishers, "high income loss increased the predicted probability of strongly agreeing to experiencing stress" by 0.31. However, the authors hypothesized that employees and deckhands may be first to lose their jobs if employers suffer losses. Moreover, "[e]ngaging in some adaptive or coping actions were associated with an increase in the probability of strongly agreeing to experiencing stress." However, engaging in alternate fishing did not increase stress. The authors stated that most commercial fishers in the Pacific Northwest have diversified fishing strategies and engaging in alternative fishing may not be associated with increased stress because commercial fishers already have the gear, licensing, and skills and knowledge for this alternate action. The authors

stated, “being able to engage in [additional] fishing activities [may] not trigger stress because occupational identity and cultural norms are sufficiently maintained.” Experiencing cultural impacts was also associated with an increased probably of experiencing stress. The authors concluded that people “who suffered greater absolute income losses were exposed to longer fisheries closures, more dependent on shellfish as a source of income, employed in the fishing industry, and owned their business […] While the fishery closures lasted only 12[%] and 13% of the season in Oregon and Washington, respectively, the probability of income losses greater than $10,000 was still over 0.50 for a typical fishing license owner in both [s]tates.”

34. **Wildlife Washington Department of Fish &. Rule-Making Order, Emergency Rule Only: CR-103E (December 2017) (Implements RCW 34.05.350 and 34.05.360): WSR 21-05-027, Amends rules for coastal commercial crab fishery. In: Wildlife WDoF, ed2021.**
On February 9, 2021, Washington Department of Fish & Wildlife (WDFW) filed an emergency rule temporarily requiring evisceration of crab to protect public health. The emergency rulemaking stated, “the viscera from crab caught between the [Washington and Oregon] border and Point Chehalis, [Washington,] including Willapa Bay are unsafe for human consumption and have issued a recommendation requiring evisceration of crab caught in this area. To strengthen the enforcement of an evisceration requirement needed to protect public health, all crab landed into [Washington State] from any [W]est [C]oast area south of Point Chehalis, Washington must be eviscerated.”

35. **RCW 34.05.350: Emergency rules and amendments, RCW 34.05.350(2021).**
RCW 34.05.350 allows for the adoption of emergency rules if "immediate adoption, amendment, or repeal of a rule is necessary for the preservation of public health, safety, or general welfare, and that observing the time requirements of notice and opportunity to comment upon adoption of a permanent rule would be contrary to the public interest." Under this statute, emergency rules expire after 120 days.

36. **OAR 635-005-0466: Dungeness Crab Closure or Evisceration Requirement Based on Biotoxin Testing. In: Legislature OS, ed2021.**
Oregon Administrative Rules (OAR) 635-005-0466 allows for evisceration of Dungeness crab if domoic acid exceeds allowable levels.

37. **Moore S. K., Dreyer S. J., Ekstrom J. A., et al. Harmful algal blooms and coastal communities: Socioeconomic impacts and actions taken to cope with the 2015 U.S. West Coast domoic acid event. *Harmful Algae.* 2020;96:101799.**
Moore, S.K. et al. conducted surveys in 2017 with 16 fishing communities on the West Coast after the 2015 harmful algal bloom (HAB) event. The authors published a number of articles based on this study; this article reports on the socioeconomic impacts of the 2015 HAB event for commercial Dungeness crab fishers. The authors stated, “[t]he societal impacts of [HABs] can be severe and include adverse health outcomes, economic loss, disruption to social and cultural practices, and losses to both individual and community wellbeing.” Communities surveyed included Grays Harbor and Baker’s Bays in Washington State. Surveys were distributed by mail and online to maximize the likelihood of reaching participants. Surveys were mailed to all commercial Dungeness crab license holders. Overall, surveys from 180 respondents who replied by mail and 201 respondents who replied online were included in analysis. About 20% of

respondents who replied by mail and 60% of respondents who replied online were from Washington State. Survey questions were based on themes identified from semi-structured interviews conducted in two communities and focused on economic impacts, sociocultural impacts, community resilience and vulnerability, and future implications of HABs events. The majority (54.6%) of respondents were employed in the fishing industry. About 93% of respondents employed in the fish industry remained in the same occupation following the HAB event, which may suggest that crabbers did not change employment, had high job satisfaction despite negative impacts from the HAB event, or preferred their occupation. Overall, 87.5% of respondents employed in the fishing industry reported that the 2015 HAB event caused stress, 87% reported it negatively impacted finances, and 80.7% reported a loss of money. About half of survey respondents thought the 2015 HAB event was part of a worsening trend and about half of respondents believed the 2015 HAB event was connected to climate change. The authors reported that 84% of survey participants were negatively impacted by the 2015 HAB event and people "employed in fishing-related occupations experienced greater financial, emotional, and sociocultural impacts than those employed in [different] sectors."

38. **King T., Kilpatrick S., Willis K., Speldewinde C. "A different kettle of fish": Mental health strategies for Australian fishers, and farmers. *Marine Policy.* 2015;60:134-140.**
King et al. present findings from a study examining the health and well-being of Australian commercial fishers. The authors sought to understand unique drivers of mental health experienced by commercial fishers as compared to different occupations (including farmers and forestry workers). Prior research in Australia found that fishers experience unique stressors from different occupations, including unstable access to fisheries, financial insecurity under management arrangements, and "relentless financial uncertainty." These uncertainties are, "a key driver of chronic livelihood insecurity, resulting in reports of stress, depression, and [death by suicide]." Commercial fishers experience high levels of mental and emotional stress, depression, anxiety, feelings of hopelessness, sleep disturbances, domestic unrest, substance use, social withdrawal, anger management, shaking, hair loss and discoloration, self-harm, risk-taking, and death by suicide. The authors also reported on previous research that found "[p]eople in the fishing industry were least likely to present a positive attitude to health as an underlying health belief, when compared with [different] industry groups […] In the fishing industry, continuity of health care was compromised for itinerant workers, and the influence of community culture prevented healthy behaviours, particularly in relation to mental health." The authors conducted the "Staying Healthy: Fishers" project in Australia. The authors completed mixed-methods, qualitative interviews and/or focus groups with 34 commercial fishing license holders, including fishers from a range of occupations (e.g., owners, skippers, deckhands), species, fishery size, and locations. Interviews were also conducted with family members, fishing industry association representatives, health care providers, and additional industry and governmental representatives. The authors used an inductive analytical approach to identify emerging themes. Overall, fishers identified 3 main concerns related to physical health: 1) Lifestyle issues (e.g., diet and exercise); 2) Environmental concerns (e.g., exposure to sun and wind); and 3) Long-term physical issues (e.g., prolonged working hours, boat conditions). Fishers reported challenges using healthcare services due to their "unusual working regimes and self-employment." All fishers identified mental health as a key challenge to health and well-being. Fishers reported experiencing stress, depression, and feeling down. Fishers primarily discussed two causes of stress: 1) Traditional risks and 2) Modern uncertainties. Fishers stated that traditional risks included dangerous

working conditions, fluctuating markets, variable catches, odd hours, being self-employed, anxiety about physical risks, and economic stressors. The authors explained that, "[t]raditional risks within fishing were about calculated risks over which fishers had some control, and which they could approach using their accumulated skill and knowledge." For example, "economic stressors that fishers have traditionally faced are manageable in part because there is an expectation that businesses will be able to bounce back in the coming months or years to make up for poor catches or markets." These traditional risks were viewed as less stressful than modern uncertainties. The authors described modern uncertainties as "unknowns that fishers have limited capacity to manage, either practically or in terms of emotional preparedness." Fishers stated that modern uncertainties included government fishery management decisions (e.g., fishery closures). The authors explained that limitations like fishery closures, or the fear of future closures, "cause fishers distress both due to the restrictions themselves but also in terms of their perplexing and uncontrollable nature." The authors stated that, "[f]ishers emphasized the perceived rapidity; the unexpected nature; and the inability to anticipate, and prepare for, such closures, as being particularly worrying." Previous research has also found that the threat of job insecurity or unemployment impacts health. The World Health Organization (WHO) stated, "health effects start when people first feel their jobs are threatened, even before they actually become unemployed. This shows that anxiety about insecurity is also detrimental to health."

39. **King T.L., Turner R., Versace V., et al. Mental health in the commercial fishing industry: Modern uncertainties and traditional risks. *Fish and Fisheries.* 2021;22:1136-1149.**

King et al. completed a 2017 national, quantitative survey in Australia with 872 commercial fishers (15.1% response rate). Building off findings from King et al. 2015, the authors sought to determine the level of psychological distress experienced by fishers and to identify stressors related to traditional risks and modern uncertainties. The authors also examined differences by occupation within the fishing industry (i.e., skippers engaged in management, crew, or deckhands) and by fishing location (i.e., inshore, offshore). The majority of respondents were fishers engaged in the management of the operation (80%) and fishers who fished offshore (52%). Overall, 22.9% of fishers reported experiencing high or very high levels of psychological distress and 53.1% reported experiencing low levels, compared to 11.7% and 68% of the Australian general population. Levels of psychological distress were not statistically different by occupation within the fishing industry or by fishing location. Of stressors, 22% were related to traditional risks (e.g., financial burdens, harvesting), 22% were related to modern uncertainties (e.g., regulation change, quota and license requirements), and 13% were related to future uncertainties (e.g., climate change, seafood stocks). The most common perceived stressors were those relating to changes in government regulation, red tape, and uncertainty about future regulatory changes. There were statistically significant differences by occupation within the fishing industry, with fishers engaged in management of the operation reporting greater perception of stressors related to modern uncertainties and crew members reporting higher perceptions of future concerns. The authors stated that fishers engaged in management of the operation may have stronger perceptions of modern uncertainties and higher levels of psychological distress related to these uncertainties as they may have "greater responsibility for decision-making, meeting regulatory and reporting obligations, and their greater financial investment compared to the crew." The authors suggest that fishers who are more exposed to changes in fishery management may be disproportionately impacted by these stressors. Fishers

who fished offshore were also statistically significantly more likely to report greater perception of traditional risks than fishers who fished inshore. Across all fishers, greater perception of traditional risks and modern uncertainties was associated with greater psychological distress. There was no evidence that perceived future concerns were associated with psychological distress for all fishers; however, stronger perceptions of future concerns were associated with greater psychological distress among crew. In summary, "while fishers are unusually stressed as a cohort, the kinds of things that cause them stress differ depending on their role and where they fish." The authors stated that stressors may be context-dependent as socioeconomic circumstances, ecological conditions, and management approaches vary by fishery, though findings would be most generalizable to fisheries with intensive management.

40. **Paul K. I., Moser K. Unemployment impairs mental health: Meta-analyses. *Journal of Vocational Behavior.* 2009;74(3):264-282.**
Paul et al. conducted a meta-analysis of 237 cross-sectional and 87 longitudinal studies that examined the relationship between mental health and unemployment. The meta-analysis of cross-sectional data revealed that unemployed persons showed significantly more symptoms of distress and impaired well-being than did employed persons. The meta-analyses of longitudinal studies and natural experiments supported the concept that unemployment is not only correlated to distress but also causes it.

41. **Stanton B., Murphy S., Klasing S., et al. Poster: Tissue distribution of domoic acid in field-collected crabs from the California and Oregon coasts. Society of Environmental Toxicology and Chemistry, North America Annual Meeting; 2018.**
Oregon Department of Agriculture (ODA) and California Department of Public Health (CDPH) published a poster presentation. The authors stated that, "[e]xisting data, and published studies, show that [domoic acid] preferentially accumulates in viscera of shellfish and finfish." Additionally, data from a paired-testing study in California showed that domoic acid has occurred above 20ppm in crab meat, but only when levels in viscera are above 30ppm. This poster presentation reports on work ODA and CDPH conducted to understand the relationship of domoic acid in Dungeness and Rock crab viscera and crab meat. For Dungeness crab, they found that "there is a statistically significant positive association between [domoic acid] in meat and viscera." Based on modelling, the authors found that the meat of Dungeness crab was predicted to exceed 20 ppm when the level of domoic acid in the viscera was above 187 ppm. However, based on testing of paired meat and viscera from each crab, levels of domoic acid in the meat of Dungeness crab exceeded 20 ppm when levels in the viscera were 46 ppm. Based on 46 Dungeness crab with detectable levels of domoic acid, the authors found that the average level of domoic acid in the Dungeness crab viscera was 51.8 ppm and the average level in the meat was 8 ppm. The authors cited former research suggesting that domoic acid accumulates in the hepatopancreas until it reaches a "break-through" concentration and begins to accumulate in additional tissues.

42. **Petroff R., Hendrix A., Shum S., et al. Public health risks associated with chronic, low-level domoic acid exposure: A review of the evidence. *Pharmacol Ther.* 2021;227:107865.**
Petroff et al. stated that chronic, low-level exposure to domoic acid at levels below the current regulatory level may have health impacts for people who live in coastal communities. The

authors noted that regulations developed in the 1980s have prevented acute illness from consuming shellfish contaminated with domoic acid. However, "[w]ith the intensification of algal bloom conditions due to climate change and recent consumption surveys identifying that many shellfish harvesters may be regularly exposed to low levels of [domoic acid], there is an urgent need to comprehensively understand the health impacts associated with chronic, low-level exposure to [domoic acid]." The authors present previous research examining domoic acid concentration, distribution, and excretion in sea lions, monkeys, and rats. Evidence from these studies suggest that domoic acid may not be widely distributed throughout the body; absorption of domoic acid through the intestines may be slow; the placenta may act as a partial barrier limiting fetal exposure to domoic acid; domoic acid may accumulate in amniotic fluid; and exposure through breastmilk is likely minimal. The authors included previous research showing that, "[i]n humans, [domoic acid] has been detected in urine from those who consumed razor clams containing low levels of [domoic acid…]." Low-level exposure to domoic acid has been shown to impact 1) learning and memory in humans and animals; 2) emotionality (e.g., anxiety-related behaviors) and motor responses in animals; 3) neurological function in animals; and 4) prenatal and neonatal development in animals. Generally, more research is needed to understand how chronic, low-level exposure to domoic acid may impact human populations. There are also some studies that suggest low-levels of domoic acid may impact cardiac, renal, and immune functions in animals and researchers have noted a need for more research to "help reveal the human subpopulations with pre-existing conditions who may be more vulnerable" to domoic acid exposure. In this review, authors noted Tribal communities along the coast of Washington State may be at risk for higher exposure to domoic acid. Measures of domoic acid levels in razor clams and data from dietary surveys with Tribal people found that, while monthly razor clam consumption rates were below the regulatory limit for domoic acid, levels were still connected with adverse health outcomes. The authors stated, "[s]ince the establishment of the regulatory threshold, several research groups have calculated [different] consumption limits, by incorporating newly available toxicological data, seafood consumption rates and patterns, and additional protective safety and uncertainty factors. The results of these assessments vary significantly from daily consumption limits consistent with the current estimate […] to limits approximately 2 to 4-times lower […]." A cohort study with Tribal people in Washington State who regularly consume shellfish containing domoic acid found that consuming razor clams with low levels of domoic acid may decrease cognitive performance, everyday memory, and verbal memory recall. Based on estimates of shellfish consumption from this cohort and domoic acid levels at the study site, researchers estimated that a daily consumption limit well below the current regulatory action level would be needed to protect consumers from decreased verbal memory recall.

43. **RCW 43.70.250, License fees for professions, occupations, and businesses, (2023).** Chapter 43.70 RCW pertains to the Washington State Department of Health (DOH). Under RCW 43.70.250, the cost of professional, occupational, or business licensing programs administered by DOH must be "fully borne by members of that profession, occupation, or business."

44. **Washington State Board of Health: Agency overview. 2023; Available at: https://sboh.wa.gov/about-us. Accessed 9/25/2023.**

This Washington State Board of Health (SBOH) webpage provides an overview of SBOH's authority and responsibility for public health rulemaking to protect and improve the health of people in Washington State.

45. **Chapter 43.20 RCW, State Board of Health.**
Chapter 43.20 RCW grants State Board of Health authority to develop public health rules to protect and improve the health of people in Washington State, including rules related to children's health, communicable diseases, vital statistics, and environmental health. All local boards of health, health officials, officers of state agencies, law enforcement officers, and state and local government employees must enforce SBOH rules.

46. **Evaluation of mitigation strategies for harmful algal blooms in the West Coast Dungeness crab fishery. 2023; Available at: https://coastalscience.noaa.gov/project/evaluation-of-mitigation-strategies-for-harmful-algal-blooms-in-the-west-coast-dungeness-crab-fishery/#:~:text=Since%20DA%20in%20crab%20tends,make%20crab%20safe%20to%20eat. Accessed 11/2/2023.**
Oregon State University, in collaboration with researchers from Washington, California, and the National Oceanic and Atmospheric Administration (NOAA), is completing a research project to examine the economic impacts of fishery management decisions and mitigation strategies (e.g., evisceration orders). Research is primarily focused on "regulatory approaches that are flexible and can increase opportunities for the industry amid [harmful algal bloom (HAB)] events, while ensuring food safety for consumers." The authors write that, "[a]llowing for the harvest and sale of eviscerated crab is one such mitigation policy adopted by Oregon." Moreover, "[m]itigation strategies may be more effective if combined with finer scale spatial management informed by HAB monitoring and forecasting data [...] it may be possible to continue harvest and sale of whole crab from areas without high concentrations [of domoic acid] and limit the need to eviscerate or hold crab to areas with high concentrations [...] However, it [...] requires a system of monitoring, regulation, and tracking of harvested crab to ensure crab from areas with high [domoic acid] concentrations are eviscerated before cooking [...]" The authors state that a cost-benefit analysis is necessary to understand the costs of evisceration compared to impacts on market value. They also note a need to evaluate mitigation strategies "against plausible scenarios for future HAB events --including potential duration, spatial pattern, and scale of contamination--in order to bound potential gains this mitigation option would provide." The project began in September 2020 and has a projected completion date of August 2024.

47. **Gien L.T. Land and Sea Connection: The East Coast Fishery Closure, Unemployment and Health. *Canadian Journal of Public Health.* 2000;91(2):121-124.**
In 1992, the cod fishery on the East Coast collapsed (not due to harmful algal bloom events), impacting “the lives of individuals and communities both directly and indirectly, causing massive unemployment.” Moreover, “[i]n addition to financial hardship, these [people] also lost a way of life which has given them a sense of identity, a sense of purpose.” The authors stated that, “[i]n addition to providing stable food and a good source of income for coastal communities, fishing has been a way of life for centuries, a source of social and cultural identity.” The authors stated that employment is an important determinant of health and “[p]ublished literature has provided ample evidence of detrimental effects of unemployment on

mental, physical, and social well-being of individuals, family and community." The authors provided background research demonstrating that unemployment negatively impacts health and family functioning. The authors conducted surveys with 681 people from randomly selected households in 23 communities in Newfoundland (Canada) impacted by the fishery closure to understand: 1) perceived impacts of unemployment on health; and 2) the psychological well-being of people who are unemployed versus employed in fishing communities impacted by the cod fishery collapse. Surveys were conducted in 1995, about 3 years after the cod fishery closure began. Approximately 43% of people surveyed were unemployed (i.e., "looking for a job"). This percentage did not include people who were forced to retire, who stopped looking for a job, or who were homemakers. Following the fishery closure, 59% of people experiencing unemployment and 49% of people who were employed stated that their life was more or much more stressful. About 33% of people who were unemployed and 26% of people who were employed reported their stress was due to finances and money. About 71% of people who experienced unemployment due to the fishery closure "considered that they and their family were financially worse off than they were before the fishery closure. Almost 35% of [people who were employed after the closure] had the same perception, indicating that the ripple effect of job loss affected not only [people experiencing unemployment] but [additional people] in the same community due to decreased spending." People who experienced unemployment following the fishery closure were more likely to experience worse mental health and less likely to report satisfaction with tasks, making decisions, and day-to-day activities. The authors noted that previous research has shown that "involuntary unemployment [is] one of the most stressful events that a person can face."

48. **Glossary: Catch Shares. 2023; Available at: https://www.fisheries.noaa.gov/national/sustainable-fisheries/glossary-catch-shares#ex-vessel-value. Accessed.**
This glossary is published by the National Oceanic and Atmospheric Association (NOAA). Among additional definitions, it includes definitions of "ex vessel value" and "fishing community."

49. **Quality Agency for Healthcare Research and. 2016 National Healthcare Quality and Disparities Report.Rockville, MD: U.S. Department of Health and Human Services;2017.**
The National Healthcare Quality and Disparities Report is mandated by Congress and has been published every year since 2003. The intent of the report is to summarize the quality of healthcare received by people in the U.S., and to identify disparities in care and access to care by priority populations. It evaluates quality of healthcare in six core areas: person-centered care, patient safety, healthy living, effective treatment, care coordination, and care affordability. The report uses four main measures for access to care: having health insurance, having a usual source of care, encountering difficulties when seeking care, and receiving care as soon as wanted. Over time, the report has found inequities in access to care based on race/ethnicity, socioeconomic status, age, sex, disability status, sexual orientation, gender identity, and residential location. The 2016 report concluded that, while inequities in health insurance status decreased since 2014, about 70% of care affordability measures have not changed since 2010 and inequities in care persisted for people who are uninsured and have low incomes in all priority areas. The report stated, people with low incomes "experienced worse access to care compared with [people with high incomes] for all access measures except one" and "more than half of measures show that

[…] low-income households have worse care than high-income households." Further, the report concluded that "significant [inequities] continue for [people with low incomes] compared with [people with high incomes] who report they were unable to get or were delayed in getting needed medical care due to financial or insurance reasons."

50. **Centers for Disease Control and Prevention. Behavioral Risk Factor Surveillance System Prevalence and Trends Data: Washington-2014. 2014; Available at: http://apps.nccd.cdc.gov/brfss/page.asp?cat=XX&yr=2014&state=WA#XX. Accessed August 16, 2016.**
Behavioral Risk Factor Surveillance System (BRFSS) 2014 data from Washington State show significant correlations between lower income and a number of health indicators including: worse overall self-reported health, depression, asthma, arthritis, stroke, oral health, tobacco use, women's health indicators, health screening rates, physical activity, and diabetes. Data also show that as educational attainment increases income level also increases.

51. **Poel A. Health of Washington State Report: Mortality and Life Expectancy. Data Update 2015. Washington State Department of Health;2015.**
Poel presents Washington State data on mortality and life expectancy. The data show that age-adjusted death rates were higher in Washington census tracks with higher poverty rates. Data also show that American Indian/Alaska Natives, Native Hawaiian/Pacific Islanders, and Black Washingtonians had the highest age-adjusted death rate and shortest life expectancy at birth compared to different groups in the state.

52. **Serafin M. Health of Washington State Report: Self-reported Health Status. Data Update 2016. Washington State Department of Health;2016.**
Washington State data on self-reported health status showed that, after accounting for age, education, and race/ethnicity, household income was a strong predictor of self-reported health status. Health status varied by race/ethnicity, with about 35% of Hispanics, 30% of American Indian/Alaska Natives, and 20% of Native Hawaiian/Pacific Islanders reporting fair or poor health. Washington Behavioral Risk Factor Surveillance System (BRFSS) data from 2012-2014 also showed that education was a strong predictor of self-reported fair or poor health after adjusting for age.

53. **Health Washington State Department of. Medically Underserved Area & Medically Underserved Population, June 1, 2023. 2023.**
This map of Washington State, published by Washington State Department of Health, shows Medically Underserved Areas and Medically Underserved Populations.