Oregon Dungeness Crab Fishery Management Plan

Oregon Department of Fish and Wildlife
Marine Resources Program

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March 2022

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Introduction

Purpose and need

Dungeness crab is a key component of the marine ecosystem along the Pacific coast. The Dungeness crab fishery in Oregon is comprised of three targeted fishery sectors (the ocean commercial, bay commercial, and recreational Dungeness crab fisheries), with the ocean commercial fishery typically constituting the most valuable single-species fishery in the state. All Dungeness crab fishery sectors are managed at the state level with Oregon Department of Fish and Wildlife (ODFW) as lead agency. Formal stock assessments are not employed to determine annual exploitation levels. Instead, ODFW manages this resource through a '3-S' management strategy limiting harvest based on crab size, sex, and season. This management system has remained relatively stable over time.

The fishery currently faces a range of complex management challenges that are described throughout this plan, along with the tools and strategies employed to address them. Current issues facing the fishery are largely social or economic in nature, or related to changing ocean and climate conditions.

The purpose of the Oregon Dungeness Crab Fishery Management Plan (FMP) is to provide management transparency and facilitate good governance. This plan comprehensively assesses the current knowledge of Dungeness crab and describes the current management strategy for harvest of the resource.

Goals

The management goals for the fishery aim to support the long-term well-being of the Oregon Dungeness crab fishery, coastal communities, and larger ecosystem. As defined in this plan, the primary management goals are:

1) **Ecological** – Ensure the long-term reproductive capacity of the Dungeness crab population, minimize impacts to other species, and support ecosystem health.
2) **Social/cultural** – Promote diverse opportunities for present and future generations to harvest, use, or enjoy the Dungeness crab resource.
3) **Economic** – Support the economic vitality of the Dungeness crab fishing industry and coastal communities.

Specific objectives that support these goals are described in the Harvest Management Strategy section of this plan.

The Oregon Marine Fisheries Management Plan Framework

The Oregon Marine Fisheries Management Plan Framework guides the development of Marine Fisheries Management Plans (MFMPs) that ensure orderly fisheries and equitable access to marine resources by different users, while maintaining ecological integrity (ODFW, 2015a). The Framework outlines a consistent approach for MFMP development involving a comprehensive evaluation of fishery resources and assessment of harvest management strategies. Specifically, the Framework details the information that should be included in MFMPs in order to achieve the following goals:

1) Provide for access to marine resources for present and future generations.
2) Minimize bycatch, incidental catch, and mortality related to fishery interactions with non-target marine organisms.
3) Coordinate the management of commercial and recreational fisheries.
4) Minimize complexity of management.
5) Consider the socioeconomic needs of local communities, including both consumptive and non-consumptive uses and values.
6) Involve the public in the fisheries management process.

Major state policies

There are several overarching policies that primarily guide the management of marine fishery resources and the development of fishery management plans in Oregon. These policies are thoroughly described in the MFMP Framework and are listed below:

- Food Fish Management Policy (1975; Oregon Revised Statute § 506.109)
- Wildlife Policy (1973; ORS § 496.012)
- Native Fish Conservation Policy (NFCP; 2003; Oregon Administrative Rule 635-007-0502 through OAR 635-007-0509)
- Oregon Nearshore Strategy (2015; ODFW, 2016)
- Oregon Territorial Sea Plan (1994; OPAC, 1994)
- Statewide planning goals (DLCD, 2010; OAR 660-015)

Document organization

This Plan is organized into two primary sections according to the Framework structure. First, the Resource Analysis comprehensively describes the status of the Dungeness crab resource in Oregon, including biological and ecological information, an analysis of stock status, factors affecting the species, and areas for future research. Second, the Harvest Management Strategy articulates historical and current management practices, goals for the resource, issues facing the fishery, and appropriate management tools for the Dungeness crab fishery.

Acronyms

ASP: Amnesic shellfish poisoning

BMZ: Biotoxin Management Zone

CCI: Climate and Communities Initiative

CDFW: California Department of Fish and Wildlife

CP: Conservation plan

CPUE: Catch-per-unit-effort

CW: Carapace width

DO: Dissolved oxygen

EEZ: Exclusive Economic Zone

ESA: Endangered Species Act

FDA: U.S. Food and Drug Administration

FEP: Fishery Ecosystem Plan

FIP: Fishery Improvement Plan

FMP: Fishery Management Plan

HAB: Harmful algal bloom

ITP: Incident take permit

LRP: Limit reference point

MFMP: Marine Fisheries Management Plan

MMPA: Marine Mammal Protection Act

MNSRFS: Marine Non-Salmonid Recreational Fishery Studies

MOU: Memorandum of Understanding

MRP: Marine Resources Program

MSA: Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act)

MSC: Marine Stewardship Council

NFCP: Native Fish Conservation Policy

NMFS: National Marine Fisheries Service

NOAA: National Oceanic and Atmospheric Administration

NWFSC: Northwest Fisheries Science Center

OAH: Ocean acidification and hypoxia

OAR: Oregon Administrative Rule

ODA: Oregon Department of Agriculture

ODCAC: Oregon Dungeness Crab Advisory Committee

ODCC: Oregon Dungeness Crab Commission

ODFW: Oregon Department of Fish and Wildlife

OFWC: Oregon Fish and Wildlife Commission

ORBS: Ocean Recreational Boat Survey

ORS: Oregon Revised Statute

OSP: Oregon State Police

OSU: Oregon State University

OWEWG: Oregon Whale Entanglement Working Group

PacFIN: Pacific Fisheries Information Network

PDO: Pacific Decadal Oscillation

PFMC: Pacific Fishery Management Council

PLD: Pelagic larval duration

PSMFC: Pacific States Marine Fisheries Commission

RAC: Rules Advisory Committee

SAC: Sport Fishing Advisory Committee

SFFMP: State-Federal Fisheries Management Program

SST: Sea surface temperature

USCG: United States Coast Guard

WCGOP: West Coast Groundfish Observer Program

WDFW: Washington Department of Fish and Wildlife

Definitions

Bait: Food fish not harvested for human consumption (OAR 635-005-0240).

Biotoxin management zone: One or more harvest areas that due to test results the Oregon Department of Agriculture, in order to protect public health from domoic acid or other biotoxin concerns, has so designated in accordance with OAR 603-025-0410 (OAR 635-005-0466).

Bycatch: Discarded catch plus retained incidental catch and unobserved mortality resulting from a direct encounter of any living marine resource with fishing gear.

Carapace: Dorsal (upper) section of the exoskeleton or shell.

Carapace width (CW): A straight line or caliper measurement made directly in front of the 10^{th} anterolateral spine (see Figure 1).

Catch-per-unit-effort (CPUE): An indirect measure of relative abundance of a target species, derived from the quantity of catch divided by a defined measure of fishing effort undertaken to obtain the catch.

Commercial fishery: The legal harvest of food fish (as defined in ORS § 506.036) utilized for commercial purposes (as defined in ORS § 506.006).

Crab pot: Any portable, enclosed device used to take crab with one or more gates or entrances that allows crab restricted entry and exit, and has a line attached to surface floats (OAR 635-005-0240).

Crab ring: Any fishing device used to take crab that allows crab unrestricted entry or exit while fishing, and has a line attached to surface floats (OAR 635-005-0240).

Derelict Dungeness crab gear: Dungeness crab gear which was lost, forgotten, damaged, abandoned or otherwise deserted (OAR 635-005-0240).

Discard mortality rate: The proportion of the discarded animals that die (immediately or after a delay) as a result of being caught, handled, and released.

Discard rate: The proportion of the total catch that is discarded.

Domoic acid: A natural toxin that can accumulate in certain shellfish and fish species and cause amnesic shellfish poisoning, a serious illness, in consumers (OAR 603-025-0410).

Endangered species: Any species which is in danger of extinction throughout all or a significant portion of its range (16 U.S.C. § 1532(6)).

Evisceration: The common processor's action of removing and discarding the entire intestinal tract, hepatopancreas, and all associated abdominal organs (OAR 603-025-0410).

Exclusive economic zone (EEZ): The zone extending to 200 nautical miles (from the nation's coastal baseline) over which the U.S. and other coastal nations have jurisdiction. Under the Magnuson-Stevens Act, the inner boundary of the U.S. EEZ is coterminous with the seaward boundary of the adjacent coastal state's territorial sea (3 nautical miles offshore) (P.L. 109-479).

Harvest area: Section of waters of this state or the Pacific Ocean off Oregon delineated for crab traceability purposes (OAR 603-025-0410).

Intertidal: The area in Oregon coastal bays, estuaries, and beaches between mean extreme low water and mean extreme high water boundaries (OAR 635-005-0240).

Landing: The portion of the catch that is landed in ports.

Nearshore: The area from the outer boundary of Oregon's Territorial Sea at 3 nautical miles to the supratidal zone affected by wave spray and overwash at extreme high tides, and up into the portions of estuaries where species depend on the saltwater that comes in from the ocean (ODFW, 2016).

Pacific Decadal Oscillation (PDO): A recurring pattern of widespread climate variability in the Pacific Basin and North America. Extreme phases of the PDO (classified as warm or cool) are defined by sea surface temperature (SST) anomalies in the North Pacific.

Recreational fishery: The legal harvest of living marine species for personal use (as defined in ORS § 506.006).

Spring transition: The transition from a winter downwelling state to a summer upwelling state along the west coast of the United States as a result of winds from the south shifting to a predominately equatorward direction.

Stock: An aggregation for management purposes of fish [or shellfish] populations which typically share common characteristics such as life histories, migration patterns, or habitats (OAR 635-007-0501).

Sustainable: Persistence over time, that is to say the ability of a population or a species management unit to maintain temporal, spatial, genetic, and ecological coherence while withstanding demographic, environmental, and genetic variation and catastrophic events from natural and human induced causes (OAR 635-007-0501).

Take:

- *As defined under the U.S. ESA* – To harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct (16 U.S.C. § 1532(19)).
- *As defined under Oregon law* – Fish for, hunt, pursue, catch, capture or kill or attempt to fish for, hunt, pursue, catch, capture or kill (ORS § 506.006).

Territorial sea: The waters and seabed extending three nautical miles seaward from the coastal baseline (i.e., mean lower low water) (OPAC, 1994).

Threatened species: Any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range (16 U.S.C. § 1532(20)).

Upwelling: The offshore movement of surface shelf waters and subsequent replacement by cold, nutrient-rich deep waters from off the shelf.

A. Resource Analysis

This Resource Analysis provides a description of the Dungeness crab resource in Oregon, along with a review of the biology and ecology of the species, synthesis of available data, and analysis of the stock status. Presented are both non-fishery and fishery-related threats to Dungeness crab and its habitat along with recommendations on sustainable harvest levels. Finally, a prioritized list of information gaps and research needs related to Dungeness crab and the Oregon crab fishery is provided.

I. Description of the Oregon Dungeness crab resource

This plan is a comprehensive management tool for the Dungeness crab (*Cancer magister*/ syn. *Metacarcinus magister*) fishery operating in the state and federals waters off the Oregon coast.

The Dungeness crab was first described by James Dana in 1852 (Dana, 1852). Taxonomically, it is a member of the suphylum Crustacea, belonging to the order Decapoda, the infraorder Brachyura, and the family Cancridae. Historical and other common names for this species include the coastal crab, market crab, Pacific edible crab, and commercial crab. Dungeness crab play an important role in both marine and estuarine waters at all life stages and supports valuable commercial and sport fisheries along the west coast of the United States and British Columbia.

In Oregon, three targeted fishery sectors comprise the Dungeness crab fishery, hereafter referred to as the ocean commercial fishery, the bay commercial fishery, and the recreational fishery. Within each fishery sector, diverse user groups exist. For a description of each sector, see *Section B.III.a.*

The Oregon Dungeness crab fishery is managed by the state, with the Oregon Department of Fish and Wildlife as lead agency. Unless otherwise noted, the information and management approach presented in this plan applies to all Dungeness crab fishery sectors operating in Oregon.

II. Biology and ecology of Dungeness crab

Effective fisheries management is dependent upon a comprehensive understanding of the life history characteristics of the targeted species. This subsection synthesizes current and historical literature on the biology and ecology of Dungeness crab.

a. Range, distribution, and stock structure

Dungeness crab occur throughout the cold and temperate waters from the Pribilof Islands in Alaska to Santa Barbara, California (Jensen, 2014). This species range encompasses three large-scale oceanographic regimes: the California Current System, the Alaska Current, and the Salish Sea (O’Malley *et al*., 2017). Each regime is associated with unique environmental characteristics that influence the habitat available to Dungeness crab and consequently the biology and ecology of the species at the local level. The Dungeness crab population off the coast of Oregon is a key component of the California Current System.

The California Current is a broad, relatively slow-moving equatorward flow that constitutes the eastern boundary of the North Pacific Subtropical Gyre from ~20° N to ~50° N (Checkley and Barth, 2009). The system is characterized by a number of complex physical processes including seasonal wind-driven upwelling, variable local wind dynamics, and freshwater input from estuaries and rivers (e.g., the Columbia River plume) (Hickey and Banas, 2008). Interannual variability in these processes is closely tied to habitat characteristics (e.g., temperature, productivity), which directly and indirectly impact Dungeness crab throughout their life cycle.

Dungeness crab are distributed throughout a variety of coastal habitats including the continental shelf, estuaries, and inland waters (e.g., Puget Sound). They are found at water depths ranging from the mid-intertidal to ~450 fathoms (2,700 feet) (Bradburn *et al.*, 2011), but are commonly fished commercially to 100 fathoms (600 feet).

Biologically, Dungeness crab are considered a single population; however, genetic subpopulations may exist. Specifically, isolated populations (e.g., those inhabiting fjord-like areas) may experience reduced connectivity with other parts of the species' range and a higher degree of relatedness compared to less isolated populations (e.g., those inhabiting the open ocean) (O'Malley *et al.*, 2017).

In 2011, a collaborative study was initiated to evaluate genetic connectivity in the California Current System. Genotypic analysis of samples collected over several years demonstrated little evidence of population structuring, though differences in genetic structure over the relative short time period were observed. The researchers hypothesize that this interannual variability is driven in part by physical oceanographic conditions influencing larval dispersal (O'Malley and Roegner, 2013; Jackson *et al.*, 2017).

b. Morphology, growth, and life history characteristics

Adult Dungeness crab vary in color, but are typically light reddish brown, sometimes with gray-purple mottling on their carapace. The carapace is broadly oval-shaped and widest at the tenth anterolateral spine (see Figure 1). Individuals have four pairs of walking legs and one pair of chelipeds with light-colored claws. The abdomen is a key morphological characteristic for differentiating between sexes. Male crab have a narrow and triangular abdomen, whereas the abdomen of female crab is broadly expanded to allow for egg-carrying.

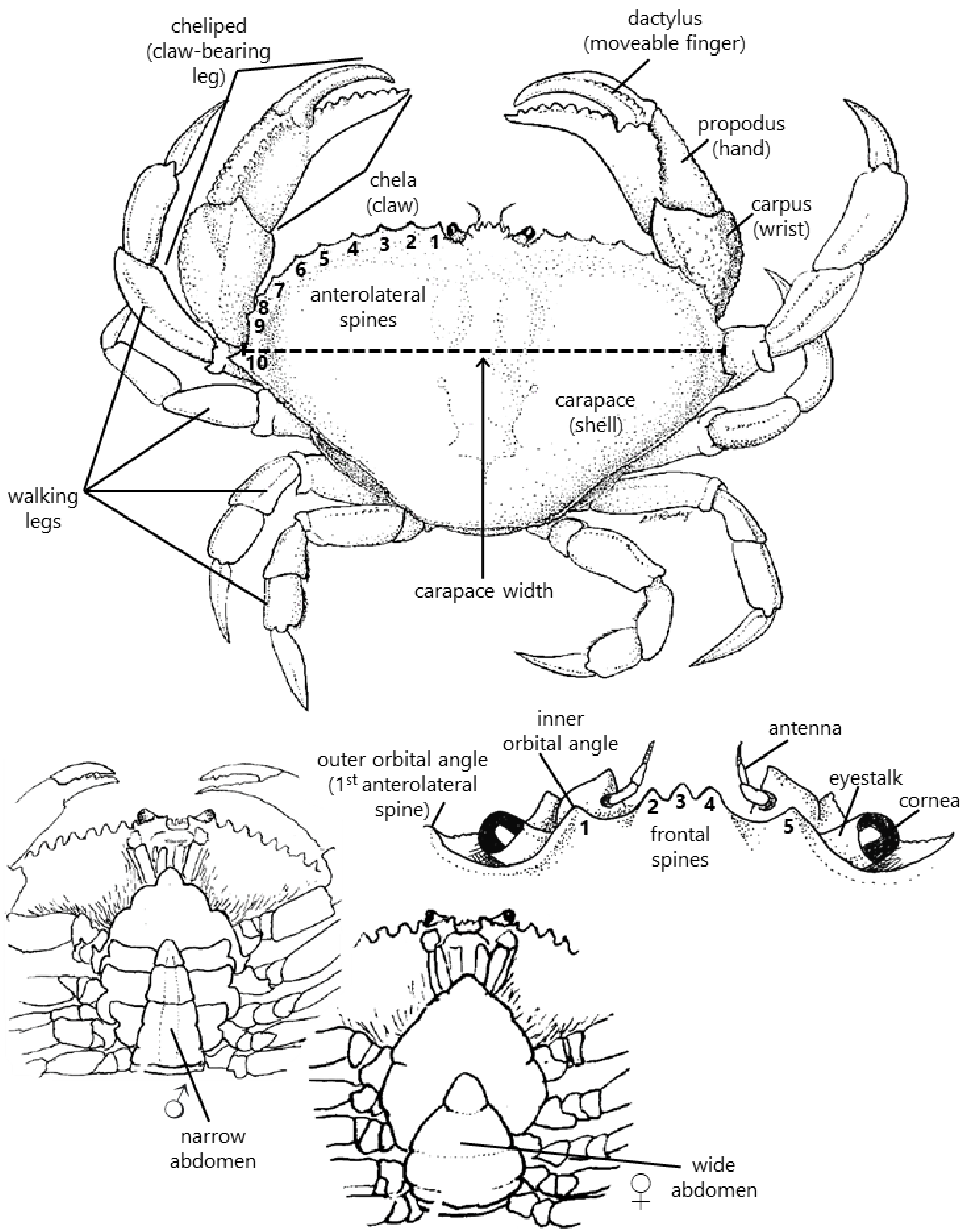


Figure 1. External anatomy of Dungeness crab: broad, oval body; 10 anterolateral spines; 5 unequal frontal spines with the largest, most advanced spine in the middle; light-colored fingers; short eyestalks with small orbits; broad and flat walking legs (especially propodus and dactylus of last pair); sexual dimorphism (i.e., narrow and triangular abdomen in males, wide and flap-like abdomen in females). Carapace width measurement is a straight line or caliper measurement made directly in front of the 10th anterolateral spine. Adapted from Pauley *et al*., 1986; Davie *et al*., 2015; Hiebert and Rasmuson, 2015.

As with other crustaceans, the body of the Dungeness crab is covered by a chitinous exoskeleton that must be shed periodically to allow for growth in a process called molting or ecdysis (Klaoudatos and Klaoudatos, 2008). The process involves the crab backing out of their existing shell through a split at the back of their carapace leaving them in a vulnerable 'soft-shell' condition. In this condition, a crab has little ability to defend itself and will often bury in the surrounding sediment immediately following molting (Jensen, 2014). Over time, the new shell hardens and the crab grows body tissue or 'fills with meat'. For a given individual, their stage in the molt cycle and maturity are the two most important factors affecting mating (Shields, 1991).

Key stages in the Dungeness crab life cycle are shown in Figure 2. Like other brachyuran crabs, Dungeness crab mating occurs between a hard-shelled male and a recently molted (soft-shelled) female. For up to two weeks prior to female molting, a male crab will grasp the female in a 'premating embrace' to deter other males (Snow and Neilsen, 1966). Shortly after the female has shed her exoskeleton, mating occurs with the male depositing spermatophores into the spermatheca of the female where it can remain viable for over two years. The hardening of some of the seminal fluid forms a sperm plug preventing access to the spermatheca during subsequent mating with other males (Jensen *et al.*, 1996). Male Dungeness crab mate with multiple females each year, so competition for females is high. Male guarding and the formation of sperm plugs serve to reduce sperm competition (Oh and Hankin, 2004).

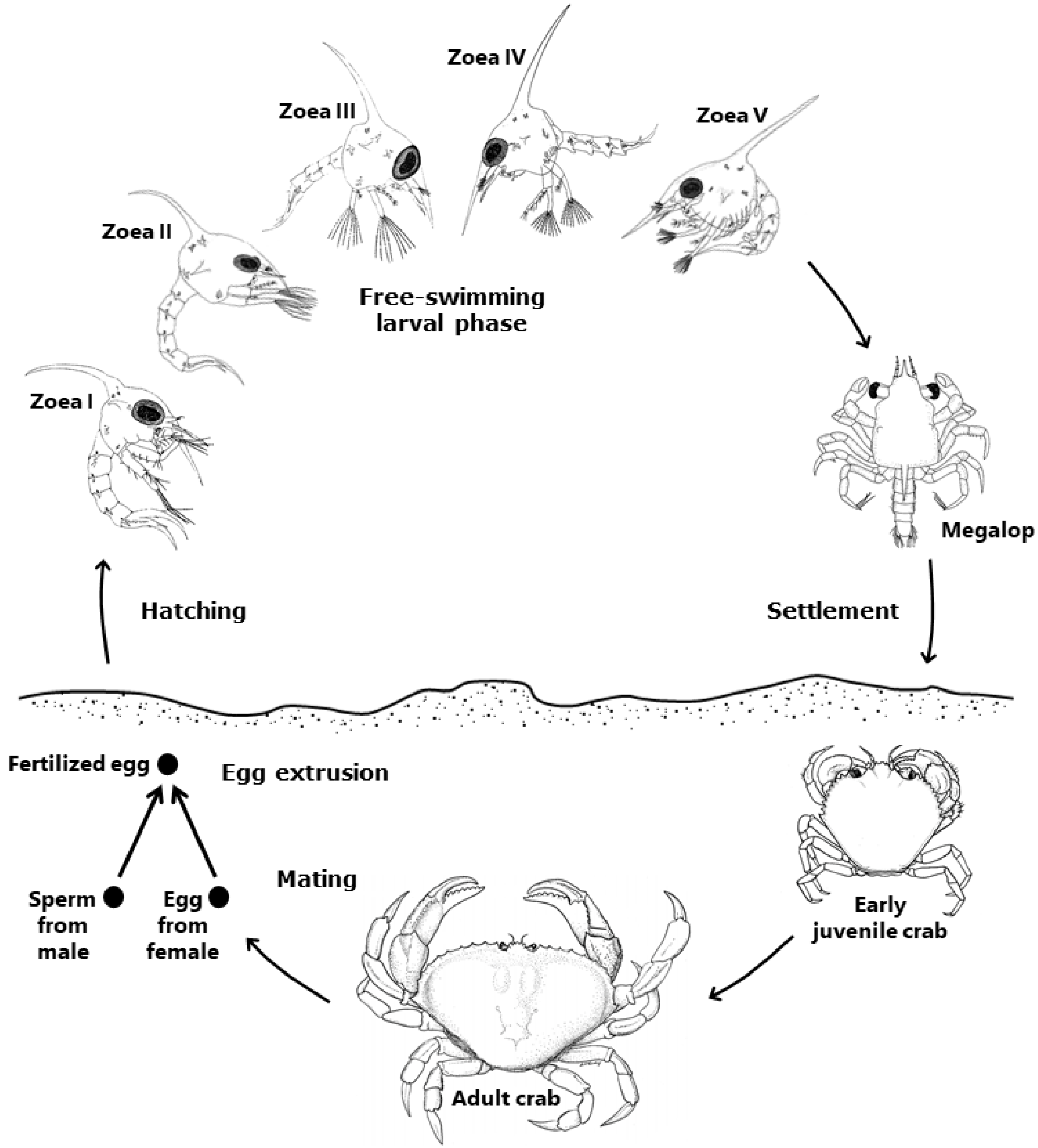


Figure 2. Life cycle of Dungeness crab. Larval development includes five zoeal stages (2.5 – 9 mm total length) and one megalopa stage (11 mm total length), each marked by a molt. At settlement, the carapace width of juveniles is ~5 mm. Crab grow through a series of molts reaching sexual maturity in 2 – 3 years at a carapace width of ~100 – 110 mm. Timing and duration of life stages vary through the range of the species (see Table 1). Adapted from Poole, 1966, Pauley *et al.*, 1986, and Hiebert and Rasmuson, 2015.

In Oregon, most mating occurs from May to July with females extruding eggs from October to December (Waldron, 1958; ODFW, 1977a) (Figure 3). Eggs are fertilized as they pass through the reproductive tract and the extruded eggs are attached to the swimmerets forming a sponge-like mass beneath the abdominal flap (Pauley *et al.*, 1986). At this stage, females are often referred to as 'berried'. When first laid, eggs are bright orange but gradually change to a dark brown prior to hatching (Cleaver, 1949). Most adult female crab extrude eggs annually, though a portion of females in southeastern Alaska skip at least one reproductive season and later extruded eggs fertilized with stored sperm (Swiney *et al.*, 2003). Ovigerous (i.e., egg-bearing) female crab carry between 0.7 and 2.5 million eggs. This large number of eggs significantly raises the abdominal flap which can limit the movement of female crab (Rasmuson, 2013).

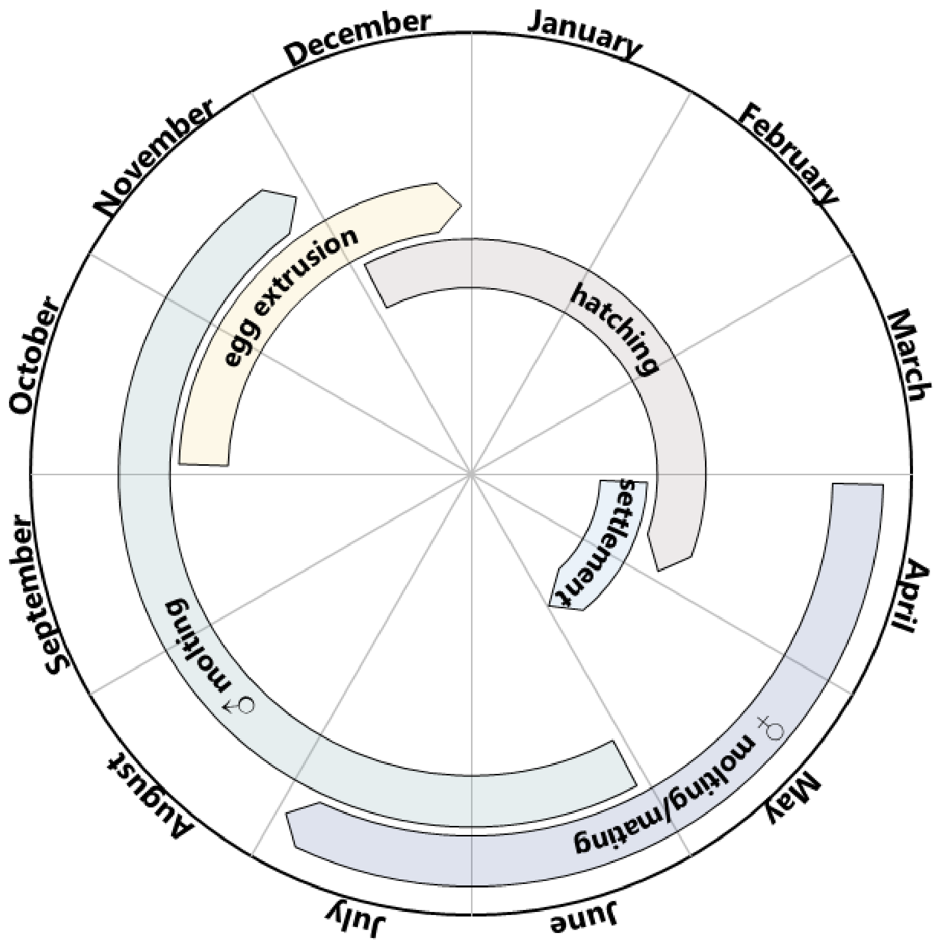


Figure 3. Timing of Dungeness crab life history events in Oregon from a review of published literature.

The timing of Dungeness crab hatching varies over its range; however, in Oregon it reportedly occurs between December and April (Reed, 1969; ODFW, 1977a). Hatching is followed by a long free-swimming larval period (89 – 143 days on average) during which time they progress through five zoeal stages and one megalopal stage prior to settlement (i.e., transition from free-swimming to benthic phase) around April or May (Poole, 1966; Lough, 1976). The timing and duration of this development time has been shown to vary latitudinally with changes in both temperature and salinity (Moloney *et al.*, 1994).

Crab settle to the benthos as juveniles at a carapace width (CW) of about 5 – 7 mm (Butler, 1961). Through molting, they continue to pass through 11 – 12 successive size increases, or instars, before reaching sexual maturity.

At this time, a direct aging technique for Dungeness crab does not exist. Instead, age is often estimated indirectly through crab measurements (e.g., CW) or molting records (e.g., molt increment) (e.g., Butler, 1961). Male Dungeness crab reach sexual maturity at a carapace width of about 110 mm, though signs of mating are apparent in a larger proportion of males of at least 140 mm (~3 years old) (PFMC, 1979). Female crab reach sexual maturity at a carapace width of 100 mm (~2 years old) (Butler, 1960; PFMC, 1979).

Crab molt at most once per year as adults, increasing in carapace width by 8.1 to 19.7 mm after each molt (Hankin *et al.*, 1989). The vulnerable post-molt or soft-shell condition lasts for approximately two months as the new exoskeleton fills with tissue (Rasmuson, 2013). Crab at more northerly latitudes tend to molt later than those in the south. Along the west coast of the United States, male crab in California and southern Oregon reportedly molt between June and October, while those in northern Oregon and Washington molt from July to November (PFMC, 1979). These differences in molt timing affect meat recovery rates (i.e., the meat content or yield extracted from crab) along the coast and have significant implications for fishery timing (see *Section B.III.f*). The current molting season appears to be changing from first-hand observations and anecdotal information. Likely correlated with changing ocean conditions, documentation of the current molting season is a research priority (see *Section A.VII.i*).

In addition to differences in molting, the timing of other early life history events and biological rates varies greatly throughout the range of Dungeness crab (Table 1). Generally, reproductive schedules occur earlier in the year at the southern end of their range than in more northern areas. Increased rates of development and larval growth also typically occur in the south. Effective management benefits from knowledge of the local timing of these events and an understanding of how that timing may be changing with oceanographic conditions.

Table 1. Timing of life history events throughout the range of Dungeness crab. Crab mate from February to July in the southern portion of their range. In British Columbia and Alaska, mating occurs later in the year (June – September) and male molting generally proceeds female molting. Egg deposition occurs from August to December, but is reported as late as February. Eggs hatch from December to April through most of the range, but later in Alaska. The pelagic larval duration (PLD) generally increases with latitude and is followed by settlement in spring/summer. Settlement in inland waters occurs later than along the outer coast and estuaries.

Location	♀ Molting/mating	♂ Molting	Egg extrusion	Hatching	PLD (days)	Settlement	Sources
Southeastern Alaska			Oct – Nov	Apr – Aug			Shirley *et al.*, 1987
	Aug – Sep[a]	May – Aug[a]					Shirley and Shirley, 1988
			Sep – Nov				Swiney and Shirley, 2001
	Jun – Sep	Dec – Mar	Aug – Oct	Apr – Jul			Stone and O'Clair, 2001
					146 – 162		Fisher, 2006
British Columbia	Apr – Sep			Dec – Jun		Jul – Aug	MacKay, 1942
	Jun – Aug		Sep – Oct	late Apr		Aug – Sep	Butler, 1956
			Oct – Nov	Jan – Mar			Jamieson and Phillips, 1990
Puget Sound						Jun – Sep	McMillan *et al.*, 1995
				Mar – Apr	150[b]		Fisher, 2006
Coastal Washington	May – Jun	early Nov	Nov – Feb	Jan – Mar			Cleaver, 1949
						Apr – May	Stevens *et al.*, 1982
	Mar – Apr						Pauley *et al.*, 1986
						May – Jun	Dinnel *et al.*, 1993
				Jan – Feb	120[b]		Fisher, 2006
Oregon			Oct – Dec				Waldron, 1958
				Dec – Apr			Reed, 1969
					89 – 143	Apr – May	Lough, 1976
	May – Jul			Dec – Apr			ODFW, 1977a
		Jun – Nov[c]					PFMC, 1979
	Apr – Jun	Jul – Aug					Snow, 1984
California	Mar – Jun		Sep – Nov	Dec – Mar[d]			Wild, 1980
				Dec – Jan	105 – 125		Reilly, 1983a
						Apr – May	Hatfield, 1983
	Feb – May	Jul – Aug		Dec – Jan			Hankin *et al.*, 1997

[a]No data provided
[b]Estimated from published opportunistic field observations
[c]Generally later in northern OR and WA (Jul–Nov) than southern OR and CA (Jun–Oct)
[d]Jan–Mar in northern CA and Dec–Feb in central CA

Female mating success

Each year, the majority of all legal-sized male Dungeness crab are harvested. Estimated exploitation rates for crab fisheries along the West Coast fluctuate widely by season and range from just over 50% to nearly 100% (Methot and Botsford, 1982; Smith and Jamieson, 1989; Richerson *et al.*, 2020). Various researchers have speculated that intensive male-only fisheries could limit the number of large males capable of fertilizing all reproductive females and impair female mating success (Paul, 1984; Smith and Jamieson, 1991), which could have major implications for larval production and eventual recruitment into the fishery.

Complete or partial sperm plugs typically remain in the female reproductive tract at least 180 days after mating, and therefore serve as a reliable indicator of mating success (Oh and Hankin, 2004). In Northern California and Oregon, high rates of sperm plug presence in mature molting females is evidence that females are mating successfully and that, under the current management system, female mating success is not likely to be a limiting factor impacting the Oregon Dungeness crab fishery (Hankin *et al.*, 1997; Dunn and Shanks, 2012).

From 2012 to 2014, an ODFW pilot program monitored female mating success throughout the female molting period in various Oregon ports and found similar fertilization rates to those that had been previously published (e.g., Oh and Hankin, 2004; Dunn and Shanks, 2012). Longer term information on female mating success across a broader geographic area may aid managers in setting more direct and effective biological reference points for the fishery (ODFW, 2014a).

Natural mortality

Natural (non-anthropogenic) mortality is an important life history characteristic that has significant implications for Dungeness crab population dynamics and fishery management. Throughout their life history, sources of natural mortality include disease, parasites, competition, predation, aging, and density-dependent reproduction (Murphy, 1995). Mortality is also impacted by direct (e.g., temperature) and indirect (e.g., prey availability) changes in environmental conditions.

Immediately following molting, natural mortality is especially high (Morado *et al.*, 1999). Taking into consideration mortality related to both molting and non-molting periods, an instantaneous natural mortality rate of 1.25 per year has been suggested for adult male crab (>155 mm CW; Zhang *et al.*, 2004).

c. Habitat and movement

Dungeness crab hatch as larvae near the coast during midwinter. Within the California Current System, there is evidence of offshore migration of crab larvae as they develop, followed by subsequent movement of megalopae back to the nearshore environment prior to settlement (Reilly, 1983a). It has been proposed that the annual abundance of returning megalopae can be largely attributed to variation in atmospheric forcing (Shanks and Roegner, 2007; Shanks, 2013). Specifically, the number of returning megalopae is correlated with the timing of the spring transition (i.e., the transition from winter downwelling to summer upwelling conditions), the amount of local upwelling, and the phase of the Pacific Decadal Oscillation (Shanks, 2013). For additional details on drivers of larval crab recruitment, see *Section A.II.e.*

Off the coast of Oregon, most megalopae settle on the continental shelf within 10 – 15 km of shore, though some migrate into estuaries before metamorphosing into juveniles (Rasmuson, 2013). Estuaries are complex habitats that provide important nursery grounds for many organisms, including commercially and recreationally harvested fisheries species like Dungeness crab. While the relative contribution of estuary habitat to Dungeness crab production has not been well characterized (see *Section A.VII.g*), estuarine nurseries provide favorable growing conditions that may facilitate faster growth and earlier maturity. Additionally, estuarine nurseries may serve as a refuge for juvenile crab from unfavorable oceanic conditions that may adversely impact juveniles in the coastal nearshore, thus providing an important buffer function for the portion of the population that settles or migrates there (Lewis *et al.*, 2020). This function may become increasingly important as climate and ocean conditions continue to change.

Within bays, newly-settled juveniles are often associated with intertidal gravel habitat combined with macroalgae or eelgrass (*Zostera marina*) beds, which offer refuge from predation (McMillan *et al.*, 1995). As crab achieve a larger size, this dependence on intertidal habitat is reduced and emigration into subtidal habitat occurs.

The continental margin adjacent to Oregon is predominately composed of unconsolidated sediments (sand, mud, or a mixture) with soft sediments (mostly sand) accounting for ~53% of the bottom substrate on the continental shelf (Romsos, 2004; Rasmuson, 2013). As adults, Dungeness crab can be found on almost any bottom type, but prefer sandy or sandy-mud bottoms (Rasmuson, 2013).

Crab tagging studies in Oregon indicate that over a nine-month period, adult crab travel between ~0.2 to ~100 km, with the majority traveling less than 20 km (Hildenbrand *et al.*, 2011). Given this information, larval transport appears to be the primary means of long-range crab dispersal.

Abiotic factors

The physiological tolerance of an organism to changes in environmental conditions (e.g., temperature and salinity) is closely tied to their distribution and habitat use. For Dungeness crab, temperature strongly influences egg development and mortality. Hatching success is reduced at high temperatures and the rate of egg development accelerates with increasing temperature (Wild, 1980).

Laboratory studies indicate that larval Dungeness crab survival is highest at temperatures between 10.0 – 13.9°C and salinities between 25 – 30 ppt, and lowest at ~22°C and 10 – 15 ppt (Reed, 1969). Elevated temperatures disproportionately impact mortality at the later zoeal stages and have been shown to drastically decrease the duration of zoeal stages (Sulkin and McKeen, 1989). Though post-larval Dungeness crab are reasonably tolerant of temperature and salinity variations (Cleaver, 1949), physiological impacts of temperature can be seen in the latitudinal variation in growth. Specifically, size at functional maturity decreases with increasing latitude for both males and females (Murphy, 1995).

Due to the diversity of habitats that they inhabit across their geographical range and throughout their life history, Dungeness crab are likely exposed to a variety of pH levels during development. Laboratory studies indicate that low pH may not impact hatching success, but likely delays embryonic and early larval development and reduces larval survival (Miller *et al.*, 2016). Collectively, these impacts to development and survival at early life stages could be a factor limiting recruitment in the wild. Adult Dungeness crab appear to have physiological mechanisms for tolerating stress from short-term changes in ocean chemistry. However, partial metabolic depression in response to this stress may have significant effects under long-term ocean acidification conditions (Hans *et al.*, 2014).

Dungeness crab commonly occupy habitats with fluctuating oxygen regimes and episodes of hypoxia (Airriess and McMahon, 1994). A number of factors including nutritional status (McGaw, 2005, 2008), community structure, and habitat characteristics (Froehlich *et al.*, 2014) impact the response of crab to low oxygen availability. While feeding activity and intake is reduced under low oxygen conditions in the laboratory, crab have been shown to possess both physiological (e.g., cardiovascular adaptations) and behavioral (e.g., feeding time and quantity) mechanisms that allow them to survive (Airriess and McMahon, 1994; Bernatis *et al.*, 2007).

d. Predator-prey relationships

The role of Dungeness crab in the trophic web changes across their life as they transition from the vulnerable early life stages to their adult role as a prominent benthic predator.

Diet

While Dungeness crab are largely considered opportunistic feeders, there is evidence that their diet changes with age (Stevens *et al.*, 1982). In laboratory studies, newly hatched Dungeness crab larvae feed on both autotrophic and heterotrophic protists that occur naturally in the water column (Sulkin *et al.*, 1998). This finding coincides with the results of field studies from the Gulf of Alaska which utilized stable nitrogen isotope ratios to demonstrate that Dungeness crab larvae are omnivores (Kline, 2002).

As juveniles, Dungeness crab consume a range of food items including small crustaceans, bivalves, macrophytes, and benthic diatoms (Stevens *et al.*, 1982; Jensen and Asplen, 1998). As with other crab species, cannibalism between cohorts is common and significantly contributes to the diet of crab at later juvenile stages, particularly in areas of high crab density (Stevens *et al.*, 1982; Fernández, 1999). A study in Washington found that during the first year post-settlement, small bivalves and crustaceans were the predominant food item consumed by Dungeness crab. In contrast, 2-year-old crab consumed large concentrations of shrimp (*Crangon* spp.) and fish (Stevens *et al.*, 1982). This shift in juvenile crab feeding patterns as they age may serve to minimize competition and cannibalism between cohorts (Rasmuson, 2013).

Adult crab feed by probing the substrate with partly opened claws (chelae) which they quickly contract to capture prey items when detected. Bivalves appear to be the most important food source for adult Dungeness crab, though crustaceans and fish also constitute a large portion of their diet (Butler, 1954; Gotshall, 1977; Stevens *et al.*, 1982). In the laboratory, crab preferentially prey upon small clams when a range of sizes are available, which may reduce the probability of claw damage (e.g., claw-tooth wear and partial claw breakage) (Juanes and Hartwick, 1990). In the wild, it is likely that claw damage has behavioral effects which may impact growth, mating success, and feeding efficiency.

Predation

As larvae and newly settled crab, the small size and widespread distribution of Dungeness crab make them highly vulnerable to predation. Larval crab serve as regular prey items for a variety of marine organisms including coho and chinook salmon (Botsford *et al.*, 1982; Hunt *et al.*, 1999), Pacific hake (Emmett and Krutzikowsky, 2008), gray whales (Darling *et al.*, 1998), Pacific tomcod (Haertel and Osterberg, 1967), nearshore rockfish (Love *et al.*, 2002), sablefish, and Dover sole (Buckley *et al.*, 1999).

Shortly after settlement, early juvenile stages of crab are highly abundant, molting frequently, and competing for limited refuge habitat which makes them highly susceptible to predation. Within coastal estuaries, staghorn sculpin are one of the most significant predators of young juvenile crab (Fernández *et al.*, 1993; Armstrong *et al.*, 1995). Other marine predators at this stage include starry flounder, English sole, and numerous other fish species (Reilly, 1983b). Additionally, cannibalism by larger conspecifics on newly settled megalopae is common and may be an important factor impacting population dynamics (Eggleston and Armstrong, 1995; Fernández, 1999).

Adult Dungeness crab have relatively few predators, but cabezon, lingcod, halibut, wolf eel, sea otters, harbor seals, sea lions, and various rockfishes (of the genus *Sebastes*) are able to consume larger crab (Waldron, 1958; Johnson, 1982; Snohomish County MRC, 2003). Additionally, nemertean worms (*Carcinonmertes errans*) are an important predator on developing eggs of Dungeness crab throughout their range (Wickham, 1979). Larval worms infect adult crab directly from the water column (Dunn and Young, 2014). They can then remain dormant on the exoskeleton of their host for months before reaching the egg clutch of a gravid female (Wickham, 1980). The worm's feeding behavior can significantly reduce the brood of a female host as they grow and reproduce. However, crab infected by this egg predator occur more frequently in the open ocean, than within estuaries. Laboratory studies have shown that juvenile and larval worms experience significant mortality at lower salinities (≤20 ppt) suggesting that salinity gradients within estuaries provide a refuge for Dungeness crab from *C. errans* (Dunn and Young, 2015).

e. Recruitment variability

Effective fisheries management is dependent upon an understanding of the factors influencing recruitment success (i.e., the number of individuals surviving to enter the adult Dungeness crab stock). A large body of historical literature and ongoing research has investigated Dungeness crab recruitment variability in Oregon; however, information from certain life stages or habitats is limited.

Rasmuson (2013) presented a synthesis of the numerous physical and biological factors impacting dispersal and annual abundance of larval crab. From this review, some of the factors that likely influence recruitment levels include the direction and magnitude of seasonal ocean transport, food availability, cannibalism, competition, and ocean temperatures. The successful return of larvae to the nearshore prior to settlement (see *Section A.II.c*) has been shown to be a limiting factor impacting Dungeness crab recruitment to adulthood (Shanks and Roegner, 2007).

Dr. Alan Shanks at University of Oregon's Oregon Institute of Marine Biology produced a series of reports exploring recruitment dynamics of Oregon Dungeness crab populations with support from the National Oceanic and Atmospheric Administration (NOAA) from 2001 to 2005 and from the Oregon Dungeness Crab Commission (ODCC) since 2006. This research has contributed a considerable amount of information on the relationship between oceanographic conditions and the annual return of Dungeness crab megalopae back to the nearshore environment in Coos Bay, OR (see *Section A.II.e*).

First, the researchers demonstrated that the annual abundance of returning larvae is largely determined by the timing of the spring transition when winds from the south shift to a predominately equatorward direction resulting in large-scale changes in coastal currents. They found that more megalopae return annually when the spring transition occurs earlier in the year (Shanks and Roegner, 2007). In subsequent work, they determined that a relationship also exists between the number of recruits and the Pacific Decadal Oscillation (PDO). During negative phase PDO years, more water is deflected to the California Current increasing the southward transport of larvae and the number of megalopae returning to shore in Oregon (Shanks *et al.*, 2010). Additionally, in most years, the spring transition instigates a change from coastal downwelling conditions to predominately upwelling conditions where deeper waters of the California Current are transported back onto the shelf. This upwelling, combined with the diel vertical migration of crab zoeae and megalopae from the surface at night to deeper waters during the day, likely represents a mechanism transporting megalopae back onto the continental shelf (Shanks, 2013). The combined effects of these physical factors (i.e., timing of the spring transition, PDO index phase, and amount of upwelling) on larval return may be indicative of interannual variation in age class strength and future harvest levels, to some degree.

This same research has produced a long-term data series (1997–2001, 2006–present) that is used each year to explore the possibility of predicting the Dungeness crab commercial catch within much of the California Current from measures of megalopal abundance. Over 20 years of sampling, the number of returning megalopae has ranged from 2,000 to 2.8 million and can be categorized by years with low (<100,000) and high (>100,000) returns. The current dataset suggests that the relationship between the number of megalopae caught and the size of the commercial catch four years later is described by two curves, depending on whether they are low or high return years (Shanks, 2020). This is complicated in years (like 2017) when the number of megalopae is right around 100,000 without a clear idea of which curve should be used (Shanks, 2017). Each year, an annual report is produced for the ODCC assessing the recruitment season in relation to the larger data series and the degree to which the observed patterns may be influenced by the physical factors described above.

While a number of studies have investigated mechanisms affecting larval recruitment, research on post-larval to pre-recruit Dungeness crab (up to 3 years old) is limited.

III. Available data

The ODFW Marine Resources Program (MRP) actively collects data and monitors the Dungeness crab resource and fishery. A variety of data sources contribute to a better understanding of crab catch, effort, size distributions, and discard in Oregon fisheries (see Table 2). This section catalogs the available fishery-independent and fishery-dependent data sources that guide in-season and long-term fisheries management along the Oregon coast.

The Oregon Dungeness crab fishery is managed under the 3-S system (i.e., sex, size, and season), which prohibits the retention of female crab, sets a minimum carapace size limit for retained males, and limits the season when harvesting occurs (see *Section B.III.d*). Under this system, data collected directly from the commercial and recreational fisheries dockside (i.e., fishery-dependent data) represent only legal-sized male crab. Fishery-independent data provide additional information on all Dungeness crab including legal males, females, and sublegal males.

ODFW Data Confidentiality

Data collected, prepared, or held by ODFW are subject to public disclosure under Oregon public records law (ORS § 192.314). However, certain fishery and other resource-related data collected by the ODFW Marine Resources Program are considered confidential data; accordingly, these data are conditionally exempt from the legal requirement to allow inspection of public records (ORS § 192.345).

In general, biological and research data about fishery species and habitats are not confidential. However, information related to fishing business operations (e.g., how and where fish are caught, income from fishing) is confidential. This includes commercial fish landing receipts, commercial fishing logbooks (e.g., OAR 635-005-0445), and operational data from recreational charter fishing vessels.

ODFW regularly receives requests for confidential data for use in various analyses (e.g., biological, regulatory, economic). ODFW evaluates all requests on an individual basis and will opt to provide non-confidential data whenever possible. To accomplish this, confidential data may be redacted, aggregated, or summarized to prevent any individually identifiable information from being released. If it is determined to be in the public interest, ODFW may release confidential data, protected through a non-disclosure agreement to restrict the use and distribution of confidential fishery data. In general, confidential data are only released to researchers conducting science that will improve the state’s ability to manage Oregon’s fishery resources.

Table 2. Primary sources of catch, effort, size, and bycatch data for Dungeness crab currently collected or provided to ODFW.

	Source	Dates[a]	Data Type: Catch	Effort	Size	Bycatch	Other data collected
Commercial[b]	Fish tickets	1969 – present	X	X			
	Logbooks	2007 – present	X	X			Location; bait use; lost & retrieved pots
	Dockside sampling	1976 – 1990; 1993 – 2005[c]; 2012 – present			X		Biological condition; management compliance
	At-sea sampling	1976 – 1990[c]; 2012 – present		X	X	X	Shell condition; rate of injury
Recreational	Bay Crab (Creel) Survey	2007 – present	X	X	X		Fishery participation; biological condition; management compliance
	Lower Columbia River Survey	2004 – present[d]	X	X	X		Biological condition
	Ocean Recreational Boat Survey	1999 – present	X	X			
	Marine Non-Salmonid Recreational Fishery Studies	2012 – present	X	X		X	
Other	Preseason testing	1993[e] – present			X	X	Meat recovery rate; biotoxin concentration; special projects
	Scientific take permitting system	2002 – present	X				
	West Coast Groundfish Bottom Trawl Survey	1977 – present[f]	X		X		
	Yaquina and Alsea Bay Sampling Project	2007 – present	X	X	X	X	Biological condition; environmental variables
	West Coast Groundfish Observer Program	2001 – present	X		X		

[a]COVID-19 pandemic impacted data collection in 2020 and 2021 for a number of sampling programs
[b]Fish tickets are a data source for the ocean and bay commercial fisheries; All other sources apply only to the ocean commercial fishery
[c]Collected sporadically
[d]Not conducted in 2018 or 2019 due to staff capacity
[e]Formal multi-state preseason testing was added to the Tri-State MOU in 1993 and has existed in various forms since; Current program including collection of fishery-independent data was initiated in 2010
[f]Current spatial/temporal coverage since 2003

a. ODFW fish tickets

In Oregon, the first recorded commercial landings of Dungeness crab totaled 6,628 pounds in 1889 (Waldron, 1958). Commercial catch has been recorded through various methods since the late 1800s, but the accuracy of early records are difficult to verify. Prior to 1963, crab landings were recorded by the dozen and then converted to pounds using a ratio of 25 pounds to the dozen (Demory, 1990). Since that time, the actual weight in pounds has been recorded. Additionally, commercial landings of ocean and bay-caught crab were not reported separately until 1971 (ODFW, 1977a).

Since 1969, commercial crab landings data have been provided by ODFW landing receipts ("fish tickets") issued to vessels by the first receiver for each harvest purchase. This landing information is archived by ODFW in a fish ticket database and by the Pacific States Marine Fisheries Commission (PSMFC) in the Pacific Fisheries Information (PacFIN) database along with data for Washington and California.

Since December 2019, all ocean and bay commercial crab fish tickets require electronic submission by the end of the next business day after a landing of Dungeness crab (OAR 635-006-0210; ODFW, 2019a). Electronic fish tickets improve ODFW's ability to efficiently and effectively monitor fishery effort and ensure compliance with various requirements (Figure 4). They also provide ODFW with near real-time harvest location data, used for spatial management such as seafood traceability for biotoxin management and marine life entanglement risk reduction (see *Sections B.IV.b and B.IV.a*).

In addition to ODFW's own uses, researchers and other agencies use fish ticket data to describe the crab resource and fishery for a number of purposes, including providing critical information to inform management. Catch and effort information from fish tickets and logbooks are confidential and provided to outside users maintaining confidentiality. For example, in recent years, fish ticket data have been used for development of seasonal ocean condition forecasts, fishery economic impact analyses, and evaluation of spatial overlap with other species to assess potential for interactions.

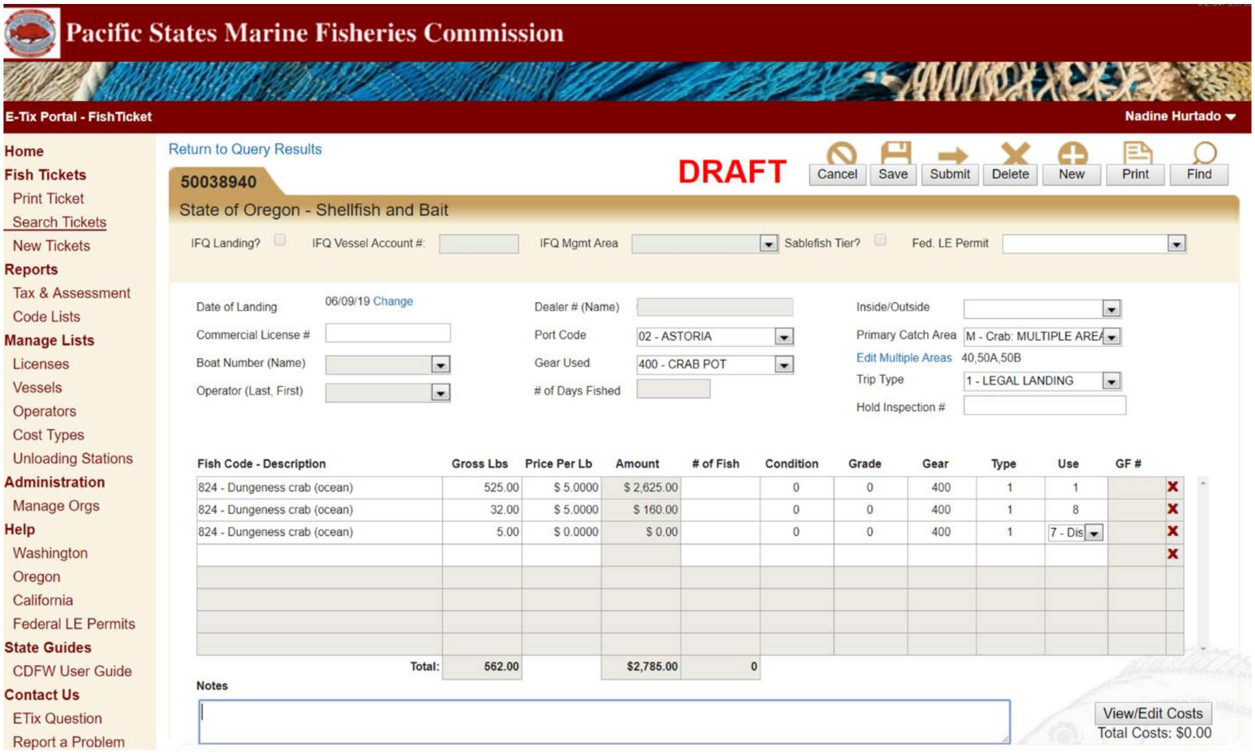


Figure 4. Pacific States Marine Fisheries Commission electronic fish ticket portal.

b. Commercial fishery logbooks

Logbooks were first introduced in the ocean commercial fishery on a voluntary basis around 1979. ODFW aimed to collect information to support commodity supply stabilization, a goal of the newly established Oregon Dungeness Crab Commission; however, attempts to gather this information were unsuccessful due to poor participation. In response to the Mineral Management Service's offshore resource extraction plans, voluntary logbooks were distributed a second time during the 1990-91 season in an effort to collect data on the location and value of crab fishing grounds, but this attempt was also unsuccessful (ODFW, 2007a). Recognizing the need for verified documentation of fishing practices, logbook requirements were adopted for the 2007-08 ocean commercial crab season. The adoption of a logbook program helped the Dungeness crab fishery to attain Marine Stewardship Council (MSC) certification in 2010.

Logbooks are a valuable source of information that aids managers in understanding fishery operations and making decisions that ensure effective management of fishery resources. Specifically, commercial crab logbooks provide information on catch, effort, location, and time (Figure 5). Ocean commercial crab logbooks also provide details on bait use, lost pots, and derelict pot retrievals.

A.

OREGON COMMERCIAL CRAB LOGBOOK

Office Use				
Date	Trip	Port	Ticket #	Lbs.

Vessel Name: ______________________ **Oregon Crab Permit No:** 96 _ _ _ **Year:** 20_ _

Federal or Oregon Vessel No: ______________________ **Port(s) of Landing:** ______________________

Date Pulled	String ID	Depth (fm)	Num Pots Pulled	Num Pots Lost	Soak Time (days)	Begin Location		End Location		Estimated Pounds	Comments
						Lat.	Lon.	Lat.	Lon.		

Bait(s) used:

Derelict Gear Retrieved: Date:______ Num Pots:____ Lat:__________ Lon:__________

Date:______ Num Pots:____ Lat:__________ Lon:__________ Date:______ Num Pots:____ Lat:__________ Lon:__________

Date:______ Num Pots:____ Lat:__________ Lon:__________ Date:______ Num Pots:____ Lat:__________ Lon:__________

Signature:______________________________________ **No:**

B.

OREGON COMMERCIAL BAY CRAB LOGBOOK

Name: ______________________ **Fishing License No(s):** ______________________

Vessel Name: ______________________ **Federal or Oregon Vessel No:** ______________________

Port of Landing: ______________________ **Year:** ________ **Dealer Name or Number** ______________________

Date	Number of Rings	Time Crabbed (hours)	Area	Begin Location		End Location		Estimated Pounds	Comments
				Lat.	Lon.	Lat.	Lon.		

SIGNED:______________________________________ **Page #** ______________

Figure 5. Sample Oregon (A) ocean commercial logbook page and (B) bay commercial crab logbook page. The bay commercial logbook was adopted into permanent rule in October 2021. The bay commercial logbook format may be modified by ODFW following an evaluation of effectiveness.

Ocean commercial crab logbooks are received, and data are entered and assessed by ODFW MRP staff. From the 2011-12 through 2017-18 crab seasons, a subset of data representing approximately 30% of trips for every port by month were entered into the ODFW database. Since the 2018-19 season, ODFW has returned to entering all data.

As with fish ticket data, ocean commercial logbook data are also used each year by researchers and/or other agencies for a number of purposes in addition to ODFW's own uses. Recent uses of logbook data include those examples provided in *Section A.III.a*, as well as other uses related to marine spatial planning. Both fish ticket and logbook data also provide the information necessary for ODFW to evaluate performance of the ocean commercial fishery in relation to the fishery's limit reference point (see *Section A.IV.c*).

Logbook data limitations are generally associated with variable compliance rates (i.e., submission and quality) and the labor-intensive data entry process that can result in backlogged data. The development of an electronic logbook or other vessel monitoring system (e.g. solar loggers) for the ocean commercial fishery remains a long-term goal of ODFW to further increase harvest area accountability and streamline the data collection process.

New bay commercial fishery management measure: Through this FMP, ODFW recommended requiring logbooks in the bay commercial fishery. Development of a pilot logbook for this fishery sector began in 2019 with implementation on a voluntary basis in 2020. A logbook requirement was implemented through temporary rule starting in September 2021, with the Oregon Fish and Wildlife Commission (OFWC) adopting a permanent rule requiring a logbook for bay commercial harvest in October 2021.

c. Dockside sampling

Dungeness crab size distributions are monitored through the collection of carapace width data. From 1976-1990, ODFW regularly conducted dockside sampling to collect carapace width information for male crab retained in the ocean and bay commercial fisheries (Demory, 1991). Sampling continued sporadically from 1993-2005. Beginning with the 2012-13 crab season, ODFW re-initiated and standardized the dockside sampling program for the ocean commercial fishery to add to this long-term data set (ODFW, 2014a) and fulfill the following objectives: identifying stock trends by comparing current data to historical data; assessing year class structure of harvest, recruitment trends, and relative abundance; evaluating the effectiveness of current and alternative management measures; and facilitating information sharing between ODFW, industry, and enforcement (ODFW, 2014a).

Dockside sampling aims to obtain a minimum representative sample of 15% of the landed pounds of crab per month in each major sampling port. Since 2012, sampling has varied between ports and years based on staffing levels and season timing. In several ports, sampling is conducted by samplers in temporary positions resulting in gaps which appear periodically across seasons. The continuity of sampling across the season also varies as other fisheries open and ODFW staff priorities change.

d. At-sea sampling

In most years from 1976 through 1990, at-sea sampling aboard ocean commercial vessels (i.e., ride-alongs) collected additional size data for both retained and discarded crab (Demory, 1991). This sampling program was reinitiated beginning with the 2012-13 ocean commercial season to allow for assessment and quantification of size distribution and bycatch rates for crab and non-crab species during normal commercial crab fishing operations.

Ongoing documentation of this bycatch provides information for assessing the potential impacts of the crab fishery on other species. This data collection is dependent upon sufficient industry participation and sample sizes remain low to date.

e. Oregon Recreational Bay Crab (Creel) Survey

Historically, recreational fishery monitoring has been intermittent. In 1971, the Oregon Fish Commission conducted an Estuary Resource Study that surveyed recreational users of food fish, shellfish, and other marine invertebrates in 16 Oregon estuaries. A series of reports produced from this study documented catch, effort, and place of origin data by estuary over an eight-month period (Stewart, 1974). A twelve-month study in 1977 and a ten-month study in 1986 provided additional, though not directly comparable, data for the recreational fishery (ODFW, 1987a). Along with catch and effort data, economic and demographic survey data are available for recreational crabbers in Alsea Bay from 1988-1989 (Demory and McCrae, 1991).

Currently, Oregon’s recreational fishery is monitored through several creel-type surveys. First, the Oregon Recreational Bay Crab Survey collects key information from the most utilized bays in Oregon that support a boat-based recreational fishery. Information is available for Yaquina and Alsea Bays since 2007 and in Tillamook, Netarts, and Coos Bays since 2008, with the exception of 2020 due to the COVID-19 pandemic. The extent and frequency of sampling is dependent upon ODFW staff availability and resources. Daily boat-based effort is estimated by expanding instantaneous bay-wide counts of buoys concentrated around the time of the tide change when crabbing activity is greatest (methods as in Ainsworth *et al.*, 2012). Effort surveys are conducted in close association with creel surveys which provide catch rate estimates. Recreational crabbers are intercepted at boat ramps or slips within a marina upon completion of their trip and interviewed to collect data including length of trip, gear type and number, number of crabbers, number of each species harvested (i.e., Dungeness, red rock, and Pacific rock crab), and hometown zip code.

Collected data are analyzed to provide estimates of weekly or monthly boat-based catch-per-unit-effort (CPUE), total catch (number of crab), total harvest (in kg), and fishery participation. Subsamples of retained crab are measured for biological data (e.g., carapace width, sex, shell hardness, injuries) as time permits. This allows ODFW to better monitor crab size distribution trends in Oregon’s estuaries and make informed management decisions to protect Oregon’s fishery resources. Catch and effort estimates for boat-based recreational crabbing from 2007 through 2011 were reviewed in an Informational Report produced by ODFW in 2012 (Ainsworth *et al.*, 2012).

ODFW also collects catch and effort data for shore-based crabbing. However, available staff resources and time limit collection of information required to similarly expand data for each land-based crabbing location to estimate daily or monthly effort (e.g. digger trips) and harvest. Therefore, estimates presented throughout this FMP for recreational crabbing effort and harvest only include boat-based crabbing.

f. Lower Columbia River Survey

Due to its large size relative to other estuaries along the coast, the lower Columbia River recreational crab fishery is surveyed using different methods than described above. The Lower Columbia River Survey derives effort estimates from a model based on counts of empty boat trailers at the Hammond boat basin (commonly referred to as Clatsop Spit) as described by Durham and Hunter (2008). In a manner similar to the Bay Crab Survey, interview and biological data are also collected and analyzed (methods as in Ainsworth *et al.*, 2012). Due to shifts in workload and funding priorities, this survey has not been completed since 2017.

g. Ocean Recreational Boat Survey

The ocean recreational fishery is monitored through the Ocean Recreational Boat Survey (ORBS) which was developed in 1979 and began collecting ocean recreational landing data on Dungeness crab in 1999 (Schindler, 2000). The ORBS program operates in all Oregon ports where marine recreational fishing occurs (methods as in Schindler *et al.*, 2015). Effort is estimated through several methods that vary by port and boat type (i.e., private/guide or charter), and is dependent upon logistical considerations (e.g., available staffing, port and fishery layout). These methods include contact with charter vessel operators, on-site or video bar crossing counts, and trailer or moorage slip counts. Total catch, effort, and released fish data are provided by dockside interviews and stratified by port, week, season type, boat type, and trip type. These data are expanded to generate monthly estimates of CPUE (crab per angler-trip), total harvest, and number of angler-trips.

h. Marine Non-Salmonid Recreational Fishery Studies

Since 2012, PSMFC observers have collected data on Dungeness crab caught aboard recreational bottomfish charter vessels that participate in the recreational crab fishery through the Marine Non-Salmonid Recreational Fishery Studies (MNSRFS). Samplers collect data on the total number of pots fished during the observed trip and the number of retained and discarded crab from a subsample of pots. These data have been used to generate estimates of the average pots used for charter trips in the recreational crab fishery. The data can also be used to refine estimates of Dungeness crab catch and effort from the ORBS program monitoring of the charter sector; however, this combined analysis has not been conducted to date.

In addition to catch information, sex data are typically collected for discarded crab. Size information and the reason for male crab discard (e.g., sublegal size, shell condition, bag limit) are not included. No data on other species of crab or non-crab bycatch have been collected to date.

i. Ocean commercial fishery preseason testing

Prior to the season opening each year, ODFW collaborates with the ocean commercial crab fleet and the ODCC to conduct preseason testing which informs crab season opening date(s) based on crab condition (i.e., meat recovery). Preseason testing typically occurs in November and December, but has taken place as early as October (prior to 2013) and has extended as late as January. Each year, an average of two at-sea observation trips aboard commercial crab boats in each major crabbing port provide meat recovery rate information for all legal-sized male crab (see *Section B.III.f* for a complete description of the preseason testing program).

Since 2010, a subset of the pots fished during preseason testing are sampled each year to provide fishery-independent carapace width information and an estimate of the relative quantity and species composition of bycatch caught in the beginning of the fishery when effort is most intensive. Any insights from these data are limited to individuals that are catchable by a standard commercial crab pot (including some sublegal-sized and female crab that are discarded at sea by the fishery).

j. ODFW's educational and scientific take permitting system

A small portion of annual crab mortality is the result of research on Dungeness crab or other research that has the potential to take Dungeness crab. This direct and indirect scientific take of crab is regulated through ODFW's educational and scientific take permitting system (ORS § 508.111).

k. U.S. West Coast Groundfish Bottom Trawl Survey

Fishery-independent data on relative abundance of groundfish species off the west coast of the United States is provided by the West Coast Groundfish Bottom Trawl Survey conducted annually by the Fishery Resource Analysis and Monitoring Division of the Northwest Fisheries Science Center (NWFSC). Research trawl surveys began in this region in 1977, but the temporal and spatial coverage varied prior to 2003 when the current standardized survey extent and design was adopted (Keller *et al.*, 2017).

Although Dungeness crab is not a targeted species, catch information is recorded. Data on crab distribution and abundance are periodically requested by ODFW and investigated as resources allow. This survey includes very few samples inside the 50 m depth isobath where Dungeness crab are abundant, so data are informative only for Dungeness crab distribution in waters deeper than 50 m.

l. Characterization and assessment of Oregon's estuarine crab populations

Beginning in 2007, ODFW staff initiated a monitoring and assessment project to better understand the crab resources in Yaquina and Alsea Bays. The objective of this ongoing study is to assess and characterize estuarine crab populations and certain environmental factors that impact bay crab throughout their life history.

The project utilizes modified recreational crab pots to periodically sample the extent of the recreational fishery grounds beginning near the mouth of the estuary. Initially, sampling occurred two to three times per month, but currently occurs bimonthly. Data collected from this project include: species composition, crab abundance, size distribution, sex ratio, shell hardness, appendage condition, microsporidian infection, nemertean worm prevalence, and certain environmental variables (e.g., salinity, temperature, and dissolved oxygen). Spatial and temporal patterns, as well as size distribution, are assessed and monitored through this project as a fishery-independent source of information. Any insights from these data are limited to individuals that are catchable by a recreational crab pot, so catch is expected to be similar to the recreational fishery but not representative of the entire population.

m. NMFS West Coast Groundfish Observer Program

The National Marine Fisheries Service (NMFS) West Coast Groundfish Observer Program (WCGOP) reports annual discard estimates for the groundfish fisheries and state-managed fisheries that take groundfish as bycatch (e.g., pink shrimp) along the U.S. West Coast. This includes discard estimates for Dungeness crab caught in most non-crab commercial fisheries in Oregon. Data are reported for all fisheries that are likely to catch Dungeness crab including the limited entry bottom trawl, fixed gear, pink shrimp trawl, and Pacific whiting fisheries (Somers *et al.*, 2017). ODFW periodically requests crab bycatch estimates and carapace width data for Oregon (most recently in July 2019).

IV. Analysis of stock status

a. Stock assessments

Many stock assessment models have been published and utilized for management of other crab populations (e.g., CBSAC, 2018; NPFMC, 2018). However, annual stock assessments are not conducted for the ocean Dungeness crab fisheries along the West Coast. While Dungeness crab biology is generally well-understood, certain essential fishery-independent data related to stock structure and productivity are not available.

Heppell *et al.* (2009) used equilibrium yield-per-recruit models and an age-structure population dynamics model to explore potential stock productivity given a range of parameters. They concluded that the data that are currently available are insufficient for model parameterization and identified the following research priorities for predictive stock assessment model development:

- Catch-per-unit-effort across seasons
- Size structure of the catch
- Sex ratio of adult population
- Recreational fishing and discard mortality rates
- Impacts of environmental conditions (e.g., El Niño, hypoxia) on recruitment

Ongoing research and monitoring efforts are addressing most of these information gaps. CPUE data are now collected through the logbook program (see *Section A.III.b*), but a longer time series is necessary to account for variance in fleet characteristics. Recent research conducted by Yochum *et al.* (2017, 2018) provides an assessment of Dungeness crab discard mortality rates in Oregon's recreational and commercial fisheries utilizing laboratory-holding and mark-recapture methods (see *Section A.V.a*).

In the absence of stock assessments to estimate annual exploitation levels, the Dungeness crab fishery has operated successfully since the early 20th century under a conservative 3-S management system (see *Section B.III.d* for details). This strategy aims to conserve the reproductive potential of the population by protecting sexually mature male crab from harvest for one to two seasons and maintaining low levels of mortality of sublegal-sized male and female crab.

Richerson *et al*. (2020) used catch and effort data in combination with a linear depletion estimator to reconstruct historical crab population estimates in California, Oregon, and Washington, to examine the relationship between preseason crab abundance and fishery landings over time. This analysis indicates that the abundance of legal-sized male crab has been stable or increasing over the past several decades, despite the fact that the large majority (75.7% on average in Oregon) of legal crab are taken in most years. Additionally, this work demonstrates the close correlation between total annual harvest and preseason abundance of legal crab, confirming that annual harvest is likely a good proxy for cohort size (or lagged recruitment success).

b. Analysis of data

Dungeness crab take

A number of human activities contribute to the direct and indirect take of Dungeness crab from Oregon waters. The largest portion of anthropogenic mortality is attributed to the targeted fisheries for Dungeness crab and, in particular, Oregon's ocean commercial fishery. This is followed by the recreational fishery and the bay commercial fishery.

In addition to recreational and commercial catch, several other activities remove Dungeness crab. Each year, crab are taken as bycatch in non-crab commercial fisheries along the West Coast. Additionally, a small amount of crab are taken for permitted educational or scientific purposes. Figure 6 shows the total take of Dungeness crab in Oregon by each of these sources from 2008 through 2018. On average, these combined activities remove around 17.9 million pounds of Dungeness crab each year in Oregon.

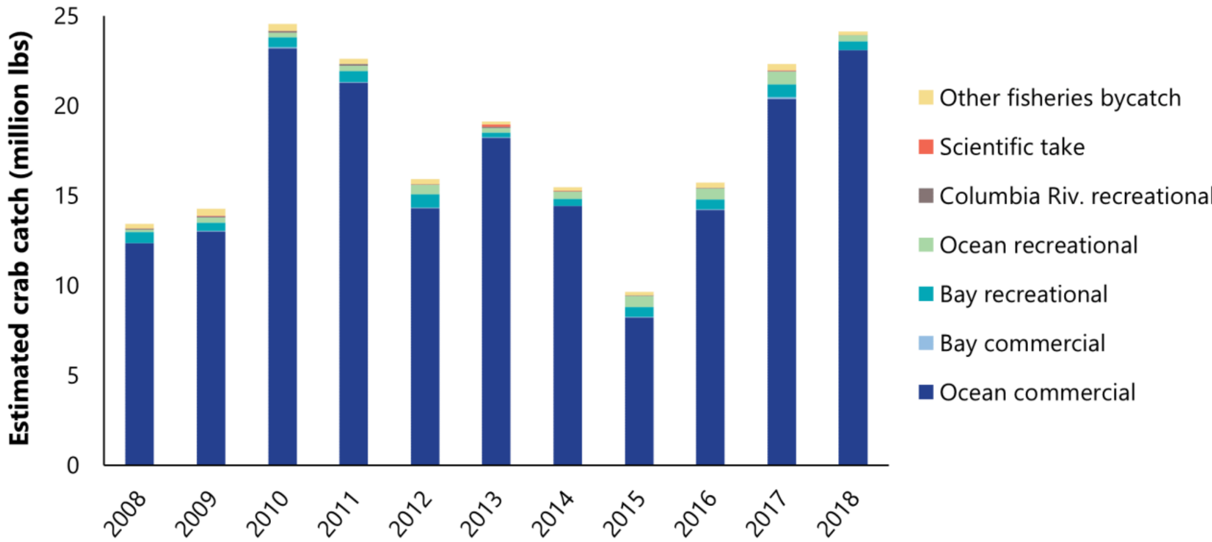


Figure 6. Estimated take of Dungeness crab in Oregon from 2008–2018. All data are summarized by calendar year, except for the ocean commercial fishery, which is presented by season (i.e., each year includes December of the previous year and any preseason testing prior to that season). Ocean and bay commercial harvest data are from ODFW fish tickets, and constitute 92.7% and 0.2% of the total estimated take over this period, respectively. Recreational harvest estimates are from creel-type surveys for select estuaries and the ORBS, and only include boat-based harvest. Columbia River data were not collected in 2018 due to limited staff capacity. Columbia River, ocean, and bay recreational harvest constitute 0.3%, 2.2%, and 3.0% of the total estimated take over this period, respectively. Scientific take, which constitutes 0.1% of the total estimated take over this period, is from the ODFW scientific take permit system and includes intentional direct and indirect mortality of juvenile and adult crab. Estimates of bycatch in other fisheries, which constitutes 1.5% of the total estimated take over this period, are from the WCGOP and from ODFW fish tickets for dockside discard.

Ocean commercial fishery effort

Catch-per-unit-effort data provided by ocean commercial crab logbooks serve as an index of the relative abundance of crab over time. This method is an improvement over the historical use of total season landings, which may be influenced by regulatory changes, market forces, or other factors that are unrelated to crab abundance. To date, ODFW has produced three reports utilizing logbook data as a crab abundance index (ODFW, 2011a, 2013, 2014b).

Figure 7 presents relative fishing effort (i.e., number of pot pulls) along the Oregon coast from a 30% subsample of commercial crab logbooks during the winter, spring, and summer months. Additional analysis of crab abundance necessary for evaluation of the ocean commercial fishery's limit reference point is in *Section A.IV.c*.

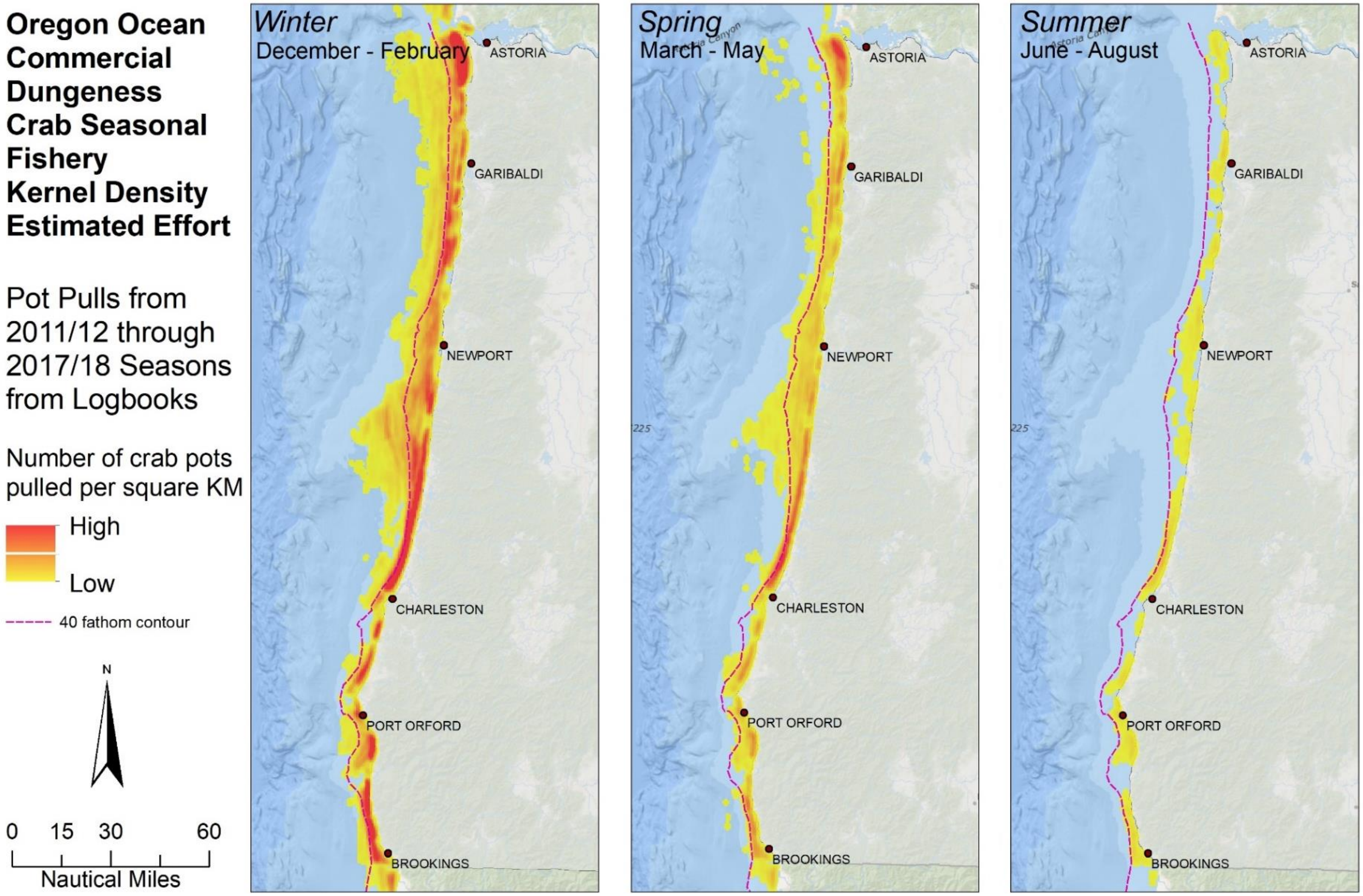


Figure 7. Relative winter, spring, and summer ocean commercial fishery kernel density estimated effort in Oregon from the 2011-12 through 2017-18 seasons. Data used to generate these maps are pot-pulls from a subsample of ODFW commercial crab logbooks representing 30% of trips (by port and month). Logbook submission non-compliance, poor data quality, sub-entering protocols, and filtering for confidentiality are contributing factors to this dataset representing less than 100% of the landings made during each crab season.

Ocean commercial fishery bycatch

Coastwide catch-per-unit effort, defined as the number of individuals per pot, from a subset of pots fished during ocean commercial preseason testing from 2010 through 2019 is shown in Figure 8. For each year, bycatch sampling indicates that CPUE is highest for sublegal male crab, followed by female crab, other invertebrates (e.g., sea stars, sand dollars), and fish species at the beginning of the ocean commercial crab season.

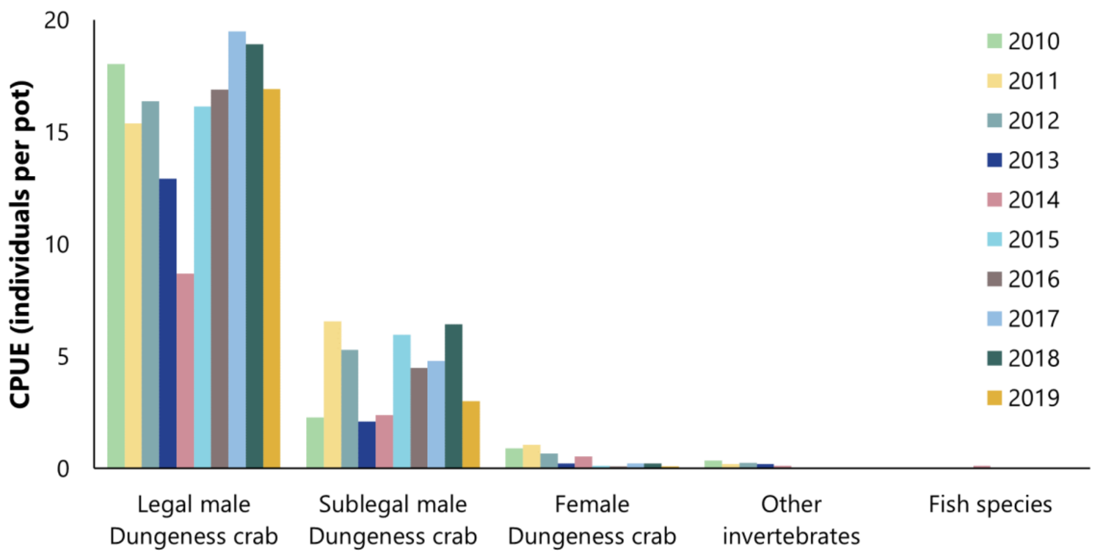


Figure 8. Coastwide catch-per-unit-effort of crab and non-crab species in a subset of pots sampled during ocean commercial preseason testing trips from October through January of 2010–2019. Due to COVID-19 restrictions during preseason testing trips, data were not collected in 2020.

On average, legal-sized males constituted approximately 77% of the crab caught during preseason testing from 2010 through 2019. Sublegal males and females accounted for around 21% and 2% of the crab caught, respectively (Figure 9).

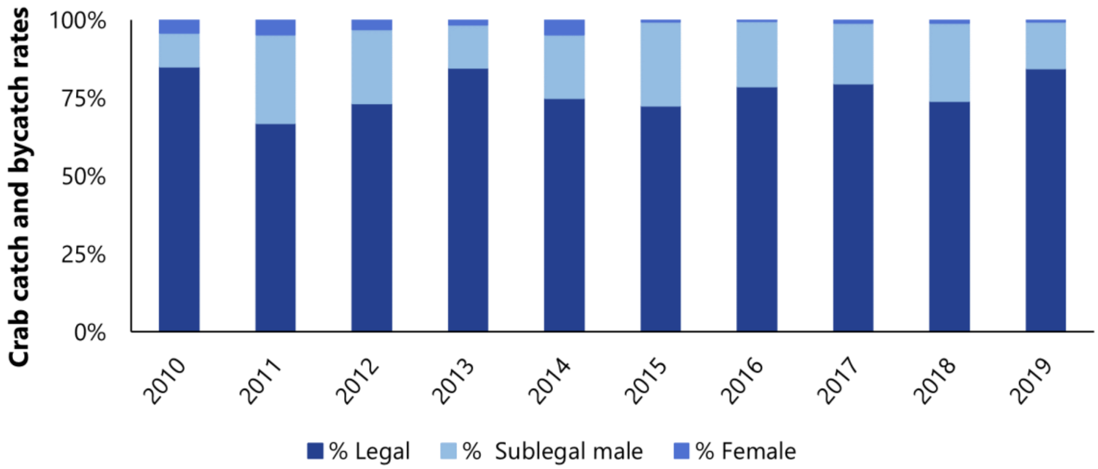


Figure 9. Percent of legal, sublegal male, and female Dungeness crab individuals (count data) caught during ocean commercial preseason testing trips from October through January of 2010–2019. Due to COVID-19 restrictions during preseason testing trips, data were not collected in 2020.

In-season catch and bycatch rates of legal, sublegal male, and female crab collected during voluntary at-sea observer trips (i.e., ride-alongs) from the 2012-13 through 2017-18 ocean commercial seasons are presented in Figure 10. The proportion of crab of different sexes and sizes varied across seasons. In-season observer trips tend to occur later in the crab season and are more representative of that part of the fishery, after the bulk of legal male crab have been removed. Pre-season test catch and bycatch data are likely a better representation of the first few weeks of the crab season, but little observer data from that part of the season exist due to logistical difficulties of conducting an observer program during the intensive derby phase.

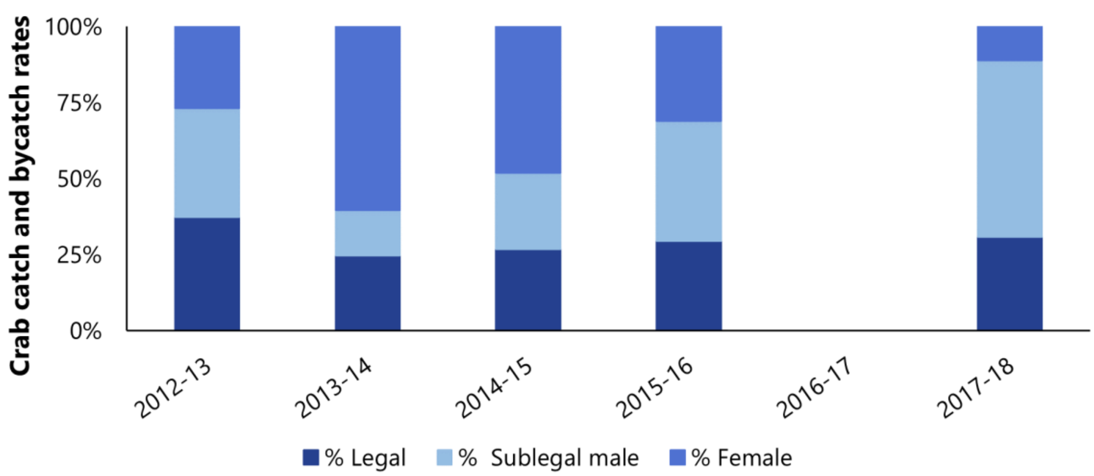


Figure 10. Percent of legal, sublegal male, and female Dungeness crab individuals (count data) caught during voluntary ODFW at-sea observer trips from the 2012-13 through 2017-18 ocean commercial seasons. No observer trips took place during the 2016-17 season.

Non-crab bycatch caught aboard ocean commercial crab vessels include a variety of fish, invertebrate, and other species. A comprehensive list of non-crab bycatch recorded during ODFW at-sea observer trips from the 2012-13 through 2017-18 seasons is provided in Table 3.

Table 3. Categories of non-Dungeness crab bycatch caught during normal commercial fishing operations from the 2012-13 through 2017-18 ocean commercial seasons. Data are from voluntary ODFW at-sea observer trips.

Invertebrate Species			
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Channeled basket snail	*Nassarius fossatus*	Short spined sea star	*Pisaster brevispinus*
Cockle	*Clinocardium nuttallii*	Sunflower sea star	*Pycnopodia helianthoides*
Coonstripe shrimp	*Pandalus gurneyi*		
Dock shrimp	*Pandalaus danae*	unidentified anemone spp.	
Giant Pacific octopus	*Enteroctopus dofleini*	unidentified clam spp.	
Giant plumose anemone	*Metridium farcimen*	unidentified crab spp.	
Oregon hairy triton	*Fusitriton oregonensis*	unidentified hermit crab spp.	
Kelp crab	*Pugettia productus*	unidentified isopod spp.	
Leather star	*Dermasterias imbricata*	unidentified jellyfish spp.	
Market squid	*Doryteuthis opalescens*	unidentified octopus spp.	
Ochre star	*Pisaster ochraceus*	unidentified sea star spp.	
Orange sea pen	*Ptilosarcus gurneyi*	unidentified shrimp spp.	
Piddock	*Parapholas californica*	unidentified snail spp.	
Red octopus	*Octopus rubesens*	unidentified sponge spp.	
Red rock crab	*Cancer productus*	unidentified worm spp.	
Sand dollar	*Dendraster excentricus*		
Fish Species			
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Black rockfish	*Sebastes melanops*	Pacific sand sole	*Psettichtys melanostictus*
Brown Irish lord	*Hemilepidotus spinosus*		
Buffalo sculpin	*Enophrys bison*	Petrale sole	*Eopsetta jordani*
Cabezon	*Scorpaenichthys marmoratus*	Quillback rockfish	*Sebastes maliger*
		unidentified fish spp.	
Halibut	*Hippoglossus stenolepis*	unidentified flatfish spp.	
Lingcod	*Ophion elongatus*	unidentified *Sebastes* spp.	
Pacific hagfish	*Eptatretus stoutii*	unidentified *Cottus* spp.	
Other			
Common Name	**Scientific Name**		
Pelagic cormorant	*Phalacrocorax pelagicus*		

Finally, crab carapace width data from ocean commercial dockside sampling from the 2012-13 through 2020-21 seasons are shown in Figure 11. Over this period, the average coastwide carapace width of male crab sampled dockside was relatively constant, ranging from 168.9 mm to 172.8 mm. While slight differences in the average carapace width of crab exists between ports within each season, trends are not consistent across seasons indicating that there is not a portion of the coast where landed crab are consistently larger or smaller than elsewhere on the coast. A small percentage of sampled crab fall below the commercial size limit. ODFW communicates with fishers about all potential violations, and routinely discusses enforcement concerns with Oregon State Police (OSP) when sublegal crab are sampled.

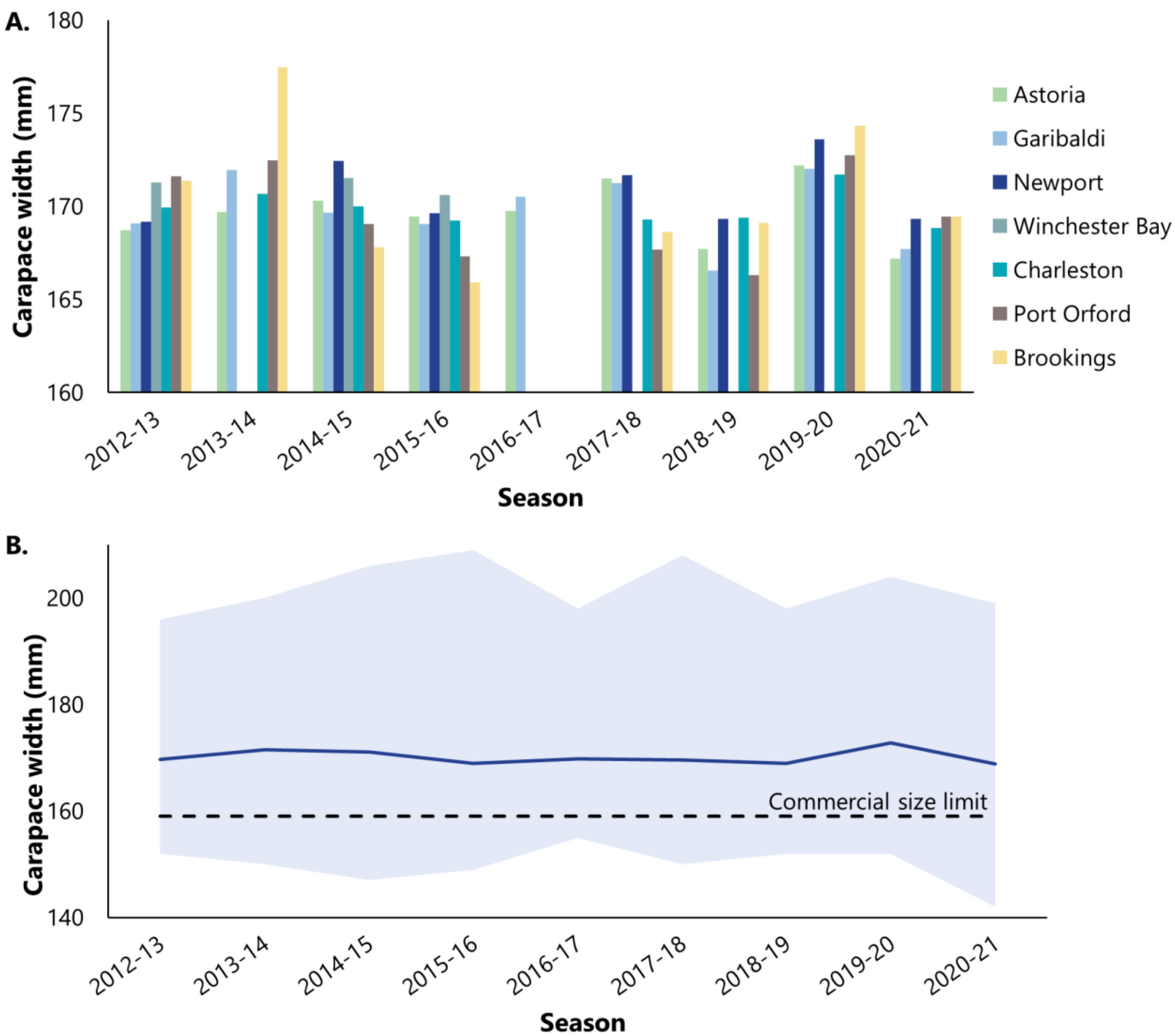


Figure 11. Average carapace width of male crab sampled during ocean commercial dockside sampling from the 2012-13 through 2020-21 seasons (A) by port and (B) coastwide (with range represented by the light blue area).

Recreational survey data

Recreational boat-based CPUE (crab per person) information from Oregon's most utilized bays is provided by the Oregon Recreational Bay Crab (Creel) Survey (Figure 12). Survey data collected from 2007 through 2018 indicate that the lowest CPUE occurs in spring while peak CPUE is typically reached in late summer or early fall.

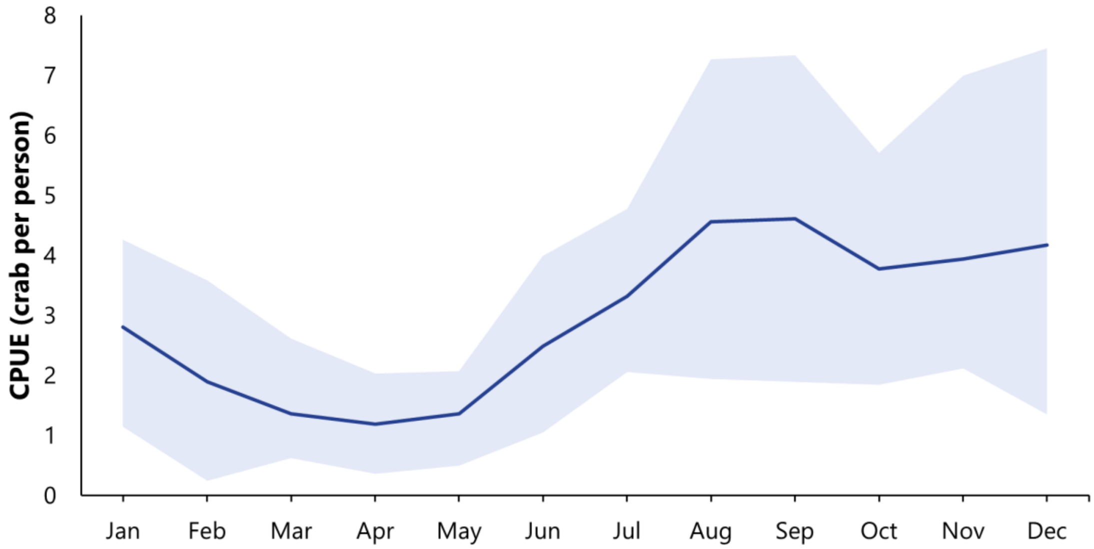


Figure 12. Average monthly CPUE (crab per person) from the boat-based recreational fishery in Oregon bays from 2007–2018. The light blue area represents the CPUE range across years. CPUE is typically lowest in spring (Mar – May) and increases over the summer to reach peak values in late summer or early fall (Aug – Sep). Data are from the Oregon Recreational Bay Crab Survey and combines data from all years and bays, except for 2007 which only includes Yaquina and Alsea Bays.

U.S. West Coast Groundfish Bottom Trawl Survey

Catch data from annual trawl surveys conducted by NOAA-NWFSC indicate that Dungeness crab are distributed coastwide in Oregon and found out to a depth of ~450 fathoms (Bradburn et al., 2011). Figure 13 shows the catch-per-unit-effort of Dungeness crab (in kg ha^{-1}) by depth during 1723 positive tows in Oregon (42°00′ N to 46°15′ N) from 2003 through 2018. The survey covers depths ranging from 55 – 1280 m (~30 – 700 fathoms). Data are presented beginning in 2003 when the current spatial and temporal coverage of the survey was established.

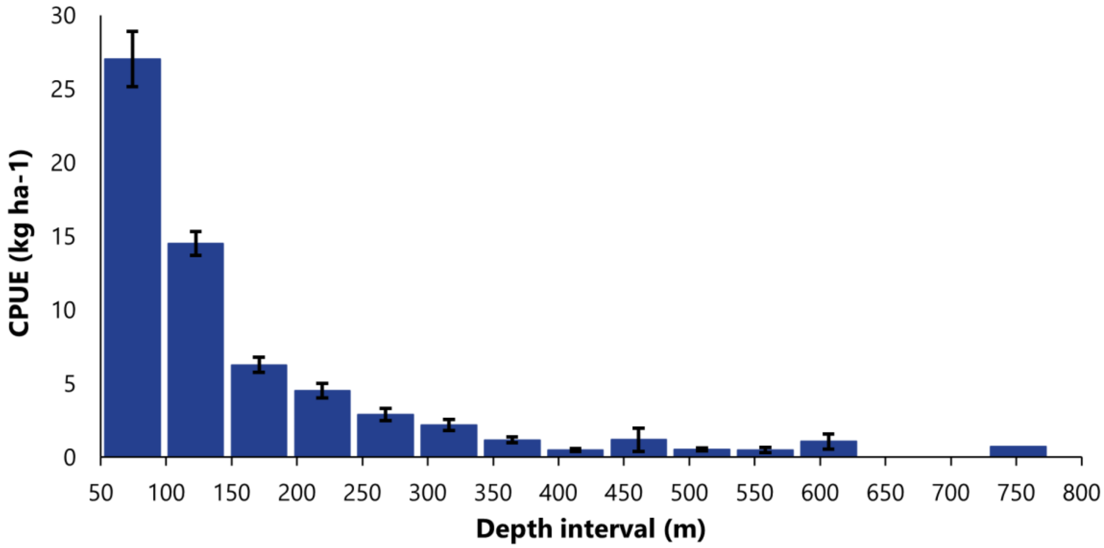


Figure 13. Catch-per-unit-effort (CPUE ± 1 SE, kg ha^{-1}) averaged by 50 m depth intervals for Dungeness crab taken in 1723 positive tows during NOAA bottom trawl surveys from 2003–2018. Surveys cover water depths from 55 – 1280 m along the entire U.S. West Coast, but data are presented for only Oregon (42°00′ N to 46°15′ N). Data are not included for a single tow in shallow waters <50 m due to the very low (unrepresentative) sampling rate.

Characterization and assessment of Oregon's estuarine crab populations

Average monthly CPUE (measured as the number of crab of both sexes and all sizes per crab pot pull) is quantified from data collected during fishery-independent sampling by ODFW in Yaquina and Alsea Bays. An assessment of these data indicates that crab abundance follows similar seasonal patterns in both bays (Figure 14). Each year, crab occur at higher abundances in the fall and lower abundances in the spring. Over the time period sampled, interannual variability in CPUE is evident in both bays.

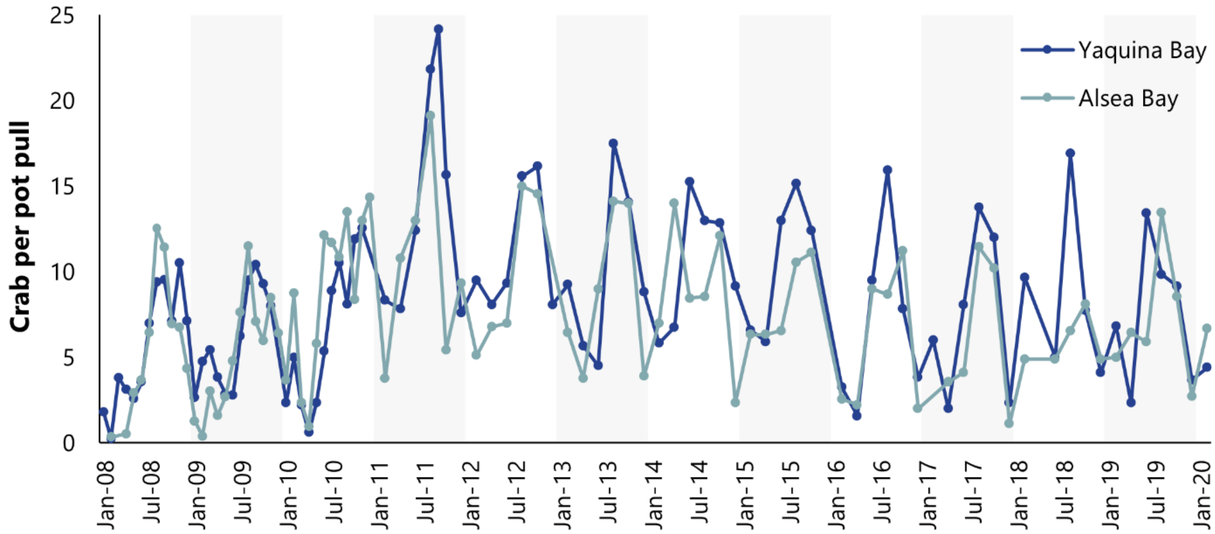


Figure 14. Monthly CPUE (crab per pot pull) of Dungeness crab in Yaquina and Alsea Bays caught as part of ODFW's fishery-independent bay crab sampling project from 2008–2020. Each point represents the monthly average number of Dungeness crab of all sizes and both sexes per pot pull. Sampling indicates similar seasonal patterns in both bays with the greatest crab abundance occurring in the fall and the least in the spring. Data are shown through February 2020, after which data are very limited due to COVID-19 disruptions to sampling.

Sampling indicates that the composition of male and female crab is not equal and that legal-sized male crab represent the smallest proportion of Dungeness crab caught in these bays (Figure 15). Overall, more male crab are caught than female crab, particularly during winter months in most years. Seasonal variation may be related to the timing of various life history events (e.g., molting, mating, egg deposition, spawning, and migration). Additionally, the male/female ratio in Alsea Bay appears to be closer to 50/50 in Alsea Bay than in Yaquina Bay during most years.

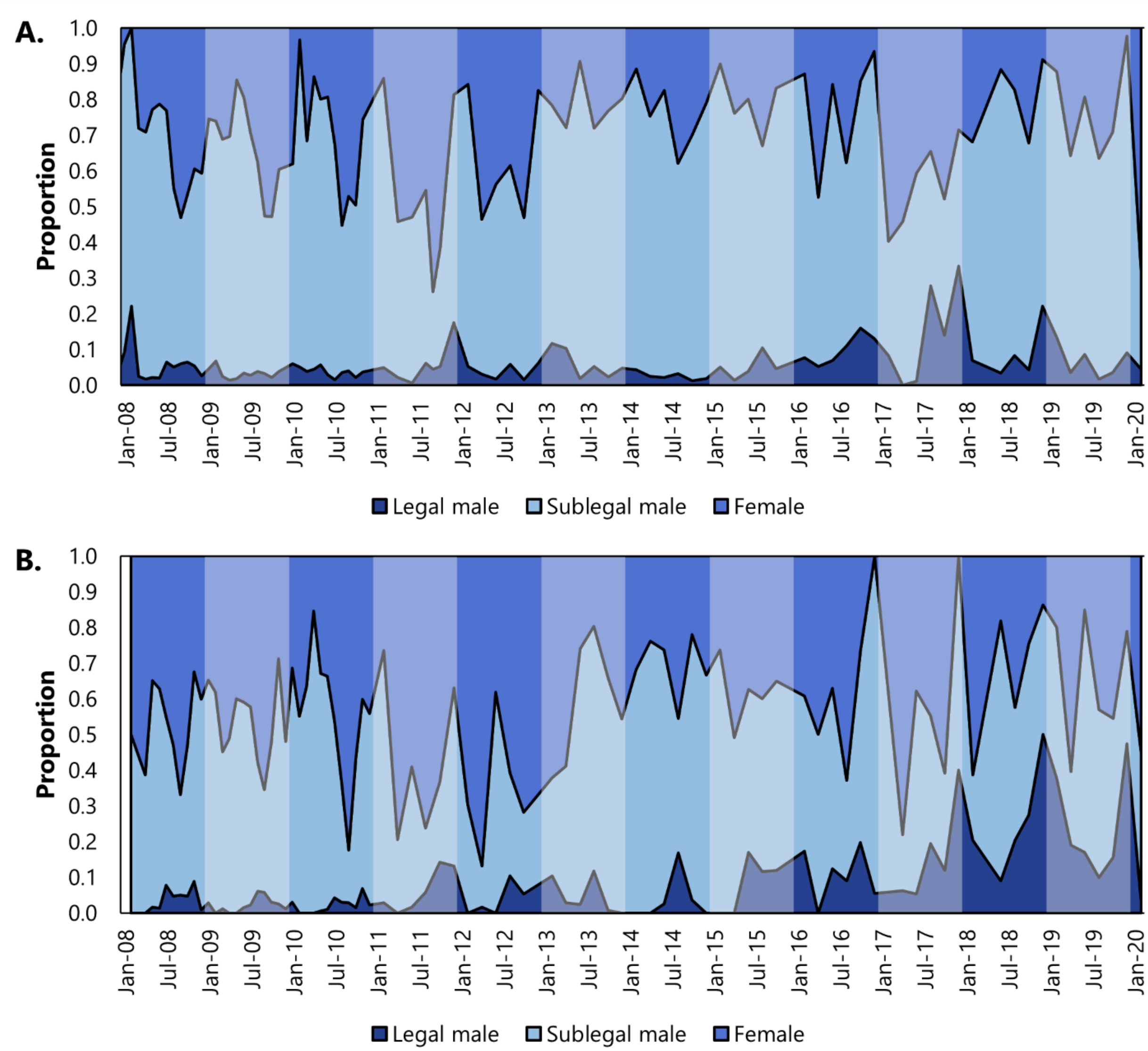


Figure 15. Proportion of legal, sublegal male, and female Dungeness crab individuals (count data) caught in (A) Yaquina Bay and (B) Alsea Bay as part of ODFW's fishery-independent bay crab sampling project from 2008–2020. Sampling indicates that the composition of each sex is not equal and that legal-sized male crab represent the smallest proportion of crab. Data are shown through February 2020, after which data are very limited due to COVID-19 disruptions to sampling.

Shell hardness data indicate that, during most years, the proportion of softshell male crab is highest from late spring to early fall (Figure 16). This pattern was present in both bays from 2008 through early 2020, though variation between years was more pronounced in Alsea Bay over this period and particularly from 2008 through 2012.

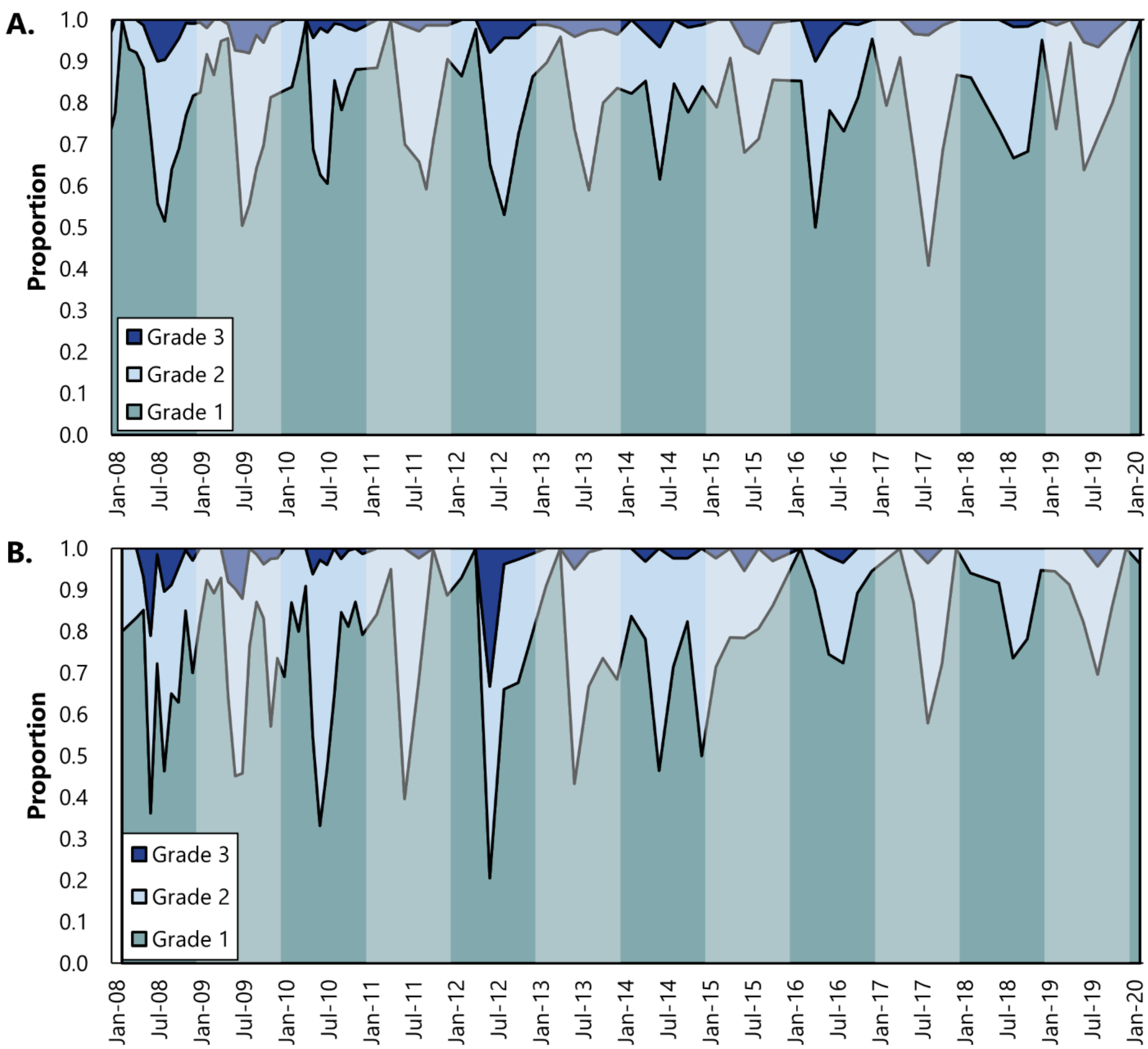


Figure 16. Shell hardness of male Dungeness crab, as a proportion of individuals caught in (A) Yaquina Bay and (B) Alsea Bay as part of ODFW's fishery-independent bay crab sampling project from 2008–2020. Shell grade 1, 2, or 3 (hard, medium, or soft) is determined by squeezing the anterior portion of the carapace by the lateral spines. Data are shown through February 2020, after which data are very limited due to COVID-19 disruptions to sampling.

The prevalence of infection by the microsporidian *Nadelspora canceri* impacts crab condition and survival (see *Section A.V.c*). In Yaquina and Alsea Bays, microsporidian infection rates follow similar seasonal patterns, but in some years the rate of infection is substantially higher in Alsea Bay (Figure 17). While there is interannual variation in microsporidian infection rates in both bays, prevalence in sampled crab appears higher in spring and summer months.

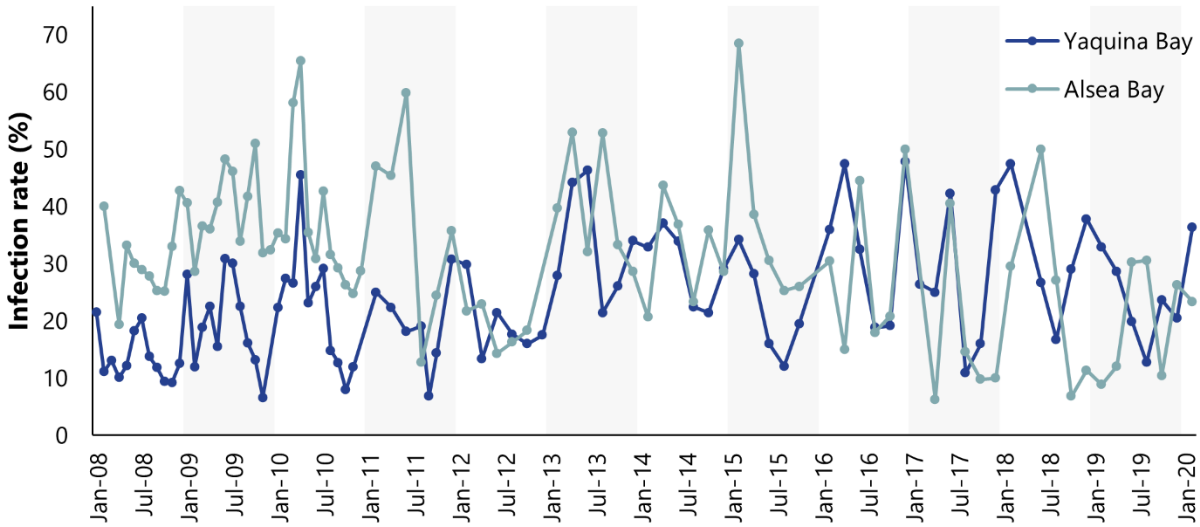


Figure 17. Prevalence of Dungeness crab individuals (count data) infected by the microsporidian *Nadelspora canceri* in Yaquina and Alsea Bays caught as part of ODFW's fishery-independent bay crab sampling project from 2008–2020. Data are shown through February 2020, after which data are very limited due to COVID-19 disruptions to sampling.

From 2008 through early 2020, infection was most prevalent in crab between 120 – 125 mm carapace width in Yaquina Bay and between 110 – 115 mm in Alsea Bay (Figure 18). This result is similar to Childers *et al.* (1996); they found highest prevalence occurring in crab within the 120 – 130 mm carapace width range along the West Coast.

Infection rates were 17% for commercially sublegal-sized crab (<159 mm CW) and 18% for recreationally sublegal-sized crab (<146 mm CW) in Yaquina Bay (Figure 18A). In Alsea Bay, 33% of crab <159 mm CW and 36% of crab <146 mm CW were infected (Figure 18B). In both bays, around 3% of commercially legal-sized crab were infected. Infection rates were 5% and 9% for recreationally legal-sized crab in Yaquina and Alsea Bays, respectively.

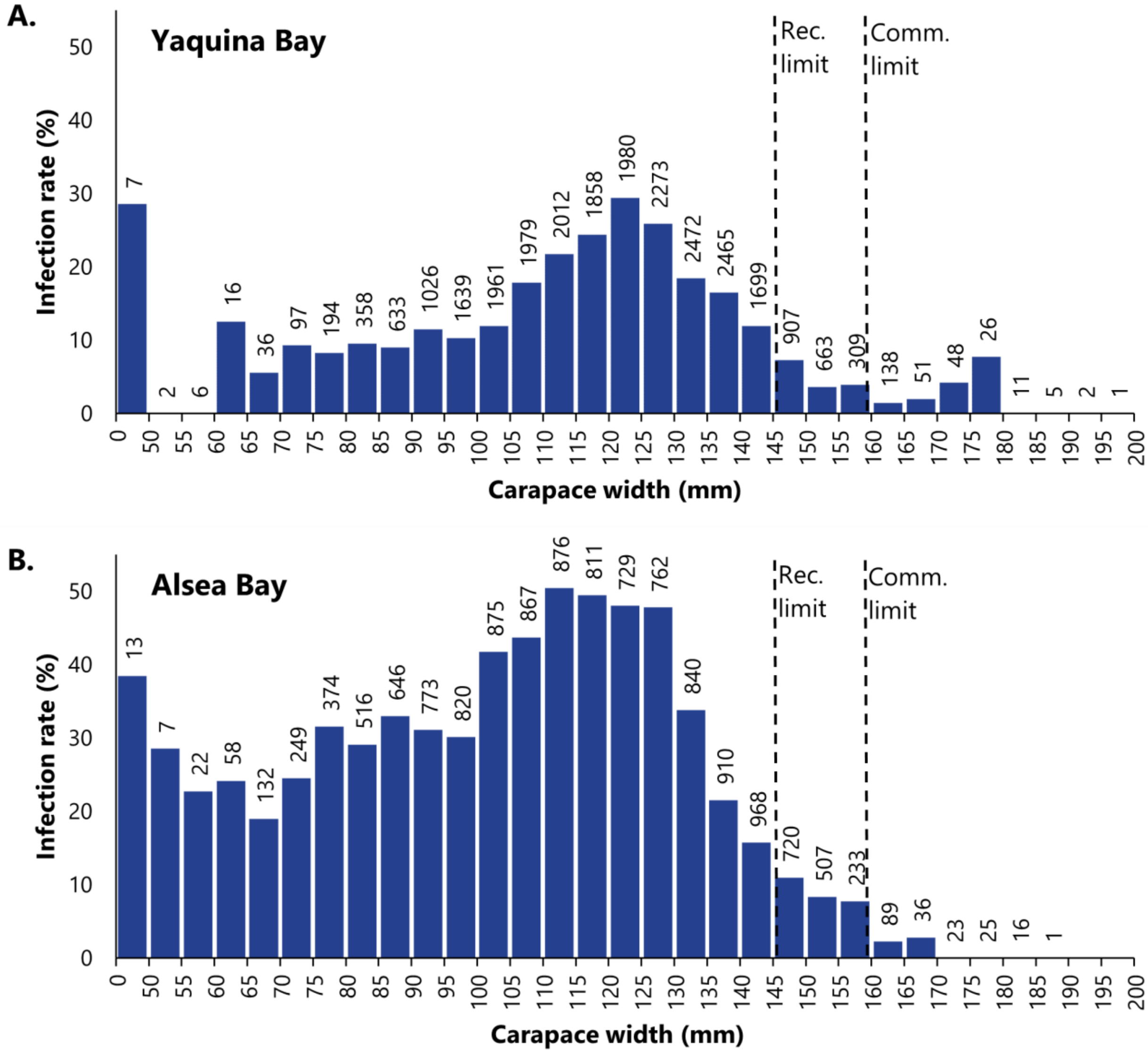


Figure 18. Prevalence of Dungeness crab individuals (count data) from different size classes infected by the microsporidian *Nadelspora canceri* in (A) Yaquina Bay and (B) Alsea Bay caught as part of ODFW's fishery-independent bay crab sampling project from 2008–2020. Crab are grouped into 5 mm carapace width intervals (>50 mm). Values above bars represent the total number of crab collected from each size interval. Recreational and commercial size limits are shown to indicate where crab become accessible to each fishery sector. Data through February 2020 are included, after which data are very limited due to COVID-19 disruptions to sampling.

NOAA-NMFS West Coast Groundfish Observer Program data

WCGOP data on the amount of Dungeness crab discarded in different groundfish fisheries in Oregon from 2002 through 2018 are included in Figure 19. Estimated fleetwide discard was expanded by sector from observed discard rates according to the methodology in Somers *et al.* (2017).

From 2002 through 2018, Dungeness crab bycatch was substantially higher in the bottom trawl fishery (i.e., limited entry groundfish trawl fishery from 2002 through 2010, bottom trawl catch share program since 2011), than in any other fishery sector observed by the WCGOP (Figure 19). The amount of crab discarded in the groundfish trawl fishery declined substantially after 2002 which coincides with the implementation of Rockfish Conservation Areas which prohibited bottom trawling over much of the continental shelf along the West Coast (PFMC, 2016). From 2003 through 2018, the annual average discard of Dungeness crab in groundfish fisheries was 318,000 lbs. Over this time, dockside discard reported on ODFW fish tickets was ~300 lbs of crab per year.

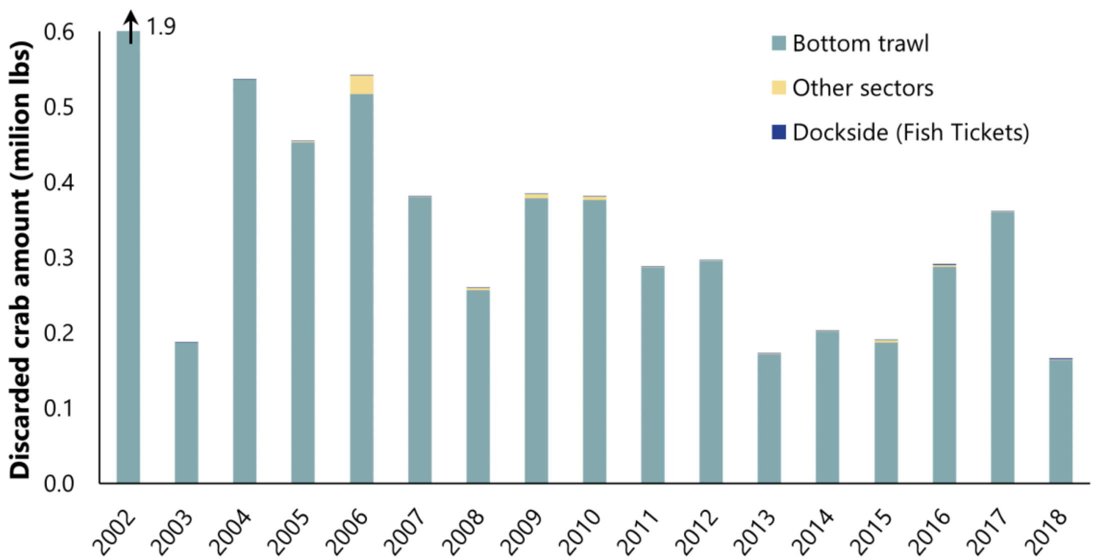


Figure 19. Estimated Dungeness crab discard (lbs) in the Oregon bottom trawl fishery and other groundfish fishery sectors from 2002–2018. Bottom trawl and other sector data were provided by the WCGOP. Dockside discard was obtained from ODFW fish tickets and represents ocean Dungeness crab caught with gear other than a crab pot or ring. Other sector data include crab discard in the hake (average ~10 lbs/year), fixed gear (average ~2700 lbs/year), and pink shrimp (average ~410 lbs/year) fishery sectors. Data from the at-sea hake sector include catcher processor and mothership fleets operating off Washington and Oregon. The 2004 pink shrimp bycatch data include Oregon and Washington. Dockside discard includes crab caught by trawl gear, bait nets, and fish pots.

c. Limit reference point

In 2014, ODFW adopted a limit reference point (LRP) for the ocean commercial fishery, which is evaluated each year within about the first eight weeks of the season to determine the status of the stock. The LRP includes criteria based on landings and abundance metrics, along with an adaptive management response that is implemented in the event that all criteria are met (see *Section B.VI.a* for a complete description).

The landings-based criteria compare a projected decline in landings sustained over four years to the 20-year average (representing approximately five generations). Landings data and year-to-year changes in landings for the ocean commercial fishery in Oregon from 1947-48 season (the current 6 ¼ inch size limit became standard in 1948) through the 2019-20 season are presented in Figure 20. The annual change in landings is expressed as: $N_{t+1} - N_t$ where N_t is the annual landings for the given year t and N_{t+1} is the landings in the following year. As such, negative values indicate declining landings between years.

During this time period, the LRP has never been reached by the fishery. Using landings as a proxy for the legal-sized male crab population (Richerson *et al.*, 2020), the data suggest that the male crab population goes through periods of decline but that, regardless of continued fishing pressure, that decline has never lasted more than three years. Generally, an increase in landings occurred within 1-2 years following any decline (Figure 20B).

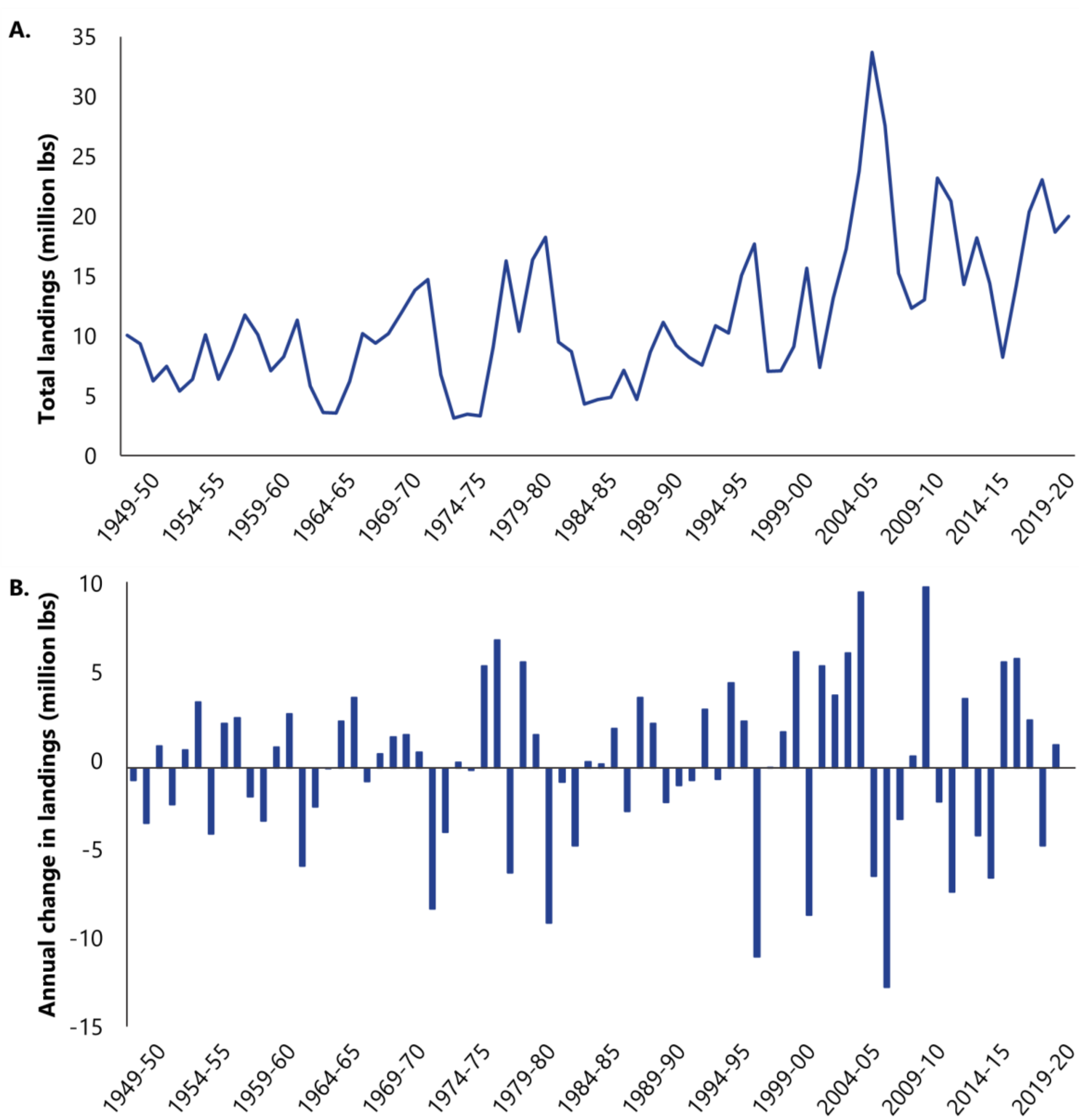


Figure 20. Ocean commercial Dungeness crab (A) landings history and (B) annual change in landings in Oregon from the 1947-48 through 2019-20 seasons.

The LRP includes an additional landings-based criterion which assesses whether a fourth season of declining landings is projected to fall below 20% of the 20-year average. Given the current 20-year average of 18.0 million pounds, this criterion would currently be met if a fourth season of decline fell below 3.6 million pounds.

Based on recommendations from ODFW's (2014b) logbook CPUE assessments, the LRP abundance metric is defined as observed logbook CPUE based on non-transformed pounds per pot day averaged across a given season. The reference period is the average CPUE predicted to have occurred from the 1980-81 through 1986-87 seasons, which was selected because these seven seasons correspond to the period of time when the fishery came closest to triggering the landings-based LRP criteria. Over the reference period, the average predicted logbook CPUE corresponds to 0.96 pounds per pot day (ODFW, 2014b).

Figure 21 shows the mean logbook CPUE from the 2007-08 through 2014-15 ocean commercial seasons. During this time period, the LRP abundance criteria has never been reached. Mean CPUE ranged from 2.08 pounds per pot day during the 2014-15 season to 5.84 pounds per pot day during the 2009-10 season.

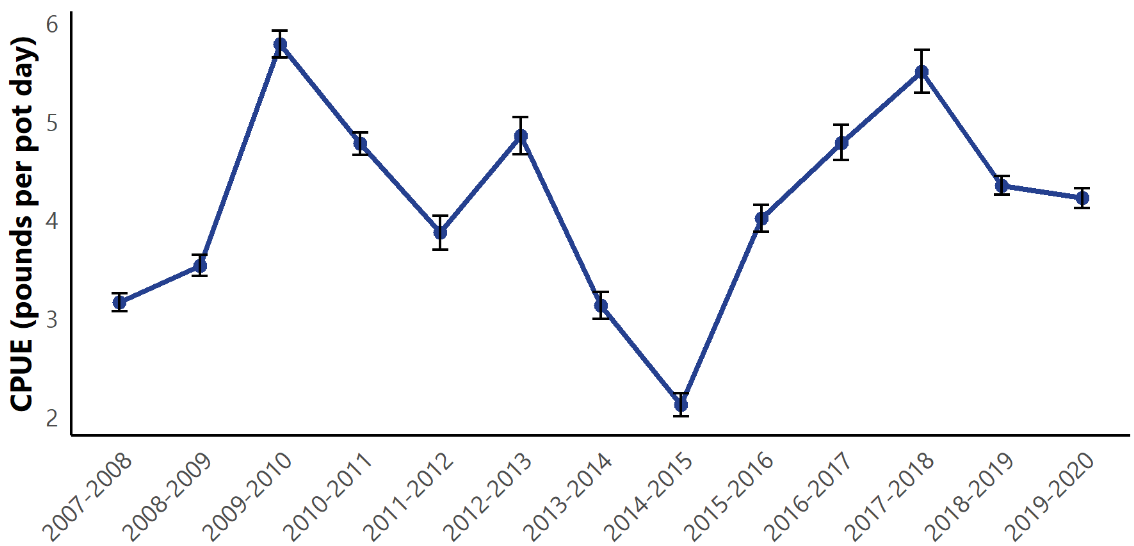


Figure 21. Mean logbook CPUE (pounds per pot day) with 95% confidence intervals from the 2007-08 through 2019-2020 ocean commercial crab seasons.

d. Synthesis of results

Collectively, the information presented in this section demonstrates that the Oregon Dungeness crab population appears resilient to current levels of fishing pressure and that the management strategy in Oregon has been effective at maintaining Dungeness crab at or above the levels necessary to ensure their continued productivity, which is a key element of this plan’s management objectives (see *Section B.I.b*).

Long-term landings in the ocean commercial fishery have been stable or increasing over time (Figure 20). As described in *Section A.IV.a*, landings serve as a good proxy for crab biomass, so the upward trend in landings is indicative of a long-term increase in crab abundance despite consistently high exploitation of legal-sized male crab.

Bycatch estimates obtained from ocean commercial fishery sampling (i.e., at-sea sampling) and from fishery-independent sampling using both commercial (i.e., preseason testing) and recreational (i.e., Yaquina and Alsea Bay Sampling Project) crab pots indicate that bycatch of non-target crab and non-crab species is low.

Seasonal and interannual variation in various CPUE metrics demonstrate fluctuations in crab abundance in Oregon waters and highlight the importance of data collection that is frequent enough to capture seasonal patterns and long enough to encompass oceanographic regime shifts and other large-scale processes. Additionally, the results of fishery-independent sampling in Yaquina and Alsea Bays show that variation exists between bays, despite relatively close proximity to each other. Therefore, caution should be used in applying findings from studies in one bay or region, to another.

Finally, an assessment of annual Dungeness crab removals (Figure 6) confirms that by far the largest contributor to crab take in Oregon is the ocean commercial Dungeness crab fishery. This emphasizes the importance of assessing crab abundance and landings relative to the ocean commercial fishery LRP to monitor the status of the stock and implement adaptive management, if necessary.

V. Threats to the Dungeness crab resource

a. Fishery-related

Discard mortality

Assessing discard mortality requires knowledge of bycatch rates (i.e., the proportion of total catch that is discarded) and discard mortality rates (i.e., the proportion of discarded crab that die as a result of being caught, handled, and released). Bycatch rates are obtained from a number of different sources described in *Section A.III*, while reliable discard mortality rate estimates have been largely unavailable until recently.

Early tagging studies by Cleaver (1949) and Waldron (1958) demonstrated increased mortality (based on recovery rates) of soft-shell crab, relative to hard-shell crab. In 1969, a series of crab condition studies were carried out in Willapa Bay, WA to investigate handling mortality of soft-shell crab. These experiments confirmed that previous low recovery rates of soft-shell crab were likely due to handling mortality. They reported average mortality rates of 4% for hard-shell crab and 16% for soft-shell crab after a single handling event. Additionally, they observed increased mortality of crab subjected to additional handling and prolonged holding periods (Tegelberg, 1970).

More recently, Yochum *et al.* (2017) used the Reflex Action Mortality Predictor approach to quantify discard mortality rates in Oregon's commercial and recreational fisheries, which resulted in lower estimates than previous studies. This method used a set of reflex actions specific to Dungeness crab to assess reflex impairment and delayed mortality in crab subjected to various fishery-related stressors. Results indicated a discard mortality rate (within 5 days of release) of 9.2% for soft-shell males, 8.0% for females, and 1.2% for hard-shell males in the ocean commercial fishery. The discard mortality rate was significantly lower for the boat-based recreational bay fishery (0.9%).

In 2017, the ODCC sponsored the development of a deterministic bioeconomic model for the ocean commercial Dungeness crab fishery in Oregon to investigate the effects of discard mortality on the economic performance of the fishery. Handling and natural mortality rates were derived from work by Yochum *et al.* (2017) and Zhang *et al.* (2004), respectively. Results indicated that natural mortality impacts are magnitudes greater than those related to handling mortality (Davis *et al.*, 2017).

Sublethal effects

In addition to immediate or delayed mortality, fishing activity has the potential to result in sublethal impacts that may impact Dungeness crab recruitment through indirect means. Several researchers have investigated the prevalence of limb loss in Dungeness crab throughout their range (e.g., Cleaver, 1949; Waldron, 1958; Durkin *et al.*, 1984; Shirley and Shirley, 1988), but little is known about the source of these injuries or the effects of injury on crab behavior.

Field studies using modified commercial crab pots demonstrated that the injury rate of male crab increases significantly as soak time increases. Further, injury rates appear to be independent of crab density, but are higher in traps with a greater ratio of sublegal to legal-sized crab (Barber and Cobb, 2007). As part of the same study, laboratory experiments investigating the ability of injured crab to compete for resources indicated that injury did not impact the ability of crab to obtain, defend, or consume food (Barber and Cobb, 2007).

In other decapod crustaceans, injury decreases foraging ability, reduces growth increments or alters molt timing, decreases mating success, and increases risk of predation and cannibalism (Juanes and Smith, 1995). Similar consequences for Dungeness crab could impact recruitment into the fishery; however, additional work is needed to investigate these relationships for Dungeness crab.

b. Habitat impacts

Dredging

Studies on dredging impacts to Dungeness crab have examined the occurrence of entrainment in dredges, the impacts of dredged material disposal, and the water quality and substrate changes associated with these practices.

Dungeness crab are entrained along with dredged materials during dredging operations that have the potential to result in mortality depending on crab size and condition, dredge type, and disposal method (Armstrong *et al.*, 1987). A dredge entrainment study at the mouth of the Columbia River found an entrainment rate of 0.06 crab per cubic yard for all age classes, with age 2+ and 0+ crab having the highest and lowest entrainment rates, respectively. The sex ratios of entrained older crab were skewed to females (i.e., 61% for 1+, 82% for 2+, and 83% for 3+ crab) (Pearson *et al.*, 2003). A series of studies in Grays Harbor, WA, estimated a similar entrainment rate of 0.05 to 0.59 crab per cubic yard from commonly used hopper dredges (Armstrong *et al.*, 1987). Mortality of crab entrained in hopper dredges varied by size class with 86% of those ≥50 mm dying and 46% of those <50 mm dying (Armstrong, Stevens, and Hoeman, 1981).

When dredged material disposal sites overlap with fishing grounds, there is concern about impacts on local crab abundance and mortality. While burrowing into sediment is a natural behavior for Dungeness crab, prolonged burial is dependent upon maintenance of a respiratory pathway to oxygen-bearing water and it likely the key factor determining burial effects from dredge disposal (Pearson *et al.*, 2006).

Studies examining dredging at the mouth of the Columbia River have shown that crab mortality from burial is significantly related to burial depth, size, and sex. At burial depths greater than 10 cm, subadult crab survival is expected to decrease and is estimated to be <10% at depths greater than 16 cm. For adult crab (>150 mm CW), survival declines at burial depths greater than 13 cm and is <10% at depths greater than 22 cm. Furthermore, survival of subadult and adult male crab is higher than female crab of the same size at any given burial depth (Vavrinec *et al.*, 2007).

Video monitoring at the mouth of the Columbia River revealed that the plume following a shallow dredge disposal event has a localized effect in which Dungeness crab are temporarily displaced before returning to the impacted site shortly after (Fields, 2016).

Pesticides

Several pesticides have been shown to affect Dungeness crab at different life stages. The insecticide Sevin® (and the active ingredient, carbaryl) was commonly used in oyster aquaculture in the past and is known to inhibit or delay molting and increase mortality of early larval crab. It also caused irreversible paralysis or death in adults crab within 6 hours after consuming cockles that had been previously exposed (Buchanan *et al.*, 1970). The Dungeness crab larval life stage was more sensitive to Sevin® than the juvenile or adult stage. Since this study was published, the active ingredient in some Sevin® products has changed from carbaryl to zeta-cypermethrin (Natter, 2018), the impacts of which are unknown for Dungeness crab.

This relationship was also demonstrated with the insectide methoxychlor (Armstrong *et al.*, 1976) and the fungicide Captan (Caldwell *et al.*, 1978), though the fungicide was comparatively less toxic than the two insecticides. The use of methoxychlor as a pesticide was banned in the U.S. in 2003 due to its toxicity (WSU, 2014). Additionally, a number of herbicides (i.e., 2,4-D, DEF®, propanil, and trifluralin) (Caldwell *et al.*, 1979) and heavy metals (e.g., arsenic, cadmium, mercury) (Martin *et al.*, 1981) impact the survival of Dungeness crab larvae.

Microplastics

The introduction, persistence, and breakdown of plastic debris in the marine environment are vexing issues that raise global concern (Jambeck *et al.*, 2015). In particular, microplastic (i.e., plastic particles that are <5 mm in length) pollution has gained widespread recognition as an emerging and pervasive threat to marine life, and management of microplastics has recently been identified as a research priority for Oregon (NOAA, 2017).

Microplastics may enter the ocean through multiple pathways and are distributed throughout marine habitats across the globe (Lusher *et al.*, 2017). Marine organisms encounter microplastic particles or filaments through many mechanisms, resulting in physical and chemical impacts from the particles themselves and from additives or sorbed contaminants (Guzzetti *et al.*, 2018; Smith *et al.*, 2018). Ingestion of microplastics has been reported for a range of species and is an active area of research (e.g., Desforges *et al.*, 2015; Collard *et al.*, 2017; Cho *et al.*, 2019; Horn *et al.*, 2019).

Currently, no studies address direct impacts of microplastics on Dungeness crab. However, these plastics affect other decapod crustaceans. For example, laboratory work demonstrated that the European green crab (*Carcinus maenas*) can take up microplastics through both ventilatory and oral routes (Watts *et al.*, 2014). Following plastic ingestion, crab exhibited reduced food consumption and growth (Watts *et al.*, 2015). Another study confirmed that Norway lobster (*Nephrops norvegicus*) ingest and retain polypropylene fibers from their food resulting in reduced condition and energy storage following prolonged exposure to microplastics (Welden and Cowie, 2016).

Ongoing research is investigating the prevalence of microplastics in Dungeness crab in Oregon (Portland State University; PhD candidate, Dorothy Horn). This study seeks to determine whether Dungeness crab megalopae, juveniles, and adults from open ocean and estuary sites are taking up microplastics. If microplastics are found, additional work is planned to investigate the physiological or behavioral impacts to Dungeness crab (D. Horn, pers. comm.).

c. Diseases

Under laboratory conditions, the egg and larval stages of Dungeness crab are vulnerable to bacterial and fungal infections (e.g., *Lagenidium* sp.), which impact hatching success and survival. Laboratory rearing efforts often require fungicides and antibiotics to prevent infections (Fisher, 1976; Fisher and Nelson, 1977).

Juvenile and adult Dungeness crab are also susceptible to infection by parasites. Although reported prevalence in wild populations is relatively rare, infection by systemic ciliates (*Mesanophrys sp.*) associated with summer molting was implicated as the cause of a mortality event in Samish Bay, WA in 1990 (Morado *et al.*, 1999). In confined systems, particular when injured crab are held in high densities, substantially higher ciliate infection rates have been reported (Armstrong, Burreson, and Sparks, 1981; Sparks *et al.*, 1982). In 1979, high mortality of crab in pots and commercial holding facilities in Willapa Bay, WA prompted a five-year study that revealed systemic infection by a *Chlamydia*-like organism during the months of December through March (Sparks *et al.*, 1985).

In the California Current system, the microsporidian *Nadelspora canceri* infects the skeletal muscles of Dungeness crab from Bodega Bay, CA to Grays Harbor, WA. The prevalence of infection in crab is low in the open ocean (0.3% off the Oregon coast) compared to estuaries and embayments (14% over the entire range) (Childers *et al.*, 1996). Microsporidian infections reduce fitness and tend to be fatal (Morado, 2011). Another relatively rare microsporidian observed in Dungeness crab in Oregon is *Ameson metacarcini*, which manifests in pink or orange colored joints (Small *et al*, 2014). ODFW found <1% infection by *A. metacarcini* through visual observation in Yaquina Bay (ODFW, unpublished data). Microsporidian infection rate information is collected by ODFW sampling in Yaquina and Alsea Bays (see *Section A.III.l* for sampling description and Figure 17 and Figure **18** for infection rates) and during at-sea sampling aboard commercial fishing vessels.

d. Non-native species

European green crab

The nonindigenous European green crab (*Carcinus maenas*) has persisted in Oregon and Washington estuaries at low densities since 1998. The green crab has a six-year lifespan and so their long-term persistence depends on strong recruitment events occurring at least every six years. Stronger *C. maenas* year classes are correlated with higher water temperatures, late spring transition, weak southward shelf currents in spring, high PDO, and strong El Niño indices (Behrens Yamada and Kaufmann, 2013).

In estuaries, lower intertidal and subtidal foraging grounds of larger juvenile Dungeness crab overlap with adult European green crab (Behrens Yamada, 2001). Laboratory experiments have demonstrated that similar-sized juvenile green crab outcompete Dungeness crab for shelter and food, but direct consumption of Dungeness crab by green crab was not observed at this life stage (McDonald *et al.*, 2001). Though the claw morphology of *C. maenas* offers a competitive advantage over juvenile Dungeness crab, feeding rate and predatory impacts depend on prey type (Behrens Yamada *et al.*, 2010). Currently, the density of green crab is too low to have a measurable effect on the native benthic community; however, oceanographic regime shifts (e.g., PDO and El Niño/La Niña conditions) could support green crab population growth (Behrens Yamada and Kaufmann, 2013) and a higher catch rate by crabbers.

In Oregon, European green crab are classified as a Controlled Crustacean (OAR 635-056-0075). This means that green crab may be harvested recreationally, but not for commercial purposes. Once harvested, it is unlawful to return green crab back to state waters.

Recent reports about the increased abundance of green crab have raised concerns about the ecological impact of this nonindigenous species to local communities and prompted public requests to allow for a greater level of harvest by recreational crabbers. Due to public uncertainty regarding species identification and likelihood of damage to red rock crab and undersized Dungeness crab, ODFW has determined that unlimited harvest of European green crab is not advisable. However, an increased bag limit provides multiple benefits including greater recreational opportunities, improved public awareness about crab species in Oregon, enhanced monitoring information, and access to spatially relevant harvest data. Historically, European green crab were part of the "Other Shellfish" catch limit in Oregon, which is an aggregate of 10 per day of any shellfish in this category. In March 2022, ODFW recommended and the OFWC adopted a species-specific and increased bag limit of 35 European green crab (of any size or sex) per person per day (ODFW, 2022).

Cordgrass

Four species of nonnative cordgrass (*Spartina spp.*) are distributed along the west coast of North America and infestations of several species are now documented in Oregon (Morgan and Sytsma, 2013). *Spartina* can dramatically alter habitat by increasing sediment accumulation, elevating tideflats, and excluding eelgrass (*Zostera marina*) and other estuarine plants which offer refuge from predation to benthic invertebrates, like Dungeness crab. As a result of this habitat restructuring, *Spartina* may also facilitate invasion by other invasive species (e.g., the European green crab) (Howard *et al.*, 2007).

In Oregon, locations that are susceptible to invasion and pathways of introduction into the state are monitored jointly by resource management agencies and interest groups outlined in the Oregon *Spartina* Response Plan last updated by Howard *et al.* (2007). A persistent infestation of saltmeadow cordgrass (*Spartina patens*) on the Cox Island Preserve in the Siuslaw River estuary is currently under control measures by The Nature Conservancy (Pickering, 2000). Smooth cordgrass (*Spartina alterniflora*) was found and subsequently removed from the Siuslaw River near the Cox Island Preserve and from a former dredge material disposal site in Coos Bay (Howard *et al.*, 2007). In addition, several estuaries north of the Coquille River have been identified as vulnerable to *Spartina* invasion (Daehler and Strong, 1996; Howard *et al.*, 2007).

e. Changing ocean conditions

Ocean conditions are changing as the result of a number of different processes operating on different spatial and temporal scales. Accurate predictions of the vulnerability of different organisms to these changes must consider the integrated effects of ocean acidification, warming ocean temperatures, decreasing oxygen levels, and other stressors acting in combination with natural variability (Hauri *et al.*, 2009).

The Oregon Coordinating Council on Ocean Acidification and Hypoxia (OAH Council) was created in 2017 to provide recommendations and guidance for Oregon's response to ocean acidification and hypoxia (OAH), along with broader challenges associated with changing ocean conditions. The OAH Council website provides more information on these issues and current efforts in Oregon to address them, and crab is a focal species for the Council's work. Dungeness crab is one species highlighted in infographics that review species vulnerability and potential risk from OAH that the website will feature in 2021.

Ocean acidification

Anthropogenic production of carbon dioxide from fossil fuel combustion and emissions continues to increase with the ocean absorbing 25% of emissions on average each year (Le Quéré *et al.*, 2016). The absorption of carbon dioxide by the ocean lowers the pH resulting in ocean acidification. As an eastern boundary upwelling system, the California Current system is naturally more acidified than other surface waters and is particularly vulnerable to the effects of ocean acidification. It also provides important nearshore habitat for many ecologically and economically significant species. Preliminary research indicates that benthic organisms may be the most affected by ocean acidification in this system due to exposure to the lowest pH and aragonite saturation states, combined with limitations to migration (Hauri *et al.*, 2009).

Currently, the vulnerability of Dungeness crab to ocean acidification impacts is not well understood. Laboratory work indicates that development and survival at early life stages may be impacted by decreased pH. In the laboratory, low pH has been shown to delay embryonic and early larval development and reduce larval survival (Miller *et al.*, 2016). Using a combination of different methods, researchers have demonstrated the vulnerability of crab larvae collected *in situ* to severe dissolution of their carapace from the effects of ocean acidification, particularly in coastal habitats under extended (1-month) exposure to strong ocean acidification conditions. Retrospective models estimate an 8.3% increase in the extent of external carapace dissolution in larval Dungeness crab over the last two decades (Bednaršek *et al.*, 2020).

Adult Dungeness crab in the laboratory were able to recover their hemolymph pH after exposure to elevated seawater pCO_2 indicating that they may have the short-term acid-base capacity to tolerate stress from large scale CO_2 sequestration. However, exposed crab exhibited a partial metabolic depression in response to this stress, which may have a significant impact on the species under long-term ocean acidification conditions (Hans *et al.*, 2014). End-to-end model results suggest that Dungeness crab biomass may not be directly affected by pH, but that declines may be seen as a result of reduced prey (i.e., benthic grazers and bivalves) due to ocean acidification (Marshall *et al.*, 2017).

Hypoxia

Low oxygen zones and episodes of hypoxia are a common occurrence in many coastal habitats, particularly during summer when temperatures are elevated and vertical stratification is more pronounced. Though hypoxia naturally occurs off the coast of Oregon, it is expected that hypoxic zones will increase in number, frequency, duration, and intensity as climate change continues and ocean temperatures rise (Gobler and Baumann, 2016).

Dissolved oxygen (DO) levels are closely tied to the performance and survival of marine organisms (e.g., Breitburg, 2002). Sampling in the offshore hypoxic zone along the Oregon coast found that higher crab biomass and condition were significantly correlated with increased bottom oxygen levels (Keller *et al.*, 2010). In the nearshore, severe and persistent hypoxia across broad areas of the continental shelf has been marked by large-scale mortality of adult Dungeness crab in shallow (50 m) waters off the central Oregon coast (Chan *et al.*, 2008). Strong impacts to marine organisms have also been observed during more rapidly occurring hypoxic events, such as a crab die-off inside research pots that was incidentally observed in July 2017 coinciding with rapidly decreasing DO levels that occurred in a matter of days in coastal waters off Newport, OR (Barth *et al.*, 2018). Dungeness crab have shown both behavioral and physiological responses to low oxygen conditions (Airriess and McMahon, 1994; Bernatis *et al.*, 2007), but additional research is needed to determine the long-term impacts of concurrent hypoxia and acidification on the species.

Climate change

In addition to changes in ocean chemistry, there are a number of other potential impacts of a changing climate on nearshore marine habitats and species. These impacts include, but are not limited to, increasing ocean temperatures, sea level rise, changing nutrient availability, increased storm intensity, and altered circulation patterns including changes to upwelling and stratification. These physical changes, in turn, may alter biological processes through shifts in species ranges, invasions and local extinctions, and ecosystem regime shifts (Brierly and Kingsford, 2009). Several climate impacts are also tied to the occurrence of harmful algal blooms (HABs), which may have major implications for Dungeness crab fisheries in Oregon (see *Section B.IV.b*).

Oregon's nearshore is a dynamic environment that is affected by both local environmental forces and large-scale changes in the Pacific acting on the California Current system (ODFW, 2012). The wide variety of habitats occupied by Dungeness crab and their relative tolerance of changes in temperature and salinity may enable them to cope with some of the impacts of climate change (Rasmuson, 2013). However, the vulnerability of Dungeness crab larvae to changes in ocean chemistry, upwelling patterns, and potential mismatches with prey species may have major implications for the species. Additional research to develop quantitative estimates of climate change impacts on crab growth, condition, and survival across life stages is critical for effective future management of Dungeness crab.

VI. Sustainable harvest levels

Dungeness crab fisheries along the West Coast are not managed through stock assessments that respond to annual changes in abundance, catch, or escapement. Instead, managers employ a precautionary approach that maintains a level of sustainability while allowing for some degree of uncertainty (see *Section A.VII* for information gaps). Managers apply greater caution when information is uncertain, unreliable, or inadequate, and the absence of adequate scientific information is not used as a reason for postponing or failing to take conservation and management measures.

The 3-S management system is designed to support the reproductive potential of the stock by minimizing alterations to the age, sex, and genetic composition. This basic structure is consistent for each West Coast state and has been stable over time. In addition to catch restrictions, the state has implemented a limited entry and pot limit system in the ocean commercial sector as effort control measures that address the number of vessel permits and pot allocation, respectively. The historical and existing management system is detailed in *Section B.III*.

A conservative limit reference point based on both landings and abundance indices (see *Section B.VI.a*) accounts for uncertainty regarding the productivity of the Dungeness crab stock. If triggered, ODFW will implement an adaptive management response based on the determined causes of the observed decline. Dungeness crab landings are commonly used as an indicator of the magnitude of the legal-sized male crab population (Richerson *et al.*, 2020). Over its history, the ocean commercial Dungeness crab fishery has exhibited periods of decline in landings, but never lasting more than three years despite ongoing fishing (Figure 20).

In 2010, the Oregon Dungeness crab fishery was evaluated and received Marine Stewardship Council certification identifying it as a "well-managed" or "sustainable" fishery (SCS, 2010). In subsequent surveillance audits, the fishery met all conditions for continued certification and it was maintained for the five-year certificate period that ended in November 2015. A complete description of the MSC process is included in *Section B.III.k*. Briefly, the MSC fishery certification program assesses a fishery based on three main principles: (1) the fishery must operate in a sustainable manner that does not lead to overfishing or depletion of the stock, (2) the fishery must be managed from an ecosystem perspective so as to minimize environmental impacts, and (3) the management system must be able to effectively adapt to changing environmental conditions and comply with relevant laws and standards. In 2020, as a step towards meeting conditions for MSC re-certification in the future, the ODCC developed and finalized a Fishery Improvement Plan (FIP) that established sustainability goals for the ocean commercial fishery, which will be achieved through collaboration between ODFW, industry, and research partners.

ODFW fishery managers, scientists, and industry members have identified key information gaps that currently exist (see *Section A.VII*). Ongoing efforts to address these research needs will allow for adaptive management that remains effective in the face of changing conditions or emerging issues.

VII. Information gaps and research needs

As a condition of the MSC certification process, ODFW (2014a) developed a strategic Oregon Dungeness Crab Research and Monitoring Plan that identified a number of research areas that would allow for improved management of Oregon's Dungeness crab fishery. Those information gaps are briefly detailed below, along with additional research needs identified from a review of literature pertaining to Dungeness crab. Additionally, a list of research priorities needed for the development of a predictive stock assessment model, if determined necessary in the future, are included in *Section A.IV.a*.

a. Recruitment variability

Multiple studies have investigated different factors (e.g., food availability, competition, ocean temperatures) that influence annual larval crab recruitment levels (see *Section A.II.e*); however, better predictive modeling of recruitment into the adult fishery stock requires information that is currently lacking. The population dynamics of brachyuran crab are closely tied to larval release and dispersal patterns. Rasmuson (2013) highlighted the apparent lack of information on the larval release patterns of Dungeness crab and the need for *in situ* studies to help discern whether larval release is synchronized to specific tides and light levels, as with many other crab species. Additionally, research on larval exchange between populations in the open ocean (e.g., Davidson Current transport to the Alaska Current) and within enclosed waters (e.g., Puget Sound, British Columbia, and Alaska) is limited (Rasmuson, 2013; ODFW, 2014a).

Information gaps on Dungeness crab life stages from settlement to pre-recruit (up to 3 years old) also exist (ODFW, 2014a). Although the majority of crab settle on the continental shelf, settlement and juvenile biology studies primarily focus on those found in estuaries (Rasmuson, 2013). Collectively, management will benefit from more targeted information on these aspects of recruitment variability that may be indicative of future stock abundance.

b. Gear selectivity

Researchers and managers often rely on fishery catch and size data to make inferences about populations. However, accurate interpretation of these data depends on an understanding of the efficiency and selectivity of the gear that is used. Studies on Dungeness crab gear selectivity are largely limited to British Columbia (e.g., Breen, 1987) and Puget Sound (e.g., Antonelis *et al.*, 2011), under conditions that may differ from those present in Oregon's crab fishery.

Additional studies investigating gear selectivity in Oregon in relation to factors such as crab population density, bait use (i.e., type and amount), soak time, and crab density within pots would likely allow for improved management of Oregon's crab fishery (ODFW, 2014a). In addition to improving interpretation of catch and size data obtained during in-season crabbing, this information would also aid in determining the potential impacts of ghost fishing and assessing the results of preseason testing which utilizes commercial crab pots.

c. Marine debris

Dungeness crab fishery management would benefit from studies on multiple categories of marine debris. First, derelict crab gear contributes to ghost fishing, gear conflicts, navigation hazards, and marine mammal entanglements; however, quantitative estimates of local ghost fishing mortality rates are lacking (ODFW, 2014a). Further research on the impacts of derelict crab gear to the marine environment would enable ODFW to better evaluate the effectiveness of the current management approach (see *Section B.III.i*).

Additionally, microplastics are a category of marine debris with demonstrated physical and chemical impacts on marine organisms. Studies have shown that other decapod crustaceans take up microplastics resulting in impacts to feeding, growth, and energetic condition, but information on the impacts of microplastics on Dungeness crab is still emerging (see *Section A.V.b*).

d. Climate change

Section A.V.e provides an overview of the current state of knowledge on the impacts of climate change, ocean acidification, and hypoxia on Dungeness crab. Research indicates that changing climate and ocean conditions may affect the distribution and productivity of Dungeness crab along the U.S. West Coast, but quantitative estimates of the impacts are uncertain at this time. This information is necessary for effective and adaptive management that works to mitigate the impacts of changing conditions on the Dungeness crab resource in Oregon.

e. Movement studies

Movement within and between populations is a key component determining Dungeness crab stock structure. Ongoing larval recruitment studies are contributing to a better understanding of larval crab movement in relation to environmental factors off the Oregon coast (see *Section A.II.e*). Continuation of this work is needed to refine these relationships and track larvae under various conditions.

Several studies have investigated juvenile and adult movement patterns along the southern Oregon coast (e.g., Roegner *et al.*, 2007; Hildenbrand *et al.*, 2011), but information throughout the range of the species is needed. Additionally, the details of this movement (e.g., distance, rate, migration corridors, seasonality) are not well understood. Further research in these areas would provide a better understanding of large-scale population dynamics to aid management of the resource, particularly in the face of changing ocean conditions that may alter Dungeness crab habitat.

f. Gear and habitat interactions

Thousands of individually buoyed crab pots are deployed and retrieved each year presenting a potential threat to benthic habitat structure. Due to the relatively small footprint of the gear being used and the stationary deployment, impacts to benthos from single fishing events are thought to be minimal (Rasmuson, 2013). However, there is no documentation of the cumulative impacts resulting from intensive fishing. Additionally, it is not well known how derelict crab gear may affect soft-bottom benthic habitat quality. Site-specific studies are needed to determine relative fishing intensity and impacts to benthos from lost gear, so that management decisions may be made that minimize adverse impacts to habitat and other species.

g. Connections between ocean and estuary populations

Dungeness crab are found in both coastal estuaries and the open ocean at all life stages; however, it is unclear how dependent they are on each environment. Pelagic larval crab are widely dispersed within nearshore and offshore waters prior to settlement in estuaries or the nearshore. Both wind-driven and tidal transport are proposed physical mechanisms regulating cross-shelf movement of megalopae (Miller and Shanks, 2004), but additional research is needed to better understand these processes and how they interact with individual behaviors to regulate movement of Dungeness crab between these habitats. Holistic information on the extent of migration and mixing, and the level of dependency on each environment by Dungeness crab at larval, pre-adult, and adult life stages may be informative for management of both recreational and commercial fishing which span ocean and estuarine environments.

h. Natural mortality

Several studies have estimated natural mortality rates for Dungeness crab, but few have accounted for additional factors related to life history and condition. Additionally, the degree of variability in natural mortality throughout the range of Dungeness crab is not known. Zhang *et al.* (2004) estimated natural mortality during molting and non-molting periods for crab on the Fraser delta near British Columbia, but this information has not been estimated for crab in Oregon waters.

Information on natural mortality of crab throughout their life history and between areas is needed to better understand Dungeness crab abundance and population dynamics. This may ultimately prove useful in developing biological reference points and informing effective management of the fishery.

i. Molt timing

The timing of life history events varies greatly throughout the range of Dungeness crab. Effective management is dependent on knowledge of the local timing and duration of these events and the factors that affect them. A thorough understanding of these processes is particularly important as climate change impacts oceanographic conditions.

Specifically, crab molt timing is key to informing season closures that are intended to minimize the harvest of crab that are in poor condition. In Oregon, most studies that examine the Dungeness crab molting schedule are several decades old (see Table 1), and recent observations suggest that the current molting season appears to be changing (see *Section A.II.b*). More recent studies at various locations along the Oregon coast are needed to better understand life history variation and inform future management decisions.

j. Marine mammal interactions

Interactions between whales and fixed fishing gear is an issue of major concern for the West Coast Dungeness crab fishery (see *Section B.IV.a*). Improved information on the gear involved in any future entanglement events is critical to making informed management decisions that reduce entanglement risk. From 2013 to 2020, just over half (51%) of the coastwide confirmed whale entanglement reports were not able to be attributed to a specific fishery or gear type (NMFS West Coast Region whale entanglement data, provided April 2021). In 2019, ODFW implemented management measures aimed at increasing accountability through enhanced gear markings in all commercial fixed gear fisheries and the recreational fishery, and improved timeliness of spatial and temporal harvest data collection (ODFW, 2019a). Collectively, these accountability measures are expected to reduce Oregon’s contribution to unidentified or unattributable fishing gear entanglements, in combination with additional accountability measures which are being considered and developed for future implementation (see *Section B.VIII.a*).

Efforts to mitigate entanglement risk also depend on a spatial and temporal understanding of whale distributions and habitat use. In 2019, a collaborative research project was initiated between ODFW, Oregon State University (OSU), Cascadia Research Collective, and the U.S. Coast Guard (USCG) to collect whale presence and absence data from monthly aerial surveys off Oregon. These data will be used to inform predictive distribution models describing species distributions relative to environmental conditions. The impetus for this project was a significant information gap identified early on by the Oregon Whale Entanglement Working Group (OWEWG), which was convened in 2017. The OWEWG found that knowledge of seasonal whale distribution in Oregon waters is lacking and must be addressed to better understand the spatial and temporal patterns of whale entanglement risk in Oregon. By combining improved data on whale distribution with relatively high-resolution data on fishery effort from ODFW fishery logbooks, maps of entanglement risk can be developed and used to guide more targeted spatiotemporal management. This project represents one major effort by ODFW and various partners to address existing information gaps related to co-occurrence between whales and crab gear and continuation of these surveys or other work to repeat empirical observations of whale distribution will continue to be a priority for ODFW to address into the future.

k. Female mating success

Female mating success is critical for larval production and eventual recruitment in male-only fisheries. Several studies examining fertilization rates in Northern California and Oregon have concluded that mating success is not likely to be a limiting factor in the Oregon Dungeness crab fishery. However, research regarding fertilization rates is temporally and spatially limited. Additional estimates of female mating success and fertilization rates over time and across a wider geographic area may provide insight on the mechanisms influencing recruitment in male-only fisheries. This information, along with information on discard mortality of female crab, may aid in the development of more direct and effective target and limit reference points (ODFW, 2014a).

l. Recreational guide and charter crabbing dynamics

Recreational crabbers sometimes hire guides or purchase trips with charter vessels to crab in nearshore ocean waters and bays. Information on crab gear deployed and crab harvested by charter vessels is provided by several surveys. ODFW's Ocean Recreational Boat Survey collects crab harvest data from all recreational angler interviews, and these data are used to estimate total crab harvest and the number of angler-trips (see *Section A.III.g*). Additionally, through the Marine Non-Salmonid Recreational Fishery Studies, Pacific State Marine Fisheries Commission observers collect Dungeness crab catch and discard data and the number of pots fished aboard recreational bottomfish charter vessels that participate in the recreational crab fishery (see *Section A.III.h*). However, several information gaps currently exist.

With the exception of MNSRFS data on charter vessels, there is limited knowledge of the number of recreational pots fished by private, guide, and charter vessels in the ocean, and limited anecdotal information on where those pots are fished and how long pots are soaked. Additionally, there is very limited data on pot loss in the recreational fishery. Finally, certain biases in the current methods for estimating the number of recreational ocean crabbing trips are likely to result in trips being overestimated. Management would benefit from additional data on crabber participation on these trips to allow for refined estimates to be made. Additional data collection or research efforts in each of these areas are needed to improve knowledge of charter crabbing dynamics in Oregon to inform future management decision making.

B. Harvest Management Strategy

This Harvest Management Strategy articulates the management practices and goals for the Dungeness crab resource and fishery in Oregon. Goals and objectives are defined considering ecological and socioeconomic aspects of the utilization of Dungeness crab. A description of historical and current management practices, fishery sectors, and current issues facing the fishery is provided and followed by an evaluation of available management tools.

I. Management approach

Consistent with the Food Fish Management Policy (ORS § 506.109) and Wildlife Policy (ORS § 496.012), Oregon's Dungeness crab fishery management is designed to prevent serious depletion of the Dungeness crab resource, while maximizing long-term economic, commercial, recreational, and aesthetic benefits for present and future generations.

The overarching management approach is driven by ecological, social/cultural, and economic goals and objectives that overlap in priority (Figure 22). Ecological objectives apply to all Dungeness crab fishery sectors, while social/cultural and economic objectives may apply to one or more of the Oregon crab fishery sectors. Objectives that are specific to the commercial fishery sectors are broadly intended to protect market quality and allow for a diversity of business plans (i.e., meaningful opportunities for participation by different vessel sizes, classes, and/or pot tiers, during different times of the year and/or servicing different markets). Those that are specific to the recreational fishery broadly strive to provide access to a reasonable recreational harvest and opportunities for coastal tourism.

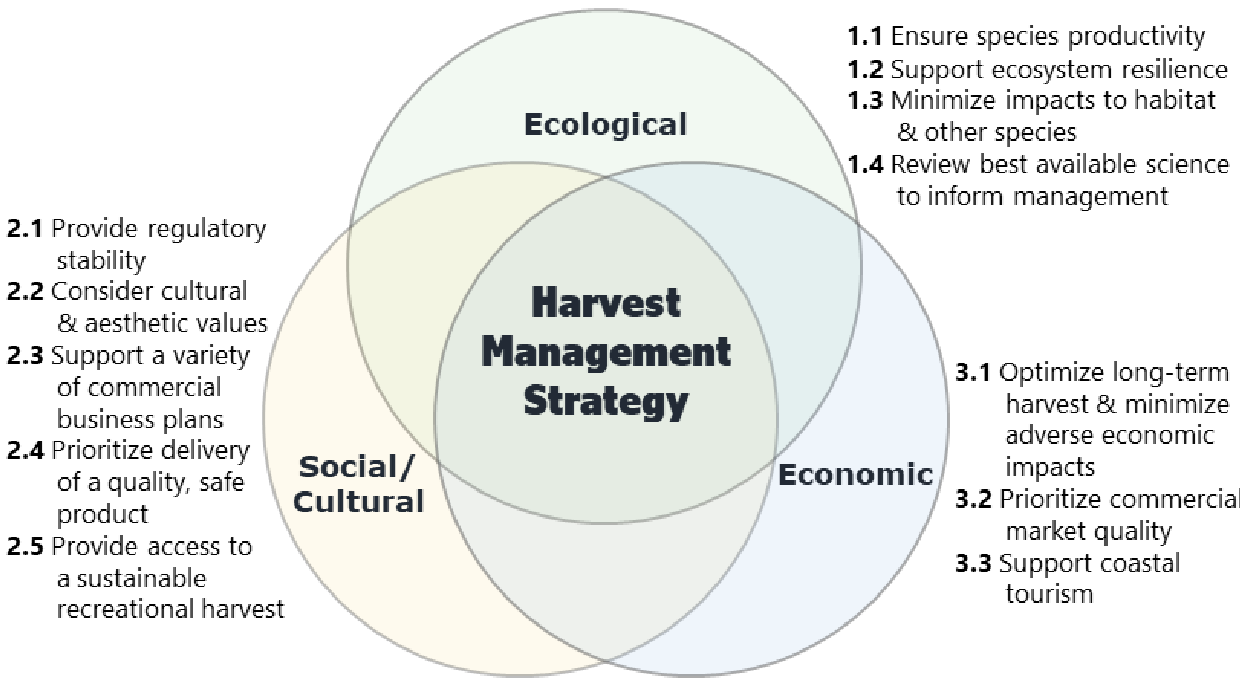


Figure 22. Management approach for the Oregon Dungeness crab fishery driven by overlapping ecological, social/cultural, and economic objectives. Ecological objectives apply to all Dungeness crab fishery sectors, while social/cultural and economic objectives may apply to the commercial fishery, recreational fishery, or both.

a. Management goals

The management goals described in this strategy apply to Dungeness crab harvested commercially and recreationally in both the open ocean and estuaries in Oregon. The identified goals reflect long-term desired outcomes for the Oregon Dungeness crab fishery, coastal communities, and larger ecosystem. These include:

1) **Ecological** – Ensure the long-term reproductive capacity of the Dungeness crab population, minimize impacts to other species, and support ecosystem health.
2) **Social/cultural** – Promote diverse opportunities for present and future generations to harvest, use, or enjoy the Dungeness crab resource.
3) **Economic** – Support the economic vitality of the Dungeness crab fishing industry and coastal communities.

b. Management objectives

To accomplish these goals, there are specific objectives that will be re-evaluated in subsequent revisions of this plan. To monitor goal achievement, these objectives are considered in relation to a number of metrics (e.g., crab harvest, crab abundance, condition, meat recovery, etc.) which are tracked through ODFW data collection programs and partnerships (see *Sections A.III* and *A.IV*).

Ecological objectives apply to all Dungeness crab fishery sectors, while social/cultural and economic objectives may apply to Oregon's commercial crab fishery, recreational fishery, or both. Management objectives include:

Ecological

- **1.1** Maintain, develop, and implement management strategies that maintain Dungeness crab at or above the levels necessary to ensure species productivity.
- **1.2** Maintain, develop, and implement management measures that prevent serious or irreversible harm to the key elements of ecosystem structure and function, and that support ecosystem structure, function, and resilience to changing climate and ocean conditions.
- **1.3** Maintain, develop, and implement management measures that minimize adverse fishery impacts to habitat, marine mammals, and other species.
- **1.4** Conduct periodic reviews of the best available information on the biological status of the resource and impacts of the fishery to inform management decisions.

The Oregon Dungeness crab fishery is managed to maintain the Dungeness crab stock at or above levels necessary to ensure their continued productivity, while also maintaining the structure, function, and resilience of the broader ecosystem. This includes minimizing adverse impacts to habitat, marine mammals, and other species, and managing the fishery in a manner that seeks to avoid serious or irreversible harm to habitat structure and function and ensure that the recovery of endangered, threatened, or protected species is not hindered by crab fishery activities. Additionally, impacts to the recruitment and survival of other species are taken into account during management decision-making processes.

The Dungeness crab stock status is closely monitored by tracking commercial landings (a proxy for legal-sized male crab abundance) in relation to the ocean commercial fishery limit reference point. This information, combined with other commercial sampling programs and recreational fishery monitoring (i.e., creel surveys and sampling), is used to assess the impacts of the fishery on the Dungeness crab resource and other species (e.g., bycatch). Fishery monitoring data also enable ODFW to evaluate the effectiveness of different management measures implemented in the fishery to control fishery effort (e.g., limited entry, pot limits, late-season restrictions) and reduce impacts to non-target species (e.g., highly selective gear design, escape ports, release mechanisms). Changing climate and ocean conditions are taken into account when developing and implementing adaptive management measures that support ecosystem resilience. Additionally, ODFW works with various research partners and organizations to ensure that management decisions are based on the best available science.

Social/cultural

- **2.1** Maintain, develop, and implement management measures that provide regulatory stability and flexibility to participants in deciding where, when, and how to fish for Dungeness crab.

2.2 Maintain, develop, and implement management measures that consider the cultural and aesthetic value of the Dungeness crab fishery and species in Oregon.
2.3 Support and allow for a variety of business plans in the commercial harvest of Dungeness crab.
2.4 Prioritize the delivery of a high quality and safe product to consumers and recreational harvesters.
2.5 Provide access to a recreational harvest of Dungeness crab that ensures harvest sustainability and considers the needs of recreational users.

Dungeness crab fishery management is implemented through an open, public process that considers the social and cultural objectives of the fishery while developing and implementing management measures. Commercial and recreational fishery sampling is conducted to monitor fishery activity and ensure a safe product for consumers and harvesters. Socioeconomic data collected through various programs are utilized when evaluating management options to ensure that decisions are effective and consider broad interests in the Dungeness crab resource and the critical symbolic importance of the species.

While many tribes have ties to areas along the Oregon Coast, there are four federally recognized tribal nations within the state's coastal zone: the Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians (CTCLUSI), the Coquille Indian Tribe, the Confederated Tribes of Siletz Indians, and the Confederated Tribes of the Grande Ronde Community of Oregon. Oregon's federally recognized tribes are each their own sovereign government and each have unique legal gathering rights, relative to state and federal regulations. These rights shall be respected (in consultation with the Tribes, as appropriate) when making any resource management decision.

ODFW participates regularly in consultation with the federally recognized tribes along Oregon's Coast regarding harvest of shellfish from Oregon marine waters. These interactions include annual meetings (to discuss fishing, hunting, shellfish harvest) with the Siletz Tribe and Coquille Tribe, and meetings with the Grand Ronde Tribe and the CTCLUSI to address specific needs. Implementing regulations in the FMP (*Appendix B*: Oregon Dungeness crab FMP implementing rules) have gone through the ODFW's routine, formal rulemaking procedure, which includes opportunity for tribal consultation.

Economic

3.1 Maintain, develop, and implement management measures that optimize long-term harvest from the Dungeness crab fishery and, to the extent possible, minimize adverse economic impacts on fishing communities.
3.2 Prioritize the commercial market quality of Dungeness crab to ensure a long-term supply of Dungeness crab to seafood markets, restaurants, and other businesses.
3.3 Support coastal tourism by maintaining recreational crabbing opportunities, considering the non-consumptive economic value of Dungeness crab in Oregon, and providing a near-year-round commercial supply of fresh, local product for visitors to the Oregon coast.

Along with social and cultural considerations, direct and indirect economic impacts to fishery participants and coastal communities are considered during crab fishery management decision making. For example, ODFW works with the ODCC and industry to monitor meat recovery prior to the start of the ocean commercial season each year to protect market quality and inform decisions about the commercial season opening structure.

Considerations for implementing objectives

Across and within all three fishery sectors, there are management measures in place that work to implement the objectives above, by ensuring that all harvesters have distinct access to the Dungeness crab resource. Each fishery sector has distinct but related goals regarding access, and management differences to ensure that each of these goals are met.

For the **ocean commercial** fishery, the management system is designed to provide equitable access to crab harvest (i.e., economic value) for a diversity of business plans. As described in *Section B.I*, this means that there are meaningful opportunities for participation by different vessel sizes, classes, and/or pot tiers, during different times of the year and/or servicing different markets. Fleet equity is the basis of fair start provisions, collective measures that work to allow small vessels to remain competitive (e.g., gear setting, barging), and efforts to enhance enforcement (e.g., hold inspections) (*Section B.III.f*). It is also central to the maintenance of a summertime crab fishery, which contributes a relatively small portion of crab landings each season but is a key business component for certain participants or vessels.

Bay commercial fishery management strives to provide access to crab harvest, specifically during the marketing niche that exists when the ocean commercial fishery is closed. This is achieved through season opening regulations that temporally separate bay and ocean commercial harvest.

Finally, the **recreational** fishery is managed to provide year-round access to crabbing opportunities and a reasonable harvest for all non-commercial crabbers, including tourists, local residents, subsistence users, and others. This goal is supported by the lower size limit for recreational crabbers that provides access to quality crab that are unavailable to the commercial fisheries (i.e., crab between 5 ¾" and 6 ¼" carapace width). Additionally, the allowance of ocean recreational harvest through October 15 (i.e., beyond the ocean commercial season closure) provides reasonable and distinct access for this fishery sector.

Additionally, management measures in all sectors contribute toward minimizing conflicts with other fisheries or ocean uses. For example, the current prohibition on longlining in the ocean commercial fishery (see *Section B.III.e*) makes it easier for crab and other fishers to determine the location of gear and avoid conflicts over gear setting. Additional examples of management actions to minimize conflict are described in *Section B.IV.c*.

II. State authority

Since the late 1800s, the West Coast Dungeness crab fishery has been managed by the adjacent coastal states. Over time, a series of legislative actions have further defined state authority over the Dungeness crab resource. A detailed description of relevant federal legislation is included in the Oregon MFMP Framework (ODFW, 2015a).

First passed in 1976, the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (P.L. 94-265) is the primary law governing the management of marine fisheries in U.S. waters. In addition to establishing federal management authority over fishery resources within the U.S. exclusive economic zone (EEZ; from 3 to 200 nautical miles offshore), it also established eight regional fishery management councils, including the Pacific Fishery Management Council (PFMC). The councils are authorized to develop and implement fishery management plans, based on the best available science, that comply with MSA's national standards for conservation and management.

In 1978, the PFMC developed a draft fishery management plan for Dungeness crab, but development was indefinitely suspended in 1979 due to workload concerns and industry opposition to federal involvement, coupled with the existing state management that was considered adequate (PFMC, 1997). At that time, the PFMC identified several unresolved issues within the commercial fishery including:

- Market difficulties and fishing effort shifts resulting from wide fluctuations in yield
- Management challenges in determining season opening dates due to latitudinal differences in the timing of crab molting
- Inter-fishery conflicts
- Concerns over the extent of capitalization

Several significant amendments to the MSA were made by Congress that impacted state authority to manage Dungeness crab. The Sustainable Fisheries Act of 1996 (P.L. 104–297) implemented a series of provisions, including one which addressed the limited ability of states to enforce regulations in the portion of the crab fishery occurring outside of state waters. The enactment of section 112(d) granted limited interim authority for California, Oregon, and Washington to apply state regulations to vessels fishing for Dungeness crab within the U.S. EEZ with permits from their state. This authority extended until 1999, or the development of a federal fishery management plan (U.S. House of Representatives, 1998), and was limited to establishment of season opening and closing dates, minimum size and crab meat recovery requirements, sex restrictions, and area closures or pot limits to meet Washington tribal requirements (see *Washington* management description below). Under this authority, the states were prohibited from enforcing limited entry programs within the EEZ for vessels not registered in their state (PFMC, 1997).

Also included in section 112(d) was a requirement that the PFMC provide a report to Congress by December 1997 describing progress in the development of a federal fishery management plan. An ad hoc committee was formed by the PFMC including representatives from the PFMC, state resource management agencies, industry members from the harvesting and processing sectors, NMFS, and the treaty tribes. Options presented by the committee, along with public testimony, were considered by the PFMC and two options were selected for public review: (1) development of a federal fishery management plan under the MSA with some delegation of state authority, or (2) a request that Congress make permanent the interim state authority. The PSMFC's Tri-State Dungeness Crab Committee (hereafter "Tri-State Committee") served as a forum for public hearings to consider these options. Following the unanimous recommendation of the Tri-State Committee, the PFMC submitted their report to Congress recommending that interim state authority be made permanent along with requirements that state regulations be applicable to all vessels harvesting Dungeness crab in the EEZ and clarification that vessels not permitted in any of the three states be prohibited from participating in the Dungeness crab fishery (U.S. House of Representatives, 1998). Several versions of the Dungeness Crab Conservation and Management Act (H.R. 3498) were drafted to permanently extend state authority in this manner, but were never enacted into law.

Instead, these efforts were followed by three repeated extensions of interim state authority. First, section 203 of P.L. 105–384 renewed Tri-State management authority until September 2001. Section 624 of P.L. 107–77 amended this sunset date to 2006 and added a subsection requiring the PSMFC to submit biennial reports to the Senate Committee on Commerce, Science, and Transportation and the House Committee on Resources detailing the status of the Pacific coast Dungeness crab fishery. In 2007, the MSA Reauthorization Act (P.L. 109–479) further extended interim state authority to 2016.

During the 114th Congress (2015-16) the House passed the West Coast Dungeness Crab Management Act (H.R. 2168) removing the sunset provision of P.L. 105–384. However, the Senate failed to pass the companion bill (S. 1143) or take action on the House legislation, so it was not enacted into law. A second, successful attempt to pass legislation in both chambers was made during the 115th Congress, with the passage of H.R. 374. The legislation was signed into law (P.L. 115–49) on August 18, 2017, thereby granting permanent authority to the states to manage the Dungeness crab fishery in adjacent federal waters.

a. Interstate management approaches

Regulations that are passed in one state have the potential to impact fishing effort or activity in other states. For example, several of Oregon's key regulations addressing commercial fishing effort and capacity have been developed in response to anticipated shifts in effort resulting from regulations adopted in California or Washington (see *Section B.III.g*). Although rules are adopted in each state through independent processes, the regulations and management structure are generally consistent; however, there are several key differences among the regulatory processes in these three states which impact coastwide Dungeness crab management.

Oregon

Oregon's crab fishery is governed by a series of Oregon Revised Statutes (ORSs) that are adopted or modified by the Oregon Legislature, and Oregon Administrative Rules (OARs) that are adopted or modified by the Oregon Fish and Wildlife Commission. Ocean commercial fishery regulations related to licensing, fees, and limited entry generally require legislative action, while rules governing the recreational fishery and the time, place, and operations of the commercial crab fishery sectors are typically adopted by the OFWC. The OFWC (established under ORS 496.090) consists of seven governor-appointed commissioners who are charged with setting policies and developing general state programs that provide for the productive and sustainable management and utilization of fish and wildlife resources by all user groups. Implementation of both ORSs and OARs is overseen by ODFW with enforcement functions carried out by the Oregon State Police.

Washington

In Washington, commercial fishery regulations related to licensing, fees, and limited entry are similarly adopted or modified by the Washington Legislature in the Revised Code of Washington, while recreational and other commercial fishery rules are adopted or modified by the Washington Fish and Wildlife Commission in the Washington Administrative Code. The Washington Fish and Wildlife Commission consists of nine governor-appointed members charged with establishing policies to preserve, protect, and perpetuate fish, wildlife, and ecosystems while providing sustainable recreational and commercial opportunities. Enforcement and administration of regulations for both commercial and recreational crab fishery sectors are carried out by the Washington Department of Fish and Wildlife (WDFW).

Washington's commercial crab fishery is divided into a coastal fishery and a Puget Sound fishery, with distinct management and harvest goals for each. Under the Tri-State memorandum of understanding (see *Section B.III.b*), the coastal fishery coordinates management actions with Oregon and California.

In 1994, a federal court ruling, known as the Rafeedie decision, upheld treaty shellfish harvest rights in Washington. Since that time, the WDFW has co-managed the coastal Dungeness crab commercial fishery with four coastal treaty tribes entitled to up to 50% of the harvestable shellfish resources in their usual and accustomed fishing grounds (U&As), encompassing approximately 50% of the Washington coastline (WDFW, 2001).

California

In California, the state Legislature maintains authority for regulating most aspects of the commercial fishery (Didier, 2002) through rules adopted in the California Fish and Game Code. As a result, development and adoption of new regulations can be a lengthy process, compared to that of Oregon and Washington. An exception to this is the authority to establish criteria and protocols to evaluate and respond to potential risk of marine life entanglement in gear from the California commercial Dungeness crab fishery, which was delegated to the California Department of Fish and Wildlife (CDFW) director by the California Legislature in 2018 (SB 1309, McGuire).

Regulations related to recreational crab fishery management in California are adopted by the California Fish and Game Commission in the California Code of Regulations. The California Fish and Game Commission is comprised of five governor-appointed members broadly charged with ensuring the long-term sustainability of California's fish and wildlife resources. Enforcement and implementation of regulations for both the commercial and recreational crab fisheries are carried out by CDFW.

Management of commercial Dungeness crab in California is divided into a northern and central fishery, with a dividing line at the Mendocino-Sonoma County border (near Point Arena). The two management areas have distinct seasons, with the northern California fishery opening coordinated with Oregon and Washington openers through the Tri-State protocol (see *Section B.III.f*).

III. Oregon Dungeness crab fishery description

The Dungeness crab fishery is conducted in both state (0 – 3 nm from shore) and federal (3 – 200 nm offshore) waters along the U.S. West Coast, and in bays and estuaries. The fishery is managed at the state level, with ODFW as lead management agency in Oregon.

Oregon's coastal waters are currently home to a number of specially designated marine areas dedicated to conservation and scientific research. There are five state-managed marine reserves (the Cape Falcon, Cascade Head, Otter Rock, Cape Perpetua, and Redfish Rocks marine reserves) and seven marine gardens (the Haystack Rock, Cape Kiwanda, Otter Rock, Yaquina Head, Yachats, Cape Perpetua, and Harris Beach marine gardens) within which ocean development and extractive activities, including commercial and recreational harvest of crab, are prohibited, except as necessary for monitoring or research. Additionally, there are several marine protected areas, research reserves, or other sites where area-specific harvest restrictions are in place. Restrictions and allowances within marine reserves and marine protected areas are specified in OARs 635-012-0020 through 635-012-0160. Regulations for other closed areas are specified in ORS chapter 511 and OAR 635-005-0260 and summarized in two annual documents: an Oregon Commercial Fishing Regulations Synopsis (e.g., ODFW, 2021a) and an Oregon Sport Fishing Regulations document (e.g., ODFW, 2021b).

New management measure for all fixed gear fisheries: Through this FMP, ODFW recommended and the OFWC adopted a rule amendment in October 2021 revising the definition of bottom contact gear (fixed gear; longlines, fish pots, crab pots) in marine reserve and marine protected area regulations to include surface buoys. This revision aids enforcement by making it so that any fishing buoy inside those areas is a violation.

a. Fishery sectors

The Oregon Dungeness crab fishery is comprised of three active fishery sectors: the **ocean commercial** fishery, the **bay commercial** fishery, and the **recreational** fishery which is active in the ocean, bays, and shores. Each fishery is managed under the same basic management structure that restricts harvest based on size, sex, and season (see *Section B.III.d*). However, separate regulations for each have been developed over many decades to provide a diversity of opportunities and maintain the sustainability of the resource.

For both commercial fishery sectors, ORSs contain regulations and requirements addressing fees, licensing, and limited entry (ORS chapters 506-513), while OARs contain rules pertaining to seasons, gear, and fishery operations, among other aspects of the fishery (OARs 635-005-0400 through 0495 and 635-005-0500 through 0515 for the ocean commercial and bay commercial fisheries, respectively). Regulations for the recreational crab fishery are included in an annual Oregon Sport Fishing Regulations document (e.g., ODFW, 2021b) that is incorporated into rule, by reference (OARs 635-039-0080 and 635-039-0090).

In most years, the ocean commercial fishery is the most valuable single-species commercial fishery in Oregon (TRG, 2021). The number of participants and annual harvest in the bay commercial fishery is much smaller; however, the fishery fills a marketing niche by providing local markets with fresh crab when the ocean season is closed. Meanwhile, recreational crabbing is a popular year-round activity in many bays throughout Oregon and from December through mid-October in offshore waters (Ainsworth *et al.*, 2012).

On average, the ocean commercial fishery represents 93.9% of the annual crab harvest in Oregon, while the recreational and bay commercial fisheries represent an estimated 5.9% and 0.2%, respectively (Figure 23).

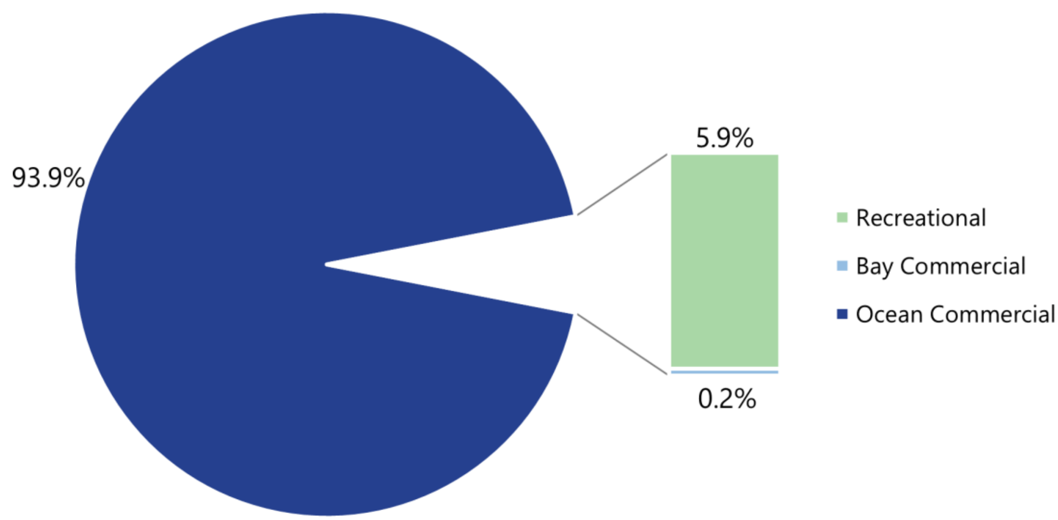


Figure 23. Average percent of Dungeness crab harvested in the recreational, bay commercial, and ocean commercial fisheries in Oregon from 2008–2017. Ocean and bay commercial harvest is documented through ODFW fish tickets. Recreational harvest is estimated from creel-type surveys and the Ocean Recreational Boat Survey. Estimated recreational harvest includes boat-based crabbing in the Columbia River, ocean, and bays, but does not include land-based crabbing from piers, docks, jetties, etc. Crabbing does occur in bays that were not sampled (and are not part of this estimate).

Ocean commercial fishery

By regulation, the ocean commercial fishery includes commercial fishing for Dungeness crab that takes place in state and federal waters off Oregon and the Columbia River. The ocean commercial fishery season is open from December 1 through August 14, with provisions to delay the opening due to insufficient meat recovery. Ocean commercial harvesters are restricted to retaining only male crab that are at least 6 ¼" in carapace width. In addition to size, sex, and season regulations, the fishery operates under a limited entry system and pot limit program (200, 300, and 500 pot tiers), which control effort in the fishery through restrictions on the number of vessels and amount of gear each permitted vessel can use (see *Section B.III.g*). Additional regulations are in place during the summer months (June to August) to limit fishing on softshell crab at the end of the season (see *Section B.III.h*).

Dungeness crab are caught in commercial crab pots that are set at depths ranging from 1 to 120 fathoms, with the majority fished at 55 fathoms or shallower (ODFW, 2014b). While fishing is allowed out to 200 nautical miles (the U.S. EEZ), logbook data indicate that effort does not extend beyond ~30 miles from shore (Figure 7). The vast majority of crab, 83 – 91% in recent seasons, are caught during the first eight weeks of the ocean commercial season (ODFW, 2020a). As of the 2019-20 season, the ocean commercial fishery harvests a long-term (25-year) average of 16.6 million pounds of crab per season.

Most crab (~99.5%) caught in the ocean commercial fishery are landed into seven major ports along the Oregon coast, with only a small amount (<1%) landed into other Oregon ports. In recent years, the largest portion of Oregon's ocean commercial crab has been landed in Newport, followed by Astoria and Charleston (Figure 24).

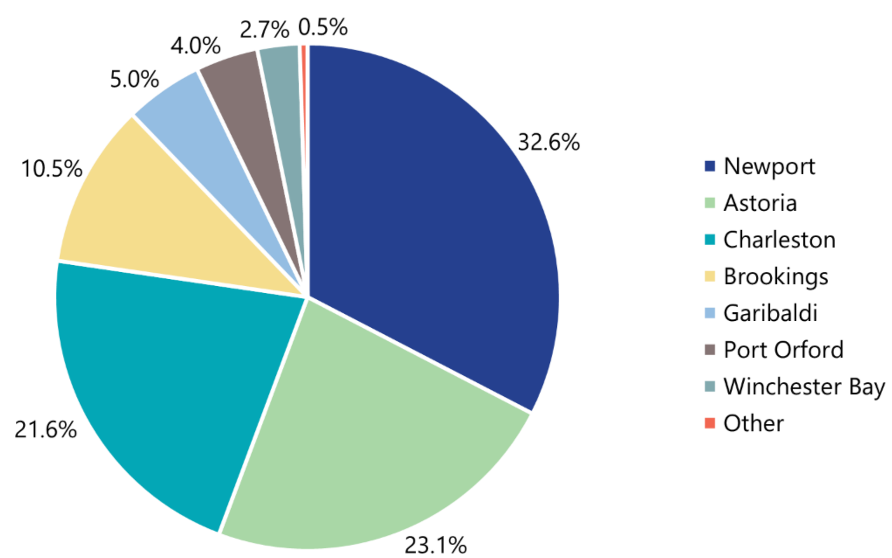


Figure 24. Percent of ocean commercial Dungeness crab landings by port from the 2000-01 through 2019-20 seasons. Ocean commercial crab are landed into seven major ports, with <1% landed into 'other' ports (Bandon, Depoe Bay, Florence, Gold Beach, Nehalem Bay, Pacific City, and Waldport). Data are from ODFW fish tickets.

Bay commercial fishery

Geographically, the bay commercial fishery is confined to the bays and estuaries of Oregon (excluding the Columbia River). The bay commercial season is open from the Tuesday after

Labor Day through December 31, excluding weekends and holidays. Additionally, the fishery closes during December if the adjacent ocean area remains closed during that time. Size and sex regulations are the same as the ocean fishery (i.e., male only harvest, 6 ¼" minimum CW).

The bay commercial fishery is much smaller than the ocean fishery, with around 20 – 30 boats participating each year (Ainsworth *et al.*, 2012). While there is some overlap in participation between the ocean and bay commercial fishery sectors, the majority of bay commercial fishery participants do not harvest ocean crab commercially. From 2011 through 2020, the percentage of bay commercial crabbers that also participated in the ocean commercial fishery ranged from 13.3% to 30.6% (n=2-12 vessels; ODFW fish ticket data). Bay commercial harvesters are limited to crab rings only (no pots) and may use no more than 15 rings per vessel. As of the 2020 season, the bay commercial fishery harvests a long-term (25-year) average of 25,850 pounds of crab per season (approximately 0.16% of the 25-year average for the ocean commercial sector; Figure 25).

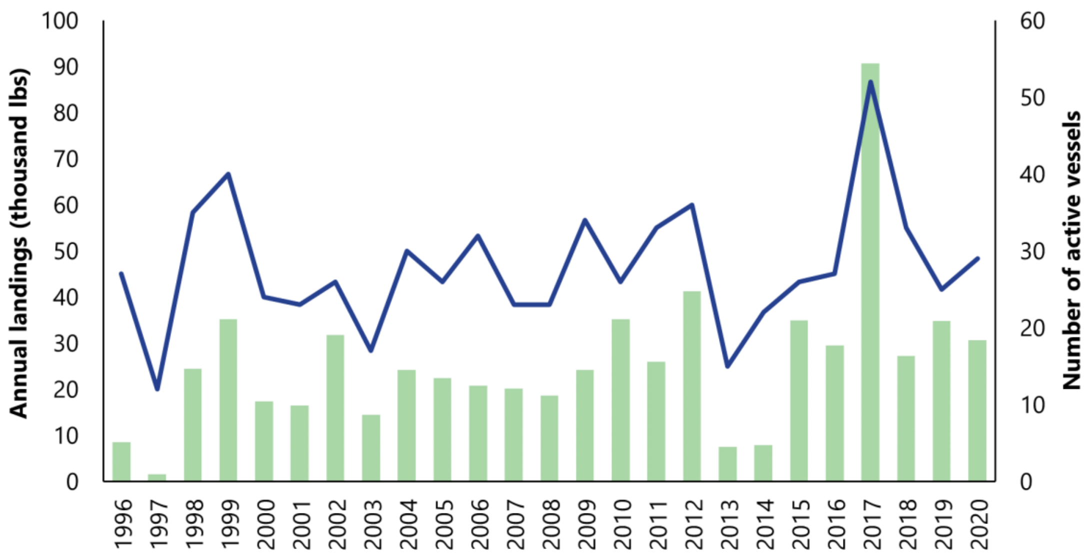


Figure 25. Annual Dungeness crab landings (green bars) and the number of active vessels (made one or more landing; blue line) in the bay commercial fishery from 1996–2020. Data are from ODFW fish tickets.

This small fishery is dynamic and participation in particular bays varies greatly by year. The majority of crab (>82%) caught in the bay commercial fishery are landed into three main ports in Oregon, with small amounts landed elsewhere along the coast. By statute, all river mouths in Curry County, OR are closed to the take of any food fish for commercial purposes; therefore, no bay crabbing occurs there (ORS § 511.306). Currently, crab landings (as a percentage of total poundage) are highest in Waldport, followed by Charleston and Newport (Figure 26).

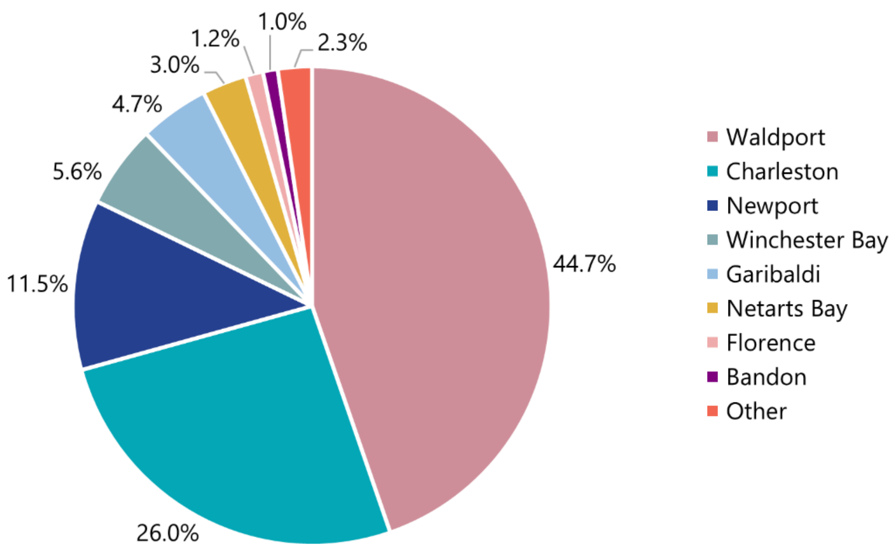


Figure 26. Percent of bay commercial Dungeness crab landings by port from 2001–2020. 'Other' ports are those that receive <1% of total crab landings or ports that are combined in order to meet confidentiality requirements including Astoria, Depoe Bay, Nehalem Bay, Pacific City, and Siletz Bay. Data are from ODFW fish tickets.

Recreational fishery

There is a long history of Dungeness crab harvest for personal use in Oregon, but no regulations were in place until around 1948 when sex and size limits were first proposed. Today, the recreational fishery includes several diverse user groups. Shore-based fishers harvest crab from piers, docks, beaches, and jetties, while boat-based fishers use private, guide, or charter vessels to harvest crab from both bays and the ocean.

Recreational users in both bays and the ocean are limited to three rings/pots/lines per person and may retain no more than 12 male crab with a minimum CW of 5 ¾". Recreational crabbing is open year-round in Oregon bays and from ocean beaches, while boat-based ocean recreational crabbing is closed from October 16 through November 30. Unlike with the commercial fishery, Columbia River recreational harvest is, by regulation, included in the bay fishery. Bay recreational harvesters are allowed to utilize holding devices or live boxes to hold up to two daily limits, while such devices are not permitted in the ocean.

From 2008 through 2017, the average boat-based recreational harvest of Dungeness crab from the ocean and bays in Oregon was estimated to be ~947,200 pounds of crab per year (approximately 5.7% of 25-year average for the ocean commercial sector). Of this, ~60% was harvested from bays and the Columbia River, and ~40% was harvested from the ocean.

In Oregon, boat-based recreational harvest from the ocean is estimated to be highest (as a percentage of total pounds) in Newport, followed by Garibaldi and Depoe Bay (Figure 27A). Recreational harvest from bays is highest in Charleston, followed by Newport and Waldport (Figure 27B).

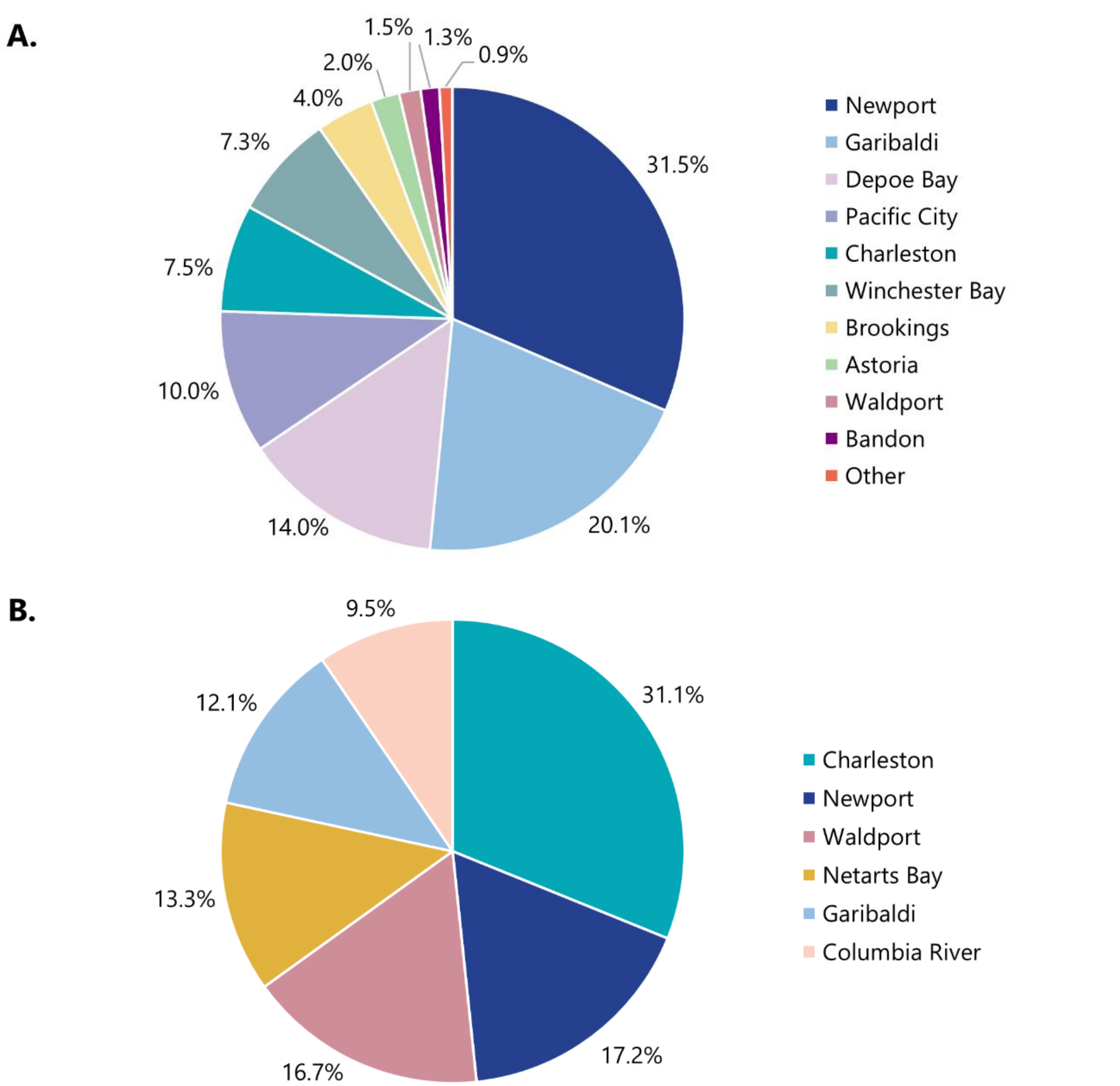


Figure 27. Estimated percent of boat-based recreational Dungeness crab harvest by port from (A) the ocean and (B) bays, from 2008–2017. Ocean data are provided by the Ocean Recreational Boat Survey. For ocean harvest, 'other' ports are those that receive <1% of total estimated harvest including Port Orford and Gold Beach. Bay data are provided by the Bay Crab and Lower Columbia River Surveys. The Lower Columbia River Survey has not been conducted since 2017. Crabbing does occur in other bays not sampled and land-based recreational harvest is not included (see *Section A.III.e*).

b. Entities involved in management

In the early years of the Dungeness crab fishery, fish and wildlife regulation in Oregon was accomplished through separate Fish and Game Commissions which were periodically reorganized to keep pace with increasing interests in game and game fish, and shifting priorities. In 1975, the separate State Wildlife Commission and State Fish Commission were integrated into a single Department of Fish and Wildlife overseen by a State Fish and Wildlife Commission (ODFW, 2010a). Today, the following entities have a legal role in the management of the Dungeness crab resource in Oregon.

Oregon Department of Fish and Wildlife

The Oregon Department of Fish and Wildlife (established under ORS § 496.080) is the executive branch of state government responsible for managing Oregon's fish and wildlife and their habitats. ODFW is authorized in statute by the state Legislature and in administrative rule by the OFWC, to administer the regulation and management of Oregon's commercial and recreational fisheries.

ODFW implements this authority for Oregon's Dungeness crab fishery through the Marine Resources Program within the agency's Fish Division. The MRP carries out state management actions through work focused on three main categories:

1) Marine resource management, policy, and regulation
2) Monitoring and sampling of marine fisheries
3) Research and assessment of marine fisheries, species, and habitats

MRP staff represent Oregon as members of numerous groups which coordinate interstate fishery management processes, such as the Pacific Fishery Management Council and the Pacific State Marine Fisheries Commission.

Oregon State Legislature

Statutes (i.e., ORSs) are created and passed by the Oregon Legislature. For the crab fishery, this includes regulations and requirements addressing fees, licensing, and limited entry in the commercial fishery sectors.

The Oregon Legislature also appropriates and allocates funding on a two-year (biennial) budget cycle to all state agencies, including ODFW. Legislative approval for ODFW's staffing and budget has generally been stable or growing since the late 1990s, including staffing and funding appropriated to the MRP.

Oregon Fish and Wildlife Commission

The Oregon Fish and Wildlife Commission (established under ORS 496.090) consists of seven governor-appointed commissioners who are charged with setting policies and developing general state programs that provide for the productive and sustainable utilization of fish and wildlife resources by all user groups. The OFWC establishes rules and regulations (OARs) related to recreational and commercial seasons, gear, and operations at monthly meetings which are open to the public.

Oregon State Police

The Oregon State Police play a key role in supporting ODFW's mission as the single entity tasked with enforcement of fish and wildlife regulations. Within the OSP Fish and Wildlife Division, seven troopers and a sergeant are assigned to a Marine Fisheries Team that is responsible for coastwide enforcement of commercial and recreational fishing regulations (ODFW, 2017). Dockside enforcement activities include offload monitoring, particularly during times of peak landings, for gear and fishery violations (e.g., sublegal-sized crab, logbook compliance, permits, closed areas). OSP also schedules and conducts hold inspections immediately prior to the start of each season (see *Section B.III.f*).

ODFW and OSP use cooperative enforcement planning as a tool to set enforcement priorities for each species. Personnel from each agency meet annually to discuss priority issues and objectives so that cooperative enforcement plans (CEPs) can be developed. This ensures that enforcement efforts are in line with ODFW's management priorities and goals (ODFW, 2017). OSP also works collaboratively with other enforcement entities (NOAA enforcement, the USCG, WDFW, and CDFW) through the PFMC process. While the Dungeness crab fishery is not a federally managed fishery, these efforts help to support broad coordination which benefits crab enforcement. Broad interagency agreements are also in place between OSP, CDFW, and WDFW to align state fish and wildlife enforcement, as necessary.

Tri-State Dungeness Crab Committee

Following the decision to not implement a federal fishery management plan for Dungeness crab, the state fishery agency directors for Washington, Oregon, and California signed a memorandum of understanding (MOU) in 1980 declaring their intent to take mutually supportive crab management actions (Fullerton *et al*., 1980). However, for the following decade, no formal forum for Tri-State management processes existed.

In 1989, the need for a formal Tri-State process was highlighted when an **ocean commercial** season opening crisis resulting from poor condition crab off the coasts of Washington and northern Oregon could not be reconciled between the two states. In response, the Tri-State Committee was formed in 1990 under the auspices of the PSMFC (LaRiviere and Barry, 1998).

The Tri-State Committee is comprised of crab industry members (i.e., fishers and processors) and state resource agency managers who hold meetings as needed, but most often annually, to provide a forum for resolving interstate issues among the three states (ODFW, 2014a). Industry members volunteer from the commercial fishing fleet and are appointed by ODFW to represent their port and Oregon at Tri-State Committee meetings. The committee provides recommendations to state managers and is facilitated by a representative from the PSMFC.

Based on recommendations of the Tri-State Committee, the Tri-State MOU was amended in 1993 to include provisions formalizing a preseason testing protocol (i.e., the 'Tri-State protocol') for determining crab condition (Didier, 2002; see *Section B.III.f*). While the early meetings of the

Tri-State Committee focused on season opening procedures, the group has since addressed a number of issues related to ocean commercial crab management. Examples include:

- Assessing support for limited entry legislation and advocating for limited entry programs in each state (see *Section B.III.g*); and
- Providing a forum for public involvement and discussion of fishery issues (e.g., biotoxin management, whale entanglement).

In implementing the MOU and protocol, Tri-State managers coordinate regularly during each pre-season testing process to discuss testing plans, meat recovery and biotoxin test results, and season openings through a series of coordination calls. Managers also frequently consult with industry during the pre-season process to inform season opening decisions.

Oregon Department of Agriculture

The Oregon Department of Agriculture (ODA) is responsible for protecting public health which includes managing the risk of marine biotoxins in recreationally and commercially harvested shellfish, including Dungeness crab. ODA's Food Safety Program routinely monitors levels of domoic acid and saxitoxin in the tissues of shellfish. Though both marine biotoxins are actively monitored, domoic acid is more readily accumulated by crab than saxitoxin. ODA oversees the collection of crab samples for domoic acid testing along the Oregon coast in accordance with the monitoring and response system described in OAR 603-025-0410. Results are used to inform recreational and commercial harvest restrictions for Dungeness crab (see *Section B.IV.b*).

Additionally, ODA is responsible for overseeing the operations of Oregon's 23 agricultural and commercial fisheries commodity commissions, including the ODCC (see below).

c. Other entities

The Dungeness crab fishery has always been managed by the state, but other entities have been and are currently involved in management processes.

Pacific States Marine Fisheries Commission

The Pacific States Marine Fisheries Commission (called the Pacific Marine Fisheries Commission or PMFC until 1989) is an interstate compact agency established by Congress in 1947 to promote the conservation, development, and management of fisheries, which are of mutual concern to their member states (i.e., California, Oregon, Washington, Idaho, and Alaska). The five member states are each represented by three Commissioners that work to support research and develop coordinated solutions that help resource managers and the fishing industry address issues related to fishery resources (PSMFC, 2010).

In the early 1970s, state and federal fisheries managers began focusing on improved mechanisms for cooperative research and management of shared fishery resources. To this end, the State-Federal Fisheries Management Program (SFFMP) was proposed and initiated on the West Coast in 1972 through small, administrative-support contracts between the National

Marine Fisheries Service and the Pacific [States] Marine Fisheries Commission. These contracts enabled the PSMFC to develop regional projects targeting fisheries that could benefit from cooperative action. The Dungeness crab fishery was selected for the SFFMP because it was subject to multiple jurisdictions which presented certain management challenges.

A two-phase work program was developed for the Dungeness Crab Project. Phase I (1972–1974) included literature review, activities to facilitate uniform data collection and management, review of sport fishery issues, comparison of economic implications of various season opening dates, and studies on female crab fertility, meat recovery, and escape ports. Phase II (1974–1976) involved an analysis of fishery effort and potential effort management options (PMFC, 1978).

By early 1976, the continuation of the SFFMP was uncertain due to the probable implications of the pending legislation that was to become the MSA. It was decided that the completed work would be consolidated into a useable form and an ad hoc committee would review and assess additional data needs to provide a basis for a federal fishery management plan required by the MSA. Completion reports from the conclusion of the project in 1977 serve as a source of historical fisheries and economic data for the West Coast Dungeness crab fishery.

In addition to this work, the PSMFC has been and is currently involved in several processes related to West Coast Dungeness crab fishery management. These include, but are not limited to:

- Maintaining landings and ex-vessel value information from fish tickets in the PacFIN database (see *Section A.III.a*);
- Facilitating the Tri-State Committee to promote coordination between Washington, Oregon, and California state fishery management agencies (see below); and
- Supporting research and facilitating coordinated solutions to fishery issues.

Oregon Dungeness Crab Commission

The ODCC is an industry-funded commission established by Oregon's Commodity Commission Act of 1977 (ORS § 576.051 to 576.455 and 576.991 (2)), that works on behalf of Oregon's **ocean and bay commercial** fishery sectors. The ODCC directs Dungeness crab marketing, but also plays an important role in scientific research, sustainability certification, education/outreach projects, and provides industry input on fishery-related regulatory and policy processes. Eight commissioners are appointed by the director of the Oregon Department of Agriculture so that a majority of members are harvesters, two members are processors, and one is a member of the public at large (OAR 645-030).

The ODCC is an important partner in several aspects of Dungeness crab management including research, advocacy, and information sharing. ODCC-supported research projects and programs have contributed to a better understanding of processes impacting the Dungeness crab resource. A number of these studies were critical to obtaining the five-year MSC certification of ocean commercial fishery in 2010 which was pursued by the ODCC (see *Section B.III.k*) and, more recently, to better understanding the potential for interactions between crab fishing gear and whales off Oregon (see *Section B.IV.a*). Examples include:

- Annual recruitment studies (see *Section A.II.e*)
- Fishery bioeconomic modeling (Davis *et al.*, 2017)
- Discard mortality assessment (Yochum *et al.*, 2017)
- Crab fishery and whale co-occurrence research (see *Section B.IV.a*)

The ODCC serves an important advocacy role working in partnership with management on issues impacting the industry. For example, the ODCC was an active supporter of Oregon legislation (House Bill 3262) that was instrumental in the development of Oregon's post-season derelict gear recovery program (see *Section B.III.i*). Furthermore, the ODCC acts as a conduit of information between resource managers and the commercial crab fishing fleet.

The ODCC also serves as a member of the Oregon Dungeness Crab Advisory Committee (ODCAC) and partners with ODFW and ODA to carry out the preseason testing program.

Oregon Dungeness Crab Advisory Committee

The Oregon Dungeness Crab Advisory Committee was formed by ODFW staff in 2001 (as the Oregon Dungeness Crab Fishermen Advisory Committee) to serve as a standing advisory council to ODFW managers on all relevant **ocean commercial** crab policy issues (ODFW, 2001). Committee membership aims to represent the diversity of the ocean commercial industry (i.e., various business plans including vessel size, class, pot tier, port of residence, etc.). Meetings are open to the public.

Since its inception, ODCAC input has been instrumental in a number of management issues including pot limit implementation, Tri-State coordination, and enforcement concerns (ODFW, 2007b), as well as season opening decisions. Over time, the ODCAC has addressed a range of topics that are of importance to industry and resource managers. In October 2019, this group was augmented to include members of the ODCC, crab associations, and industry members from the Oregon Whale Entanglement Working Group to further advise ODFW on regulatory proposals to mitigate whale entanglements in crab gear (see *Section B.IV.a*).

Sport Fishing Advisory Committee

ODFW also maintains the Sport Fishing Advisory Committee (SAC) comprised of private boat sport fishers and charter operators that serve as an advisory council to ODFW managers on policy issues that impact ocean and bay recreational fishers. Traditionally, this group has primarily engaged on fish (e.g., groundfish, albacore, halibut) management issues, but has been consulted several times on issues impacting recreational crab harvesters. For example, this group was consulted during development of gear marking regulations in the recreational fishery to improve accountability and identification of fishing gear involved in any future whale entanglements (see *Section B.IV.a*). In the future, SAC is likely to serve as a forum for soliciting input on any potential gear requirements in the recreational fishery.

Research institutions

ODFW partners with a variety of researchers and natural resource professionals from different institutions to expand research and monitoring efforts that are critical to informing effective management of Oregon's fishery resources. A recent example is the partnership between Oregon State University's Marine Mammal Institute, ODFW, the ODCC, the USCG, and the Oregon Whale Entanglement Working Group to conduct whale distribution surveys and develop predictive models to fill key information gaps needed to address whale entanglements.

Industry associations

There are a number of industry associations that serve as supporters or advocates for the interests of fishers, processors, and other parties connected to the Dungeness crab fishery. These associations may become involved in specific issues that affect them and ODFW engages with them on those issues. Examples include the Newport Fishermen's Wives, the Columbia River Crab Fishermen's Association (CRCFA), the West Coast Seafood Processors Association (WCSPA), Fishermen Involved in Natural Energy (FINE), and a number of port marketing associations.

d. 3-S management structure

The West Coast Dungeness crab fishery is managed using a 3-S management strategy combined with a series of gear requirements and effort controls. Size, sex, and season regulations are generally consistent across states and have remained largely unchanged since the 1960s. Current size and season regulations for commercial and recreational fisheries throughout the range of Dungeness crab are included in Table 4. Female crab may not be retained in any fishery, except for the recreational fishery in California.

Table 4. Recreational and commercial size and season regulations throughout the range of Dungeness crab. Female crab may not be retained in any fishery, except for the California recreational fishery.

	Location	Legal size[a]	Season
Commercial	Alaska	**5 AAC 32.055** 6 ½″	Variable by registration area
	British Columbia	**SOR/93-54** 6 ½″	Variable
	Puget Sound	**WAC 220-340-420** 6 ¼″	**WAC 220-340-455** Oct 1 – Apr 15
	Coastal Washington	**WAC 220-340-420** 6 ¼″	**WAC 220-340-450** Dec 1 – Sept 15
	Oregon (ocean & Columbia River)	**OAR 635-005-0495** 6 ¼″	**OAR 635-005-0465** Dec 1 – Aug 14
	Oregon (bays except Columbia River)	**OAR 635-005-0515** 6 ¼″	**OAR 635-005-0505** Day after Labor Day – Dec 31 (ends Nov 30 if adjacent ocean area remains closed; excludes weekends and holidays)
	California	**FGC § 8278** 6 ¼″[b]	**FGC § 8276** Dec 1 – July 15 in Del Norte, Humboldt, and Mendocino counties; Nov 15 – June 30 all other counties
Recreational	Alaska	**5 AAC 77.662** 6 ½″	**5 AAC 77.662** Year round
	British Columbia	**SOR/96-137** 6 ½″	**SOR/96-137** Year round
	Puget Sound	**WAC 220-330-050** 6 ¼″	**WAC 220-330-040** Variable by Marine Area
	Coastal Washington	**WAC 220-330-050** 6″	**WAC 220-330-040** Dec 1 – Sept 15 for pot gear in Grays Harbor, and Marine Areas 1-3 and 4; Nov 15 – Sept 15 for pot gear in Willapa Bay; Year round for other gear
	Washington (Columbia River)	**WAC 220-330-050** 5 ¾″	**WAC 220-330-040** Year round
	Oregon	**OAR 635-039-0080** 5 ¾″	**OAR 635-039-0080** Year round in bays, beaches, estuaries, tide pools, piers, and jetties; Dec 1 – Oct 15 in ocean
	California	**14 CCR § 29.85** 5 ¾″	**14 CCR § 29.85** First Saturday in Nov – July 30 in Del Norte, Humboldt, and Mendocino counties; First Saturday in Nov – June 30 all other counties

[a]Shortest distance through the body from edges of shell directly in front of points (lateral spines)
[b]One percent in number of any load/lot of crab may be <6 ¼″ in breadth but not <5 ¾″ in breadth

Size regulations

Minimum size limits are intended to allow male crab to reach sexual maturity and reproduce for one or two seasons before becoming vulnerable to harvest (PFMC, 1979).

Minimum size regulations were first introduced in California in 1903 (Didier, 2002), followed closely by Washington. In 1907, the master fish warden for Oregon urged the state Legislative Assembly to adopt a law similar to that passed two years earlier by the Washington state Legislature prohibiting the take of crab less than six inches across the back (State of Oregon, 1908). From 1909 to 1933, a 6 ½″ minimum size limit was applied to commercially sold crab. This size limit was measured across the back of the crab until 1925 when point-to-point measurement was specified. From 1933 to 1948, the commercial size limit was set at 6″ (Waldron, 1958). At this time, no regulations were in place limiting the harvest of crab for personal use; however, it was recognized that the take of small crab was potentially wasting food (OFC, 1948a).

In 1948, a distinction between size limits in bays and the ocean was made based on the belief (which is no longer considered valid) that bay crab constituted a smaller, separate population than ocean crab (ODFW, 1977a). The commercial and sport size limit for crab taken from bays or estuaries (except for the Columbia River) was set as 6″ across the points, while the limit for those taken from the ocean and Columbia River was changed to 6 ¼″ shoulder-to-shoulder (i.e., across the back, immediately in front of the lateral points). At the same time, a daily bag limit of two dozen crab per person (without a commercial license) was recommended in order to better enforce commercial fishing license requirements (OFC, 1948a). In 1949, the requirement for crab from bays and estuaries (commercial and recreational) was set as 5 ¾″ shoulder-to-shoulder (Waldron, 1958) in order to standardize methods of measurement in the bays and ocean (OFC, 1949).

In the mid-1960s, California, Oregon, and Washington also standardized methods (Didier, 2002) as the shortest distance (caliper measurement) across the back from shell edge to shell edge directly in front of the tenth anterolateral spines. Around 1964, the bay commercial size limit was increased to 6 ¼″ (ODFW, 1984a), while the recreational size limit was kept at 5 ¾″. Since this time, options for changing minimum size limits have been presented several times (e.g., PFMC, 1979) but regulations have remained unchanged. The present difference in size limits for recreational and commercial crab harvest is maintained to ensure that recreational users have distinct access to harvest (ODFW, 1977a; see *Considerations for implementing objectives* in *Section B.I.b*.).

Timeline of size regulations

1909 – 6 ½″ commercial size limit (across the back) adopted

1925 – Point-to-point measurement specified for both sexes

1933 – 6″ commercial size limit

1948 – 6″ (point-to-point) commercial and sport size limits for bay crab (except Columbia River); 6 ¼″ size limit (shoulder-to-shoulder) for ocean and Columbia River crab

1949 – 5 ¾″ commercial and sport size limit (shoulder-to-shoulder) for bay crab adopted in order to standardize bay and ocean methods of measurement

mid-1960s – California, Oregon, and Washington standardized methods of measurement as the shortest distance (caliper measurement) across the back from shell edge to shell edge, directly in front of the tenth anterolateral spines

~1964 – 6 ¼″ bay commercial size limit; recreational limit kept at 5 ¾″

Sex regulations

In 1897, the first legislation protecting Dungeness crab was enacted in California in response to concerns over declines in the supply of crab in San Francisco Bay. The law prohibited the take and sale of female crab in an attempt to minimize impacts to the reproductive capacity of the stock (Dahlstrom and Wild, 1983). A similar regulation prohibiting female harvest was passed in Washington in 1927 (Didier, 2002) and in Oregon in 1948, though many fishers already voluntarily released females (Waldron, 1958).

In the mid-1970s, the State-Federal Fisheries Management Program conducted a literature review to consider the advisability of harvesting female crab. There was a belief at this time that most females over 6 ¼″ (the legal size limit for males) may be barren and, therefore, represent a latent resource which could contribute to the fishery without affecting reproductive output. They found that this was not true and that most female crab over 6 ¼″ are not barren. It was also determined that meat recovery from females is substantially lower than from males and that most processors and fishers were opposed to harvesting females. Given these findings, the SFFMP recommended that female crab not be harvested at that time and that routine sampling incorporate information on female egg bearing (PMFC, 1978).

Though the commercial industry remained opposed to female harvest, recreational harvesters expressed a desire to do so in the late 1980s (ODFW, 1991a). The OFWC adopted rule changes in 1991 allowing female crab to be harvested recreationally in coastal bays and estuaries, except for the Columbia River. The intent of the rule was to provide additional opportunities in the crowded bay fishery, while keeping the ocean fishery limited to male harvest only. However, confusion existed over the interpretation of this rule. At a meeting of the OFWC in 1993, ODFW staff sought rule changes to clarify the intent of the original regulation. Meanwhile, several members of the public also testified in support of returning to the original restriction on female harvest. In response to public opinion, the OFWC voted to rescind the recreational take of female crab (ODFW, 1993).

Timeline of sex regulations

1948 – Harvest of female crab prohibited

1991 – Recreational harvest of female crab allowed in bays and estuaries, except for the Columbia River

1993 – Recreational harvest of female crab prohibited

Season regulations (ocean commercial)

Ocean commercial crab seasons are set to provide some measure of protection during the time of year when molting typically takes place. Softshell crab are more vulnerable to the impacts of handling, so injury and mortality is reduced by restricting harvest of poor condition crab. Additionally, a higher meat recovery is provided by crab that are in a hardshell condition (PFMC, 1979).

At the request of several fishermen, the first seasonal closure to avoid catching softshell crab was established in California in 1903 (Dahlstrom and Wild, 1983). In 1927, a summer closure was enacted in Washington, and later revised in 1943 to account for different softshell periods in the Puget Sound and coastal fisheries (LaRiviere and Barry, 1998). In Oregon, a 1911 regulation made it unlawful to take crab from July through September, for the purposes of canning or shipping out of the county of harvest.

In 1948, this restriction was replaced by a closed season to reduce harvest of crab in poor condition and increase annual meat recovery. From July through September, the Fish Commission conducted sampling to determine the number and location of all pots, and the proportion of legal-sized males found in softshell condition. This local information was then expanded to determine a percentage of softshell, legal-sized male crab in the area north and south of Cascade Head (OFC, 1948b), with the closed season occurring when 10% or more of the legal-sized males were softshelled (Waldron, 1958). This method was used to determine the closing and opening of the 1947-48 and 1948-49 seasons, respectively. However, the uncertain season start date brought complaints from industry members who felt it was difficult to know when to prepare for the opening. Additionally, the sampling program was costly, time-intensive, and subject to inclement weather. In the same year, this system was replaced by a fixed closed season with dates based on these sampling efforts. To account for latitudinal variation in the timing of molting, the closed season north of Cascade Head (Area I) was set as September 15 to December 15, while the closed area south of Cascade Head (Area II) was set as August 15 to November 15 (Snow, 1962).

Until 1962, the closed seasons remained unchanged. Biologists were unable to establish any seasonal molting patterns in the estuaries south of the Columbia River and it was assumed that the same was true for the Columbia River. Therefore, seasonal regulations were not adopted for Oregon estuaries. However, a series of crab condition and tagging studies in 1957 and 1958 indicated a similar softshell period and substantial movement between the Columbia River and the ocean (Snow, 1962). Consequently, a closed season was adopted for the Columbia River corresponding to the ocean season (OFC, 1962).

In 1960, Oregon fishery records were used to examine the incidence of softshell crab landed early in the season during certain years. Researchers concluded that a later opening date would be unlikely to reduce the total crab harvest, but that a higher proportion of the landed catch would be in prime condition (Snow, 1960). Season opening dates were changed, beginning with the 1961-62 season, from December 15 to January 1 for Area I and from November 15 to December 1 for Area II. However, a portion of the crab industry felt that different opening dates for the two areas were not warranted based on crab condition (Snow, 1962).

The determination of open seasons has been a topic of debate since the early days of the fishery due largely to the spatial and temporal variation in molting patterns, fluctuations in harvest, and socioeconomic considerations. A coastwide season opening December 1 and closing no later than August 15 was first recommended in 1963, along with a call for additional studies of crab condition (Snow, 1963). Since this time, the season opening date has remained unchanged, though provisions have been added to delay opening when crab condition is poor (see *Section B.III.f*). The regulatory season closure date remained in August through 1977; however, extensions of up to 30 days were enacted five times at the request of industry. In 1978, the season was changed by rule to extend through September 15 (ODFW, 1982a). Following several years of high fishing effort on poor condition crab at the end of the season, the closure date was moved back to August 15 in 1984 and has remained unchanged since (i.e., fishing is allowed through August 14) (ODFW, 2000a).

The season opening process is further described in *Section B.III.f*, and summer fishing and the season closure is further described in *Section B.III.h*. A complete record of ocean commercial season opening dates, closures, and delays are included in Appendix A.

Timeline of ocean commercial season regulations

The timeline below includes regulatory changes in crab season structure, but does not include temporary season extensions, weather, or industry delays which are detailed in Appendix A.

1911 – Unlawful to take crab out of county for canning or shipping from July through September

1948 – Closed season established for areas north and south of Cascade Head based on annual crab condition sampling by the Fish Commission

1949 – Fixed closed season established as September 15 to December 15 for Area I (north of Cascade Head) and August 15 to November 15 for Area II (south of Cascade Head)

1958 – Closed season adopted for the Columbia River corresponding to ocean season

1961 – Season opening dates changed from December 15 to January 1 for Area 1 and from November 15 to December 1 for Area II to harvest crab in prime condition

1963 – Coastwide season established opening December 1 and closing August 15

1978 – Season changed to December 1 through September 15

1984 – Season closing date moved back to August 15 to limit fishing on poor condition crab

1993 – Tri-State MOU amended to include Tri-State protocol for preseason testing and determination of season opening delays when necessary (see *Section B.III.f* for full description including subsequent revisions to the Tri-State protocol)

Season regulations (bay commercial)

While size and sex regulations on commercial crabbing in bays were implemented in the late 1940s, the season remained open all year through the mid-1980s. At this time, growing conflicts between recreational and bay commercial crabbers led the OFWC to adopt a regulation prohibiting commercial crabbing in bays on weekends and holidays, along with a restriction of 15 rings per vessel. Over the next few years, tensions between the user groups remained high and so, in 1987, the OFWC adopted a bay commercial season open from the day after Labor Day through the end of December (ODFW, 1991b). Additionally, the bay commercial season now closes on November 31 if the season in the adjacent ocean area remains is delayed, and re-opens when the adjacent ocean area opens, if that occurs before December 31. This ensures that all commercial fishing remains closed during the lead up to ocean commercial season opener, to reduce potential avenues for poached crab to be sold.

Season regulations (recreational)

Season regulations are different for the recreational fishery operating in Oregon bays and from ocean beaches, and for boat-based ocean crabbing. Bay and beach recreational crabbing is open year-round for 24 hours per day. In the 1940s, a closed ocean season was established which presumably applied to boat-based harvest of crab from the ocean for sport use as well. The boat-based ocean recreational season continued to mirror the ocean commercial season through 2008. The seasonal closure ensures an orderly and easily enforceable period with no crab gear in the ocean prior to the start of the commercial season. In 2009, a regulation was passed extending the boat-based ocean recreational season end date from August 15 through October 15 as a compromise lobbied by recreational harvesters for longer access to high quality ocean crab (ODFW, 2009a). This continues today with boat-based recreational harvest allowed in the ocean from December 1 through October 15 (ODFW, 2021b).

The recreational fishery is not subject to season opening delays for low meat yield. Instead, a consistent season opening date simplifies enforcement and maintains access to recreational crabbing opportunities, while harvesters individually decide whether meat yield is acceptable for their own purposes.

e. Crab fishing gear

Historical gear design

Several types of gear have been used throughout the history of the West Coast Dungeness crab fishery to harvest crab recreationally or for the commercial market.

Historically, long-tined crab rakes have been used to uncover crab buried in sand in shallow waters and the intertidal zone contributing to small commercial harvests in some areas (Waldron, 1958). Today, rakes are only occasionally used by recreational crabbers.

Crab rings (also called hoops or hoop nets) have been used throughout the history of the Dungeness crab fishery and remain an important gear type today. Crab rings consist of two round metal hoops connected by webbing to form a basket with bait attached inside. The basket is lowered into the water where it collapses on the sea floor allowing crab unrestricted entry and exit. At intervals, the ring is rapidly raised to form a basket trapping crab inside (Phillips, 1935; Waldron, 1958).

The use of commercial crab rings was widespread in the early years of the ocean and bay fisheries. At the end of the 19th century, around 90% of the crab harvested in San Francisco County were taken with rings, while the remainder was caught in trammel nets (Wilcox, 1902). While rings remained the primary gear type in California at this time, reports from several counties in Washington described the use of early rectangular crab pots which were similar to New England lobster pots, baited with clams and refuse fish and anchored in around 3 fathoms of water (Wilcox, 1902). Early pots had a wooden or iron frame enclosed with cotton mesh or wooden slats. Sizes ranged from 3 to 4 feet long, 15 to 20 inches wide, and 14 to 20 inches tall, with a funnel at each end (Radcliffe, 1919).

By the mid-1930s, rings were largely replaced by pots for offshore crabbing in Oregon, though still used exclusively within bays. Waldron (1958) described the commercial crab pots of the time as cylindrical containers constructed of iron or stainless steel rod covered with stainless steel mesh. By this time, most pots also included ports or holes introduced by fishers that were designed to allow undersized crab to escape. Escape ports have been required since at least the mid-1970s for commercial crab pots in Oregon (ODFW, 1978) to reduce handling mortality of females and sublegal males, minimize injury from density-dependent interactions (e.g., fighting, cannibalism), enable sublegal crab to escape from lost pots, and decrease sorting time for fishers (PFMC, 1979).

In the early 1960s, polypropylene and polyethylene lines began to be used as a durable and lightweight replacement for manila rope buoy lines. At the same time, early cedar, cork, or copper floats began to be replaced by buoys made from lightweight alternatives such as Styrofoam and spongex (Dahlstrom and Wild, 1983). The transition to gear made from synthetic materials has allowed for improved durability and handling, but has also contributed to the impacts of ghost fishing as these materials are able to persist in the environment substantially longer than natural alternatives.

Current gear design and configuration

Today, rings are the only gear allowed in the bay commercial fishery (OAR 635-005-0510), while both crab rings and pots may be used to harvest crab in the ocean commercial fishery (OAR 635-005-0475). Recreational crabbers may harvest crab using pots, rings, or baited lines (limited to 3 pieces of gear per person), or by hand, dip net, or rake (ODFW, 2021b).

Gear specifications for the **ocean commercial** Dungeness crab fishery are found in OAR 635-005-0475. Commercial crab pots are limited to a volume of 13 cubic feet calculated by the external dimensions of the pot. This volume limitation helps to maintain safety and support fleet equity by ensuring a maximum crab pot size that can be safely handled and transported, by different vessel classes. Pots must be equipped with at least two 4 ¼ inch (inside diameter) escape ports on the top or side (upper half only) of the pot, in addition to a release mechanism (Figure 28).

Modern ocean commercial crab pots are designed to be practical, effective, and highly selective, while minimizing impacts to crab, habitat, and other species (Figure 28). Most crab pots are cylindrical and constructed with welded steel frames wrapped with rubber to insulate from seawater corrosion and minimize handling difficulty. Frames are covered with stainless steel mesh and include tunnels on opposite sides that allow crab one-way entry. Pots are attached to a single nylon line typically with two surface buoys marked with a color pattern for distinguishing between pots from other vessels (Goblirsch and Theberge, 2008). A hinged lid allows crab to be easily taken from the pot and is secured with a rubber strap and metal hook.

Series of commercial pots, referred to as strings, are individually deployed in the ocean with a line attaching the pot to a surface buoy. It is currently unlawful to connect pots to each other by a common ground line, referred to as "longlined pots" (see below). Generally, strings are deployed along a bathymetric contour and left to soak for one to 14 days (ODFW, 2014b), though logbook data indicate variable soak times depending on location, season, and weather conditions. After this time, pots are typically emptied and redeployed in the same or a different location. In most cases, this process is repeated for the duration of that vessel's season, at which time the pots are 'stacked out' (i.e., removed from the water) over several trips.

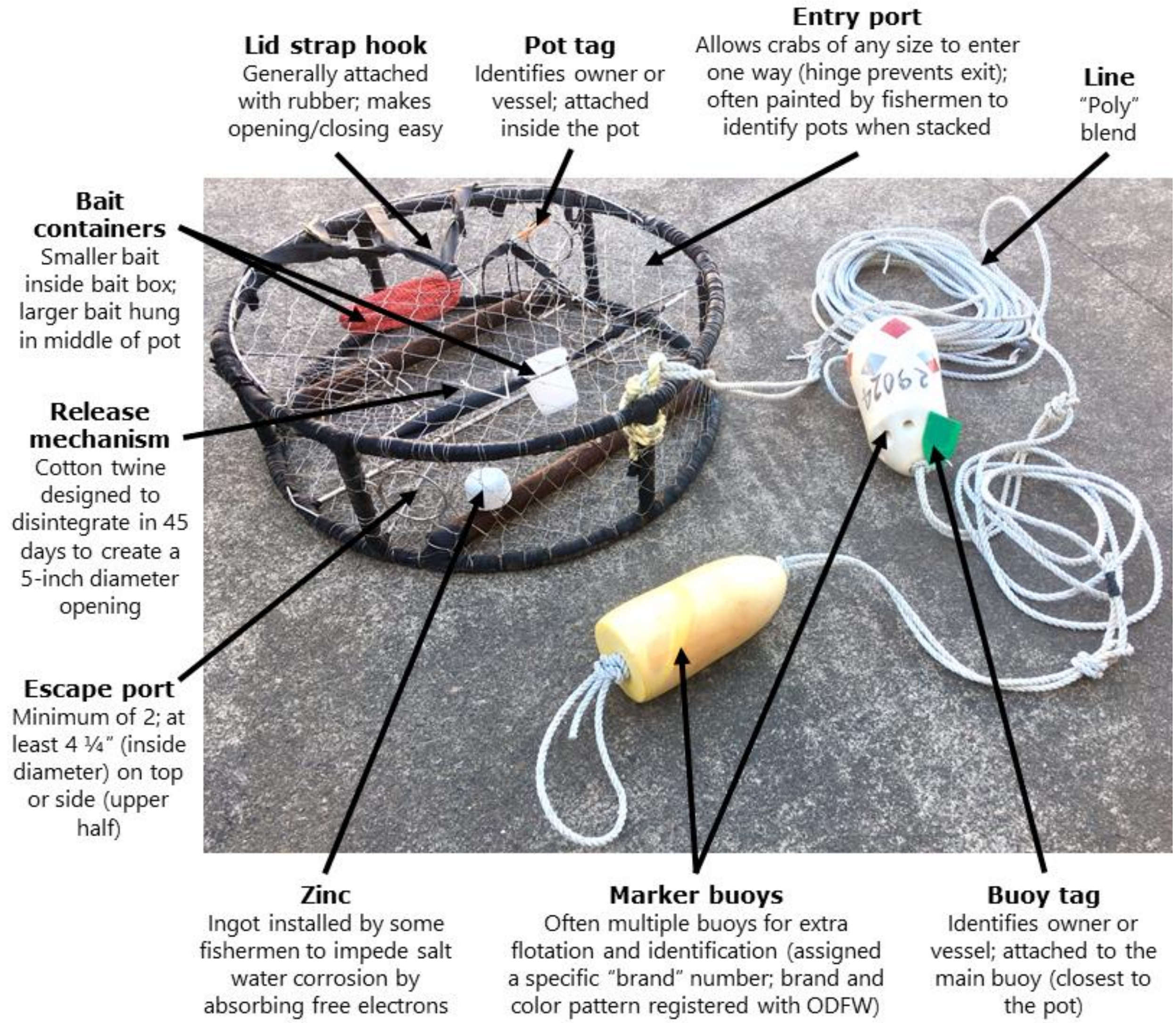


Figure 28. Anatomy of a modern ocean commercial crab pot.

Crab rings, which may be used in all three sectors, and are the only gear permitted to be used in the **bay commercial** fishery, are defined as any fishing device used to take crab that allows crab unrestricted entry or exit while fishing, and has a line attached to surface floats (OAR 635-005-0240). This limitation serves to minimize conflicts between bay commercial and recreational fishers over access to Dungeness crab (see *Bay commercial fishery* description in *Section B.III.g*). Typical soak times for crab rings used in the bay commercial fishery range from 30 to 60 minutes, but can be longer depending on the capacity of the crabber and vessel.

Boat-based **recreational** crabbers fishing in bays or estuaries commonly soak crab rings for 10 to 45 minutes, or crab pots for 30 to 90 minutes. Recreational ocean crabbers or charters can soak pots for longer durations, anywhere from one to 24 hours or more. Soak times are highly variable and depend on the number of people, experience, boat capabilities, weather conditions, and other factors. Soak times for recreational pots can also increase when paired with other fishing activities in both bays and the ocean (ODFW Shellfish Program staff, personal communication). Rings and pots fished recreationally from docks, piers, or beaches are often deployed for shorter time periods and can include small crab traps that are deployed by line or fishing pole which are commonly checked every five to 15 minutes. Additionally, a very small proportion of crabbers harvest crab by hand, raking on beaches and intertidal flats, and by SCUBA or free-diving.

Gear marking

To aid in enforcement, ODFW staff considered options in 1984 for a uniform crab pot buoy marking method that was compatible with existing requirements in Washington. Several methods were already in use at this time and industry members were generally supportive of a uniform marking system, given that it was simple and low cost. Enforcement personnel favored a simple numbering system, as opposed to colors or designs which become faded and are difficult to differentiate (ODFW, 1984b). That year, the Oregon Fish and Wildlife Commission adopted a regulation requiring a brand number on all crab buoys after November 25, 1985. Approximately 500 numbers were registered by the end of 1985 (ODFW, 1986a).

Current buoy tag and gear marking requirements for the **ocean commercial** fishery are found in ORS § 509.415 and OAR 635-005-0480. Crab rings or pots used to commercially harvest crab are required to have a tag identifying the owner or vessel from which the gear is operated. Additionally, a buoy tag must be attached to the main buoy (closest to the pot) identifying the owner or vessel from which they are operated (Figure 29). Buoys must be clearly marked with a specific brand number and color pattern registered with ODFW. Replacement buoy tags, which are easily distinguishable by color from primary tags, may be issued for tags lost due to catastrophic loss (as defined in ORS 635-005-0240) or due to an extraordinary event (requirements defined in OAR 635-005-0480).

Prior to 2020, a standard replacement tag allowance permitted replacement tags to be issued for lost tags as of the first business day after 30 days following the season opening and up to 10% of the permit holder's pot limit. This standard allowance was eliminated beginning with the 2020-21 ocean commercial crab season as a conservation measure for the reducing the risk of marine life entanglements (ODFW, 2020b; see *Section B.IV.a*).

Also related to the issue of marine life entanglements, crabbers that fish after May 1 during the 2020-21, 2021-22, and 2022-23 crab seasons are required to affix an additional late-season tag to each pot, along with the primary season tag which is already required. This late-season tag is part of a series of measures adopted by the OFWC in September 2020 to reduce entanglement risk during the late-season when humpback whales and other protected species are present in higher abundance off Oregon. The tag itself serves multiple purposes related to enforcement and accountability. These rules include a three-year sunset date after which ODFW will evaluate the effectiveness of the measures and provide recommendations to the OFWC to modify or extend them.

New ocean commercial fishery management measures: Through this FMP, ODFW recommended and the OFWC adopted a rule amendment in October 2021 extending the late-season tag attachment window to allow late-season tags to be attached up to three weeks before May 1. Prior to this amendment, late-season tags were allowed to be attached up to two weeks before May 1 with all tags required to be attached by May 1. A limited attachment window provides important information on the timing of any future entanglements; however, the additional week provides more flexibility for crabbers to choose when, and under what conditions, they attach late-season tags. Also, ODFW recommended and the OFWC adopted a rule amendment in October 2021 explicitly prohibiting landing of crab after May 1 by vessels that do not purchase late-season tags. In practice, this was already illegal because gear used to take crab after May 1 was illegal without late-season tags attached; however, the amendment provides a more direct and explicit prohibition to ease enforcement of the new tag requirements.

Figure 29. Example ODFW-issued primary season buoy tag, late-season buoy tag, and replacement tag for vessels participating in the ocean commercial fishery. All tags are double-sided with replicate information on both sides. The valid permit year will be specified on late-season buoy tags beginning with the 2021-22 season, but is not pictured here.

Gear marking requirements for the **bay commercial** fishery are found in OAR 635-005-0510. Since 1998, crab rings fished commercially in Oregon bays and estuaries have required a tag identifying the vessel from which they are operated (ODFW, 1998a). Effective January 1, 2020, each crab ring must also have a surface buoy visibly labeled with the vessel's federal documentation number or state registration number (ODFW, 2019a).

Also effective January 1, 2020, surface buoys used to mark pots or rings used by **recreational** crabbers must be visibly marked with identifying information including the owner's name or business name and at least one of the following: permanent address, phone, number, angler ID, federal vessel documentation number or state vessel registration number (OAR 635-039-0090; (ODFW, 2019a).

Release mechanisms

Release mechanisms or "rotten cotton" (previously called "destruct devices") refer to degradable materials incorporated into the lid or stainless steel mesh of a crab pot to allow for the escape of legal-sized crab and other fish or shellfish species from lost or derelict fishing gear once the material degrades. Release mechanisms were first considered for the Oregon commercial Dungeness crab fishery in the 1970s, but a requirement for such a device was not initially supported due to limited information on the extent of crab mortality from lost pots (PFMC, 1979). In 1982, due to rising concern about an increase in number of vessels and pots, the ODCC asked ODFW to consider and test release mechanism options (ODFW, 1982b).

Release mechanisms were required in the **ocean commercial** fishery beginning in 1983 (Demory, 1984). Several rule modifications to clarify intent and remove ambiguity (e.g., ODFW, 2010b) have led to the current requirements regarding acceptable release mechanisms as defined in OAR 635-005-0475.

Release mechanisms are not necessary for crab rings, as the basket stays in a collapsed position unless it is being actively fished. Release mechanisms are also not required for crab pots fished in the recreational fishery, where other crab species (e.g., red rock crab, Pacific rock crab) may be present and are able to be retained.

Vessels

Early on in the commercial fishery, skiffs and small boats were commonly used to catch crab in the bays and nearshore waters. As the fishery expanded and moved further offshore, vessel size increased and the fleet transitioned toward small gasoline boats (Wilcox, 1902). Concurrently, advances in technology led to the widespread use of a demountable davit arm and power-driven gurdy to haul nets and pots (Phillips, 1935).

From 1909 to 1933, commercial fishers in Oregon were subject to daily and/or weekly catch limits. In 1933, the repeal of the law limiting fishers to 60 dozen crab per week likely contributed to the rapid increase in crab landings which followed, as the opportunity for greater production incentivized a transition toward larger boats and improved gear (Waldron, 1958). Around 1937, Newport commercial fishers initiated the practice of retaining crab in a watertight compartment regularly circulated with seawater in the vessel's hold. A decade later, fishers began replacing this compartment with a removable steel tank that could be raised or lowered to more easily remove crab during offloading (Waldron, 1958). These advancements allowed crab to be held for longer periods of time (up to 3 or 4 days) and in better condition.

Over time, a series of innovations led to increased efficiency within the ocean commercial fishery. Navigational capabilities were improved as boats were equipped fathometers, radio direction finders, and LORAN (i.e., long range navigation) (Waldron, 1958). The introduction of the hydraulic power block in the early 1960s provided a method for pulling heavier gear and a larger number of pots (Dahlstrom and Wild, 1983). The emergence of deck lights provided many vessels the opportunity to conduct 24-hour-a-day crabbing operations and land more crab during individual trips (Demory, 1990).

By the late 1970s, the typical **ocean commercial** crab boat was a wood-hulled, diesel-powered vessel equipped with a power block, ranging in length from 28 to 85 feet, though steel or fiberglass vessels up to 70 feet were in operation (PFMC, 1979). Larger vessels with better equipment allowed for improved mobility and the ability to search out the best harvest opportunities instead of relying only on local crab stocks (LaRiviere and Barry, 1998). Today, ocean commercial vessels range from small boats that fish for several hours and hold less than 1,000 lbs of crab, to those that spend two weeks at sea and return with 150,000 lbs.

The size and efficiency of vessels used in the **bay commercial** fishery vary widely depending on the scale of the operation and the fishing location, but most are equipped with a crab block (hydraulic, gas-powered, or manual) to pull rings.

Boats used in the **recreational** fishery vary widely in terms of size, equipment, and seaworthiness. It is common for crab to be caught from kayaks, canoes, small skiffs, and vessels up to 25 feet that passively fish crab while targeting other fisheries. A smaller number of private vessels and many guide or charter vessels are over 25 feet in length. Some recreational vessels have a manual or power crab block, while others do not. Ocean-going boats often have a fish hold, whereas fewer boats crabbing in bays and estuaries possess holds (ODFW Shellfish Program staff, personal communication).

Longlining

The use of a longline crab pot system in the **ocean commercial** fishery was investigated in the early 1970s and found to offer economic advantages and opportunities for improved efficiency in certain circumstances (Fisher, 1972). The longline configuration involves stringing pots together in lines marked at each end by a surface buoy. This system offers practical advantages in areas of heavy vessel traffic where buoy cutoff is a concern, and in deeper waters where longlining provides for expedited pot retrieval and setting (ODFW, 1994).

The Tri-State Committee reported in 1991 that longlining of pots appeared to be increasing and contributing to conflicts with other gear users (e.g., single pot, trawl gear). Options for addressing the issue were discussed but no consensus was reached (ODFW, 1991b). In 1994, concerns over overcapitalization and incidence of gear conflict prompted action by the Oregon Fish and Wildlife Commission to clarify the rules for this type of gear (ODFW, 1994). Initial rules were adopted which designated longlining gear as legal but subject to several limitations (i.e., marking requirement, only permitted outside of 40 fathoms, and prohibited in November) (ODFW, 1996). Additionally, a rule was adopted (and later modified to clarify intent) which prohibited longlining entirely after August 15, 1997 (ODFW, 1997a). This was reinforced in 2006 by the adoption of pot limitation rules (see *Section B.III.g*) which included language that prevents the attachment of one crab pot to another by a common groundline or any other means (OAR 635-005-0485) and requires that each pot be marked by an individual buoy (OAR 635-005-0480).

This prohibition on longlining supports enforcement of pot limits, eliminates the potential for derelict longline strings of crab gear, and makes it easier for crab and other fishers to determine the location of gear and reduce conflicts over gear setting. However, some form of a modified longline has been brought up as a potential technique for reducing interactions between whales and vertical fishing lines (see *Section B.VIII.a*). This remains a topic of discussion and a measure under long-term consideration within the crab fishery

Helicopter crabbing

Helicopters were used briefly in the **ocean commercial** fishery in 1977 and 1978 to pull oversized crab pots in the Dungeness crab fishery off the southern Oregon coast. Pots retrieved by helicopters were typically six feet in diameter with four escape ports, though some were up to nine feet with an open center where bait was suspended. Helicopter pots were set in around five fathoms of water, retrieved with a six-foot grappling hook on a 25-foot line, and then flown to a landing site within around one mile of the pot line. Sorting at sea was not possible, so female and sublegal crab were sorted ashore and then flown back to the fishing grounds in a dump container. Helicopters traveled up to 60 mph at a height of 20 feet or more causing some concern about wind stress, drying out, and the death of undersized crab that fall out en route (Demory, 1978; PFMC, 1979).

In 1977, ODFW staff reported on observations of helicopter crabbing and recommended that the practice was no more damaging to the resource than normal boat fishery operations (ODFW, 1977b, 1977c). However, helicopter operations ceased in 1978 due to economic considerations and safety concerns following several accidents (Demory, 1978).

f. Season opening (ocean commercial fishery)

A number of processes take place prior to the start of the ocean commercial Dungeness crab season to ensure that a safe, quality product is available to consumers and that fishers have orderly, equitable access to the Dungeness crab resource.

Historical crab condition monitoring

Criteria based on shell hardness were first developed in 1948 to assess crab condition and inform season opening and closing dates (Waldron, 1958). Shell condition was evaluated intermittently until around 1960 when routine monitoring of crab grade based on shell hardness began. In 1969, the Fish Commission partnered with the crab industry to initiate a sampling program that gathered information on meat recovery, in addition to shell condition, in major ports. This combined information was used to determine the 1969-70 season opening date (OFC, 1970).

In 1975, a report prepared for the State-Federal Fisheries Management Program detailed criteria for standardized crab condition sampling that could be applied coastwide. At this time, two acceptable methods for determining crab condition were identified. First, shell condition could be tested by applying pressure to a crab’s exoskeleton to assess how recently it had molted.

Second, meat recovery could be estimated from pick-out percentages. Meat recovery was recognized as the better measure of crab condition; however, pick-out procedures were inconsistent, and processors had different views on the acceptable pick-out percentage. Accordingly, shell condition was recommended as the basic method for determining crab quality, with additional pick-out data collected whenever possible. It was proposed that season delays should be considered when preseason sampling indicated that less than 80% of crab would be hardshelled by the opening (Snow *et al.*, 1975).

In 1980, state fishery agency directors from Washington, Oregon, and California entered into the Tri-State MOU to formalize their commitment to interstate cooperation in coastal Dungeness crab management. However, the Tri-State MOU proved ineffective at reconciling season opening issues resulting from poor crab condition at the start of the 1989-90 ocean commercial season. Fishers, buyers, retailers, and the public expressed widespread concerns about non-uniform season openings caused by poor crab condition which prompted the formation of the PSMFC's Tri-State Committee (LaRiviere and Barry, 1998; see *Section B.III.b*).

Early meetings of the Tri-State Committee focused on the development of a coastwide Tri-State protocol for determining season openings based on crab condition. The result was the signing of an amended Tri-State MOU in 1993 including Tri-State Committee recommendations for a preseason testing procedure (i.e., the 'Tri-State protocol') for determining crab condition north of Cascade Head (Didier, 2002). Early iterations of the Tri-State protocol set a preseason testing schedule and procedure to be initially conducted by WDFW, with additional sampling by ODFW in northern Oregon if needed. If a season delay was deemed necessary, a northern and southern fishing zone was established taking into account existing fishing patterns. Opening dates were delayed by 15-day increments until meat recovery was projected to be 23% or higher, or until January 15 (Gibbons *et al.*, 1993). In 1994, a similar preseason testing program was authorized in California, modeled after the northern Oregon and Washington agreement, but with a minimum meat recovery requirement of 25%. Industry-funded testing began there in advance of the 1995-96 season. This program was endorsed by the Tri-State Committee in 1996 and it was recommended in 1997 that Washington and Oregon fishery agencies adopt complementary regulations (Didier, 2002).

In 1999, ODFW partnered with the ODCC and industry to conduct preseason testing at various locations south of Cascade Head for the first time. Meat recovery rates were highly variable and did not all meet the 25% meat recovery rate that was considered acceptable to industry. After much debate, ODFW opted to not delay the December 1 season opening, but crabbers delayed fishing through December 2 while final test samples were evaluated. While many vessels went fishing on December 3, a large portion of the fleet decided to wait until crab meat recovery rates improved. Particularly south of Florence, fishing generally did not start until after December 10 (ODFW, 2000a).

Following the 1999-00 season opening, the Oregon crab industry requested that ODFW implement a substantial preseason testing program south of Cascade Head for the upcoming season (ODFW, 2000b). In 2000, the OFWC adopted rules supported by the Tri-State Committee for preseason testing along the entire Oregon coast, with a dividing line at Cascade Head. The preseason meat recovery requirements were 23% and 25% in the northern and southern zones, respectively. Since this time, several revisions to the Tri-State protocol have been made to change testing locations, remove the ability to make season opening decisions based on projections of meat recovery, establish a minimum industry notification period, and adjust meat recovery requirements to disallow rounding.

Most recently, two modifications to the Tri-State protocol were agreed upon (one each in 2019 and 2020) that allow more flexibility with season opening dates and areas within the Tri-State region. First, in September 2019, the OFWC incorporated into rule a modification to the Tri-State protocol that allows establishment of more than two separate area openings when low meat yield test results indicate that a portion of the Tri-State region does not have marketable crab but other areas do (ODFW, 2019a). In September 2020, the OFWC incorporated another modification into rule that reduced the meat yield criteria south of Cascade Head from 25% (rounding allowed) to 24% (no rounding) (ODFW, 2020b). Both of these changes provide flexibility in strategically opening discrete areas for harvest and allowing areas with marketable crab to open earlier, which have important implications for adapting to biotoxin and whale entanglement issues (see *Sections B.IV.b* and *B.IV.a*).

Tri-State preseason testing protocol

Since its adoption, the Tri-State protocol has been revised several times to ensure a standardized and consistent coastwide procedure from Point Arena, CA to the United States-Canadian border. The latest revision of the preseason testing protocol for the Tri-State coastal Dungeness crab commercial fishery was signed in May 2020.

In accordance with the Tri-State protocol, ODFW partners with the commercial crab industry andODCC to collect crab from eight test areas consisting of one or two stations each. Strings of six standard commercial 38" Dungeness crab pots are deployed at each station at depths of 15, 30, and 45 fathoms. Pots are baited with two baiters each containing ~1 pound of squid and soaked for 24 hours. For each string, all legal-sized males are collected for meat recovery, regardless of shell condition. Crab from each depth and station are combined and processed to obtain a single meat recovery rate for each area. A sampling schedule and meat recovery testing procedure are detailed in the Tri-State protocol.

Meat recovery results, including any deviations from the protocol, are provided to each state and the PSMFC as soon as possible. WDFW, ODFW, and CDFW then consult and a decision to open the season on December 1 or delay is made based on a recommended meat recovery rate of 23% north of Cascade Head and 24% south of Cascade Head (without rounding). In the case of a season delay due to poor meat recovery rates, two or more fishing zones may be established, taking into account traditional fishing patterns, by mutual agreement of WDFW, ODFW, and CDFW.

In addition to meat recovery rates, other information that is important for management is provided by preseason testing in Oregon. Six legal-sized male crab are collected from each test station (i.e., one from each pot) for ODA domoic acid tests, as needed (see *Section B.IV.b*). The total catch from two pots per string are also examined by an ODFW at-sea observer to quantify and describe the species composition of bycatch in the early portion of the season. The sex and size of all Dungeness crab (i.e., legal, sublegal male, and female crab), and the amount and species composition of all other bycatch is recorded. ODFW has also collected samples (e.g., genetic samples, water samples for HABs research, whole crab for microplastics research) for various research projects during preseason testing trips.

Gear setting

In the mid-1960s, a rule was adopted allowing fishers to set commercial crab pots during a 96-hour gear setting period prior to the season opening. The law was enacted at the request of crabbers to provide equal opportunity to small boats with a limited capacity to transport pots, reduce congestion at the docks, and improve safety. As the number of vessels increased, competition drove crabbers to set gear as early as possible with some reports of gear setting in the middle of the night before the prescribed time. In 1983, the gear setting period was changed to 84 hours to improve enforcement ability and rule compliance by allowing gear setting to begin during daylight hours (ODFW, 1983).

Prior to the 1986-87 season, an 88-hour gear setting period was adopted in Oregon to match Washington's regulation and address enforcement challenges caused by the lack of uniform regulations across states (ODFW, 1986b). Shortly after, a 64-hour soak period was adopted in Oregon, California, and Washington allowing fishers to set pots two days prior to the season opening, beginning at 8 am (ODFW, 1988a). Finally, in 2014, the current 73-hour gear setting period (OAR 635-005-0485) was adopted to facilitate a 9 am fishing start time for the season opening and avoid starting a derby-style fishery at 12 am which was a safety concern for some crabbers (OFWC, 2014).

Preseason gear setting is prohibited in the bay commercial and recreational Dungeness crab fisheries in Oregon, since bay commercial harvesters are limited to using only crab rings making gear setting obsolete and limits on the amount of gear used in the recreational fishery preclude many of the issues that are addressed by gear setting regulations in the ocean commercial fishery.

Barging

Under OAR 635-005-0405, an Ocean Dungeness Crab Permit is not required for vessels engaged solely in gear setting for a permitted vessel in the ocean commercial fishery. This practice, referred to as barging, allows smaller vessels to remain competitive and safe on opening day by having the option to enlist a larger vessel to haul and set some or all of their pots.

When limited entry was established in the ocean commercial fishery in 1995 (see *Section B.III.g*), there was not public dialogue about how the practice of barging may be affected. However, during the 1997 season opener, a vessel was cited by OSP for setting crab gear without a crab permit. This prompted ODFW to consider and recommend the adoption of a rule exempting crab gear setting vessels from crab permit requirements (ODFW, 1998b). The rule was adopted by the OFWC in 1998 and has remained since, although the OFWC heard testimony both for and against barging regulations during development of a pot limit plan in 2006 (ODFW, 2006).

In 2019, the language in OAR 635-005-0465 was adjusted to clarify that vessels involved only in barging are not subject to the fair start provisions (see below) of the Tri-State protocol (ODFW, 2019a).

Hold inspections

All harvesters participating in the first 30 days of the ocean commercial Dungeness crab fishery are required to have their vessel holds inspected and certified to be free of crab as described in OAR 635-005-0465. Hold inspections are conducted by OSP with assistance from ODFW.

Hold inspections were first implemented during the 1986-87 ocean commercial season to address observed abuses of the preseason gear setting period (ODFW, 1988b). At this time, the rule required that prior to January 1, all vessel holds be inspected before landing crab in Oregon (ODFW, 1986b, 1987b). When the preseason testing protocol was adopted in 1993, language was included for additional regulations that go into effect in the event of a season delay. This included a requirement that fishers declare their intention to fish in either the northern or southern zone during hold inspections and clarification that inspections are required immediately prior to the opening of the selected fishing area (Gibbons *et al.*, 1993).

In 2003, the rule language was again modified to include a requirement that the maximum number of pots that will be used during that season must be declared and certified on the Oregon hold inspection certificate form (ODFW, 2003). This change was made in order to provide ODFW and OSP a direct mechanism for quantifying the actual number of pots deployed each year in the Oregon fishery (ODFW, 2002a).

The original rule language required all vessels to obtain a hold inspection on a single day, November 30, or wait until after January 1 to participate in the fishery. A rule was adopted for the 2011-12 season allowing hold inspections to be conducted beginning on the day prior to the season opening, and by appointment on any day after. This hold inspection date flexibility was supported by industry and improved the ability of OSP to effectively enforce fishery regulations (ODFW, 2011b).

Fair start provisions

Since the first iteration of the Tri-State protocol in 1993, the procedure for establishing fishing zones has included a fair start provision. As the name suggests, this provision is intended to provide fishery participants that choose to wait and fish in a delayed zone with a fair opportunity to harvest crab without competition from participants that have already landed crab in another zone. In this way, fair start provisions promote an equitable and orderly season opening.

If the season opening is delayed and the coastal fishery is divided into fishing zones, fishers may elect to fish crab in any zone and must declare which zone they will fish in during preseason hold inspections. A vessel used for fishing crab in an open zone is prohibited from fishing in any zone that opens later within the same crab season until 30 days after the later-opening zone has opened. Vessels that only set pots for another vessel (i.e., barging) during the gear setting period prior to the start of the season are not subject to fair start provisions.

The 2020 Tri-State protocol includes a fair start regulation clarification table with additional details for each state.

Price negotiations

In addition to regulatory season delays (e.g., meat recovery, domoic acid), ocean commercial seasons have historically been delayed by industry for several reasons. In some cases, a price is not agreed upon in time for the season opener resulting in a delayed start.

In 2003, the Oregon Legislature passed SB 673 which established a state-supervised price negotiation process for seafood harvesters and processors to collectively bargain for a season starting price. The process is overseen by ODA at the request of harvesters and dealers representing at least 51% of the active permits and buying capacity in the state, respectively (OAR 603-076-0052). Participation is voluntary for all individuals or entities, but involved parties are bound to the terms of the price agreement negotiated by the parties and ratified by the ODA director. ODFW is not involved in the negotiation process.

Price negotiations serve as a mechanism for establishing an opening price, so that crabbers can set gear and proceed with the season safely and efficiently. Processors are able to ensure a dependable product flow to markets. However, the process does not occur in years when not enough permitholders and/or buyers request that it takes place.

g. Limitation of fishery effort and capacity

Ocean commercial fishery

Fishery effort is typically measured by the number of vessels, pots, or trips in a given time period. In Oregon's ocean commercial Dungeness crab fishery, the number of vessels increased slowly through 1969, but generally remained below 100 boats (Figure 30). The number of vessels doubled over the next three years and continued to increase to a maximum of 465 vessels during the 1979-80 season. The estimated number of pots fished each year followed a similar pattern increasing from 29,200 pots in 1969 to over 125,000 pots during the 1979-80 season.

As early as the 1970s, PMFC (1978) determined that the West Coast crab fishery was overcapitalized prompting analysis of various effort management strategies. At this time, it was determined that more information was needed before any effort limitation was attempted.

Through the 1980s, the number of boats and pots remained high, while the average annual pounds landed per boat and the pounds of crab caught per pot decreased (Demory, 1990). This led to growing competition and the concentration of effort in the first weeks of the season. By the early 1990s, the largest vessels were deploying over 700 pots (and up to 1600 pots), making several large landings, and then leaving the fishery after a few weeks (ODFW, 1992a).

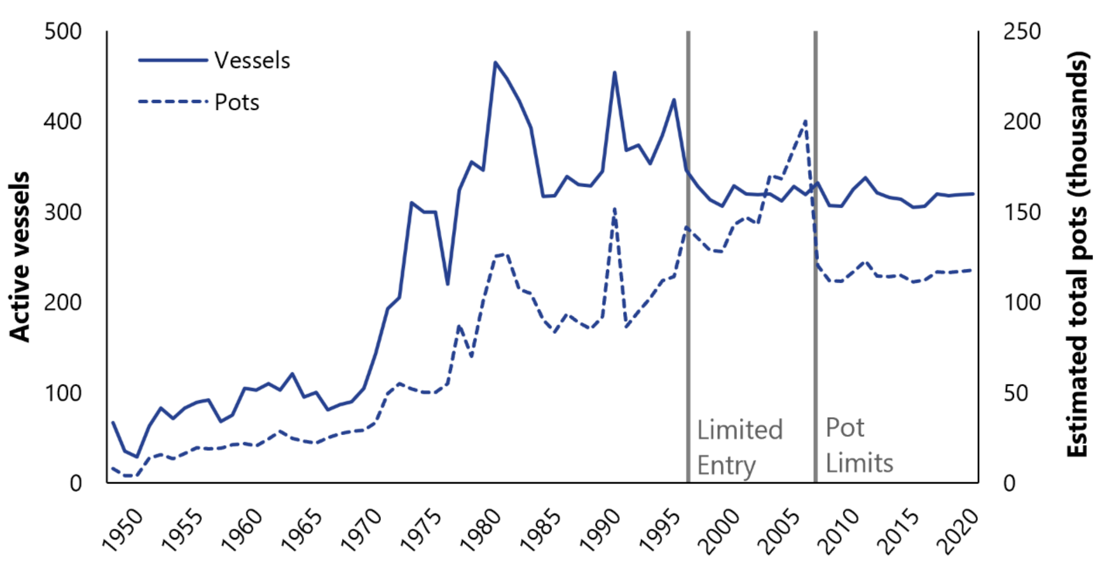


Figure 30. Number of active vessels and estimated total pots fished in the ocean commercial Dungeness crab fishery from the 1947-48 through 2019-20 seasons. Historically, the total number of pots was expanded from port estimates obtained through fisher interviews and vessel counts. Beginning with the 1986-87 season, estimates were derived from pot declarations collected during hold inspections. Since the implementation of pot limits in 2006-07, estimates are made by summing pot tiers for all permits making landings into Oregon. These estimates do not account for vessels that are not fishing their full allotment of pots or vessels that harvest crab in Oregon but land all crab into another state (see *Section B.III.g*).

Limited entry

By the early 1990s, some level of license limitation was being planned or already in effect in the West Coast salmon, scallop, pink shrimp, and groundfish fisheries. There was concern that these license limitation programs may lead to increased participation in the open access commercial crab fishery (Didier, 2002).

The recently formed Tri-State Committee (see *Section B.III.b*) prioritized limited entry as one of four major issues in need of attention and subsequently carried out a coastwide survey assessing industry support. In October 1991, the OFWC reviewed recommendations from the Tri-State Committee that each state pursue limited entry legislation (ODFW, 1991b) and took action to establish August 14, 1991 as an eligibility date for participation in any future limited entry program (ODFW, 1992a).

In 1992, Washington established an eligibility date of September 15, 1991 in anticipation of a future limited entry program (LaRiviere and Barry, 1998). In the same year, the California Legislature passed legislation, effective for three years, that required fishermen to possess a specific license to land Dungeness crab, and limited license issuance to only individuals who had landed crab during one or more of the previous ten commercial seasons (Didier, 2002). In 1994, both Washington and California passed legislation establishing limited entry programs which became effective in 1995 (Didier, 2002).

The Oregon crab industry was unsuccessful in its first attempt to secure license limitation (SB 911) in 1993. In 1995, the 68th Oregon Legislative Assembly found the Oregon ocean commercial fishery to be overcapitalized and economically unstable due to excess fishing effort (ORS § 508.921). The Legislature passed HB 3094 which created a limited entry system for the fishery restricting participation based on specific vessel permit qualification criteria (ORS § 508.931). The OFWC then adopted a series of rules implementing portions of the program related to annual renewal, transferability, and vessel length modification requirements (currently found in OARs 635-005-0430, 635-005-0440, and 635-005-0450). Several amendments have further defined or clarified the original rule language.

Limited entry became effective in all three states prior to the start of the 1995-96 season, with 465 vessels initially qualifying for permits in Oregon (ODFW, 1997b). As of 2020, the number of permits has dropped to 423 due to non-renewal. From the 2010-11 through 2019-20 seasons, 318 different permit holders, on average, made landings into Oregon ports. Each year, there is a portion of vessels with Oregon permits that do not make landings into Oregon, or do not participate in any state. While some of these vessels do not participate in the Oregon crab fishery entirely, others may fish off Oregon, but land crab exclusively in other states if they possess permits for both or all three states. These vessels are referred to as dual- or tri-permitted vessels, respectively.

During the 2014-15 through 2018-19 seasons, an average of 32 dual-permitted vessels (possessing both Oregon and Washington permits) made landings only in Washington and 11 dual-permitted vessels (possessing both Oregon and California permits) made landings only in California (Table 5). Over the same time period, an average of eight tri-permitted vessels made landings in another state (Washington and/or California) but not in Oregon, and 59 permits (single, dual-, or tri-) were not active in any state.

Table 5. Average number of active (made one or more landing) and inactive (made no landings) single, dual-, and tri-permitted vessels in the ocean commercial fishery from the 2014-15 through 2018-19 seasons.

	Single OR permit	**Dual-permit (OR+WA)**	**Dual-permit (OR+CA)**	**Tri-permit (OR+WA+CA)**	**Total permits**
Active in OR	248	30	30	6	314
Inactive in OR, but active in other state(s)	0	32	11	8	51
Inactive in all states	55	1	2	1	59
Total vessels	303	63	43	15	424

Vessel length

During the 1981-82 through 1990-91 seasons, around 67% of the vessels landing ocean commercial crab in Oregon were between 30 and 50 feet long, while about 15% were less than 30 feet long and 17% were over 50 feet in length (PSMFC, 1993). The portion of vessels over 50 feet in length had grown to 30% by the 1995-96 season and to over 32% by the 1999-00 season (ODFW, 2002b). By 2004, there was growing concern among the commercial crab industry that the trend toward larger boats in the fleet would continue to increase fishing effort and impact the character of the fishery (ODFW, 2004).

Over time, a series of vessel length restrictions have been implemented to address these concerns. The original limited entry program provided for permit transfers once every five years with a maximum increase of 10 feet in vessel length per transfer, up to 99 feet overall length, except for a subset of vessel permits that qualified under subsection (1)(e) of ORS § 508.921 which can only be transferred to vessels that are 26 feet or less in length (ODFW, 1997b). In 2005, the Oregon Legislature passed HB 3472 permanently limiting vessel length increase to 10 feet of the permit held on January 1, 2006, with the possibility of waiver if "undue hardship" would result (as defined in 635-005-0240; ODFW, 2005a). In 2014, the Oregon Legislature passed HB 4049 which allows permits that were transferred to a vessel more than 10 feet shorter than the vessel that held the permit on January 1, 2013 to be subsequently transferred back to a vessel that is equal to or smaller than the vessel that held the permit on January 1, 2013 (ODFW, 2014c). This allows permit holders to transfer permits to smaller vessels without permanently reducing the size of vessel that the permit could be transferred to in the future. Current ocean Dungeness crab permit transfer restrictions are found in OAR 635-005-0440 (prescribed by ORS § 508.936).

The original limited entry program also included a provision restricting vessel length modification increase to no more than 10 feet during any 60-month period (ODFW, 1997b), which remains unchanged today (OAR 635-005-0450). In practice, this means that a permitholder can lengthen their own permitted vessel to exceed the allowed transfer length, in which case they would only be able to transfer the permit to a smaller vessel.

Today, a wide range of vessels are used in the ocean commercial fishery supporting a diverse array of business plans (see *Vessels* description in *Section B.III.e*). Vessels that made landings into Oregon during the 2020-21 season ranged from 21 to 103 feet, with 22% over 60 feet. Figure 31 shows the average number of active permits and average landings made by month by vessels in different length classes (<40 feet, 41-60 feet, and 60+ feet) from the 2012-13 through 2019-20 ocean commercial seasons. As of the 2020-21 season, there are 26 vessel permits that constitute the subset that are restricted to transferring only to vessels that are 26 feet or less in length (ODFW, unpublished data).

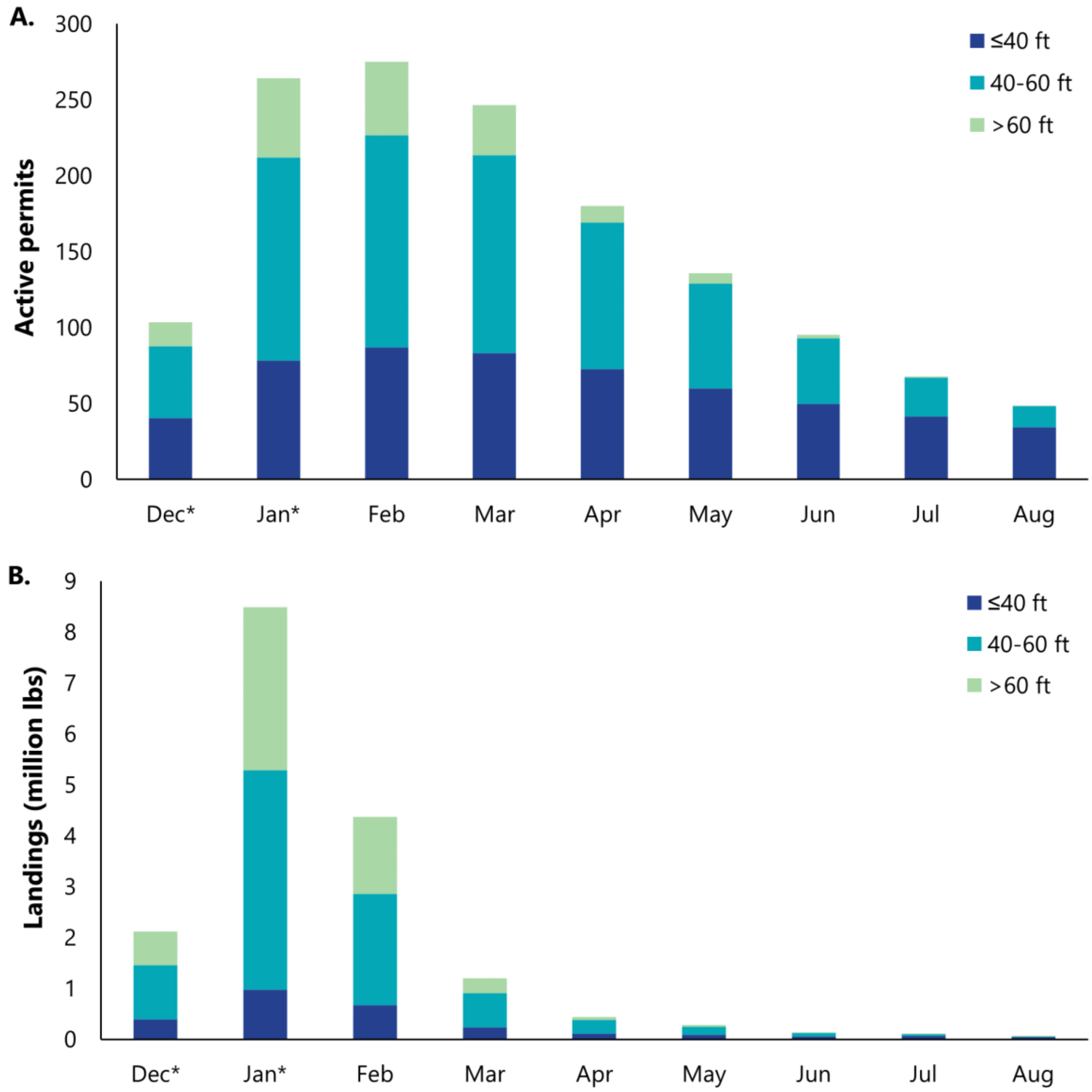


Figure 31. Average (A) number of active permits (made one or more landing) and (B) landings made by month by vessels in different length classes (≤40 feet, >40 and ≤60 feet, and >60 feet) from the 2012-13 through 2019-20 ocean commercial seasons. Data for December and January reflect various season opening structures including delayed and split openers that occurred during this time. Data are from ODFW fish tickets.

Limited entry jurisdiction out to 200 miles

At the September 2004 meeting of the Tri-State Committee, discussions began about mechanisms for reducing effort shifts and increases between ocean commercial fisheries in each state (ODFW, 2004).

Under the Magnuson-Stevens Act, each state has jurisdiction over their own permit holders and those making Dungeness crab landings in their state. At this time, commercial crabbers were not able to fish in the waters of a state that they were not permitted in (within three miles of shore), but could fish in federal waters anywhere in the Tri-State area (from three to 200 miles).

Each state agreed to consider the potential impacts of limited entry jurisdiction out to 200 miles, termed 'LE 200', under which each state would restrict its permit holders from fishing out to 200 miles off of neighboring states. In turn, each state would have the ability to manage the fishery off their state without the potential for additional effort from other states. It would also allow each state to better assess the level of effort in the fishery. The matter was discussed in 2005 at the Oregon Dungeness Crab Summit and meetings of the Tri-State Committee. The majority of the Oregon crab industry supported implementation, though there was some opposition from fishers on the north coast (ODFW, 2005b).

In 2005, Oregon and Washington adopted rules prohibiting their permit holders from crabbing out to 200 miles off the coast of the other state, but California was unable to do so without legislative action. In 2007, reciprocal LE 200 rules were adopted for California and Oregon waters (ODFW, 2007c).

The valid harvest areas for fishers with Oregon Dungeness crab permits are designated in OAR 635-005-0460.

Pot limits

Since the 1970s, pot limitation has been a topic of discussion regarding effort management in Oregon's ocean commercial fishery. While limited entry legislation in 1995 effectively limited the number of vessels participating in the commercial Dungeness crab fishery, the number of pots continued to increase (Figure 30). In 2000, Washington implemented a pot limit system which added to the urgency and desire to address the pot limit issue in Oregon. Additional factors exacerbated concerns about increased effort and gear in Oregon's crab fishery, including: (1) reduced opportunities in Alaska fisheries and the West Coast groundfish fishery, (2) increased amounts of gear per vessel, and (3) concentrated fishing effort early in the season adding to pot loss, wastage, and safety concerns (ODFW, 2002b).

In August 2002, a one-year interim pot limit plan was proposed to the OFWC with the intention of developing a more permanent option prior to the 2003-04 season. At this time, a survey of industry indicated that 87% of respondents supported some kind of pot limitation program (ODFW, 2002a). The plan was not adopted by the OFWC, but a control date of August 14, 2001 was established as eligibility criteria based on past participation for any future pot allocations (OAR 635-005-0405; ODFW, 2006).

In 2004, industry representatives wrote a detailed letter urging ODFW to pursue options to address the increasing amount of gear used in the fishery. Additionally, at the 2005 Oregon Dungeness Crab Industry Summit hosted jointly by the ODCC and ODFW, many members of the crab industry expressed strong support for a pot limit plan, though a consensus was not reached on plan criteria (ODFW, 2005b). After considering significant input from the crab industry, public comment, and guidance provided by the OFWC, ODFW brought four pot limit options to the OFWC for consideration in June 2006 (ODFW, 2006).

Beginning with the 2006-07 season, the OFWC adopted a three-tiered pot limitation system (200, 300, and 500 pots) designed to limit the total number of pots fished in Oregon to 150,000. This number was selected because it was consistent with the number of pots declared at the control date and with industry consensus at the summit. It also represented a sufficient reduction (about 50,000 pots less than the 200,000 pots declared for the 2005-06 season) that would promote efficiency while still providing enough capacity for the fleet (ODFW, 2006).

The adopted system was considered the most simple to administer and enforce, and had the majority of support in public comment relative to the other options. A single pot limit was assigned to each Oregon crab permit based on documented landings of ocean Dungeness crab into Oregon, Washington, or California from December 1, 1995 through August 14, 2001 (OAR 635-005-0405). As part of the pot limit system, additional measures were adopted which included a pot limit appeals process (OAR 635-005-0425), gear specifications (OAR 635-005-0475), buoy tag requirements (OAR 635-005-0480), and a gear leasing prohibition (OAR 635-005-0485). Several minor revisions to the adopted rules have followed to improve implementation of the program.

ODFW was directed by the OFWC to conduct a review of the pot limit program after three years to determine its effectiveness. In October 2009, ODFW reported that the Oregon fishery had maintained productivity following pot limit implementation in terms of landings and ex-vessel value. Patterns of monthly effort were similar before and after pot limits, indicating that most fishers were adapting well to pot limits. ODFW recommended several minor adjustments to the pot limit program, including development of a long-term derelict gear retrieval program to support the goals of the program and aid in enforcement (ODFW, 2009b). This was addressed through the ODFW Post-season Derelict Gear Recovery Program first implemented in 2014 (see *Section B.III.i*).

Since the introductions of pot limits, an average of 115,600 pots are fished in Oregon’s ocean commercial fishery each year (Figure 30). Figure 32 shows the average number of active permits and average landings made by month by vessels from different pot limit tiers (200, 300, 500) from the 2012-13 through 2019-20 ocean commercial seasons.

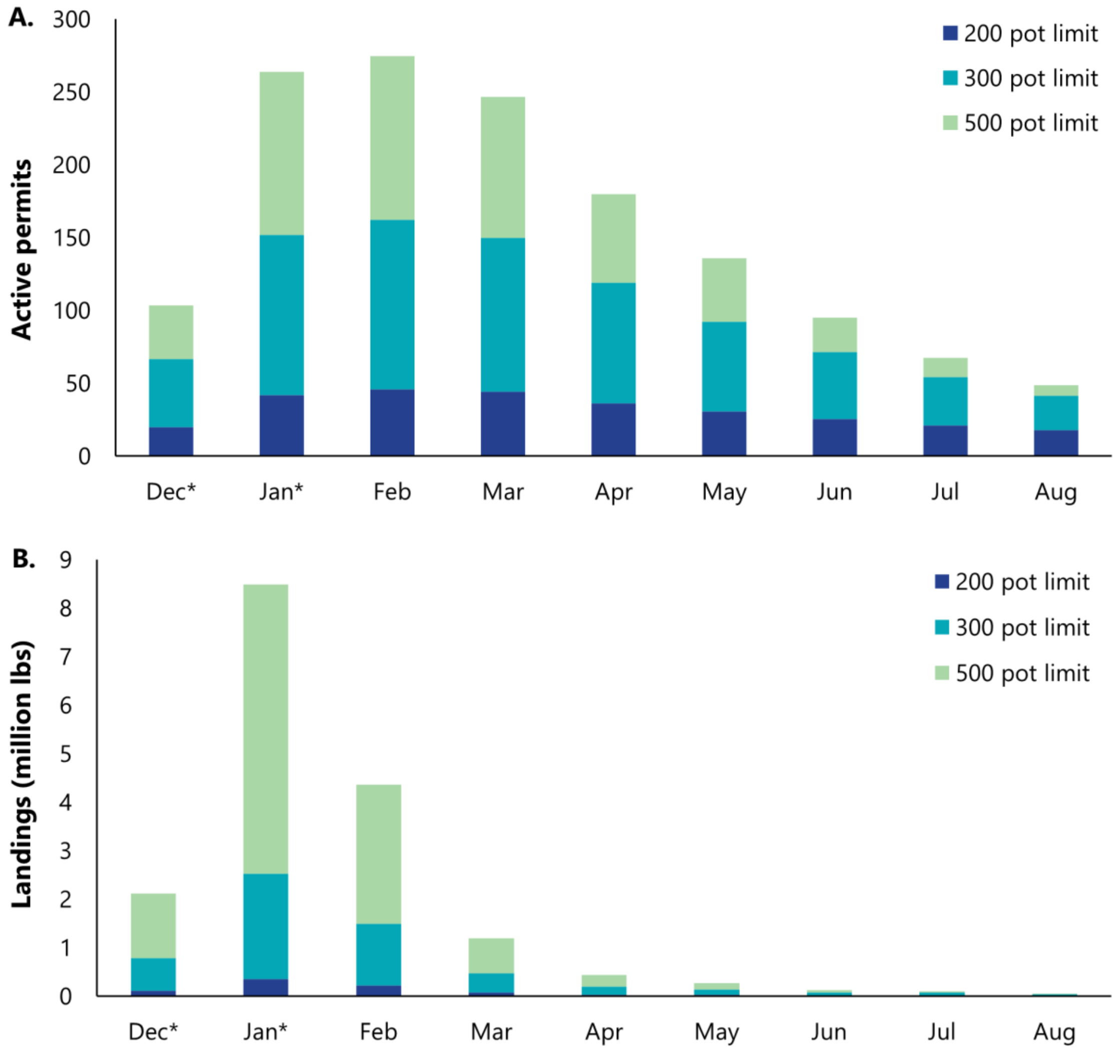


Figure 32. Average (A) number of active permits (made one or more landing) and (B) landings made by month by vessels from different pot limit tiers (200, 300, 500) from the 2012-13 through 2019-20 ocean commercial seasons. Data for December and January reflect various season opening structures including delayed and split openers that occurred during this time. Data are from ODFW fish tickets.

Bay commercial fishery

Commercial crabbing has historically occurred in most bays in Oregon, but reliable catch and effort data are limited prior to the 1970s. In the mid-1980s, ODFW reported an increase in the incidence of conflicts between bay commercial and recreational fishers over access to the Dungeness crab resource. At this time, an unlimited number of rings were permitted in all estuaries, and pots were also allowed in Tillamook, Netarts, Siuslaw, Umpqua, and Coquille estuaries (ODFW, 1984a).

To address the growing conflicts, the OFWC adopted gear restrictions for vessels participating in the bay commercial fishery, effective September 15, 1984 (ODFW, 1984c). Since this time, crab pots are prohibited in all bays and vessels are limited to a maximum of 15 crab rings (OAR 635-005-0510).

Recreational fishery

By the late 1940s, a considerable, unregulated sport fishery for Dungeness crab existed in Oregon (OFC, 1948a). Beginning in 1948, a series of regulations were proposed to limit the take of crab for personal use. Since at least 1963, this has included rules in the recreational fishery for a bag limit of no more 12 crab caught, using no more than three pieces of gear (i.e., rings/lines/pots) per individual harvester (Long and Horton, 1963; ODFW, 2021b).

h. Summer fishing and season closure (ocean commercial fishery)

Until the late 1970s, relatively few commercial vessels fished for crab past the end of May and the number of trips during summer months remained low. However, an increase in late season fishery effort in the following years raised concern among industry and managers about the effects of increased sorting and landing of softshell crab (ODFW, 1984d).

Historically, the season closure date has been the primary tool for protecting newly molted crab from harvest impacts, though other methods have been considered (e.g., trip limits, depth restrictions, gear limits, quality control regulations) (ODFW, 1992a). In 1992, the OFWC adopted a rule limiting ocean commercial landings after May 31 to ten percent of the crab landed from December 1 to May 31. If this threshold is met, the commercial season is closed by temporary rule until the following season opener (OAR 635-005-0465). This option was considered easy to administer and enforce, and it served the purpose of minimizing damage to softshell crab while still maintaining a small-scale summer fishery (ODFW, 1992a).

From the 1992-93 through 1997-98 seasons, the ten percent quota was approached but not exceeded (3.5 to 9.7%; ODFW, unpublished data), and the summer softshell crab issue remained a primary topic of debate. Furthermore, there was growing concern that effort may increase in the Dungeness crab fishery in the future due to diminished opportunities in other fisheries (e.g., groundfish, salmon) (ODFW, 2001). In 1999, an additional summer fishery regulation was adopted which restricted ocean commercial landings from the second Monday in June through the end of the season to 1,200 cumulative pounds per vessel per week (OAR 635-005-0470). At the same time, the summer catch ceiling was reduced to seven percent, but shortly changed back to the current ten percent in 2002 (ODFW, 2002c). From the 1998-99 through 2020-21 seasons, the summer catch ceiling has never been exceeded, with ocean commercial landings after May 31 ranging from 0.8 to 6.2% of the crab landed from December 1 to May 31 (ODFW, unpublished data).

The impact of softshell crab discard mortality on future harvestable biomass has remained a conservation concern among managers and industry. In 2017, the ODCC sponsored the development of a deterministic bioeconomic model to assess the economic impacts associated with potential softshell management actions (Davis *et al.*, 2017). In particular, the model was developed to explore potential impacts of season closures to protect softshell crab, but it also allowed for evaluation of altering effort and/or delaying the season opening in combination with a range of environmental and economic variables. Results indicated that reduced season length did not result in significant economic benefits and that, for most management actions, there were winners and losers among different vessels classes or business plans. Additionally, the model demonstrated that the effects of natural mortality are magnitudes greater than the effects of handling mortality. Therefore, any potential savings gained by softshell management actions is very small compared to the loss of biomass due to natural mortality (Davis *et al.*, 2017).

In recent years (2012-13 through 2019-20 crab seasons), the number of permits active in the fishery during the second half of June has ranged from 49 to 95, with 68 permits on average. This number continues to decline slightly as the summer progresses to a range of 35 to 62, and an average of 48 active permits in August.

Post-season gear removal

Commercial crab gear must be removed from the ocean, bays, and Columbia River during closed seasons, except during the legal gear setting period (see *Section B.III.f*). Prior to the 2018-19 crab season, unbaited gear with open release mechanisms was allowed to be left in the Pacific Ocean (not including the Columbia River) during a 14-day post-season gear "clean-up" period following the closure of the ocean commercial season. The intent of this grace period, in effect since the 1991-92 season, was to allow commercial crabbers to more fully utilize the season (ODFW, 1990). Starting with the 2018-19 season, the two-week post-season "clean-up" period was eliminated in order to reduce the risk of whale entanglement (see *Section B.IV.a*) by reducing the number of vertical lines in the water at the end of the season when whales are present in higher abundance (ODFW, 2019b; ODFW, 2020b).

i. Derelict gear

Derelict crab gear has been shown to contribute to ghost fishing, gear conflicts, pollution, habitat degradation, navigation hazards, and marine mammal entanglements (see *Section B.IV.a*; ODFW, 2014a). To address this issue, ODFW has implemented a number of management measures to reduce the incidence of pot loss and minimize the impacts posed by derelict gear. This management approach includes vessel and pot limits, gear requirements, and post-season gear retrieval efforts.

Due to the magnitude of each crab fishery sector, ODFW has prioritized efforts aimed at addressing derelict gear associated with the **ocean commercial** fishery sector. However, the issues described below are relevant for all three sectors.

Pot loss and ghost fishing

Due to its effective design, crab gear that is lost or abandoned during regular fishing operations tends to continue to fish (i.e., ghost fish) resulting in the catch of both target and non-target species, loss of a portion of the harvestable catch, degradation of seafloor habitat, and costs to the fishing industry (Arthur *et al.*, 2014).

The impacts of ghost fishing are dependent on three components: the annual pot loss rate, the ghost fishing rate (i.e., the proportion of lost pots that are actively ghost fishing), and the length of time over which ghost fishing occurs. Each of these components is further related to fishery intensity, gear conflicts, environmental conditions (e.g., storms, sedimentation), and pot design (e.g., entrance configuration, escape mechanisms, degradation time) (Maselko *et al.*, 2013).

Estimates of pot loss and ghost fishing rates vary, but multiple studies suggest that they may be substantial. Breen (1987) estimated that 11% of Dungeness crab pots are lost annually and that mortality from ghost fishing is equivalent to 7% of the annual reported landings in the Fraser River District of British Columbia. Removal operations in Puget Sound, WA revealed that 37% of recovered derelict crab pots were still actively fishing for at least one year. Recent work has estimated lower crab mortality from derelict gear translating to 4.5% of the annual harvest value in the Washington State waters of the Salish Sea (Antonelis *et al.*, 2011).

An early report of lost crab gear in Oregon from 1970 details 140 abandoned crab pots that were found off Cannon Beach after at least 30 days of fishing. Of these, 117 were retrieved containing 3,629 crab of which 91% were legal males, 6% were sublegal males, and 2% were females (Demory, 1971). Currently, lost crabbing gear is tracked by ODFW through annual replacement buoy tags and the logbook program (see Figure 33).

A release mechanism or “rotten cotton” is required for any crab pot used in the ocean commercial fishery, and is commonly used (though not required) for crab pots used in the recreational fishery (see *Section B.III.e*). This refers to a degradable material incorporated into the lid or mesh of a crab pot to allow for the escape of legal-sized crab from lost or derelict fishing gear once the material degrades to avoid ghost fishing by derelict gear.

Early derelict gear recovery efforts

In 2006, several organizations collaborated to fund and implement two pilot programs aimed at derelict gear recovery in Oregon. The first was led by the Oregon Fishermen’s Cable Committee and involved partnering with fishers and volunteers to retrieve lost and abandoned crab and trawl gear. A series of temporary rules were adopted to allow for these gear retrieval efforts. In addition to cataloging the number and condition of the retrieved pots, catch composition was also recorded. The second project was led by the ODCC and focused on designing and obtaining funding for a long-term crab pot recovery program. Additionally, a reporting hotline and database for lost gear was established to guide future recovery efforts ("Marine debris removal project", 2006; ODFW, 2008a).

Under permanent rule, a vessel is not permitted to possess, use, control, or operate ocean commercial Dungeness crab gear without legally required markings identifying it as belonging to that vessel (OAR 635-005-0480). In 2007 and 2008, temporary rules were adopted to facilitate a voluntary derelict gear retrieval program by allowing any commercial fishing vessel to retrieve lost or abandoned crab gear after the end of the two week “clean-up” period through the end of October (ODFW, 2008b).

In-season derelict gear recovery

In 2009, during a three-year review of the pot limitation program, ODFW reported that while initial concerns over pot limit implementation were easing, there was growing concern over the issue of derelict crab gear recovery. Building upon the temporary rules adopted during the last three seasons, ODFW recommended and the OFWC adopted permanent rules outlining conditions for derelict gear retrieval (ODFW, 2009b).

Regulations for in-season derelict crab gear recovery by commercially licensed vessels are found in OAR 635-005-0490. No more than 25 derelict pots or rings may be retrieved per trip from the start of the ocean commercial season through the second Monday in June, while no more than 50 pots or rings may be retrieved per trip from the second Monday in June through August 14. From August 15 through October 31, an unlimited number of derelict pots may be retrieved. Any retrieved gear must be transported to shore during the same trip and documented (i.e., date, time, number of pots or rings, location, gear owner identification) in the retrieving vessel’s logbook. During the season and in open areas, legal crab may be retained from derelict gear retrieved (that was otherwise lawful gear) by crab permitted vessels, but all gear must be returned to the owner. This allowance is intended to further incentivize derelict gear recovery in-season.

Post-season Derelict Gear Recovery Program

In 2013, the Oregon Legislature passed the ODCC-supported HB 3262 which allowed the OFWC to authorize a permitted derelict gear recovery program for the ocean commercial fishery. Under this legislation, pots left in the ocean 15 or more days after the end of the season are exempt from Oregon’s personal property law and eligible for retrieval through an approved program. In effect, this exemption worked to incentivize derelict gear retrieval by providing flexibility for permitted gear retrievers to decide what to do with retrieved pots (ODFW, 2014d).

Subsequently, the OFWC adopted regulations allowing ODFW to issue Post-Season Derelict Gear Recovery Permits to commercially licensed vessels (OAR 635-005-0491). Permits are subject to a number of conditions, including a prohibition on harvesting any crab or non-crab species taken with the retrieved gear. All recovered gear must be registered according to the permit conditions and post-recovery registration forms are posted on ODFW’s website to allow any interested previous gear owners the opportunity to negotiate with the retrieving vessels for their previously owned pots. After documenting retrieval of the gear, retrieved gear may be disposed of at the permit holder’s discretion (e.g., keep, sell, return to owner); again, retention of gear is only allowed for derelict gear that is recovered during the program by a permitted individual. ODFW maintains a post-season derelict gear program webpage which includes a list of the locations of any derelict gear reported to ODFW after August 14 each year.

The goal of the program is, first and foremost, to remove derelict gear from the ocean to minimize impacts posed by derelict gear (see above). In addition, the industry-driven program is intended to keep the costs of gear retrieval low by maintaining a low administrative burden. Finally, the program is designed to be transparent so that previous gear owners are able to track registered derelict gear brought in through the program. Since the program's inception, ODFW has continued to work with industry to address derelict gear by growing or modifying the program over time, including: 1) streamlining the notification process, 2) extending the duration of the program two weeks into October, and 3) soliciting and cataloging derelict gear reports for program participants to target recovery efforts throughout the program.

Figure 33 shows the estimated number of crab pots lost in the ocean commercial Dungeness crab fishery, along with the number of replacement buoy tags issued each season, the estimated number of derelict pots retrieved in-season, and the number of derelict pots retrieved through the post-season recovery program. The estimated number of lost pots and estimated pots retrieved in-season are from summarized logbook data with expansion factors applied based on landings (except for the 2018-19 season when ODFW returned to full logbook data entry). From the 2008-09 through 2018-19 seasons, an estimated 5507 pots were lost each year on average, with 3148 replacement buoy tags issued annually (see *Gear marking* in *Section B.III.d* for a description of the elimination of the standard replacement tag allowance in 2020 as a conservation measure for reducing the risk of marine life entanglements). Estimated in-season derelict gear retrieval is on average 1096 pots per year, with an additional 747 pots retrieved on average during the post-season each year since 2014.

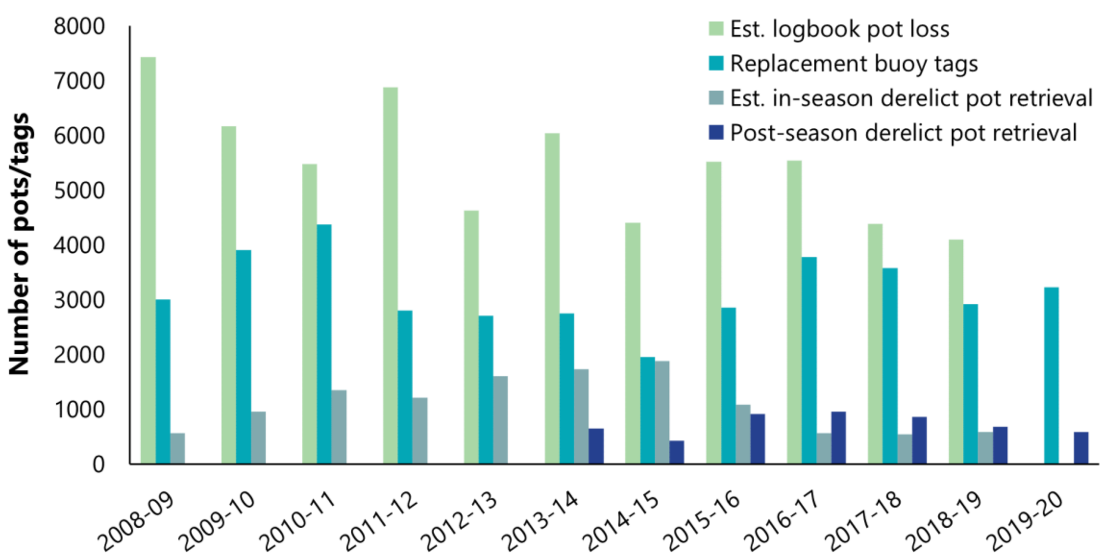


Figure 33. Estimated number of pots lost in the ocean commercial Dungeness crab fishery, along with the number of buoy tag replacements, estimated in-season derelict pot retrieval, and post-season derelict pot retrieval from the 2008-09 through 2019-20 seasons. Pot loss and in-season derelict pot retrieval estimates are from summarized and expanded logbook data (not yet available for 2019-20), except for 2018-19 when data expansion was not necessary. Replacement buoy tag and post-season retrieval data are from ODFW Licensing Division's

replacement tag records and post-season derelict pot retrieval registration, respectively. The post-season derelict gear retrieval program was implemented during the 2013-14 season.

j. Bait use

In the early commercial Dungeness crab fishery, herring (*Clupea pallasii*), cockles (*Clinocardium nuttallii*), and various clams (including razor clams, *Siliqua patula*) were commonly used for bait along the Oregon coast. By the late 1950s, razor clams and squid (*Loligo* sp.) imported from California were most frequently used (Waldron, 1958).

Today, many types of bait are used to attract crab. Bait use estimates for the **ocean commercial** fishery derived from logbook information indicate that squid are the most used bait species, followed by clams and sardines (Figure 34).

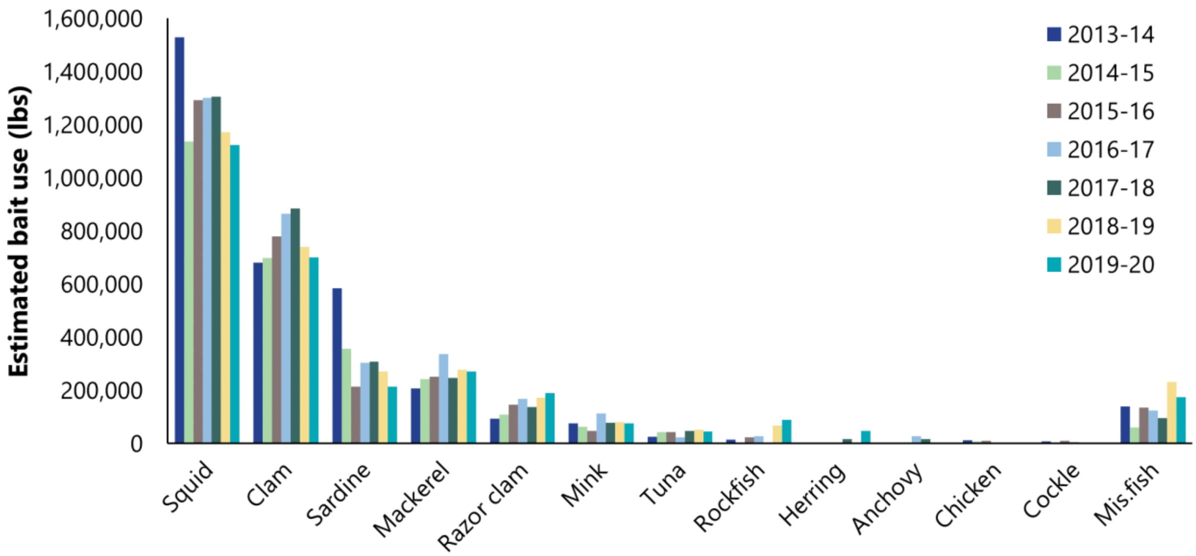


Figure 34. Estimated pounds of bait used in the ocean commercial fishery from the 2013-14 through 2019-20 seasons. Estimates are derived from fishery logbook data (i.e., number of pot pulls and proportion of bait type recorded) and an average per pot bait used of two pounds per pot. If multiple baits were listed for a string, estimates account for equal baiting of all bait types listed as a proportion of the bait used for each pot. 'Misc. fish' include hake, halibut, black cod, salmon, petrale, and other fish not specified by the fisher.

A huge assortment of bait are used by **recreational** crabbers, but the most common types include chicken, fish, mink, and clams. Limited information is available on bait use in the **bay commercial** fishery, but bait types are likely similar to the ocean commercial and recreational sectors (ODFW Shellfish Program staff, personal communication).

Commercial bay and razor clam harvest for crab bait

In Oregon, several bay clam species (i.e., cockles, gaper clams, butter clams) are commercially harvested for the primary purpose of being used as bait, with a much smaller amount used for human consumption (ODFW, 2014e). Human consumption authorization for clams is under the authority of the Oregon Department of Agriculture. Due to limited agency resources and the workload associated, only a limited number of commercial shellfish harvest areas are monitored and, therefore, able to be classified and managed for human consumption.

In recent years, the level of commercial bay clam landings in some Oregon bays (i.e., Tillamook Bay, Netarts Bay, Yaquina Bay) raised concerns over the allocation of bay clams to recreational and commercial user groups. In 2015, ODFW recommended and the OFWC adopted regulations adjusting commercial landings limits, size limits, and commercial harvest areas to improve the management of these resources and minimize conflicts among commercial and recreational harvesters, as well as other stakeholders. In particular, annual landing caps were established for several species of bay clams harvested by commercial divers from the subtidal zone of Tillamook Bay using stock estimates, species life history traits, and input from stakeholders, to sustain populations for future use and enjoyment (ODFW, 2015b).

In 2018, over 816,000 pounds of bay clams (i.e., cockles, gaper clams, butter clams) were commercially harvested (ODFW, 2019c). This represents a sharp increase from the ten-year average of 418,000 pounds of bay clams harvested each year from 2009 to 2018 (ODFW, 2019d). While the human consumption market has grown, demand for bay clams as Dungeness crab bait on the West Coast largely drives this increase (ODFW Shellfish Program, personal communication). ODFW plans to develop a fishery management plan for Oregon's bay clam fisheries, which will include additional details on harvest patterns after the Tillamook Bay Clam Advisory Committee provides recommendations for bay clam management for ODFW to consider.

A proportion of the commercial harvest of razor clams (i.e., 25% of the total annual harvest from Clatsop Beaches) is also used for bait (ODFW, 2019c). From 2009 to 2018, this translates to around 13,500 pounds of razor clams (25% of the 10-year average of 54,000 pounds) that were harvested each year to be used as bait (ODFW, 2019d). In recent years, the proportion of razor clam harvest used for bait has increased due to demand for West Coast crab bait and reduced supply of razor clams from other sources. This increased demand corresponded with increased value in 2020 when the price per pound for bait clams was at or above the human consumption price (Shellfish Program, personal communication).

k. Social and economic components

The Dungeness crab fishery has been a mainstay of the Pacific coast for decades. Today, Dungeness crab is considered an iconic retail product which many visitors anticipate finding on restaurant menus and in stores year-round.

Commercial utilization

In the early years of the fishery, Dungeness crab was marketed as a fresh-cooked product that was largely limited to coastal areas. Over time, the market expanded throughout the country with the improvement of transportation, refrigeration, and processing facilities (Waldron, 1958).

By the mid-1960s, more than 75% of the crab landed in Oregon were exported to other states, with the majority sold into California markets (Youde, 1967). In recent decades, the demand for live seafood has driven a sharp increase in exports of Dungeness crab from Oregon to international markets (Roegner *et al.*, 2007).

Today, crab are utilized in various product forms including whole-cooks (fresh or frozen), sections (frozen), picked meat (fresh, frozen, canned), and live (Davis *et al.*, 2017). The first few weeks of the season are typically characterized by a large pulse of fresh crab when harvest volume is highest. Large processors are able to manage the flow of product into the market by freezing crab sections for picking throughout the season (Hankin *et al.*, 2005). Traditionally, a holiday market exists in December and January driven by demand for fresh, whole cooked crab as a seasonal or luxury item. This is in addition to fresh cooked and live markets which persist throughout the season.

Ocean commercial ex-vessel value

Fluctuations in crab abundance off the Oregon coast have resulted in variable landings in the **ocean commercial** crab fishery over time. Variations in landings and the price per pound of crab impact the ex-vessel value received by fishers. Generally, ex-vessel value has increased over time with an average of $50.9 million (in 2020 dollars) over the last twenty years (Figure 35). The 2017-18 season brought in $76.5 million (in 2020 dollars), a record high for the crab fishery.

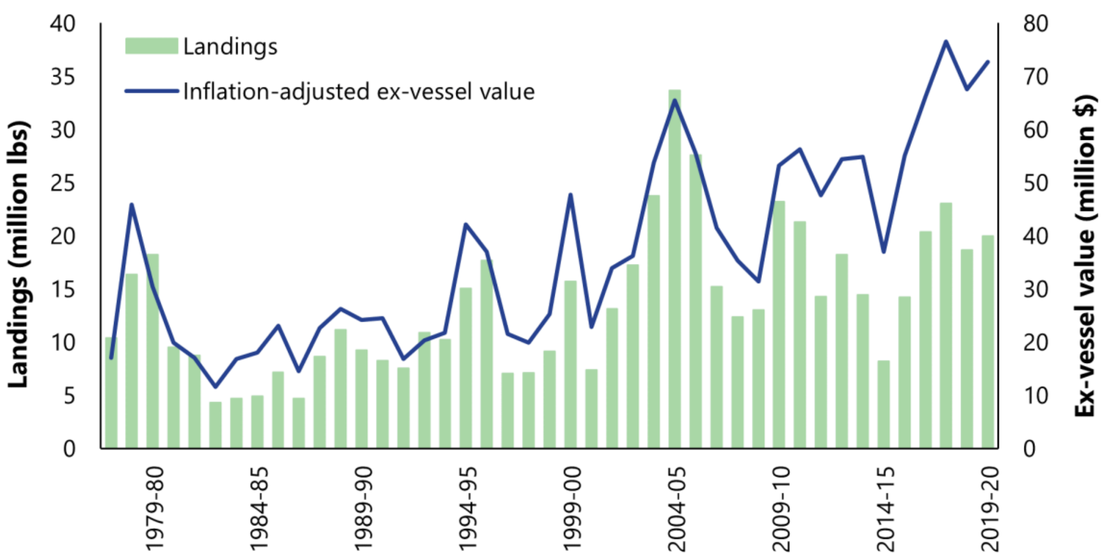


Figure 35. Dungeness crab landings and inflation-adjusted ex-vessel value (in 2020 dollars) in the ocean commercial fishery from the 1977-78 through 2019-20 seasons. Data are from ODFW fish tickets. Inflation adjustment based on CPI data for all urban consumers, U.S. Bureau of Labor Statistics, retrieved on May 5, 2021.

Dungeness crab is a key source of revenue for onshore commercial harvests in Oregon. The more than 20 million pounds of crab harvested during the 2016-17 season, supported over 1,600 jobs (direct and indirect, in full-year equivalents or FYE). During that season, the fishery supported $212.3 million in economic output (i.e., gross value of goods and services produced, including income), of which $113.1 million was paid to workers in labor income (ODFW, 2019e). In 2019, commercial Dungeness crab provided the highest economic contribution to statewide income of any single-species fishery (22%), equating to $122.7 million (in 2019 dollars; TRG, 2021).

Marine Stewardship Council

In 2004, the ODCC initiated the process of obtaining Marine Stewardship Council certification for Oregon's **ocean commercial** fishery. This environmental standard certifies that a fishery is well-managed and sustainable based on internationally accepted fisheries science and management principles. The MSC label may provide a fishery with enhanced access, visibility, and promotional opportunities.

All stages of the MSC assessment process were carried out by a third-party accredited certifier, Scientific Certification Systems, Inc. (SCS). The process began with a pre-assessment to identify any potential challenges to certification and was followed by a full assessment including opportunities for stakeholder input and peer review. Throughout the process, ODFW worked with the ODCC to provide the necessary data and documents to demonstrate the fishery's performance. The fishery was awarded an MSC certificate in December 2010 following the MSC required assessment process and agreement to develop an action plan for meeting certain conditions for continued certification. The full assessment process is detailed in the MSC Public Certification Report (ver. 5; SCS, 2010).

During the five-year certificate period, annual surveillance audits were conducted and the fishery complied with all conditions for continued certification (SCS, 2014). During this time, ODFW developed a research and monitoring plan and a limit reference point for the fishery in furtherance of the agency's management goals and as specific deliverables outlined in the MSC process (ODFW, 2014a).

The MSC certificate expired in November 2015 and the ODCC opted to not pursue re-certification (ODCC, 2015). At that time, the ODCC felt that the economic benefits of the MSC label were largely unrealized. However, renewed interest in sustainable food labeling led the ODCC to pursue a new pre-assessment in 2018 (ODCC, 2018). In 2020, the ODCC developed and finalized a Fishery Improvement Plan as a step towards meeting conditions for future MSC re-certification. The FIP establishes sustainability goals for the fishery, which will be achieved through collaboration between industry, ODFW, and research partners.

Recreational fishery economic contribution

Recreational crabbing is one of the most popular shellfishing activities for Oregon residents and visitors alike and plays an important role in the economy of coastal Oregon communities. Effort and harvest in the recreational fishery are less strictly monitored than in the commercial fisheries, making it difficult to quantify the economic impact of the statewide fishery; however, some estimates have been made.

The estimated number of recreational crabbing trips made annually from 2007 to 2011, ranged from 71,000 to 133,000 trips (Ainsworth *et al.*, 2012). Crabbing trips are an important contributor to shellfishing expenditures which in 2008 totaled $36 million for overnight and day trip travel (e.g., accommodations, food, transportation, retail, guide or charter fees, etc.), and local recreation activities combined. During the same year, an additional $136 million was estimated to be generated from equipment (e.g., gear, fuel, bait, boats) expenditures made in Oregon for all shellfishing activities (Dean Runyan Associates, 2009).

Interactions between crab sectors

Conflicts between recreational and commercial crabbers in Oregon bays and estuaries have been reported to some degree since at least the late 1970s (ODFW, 1977a). The extent of such conflicts varied over time and between bays. In the 1980s, conflicts between these fishery sectors increased leading some recreational crabbers to request that commercial crabbing be prohibited in bays. Aiming to alleviate these conflicts, a series of management actions were taken to implement restrictions in the open access bay commercial fishery including gear requirements, a prohibition on weekend and holiday commercial crabbing in bays, and season regulations (ODFW, 1991b; see *Section B.III.d*). ODFW recommended and the OFWC adopted a permanent rule for a bay commercial crab logbook in 2021 to better track the spatial and temporal activity of the fishery that may help inform and address these conflicts (see *Section A.III.b*). Less controversial but still present, there has been conflict between the ocean participants of the recreational sector and the ocean commercial sector. This conflict has led to different season structure, size limits, and other measures to provide separation between the harvest activities. These inter-sector conflicts have led to administrative actions and regulatory recommendations to provide discrete harvest access and opportunities for each of the three sectors, which are articulated in *Considerations for implementing objectives* in *Section B.I.b*.

Non-consumptive value

Historically, the economic value of fishery species has been attributed to their consumptive use. However, Dungeness crab can also be thought of in terms of the non-consumptive economic value provided to current and future generations by their preservation in the coastal and marine ecosystem. Non-consumptive value is derived from the knowledge that Dungeness crab exist today and will be available for future generations (e.g., option, bequest, existence values). The impacts of specific management actions on non-consumptive use and the value placed on Dungeness crab by non-consumptive users could be significant.

IV. Current issues

There are several prominent issues currently facing the Dungeness crab fishery in Oregon. Some of these present complex management challenges that are active areas of research and discussion.

a. Marine life entanglement

All marine mammals off the Oregon coast are protected under the Marine Mammal Protection Act (MMPA), with additional protections in place for threatened or endangered populations under the Endangered Species Act (ESA). NOAA-NMFS is responsible for the management of marine mammals and their habitat, and works with regional and state managers to ensure that commercial and recreational fisheries remain in compliance with federal laws.

Oregon waters are utilized to a varying degree by a number of large whale species including humpback (*Megaptera novaeangliae*), gray (*Eschrichtius robustus*), blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*), minke (*Balaenoptera acutorostrata*), sperm (*Physeter macrocephalus*), and other whales. Of these, several whale species, subspecies, or distinct population segments (DPSs) are listed under the ESA (Saez *et al.*, 2013).

Observed entanglements

Large whale entanglements in fishing gear have historically occurred at low levels on the U.S. West Coast. However, an increase in the number of marine mammal entanglements in fixed fishing gear since 2014, driven largely by interactions with humpback whales and commercial Dungeness crab gear, has emerged as a management challenge across the entire West Coast fishery. A number of complex factors may be contributing to the increased occurrence of entanglements including changing environmental conditions, altered whale and prey abundance and distribution, shifting fishery effort, and improved public reporting (NOAA, 2019).

Most entanglement reports are the result of opportunistic sightings which are “confirmed” by NMFS using photos or videos of the entangled whale, follow-up observations by NOAA staff, or consultation with experienced partners from the West Coast Region Marine Mammal Stranding Network. If these criteria are not met, then reports cannot be confirmed (NOAA, 2019).

While reporting and response efforts are continually improving, there is still a high degree of uncertainty about the source of entanglements. Whales travel great distances which can make it incredibly difficult to determine the timing and location of entanglement occurrence. This is compounded by the fact that in roughly half of confirmed reports (51% from 2013 to 2020), it is not possible to identify the gear type or specific fishery it is associated with. However, of the identifiable entangling gear, the majority has been attributed to trap or pot fisheries, and particularly the West Coast commercial Dungeness crab fishery (NMFS West Coast Region whale entanglement data, provided April 2021).

Humpback whale entanglements in Oregon Dungeness crab gear have increased since 2014, concurrent with the coastwide increase in humpback whale entanglements. From 2003 through 2020, 13 confirmed whale entanglements in Oregon ocean commercial Dungeness crab gear have occurred, of which, just over half have involved humpback whales (Figure 36). Of the seven humpback whale entanglements confirmed in Oregon crab gear, one was reported prior to 2014 and six have been reported since. Humpback whale entanglements have been reported from

April through October and observed in waters ranging from Washington to Mexico (NMFS West Coast Region whale entanglement data, provided April 2021).

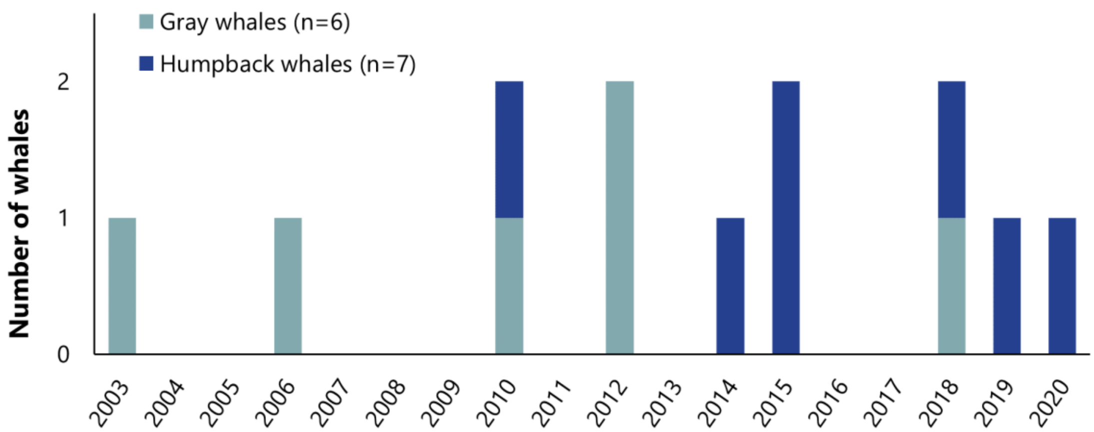


Figure 36. Annual number of confirmed whale entanglements from 2003–2020 in Oregon commercial Dungeness crab gear. The frequency of whale entanglements in Oregon gear has increased, driven largely by humpback whale entanglements. Data provided by NMFS West Coast Region, April 2021.

Mitigation

State management agencies along the West Coast are actively working to reduce the risk of whale entanglements in Dungeness crab and other fixed gear. In Oregon, ODFW is working with researchers, industry, state and federal partners, and the Oregon Whale Entanglement Working Group to develop management measures and strategies to supplement existing regulations that reduce entanglement risk (e.g., limited entry and pot limits, summer fishery trip limits, post-season derelict gear retrieval program, etc.).

In April 2019, ODFW formalized the intent to develop and submit a Conservation Plan (CP) to reduce the risk of entanglement in Oregon ocean commercial Dungeness crab gear, for consideration by NOAA-NMFS to issue an Incidental Take Permit (ITP) as required under the ESA for the incidental take of ESA-listed species. ODFW is requesting ITP coverage for humpback whales, blue whales, and leatherback sea turtles, which are all ESA-listed species that occur off Oregon and have been confirmed entangled in West Coast crab gear (from Washington, Oregon, and/or California). ODFW continues to work on development of the CP, targeting submission to NMFS in late 2021.

There have been two regulatory phases for adoption of management measures that are at the core of the CP. Collectively, these measures support the CP's overarching vision of aligning management with conservation to support the co-existence of an economically viable commercial Dungeness crab fishery and thriving ESA-listed marine life populations in Oregon.

Phase I was adopted by the OFWC in September 2019 and was implemented at the start of the 2019-20 crab season for ocean commercial fishery regulations and at the start of 2020 for recreational or other commercial fixed gear fisheries (including the bay commercial fishery) (ODFW, 2019a). Whale entanglement mitigation measures in this regulatory package were largely focused on better surface gear marking to improve accountability and increase the likelihood that the origin of gear involved in any future entanglements will be identifiable. Specific regulations require:

- Registration of buoy color patterns by all commercial ocean and Columbia River Dungeness crab permit holders planning to harvest crab off Oregon;
- Recreational crab gear buoy marking;
- Commercial buoy marking for all fixed gear commercial fisheries where it is not already required, including the bay commercial fishery; and
- A control date of August 14, 2018 for participation in a potential "late season" limited entry system in the ocean commercial fishery. The intent of a "late season" fishery would be to reduce the number of vertical lines in the water when whale feeding aggregations are most commonly found off Oregon, but the details of any such program have not yet been determined.

Phase II was adopted by the OFWC in September 2020 and was implemented at the start of the 2020-21 ocean commercial crab season (ODFW, 2020b). Management measures in this package focused on mitigating risk by reducing the amount of crab gear (vertical fishing lines) in the water when and where ESA-listed species are feeding in Oregon's coastal and offshore waters. Specific regulations include:

- Late-season 20% pot limit reduction in combination with a 40-fathom depth restriction and late-season buoy tag requirement, beginning May 1 of the 2020-21, 2021-22, and 2022-23 crab seasons (to be followed by evaluation and development of recommendations to extend or modify);
- Elimination of standard replacement tag allowance;
- Elimination of two-week pot-season gear clean-up period;
- Requirement for taut line best practice; and
- Prohibition on the use of other West Coast fishery buoy line markings.

Both phases also included modifications to the Tri-State protocol that were adopted into rule by the OFWC to increase flexibility in order to minimize season opening delays.

In addition to the regulatory changes described above, the agency is engaged in a collaborative research project, initiated in 2019, between ODFW, Oregon State University, Cascadia Research Collective, and the U.S. Coast Guard. Whale presence and absence data are being collected from monthly aerial surveys along standardized track lines to inform predictive distribution models describing species distributions relative to environmental conditions. This study was first identified as a high priority by the OWEWG and the ODCC invested funds to initiate it as a pilot project. Subsequently, the project was fully funded by a grant from NOAA-NMFS through Section 6 funds for research on ESA-listed species.

b. Biotoxin management

Along the U.S. West Coast, the frequency, magnitude, and persistence of algal blooms, both benign and harmful, are increasing (Anderson *et al.*, 2008; Kahru *et al.*, 2009). Harmful algal blooms occur when the rapid growth or accumulation of algae has a negative impact on living organisms, which can pose a threat to fisheries, coastal economies, ecosystems, and public health. HABs can be harmful in several different ways including through the production of natural biotoxins which may accumulate in certain shellfish species and pose a threat to those that consume them.

Domoic acid is a naturally occurring neurotoxin that is produced under certain conditions by several marine algal species (*Pseudo-nitzschia* spp.) and can accumulate in shellfish and fish species, including Dungeness crab. The consumption of contaminated seafood can cause a serious illness, amnesic shellfish poisoning (ASP), and has resulted in commercial and recreational fishery closures and season opening delays along the West Coast. Domoic acid monitoring is a crucial component of ensuring safe, quality crab for consumers and harvesters.

Historical occurrence and determination of regulatory limits

In 1987, the first known occurrence of ASP in humans occurred in Canada and was traced to consumption of contaminated, commercially cultivated blue mussels (Bates *et al.*, 1989). This was followed in 1991 by the first outbreak of domoic acid poisoning along the U.S. West Coast that resulted in an episode of seabird mortality traced to the consumption of contaminated northern anchovies in California (Fritz *et al.*, 1992). In late October of the same year, domoic acid was detected in razor clams from Washington and Oregon, prompting the first domoic acid-related closure of shellfish fisheries. The 1991-92 ocean commercial Dungeness crab season opened on December 1 along the West Coast. However, further testing revealed domoic acid in Dungeness crab viscera and meat from Washington resulting in a closure of the Washington coastal commercial and recreational fisheries on December 7 (WA DOH, 1991). At the request of industry, the commercial season was closed in Oregon on December 11 and did not reopen until December 22 (ODFW, 1995a).

Data on estimated dosage levels and severity of symptoms from the Canadian ASP outbreak were analyzed to quantify the toxicity of domoic acid and determine regulatory limits to ensure seafood safety. The lowest observed adverse effect level was estimated to be 1 mg kg^{-1} (i.e., mg domoic acid per kg of human body weight). As a safety factor to control for sensitive populations, this value was lowered by an order of magnitude to determine a tolerable single day intake of 0.1 mg kg^{-1}. Assuming an average intake of 300 g shellfish and a human adult weight of 60 kg, a precautionary limit of 20 µg domoic acid g^{-1} shellfish (or 20 parts per million, ppm) was determined as the highest amount tolerated for human consumption (Toyofuku, 2006).

A 20 ppm public health standard was established by Health and Welfare Canada in 1988 and by the U.S. Food and Drug Administration (FDA) in 1992 for determining shellfish commercial fishery closures. In 1993, new data were presented on crab meat and crab viscera weights which indicated that a 20 ppm limit was unnecessarily stringent when applied to a whole crab. Since a single legal-sized Dungeness crab contains more meat than viscera, it was agreed that a higher level of domoic acid in crab viscera should be tolerated (USFDA, 1993). Consequently, the FDA raised the action level for crab viscera from 20 ppm to 30 ppm (California Ocean Science Trust, 2016), while the action level for meat remained at 20 ppm.

Alert levels for domoic acid in Oregon follow the thresholds established in the FDA Fish and Fishery Products Hazards and Control Guidance (known as the Seafood Hazards Guide). These levels are ≥20 ppm in all seafood, except ≥30 ppm in viscera of Dungeness crab (OAR 603-025-0410).

Domoic acid monitoring and response

ODFW began partnering with ODA and industry in 1992 to conduct several rounds of domoic acid tests prior to the start of the ocean commercial season (ODFW, 1992b, 1995b, 1996). Today, domoic acid testing is done in conjunction with preseason meat yield testing (see *Section B.III.f*). Six crab are collected for domoic acid testing from each preseason station, representing 12 harvest areas off the Oregon coast (Figure 37). If domoic acid levels in the viscera are above the alert level but levels in the meat are not, ODFW, in close coordination with ODA and industry advisors, can delay the opening of the ocean commercial crab season through temporary rule and continue testing or proceed with opening the season. If the season is opened under these conditions, ODA will designate one or more harvest areas as biotoxin management zones (BMZs) and will issue an evisceration order (i.e., processors must remove and discard the entire intestinal tract, hepatopancreas, and all associated abdominal organs) for the area(s).

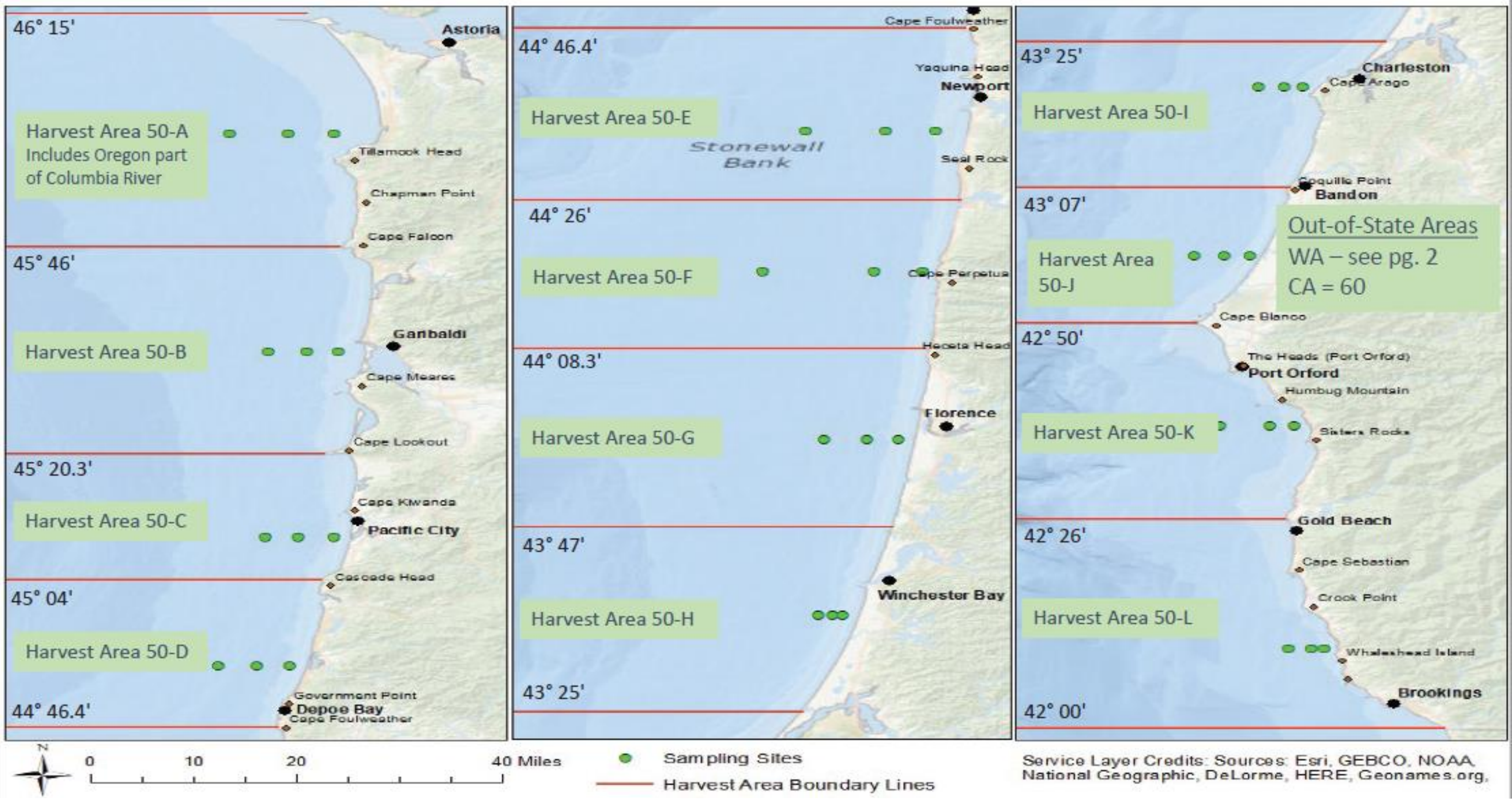
ODA also conducts bi-monthly sampling during winter months and weekly sampling during warmer months for domoic acid in various shellfish species, and these results provide the basis for testing crab during the season. Procedures for in-season crab sampling and domoic acid testing are outlined in OAR 603-025-0410. Briefly, if domoic acid levels at or above 20 ppm are detected in razor clams or another indicator species, ODA will oversee crab sampling every two to four weeks in that harvest area for domoic acid testing. Results are used to inform recreational shellfish safety closures and commercial BMZs or evisceration orders throughout the season.

Detailed procedures for domoic acid monitoring and determination of harvest restrictions for Dungeness crab are found in OAR 603-025-0410, which was developed in 2017 through a Rules Advisory Committee (RAC) process co-led by ODA and ODFW. The RAC process and subsequent input from ODCAC during season opening discussions made clear that evisceration is the preferred option of the commercial industry for in-season management of domoic acid when gear is in the water and crabbing is underway, but is viewed as a measure of last resort to open a season because of the negative impact on crab value due to the limitation on product forms that can be produced under an evisceration order. For example, if the season is delayed to such an extent that the risk of whale entanglement is substantially increased by shifting crab effort later into the spring and summer months when whales are more abundant off Oregon, opening under an evisceration under may be the preferred option. To the extent possible, ODFW considers these factors in season delay decisions.

Evisceration is not a management tool used in the recreational fishery since it is not possible to enforce compliance and therefore would be insufficient to ensure public health and safety. Instead, a recreational shellfish biotoxin closure is implemented if domoic acid test results indicate that an alert level has been met.

New ocean commercial fishery management measures: Through this FMP, ODFW recommended and the OFWC adopted a rule amendment in October 2021 updating the Dungeness crab harvest area map (Figure 37) to include finer scale areas in Washington, and allowing crab to be landed into Oregon for evisceration if they are from an area in another state that is under an evisceration order due to elevated biotoxins. These two separate but related measures were implemented during the 2020-21 ocean commercial season through temporary rule.

Dungeness Crab Harvest Area Map effective October 15, 2021



For **eviscerated crab product only** records of specific harvest area are optional, and Harvest Area code 50 (Oregon) may be used.

Figure 37. Dungeness crab harvest areas recorded on all ODFW fish tickets. The complete map including out-of-state areas is available on ODFW's commercial crab webpage.

Timeline of domoic acid monitoring and response

Below is a timeline of historical domoic acid events, monitoring, and response that are relevant to Dungeness crab biotoxin management in Oregon. Only events resulting in regulatory action or change are included.

1987 – First known occurrence of amnesic shellfish poisoning in humans in Canada

1991 – First domoic acid poisoning along U.S. West Coast in California seabirds; First domoic acid-related closure of shellfish fisheries in Washington and Oregon, including Oregon's ocean commercial fishery early in the 1991-92 season

1992 – A 20 ppm public health standard established by the U.S. FDA for determining domoic acid-related shellfish commercial fishery closures; ODFW began partnering with ODA and industry to conduct preseason domoic acid testing

1993 – FDA action level for crab viscera raised from 20 ppm to 30 ppm

2000 or earlier – Domoic acid testing began being conducted in conjunction with preseason meat recovery testing

2003 – First documented in-season evisceration order issued for a portion of the Oregon coast during the first few weeks of the 2003-04 ocean commercial season

2015 – Evisceration advisory issued in early November for the recreational fishery (bays, piers, and jetties) on Oregon's south coast; Closure of the recreational and bay commercial fisheries on the south coast in mid-November with recreational fishery re-opening in early and late December on the north and south coast, respectively; First ocean commercial season delay due to elevated levels of domoic acid

During each year from 2016 through 2020, commercial crab fishery sectors in Oregon have been subject to domoic acid-related delays, in-season closures, and/or evisceration requirements during some portion of the year. The recreational fishery also faced closures in most years. Specific season delays and in-season events for the ocean commercial sector are detailed in Appendix A.

c. Gear conflicts

Prior to around 1980, conflicts between crabbers and participants in other fisheries were considered minor and were concentrated in the high traffic area around the Columbia River (PFMC, 1979). In 1980, the development of an intense scallop fishery which overlapped crab fishing grounds north of the Umpqua River raised concerns over the potential loss of crab in scallop gear and eventually led to requests that the scallop fishery be closed during the first months of the commercial crab season (PMFC, 1981). Beginning in 1981, Oregon established a license moratorium in the scallop fishery and, by 1992, the fishery had declined to the extent that it was essentially discontinued (PMFC, 1982). Gear regulations since that time have made the dredges that were once used in the fishery illegal and no recent fishery efforts have been documented.

Conflicts occurred at low levels between crabbers and both trawlers and salmon trollers through the 1970s (PFMC, 1979). Beginning in the late 1980s, an increase in ocean commercial fishery effort late in the season resulted in crab gear being deployed at greater than usual depths for several seasons in a row. As a result, reports of conflicts with nearshore trawlers and sport and commercial salmon trollers increased and contributed to ODFW's decision (along with concerns over softshell crab harvest) to consider options in 1992 for limiting harvest opportunity in the late season (ODFW, 1992a). Shortly after, gear conflicts with trawl gear and other crab gear users were a contributing factor to management decisions regarding crab pot longlining (see *Section B.III.e*).

In recent years, concerns over derelict crab gear entangling salmon fishing gear have been a focus of management efforts targeting derelict gear recovery efforts. Most recently, an emerging purse seine fishery for market squid in Oregon's nearshore waters, which overlaps substantially with crab fishing grounds, has been a source of gear conflict. Crabbers have reported crab pots being moved or lost due to interactions with seine nets, and buoys being cut off by vessels searching for squid at night. Interfering with actively fished crab pots is unlawful under current regulations, and ODFW has used an outreach and education approach to address this conflict to date.

d. Vessel safety – Ocean commercial

Commercial fishing is a high-risk occupation associated with a number of safety hazards including on-board medical emergencies, fires, equipment failure, flooding, capsizing, and falling overboard (Croteau and Zoller, 2011). Relative to other fisheries, the West Coast Dungeness crab fishery is particularly hazardous due to certain characteristics, including (Hardin, 2010):

- Ports in Oregon and Washington are typically located at bays with bars where wave action increases hazardous conditions;
- The crab season opening and highest consumer demand coincide with the most extreme weather conditions of the year off the coast;
- The majority (83 – 91%) of ocean commercial landings occur during the first eight weeks of the season (ODFW, 2020a), which contributes to the highly competitive derby nature of the fishery;
- Most pots are deployed in relatively shallow water where extreme surf conditions are often present;
- Heavy crab gear is deployed over the side of vessels which are often relatively small and must travel at slow speeds; and
- Loaded pots are stacked on deck which can lead to vessel instability.

While safety decisions are largely left to vessel operators, several existing management measures have components intended to maintain at-sea safety (e.g., gear setting, barging).

Vessel safety is a strong consideration during management decision-making and ODFW staff will continue to engage with the commercial crab industry about the impacts of potential management actions, including vessel safety concerns and options for minimizing risk.

United States Coast Guard

The U.S. Coast Guard is the primary agency responsible for maintaining vessel safety, conducting rescue operations, and providing at-sea enforcement of fishery regulations (e.g., season closures, gear removal requirements) (SCS, 2010). Under the Commercial Fishing Industry Vessel Safety Act of 1988 (P.L. 100–424), the USCG has regulatory authority to develop and implement basic safety regulations, largely pertaining to safety and survival equipment (e.g., immersion suits, life rafts, visual distress signals, emergency position indicating radio beacons, and fire protection equipment). Efforts are made to both minimize the risk of accidents and to effectively respond if an accident does occur. To minimize risk at-sea, USCG personnel monitor departing vessels and may require those that are overloaded and/or lacking safety gear to return to port until the conditions are corrected.

In 2000, the Coast Guard Pacific Area initiated Operation Safe Crab which aimed to reduce loss of life and property in the fishery through voluntary dockside vessel safety compliance spot checks prior to the start of the season. USCG safety examiners accomplished these goals by assessing the condition and accessibility of primary lifesaving equipment, providing general safety training and information packages to vessel operators, and preventing unsafe vessels from getting underway using applicable USCG authority (USCG, 2001). Currently, the USCG's annual Operation Safe Crab includes required dockside safety exams and safety spot checks, as well as efforts to engage with vessel operators through commercial fishing vessel Drill Conductor courses, discussions during dockside exams, and safety information packages (USCG, 2019).

In 2010, mandatory dockside safety examinations came into effect requiring all commercial vessels operating beyond three nautical miles from the territorial sea baseline to be checked at least every five years for required safety and lifesaving equipment and overall boat condition. Vessels that pass the exam are issued written documentation and a USCG Commercial Fishing Vessel (CFV) Safety Decal which is valid for two years. Vessels that have an expired decal but have not yet reached the five-year mandatory exam date may be subject to more rigorous safety inspections if boarded by the USCG.

V. Other social and cultural uses

Across coastal communities, there are significant cultural values associated with the iconic Dungeness crab fishery. Each December, there is palpable excitement surrounding the commercial season opening, to the point that many coastal residents think of Dungeness crab as a symbol of the holidays and family celebrations. Similarly, for many, recreational crabbing is considered a must-do activity that features heavily in Oregon travel guides, tour packages, and has even been described in several how-to guidebooks dedicated solely to the sport.

Visitors to the coast will quickly realize that the seafood industry and working waterfronts are an integral part of Oregon coastal communities that serve to sustain local cultural heritage and connect the community to the environment (Kellner, 2009). The crab industry is on display in many Oregon port cities contributing to the popularity of these locations for tourists that are looking for an authentic glimpse at the history and character of the community. The critical symbolic importance of Dungeness crab to coastal tribes, fishers, consumers, and environmentalists can be seen through the diversity of social and cultural activities that center on the species.

a. Oregon State crustacean

On June 19, 2009, Dungeness crab joined the Chinook salmon, Douglas fir, and American beaver as a state symbol of Oregon. With the strong support of fourth graders from Sunset Primary School in West Linn, House Joint Resolution 37 was passed designating Dungeness crab as the official crustacean of the State of Oregon (Oregon Legislative Assembly, 2009). Among other factors, the resolution recognizes the economic value, symbolic importance, sustainable management, and overall deliciousness of Dungeness crab.

b. Festivals and crab feeds

All along the coast and throughout much of Oregon, crab is featured heavily at seafood festivals, crab feeds, and other community events. In 1938, the inaugural Newport Crab Festival drew 25,000 visitors to Newport for a free crab lunch and other festivities including a festival court and parade (Russell, 2013). This event, the precursor to the Newport Seafood & Wine Festival, is an example of the long history of coupling the abundance of crab on the coast with a desire for community support and coastal tourism.

VI. Biological Reference Points

Biological reference points are quantifiable metrics which are utilized by fishery managers to determine the status of a stock or population. A limit reference point defines an undesirable state for a fishery or resource which management should take action to avoid, or recover from if reached (Caddy and Mahon, 1995).

a. Ocean commercial fishery limit reference point

As part of the Marine Stewardship Council certification process, the ODCC commissioned a study which explored reference point options for the ocean commercial fishery in Oregon and, ultimately, recommended an initial LRP founded on landings-based criteria (Heppell *et al.*, 2009). In 2014, ODFW implemented a slightly modified LRP with an additional criterion based on abundance (ODFW, 2014c). The LRP is designed and intended to notify managers when the crab population is critically low and warrants extraordinary management measures to sustain the species. The LRP is evaluated annually, within about the first eight weeks of the season, and is considered to have been reached when all of the following conditions are met:

1) Fish tickets indicate landings have declined for three consecutive seasons;

2) Landings are projected to decline for a fourth consecutive season (based on early season landings in the fourth season);
3) Fourth season landings are projected to decline below 20% of the 20-year average; and
4) Logbook catch-per-unit-effort falls below the average level predicted to have occurred over the 1980-81 through 1986-87 seasons.

In the event that the fishery reaches the LRP, ODFW will work with industry and/or through directed research to attempt to discern the primary cause(s) of the observed decline (see *Section A.IV.c* for an analysis of historical landings and abundance). Based on this analysis, ODFW will implement an adaptive management response.

If ODFW determines that immediate action is in the public interest, management actions may be implemented through temporary rule within the fourth season of a decline. Subsequent actions or extension of the temporary rules beyond six months would be implemented through the standard OFWC rulemaking process. In each case, recovery criteria that are specific to the management action taken would also be established so that actions can be continued in subsequent seasons until there is sufficient evidence to determine that the population is recovering or has recovered.

An adaptive management response may involve management actions including:

1) **Season closure**
    - Early closure of the season (e.g., April 1 or earlier) may reduce fishing mortality of the remaining legal-sized males so that more large crab are available for reproduction. Additionally, reduced handling of sublegal male and female crab, particularly during molting periods, may reduce discard mortality allowing more female crab to molt and mate successfully.
    - Alternative measures may include fishery closures only during the female molting/mating period or the male molting period.
    - Closures can be readily implemented and enforced throughout the season.

2) **Pot limit reduction**
    - Reductions in the number of pots that each vessel is allowed to fish would directly reduce overall fishery effort, and potentially indirectly result in further reductions from traditional participants choosing not to fish. To effectively reduce fishing mortality, pot limit reductions would likely have to be severe since crabbers may choose to fish their allotted gear more intensely.
    - Pot limit implementation would be easiest just prior to the season opening, when buoy tags are issued.

3) **Trip limits**
    - Current regulations limit vessels from landing more than 1200 pounds per week from the second Monday in June through the end of the season (August 14). An extension of this trip limit time period, a reduction in the amount of crab that a

vessel may land during this time, or some combination of both, may limit fishery effort and crab fishery mortality.
- Trip limits are relatively easy to implement and enforce throughout the season.

4) **Area closure**
   - Closures of specific areas to crab harvest may protect the crab stock in that area from fishery mortality depending on the size and duration of the closure. Area closures may offer protection of all crab life stages allowing for population recovery.
   - Alternative measures may include closing a particular depth zone during certain times of the year to relieve fishing pressure during critical life stages or processes. For example, closing a particular depth zone to avoid fishing during a time that female bycatch rates are high, to the extent that such determinations can be made.
   - Area closures are easy to implement for all or part of the season, but enforcement difficulty is dependent on the number, size, and location of closures.

5) **Increased minimum size limit**
   - Increasing the minimum size limit (from the current 6 ¼”) would leave a higher proportion of large male crab available for mating. The current size limit is designed to allow male crab one or two years to reproduce before achieving a size that is harvestable by the fishery. However, crab morphology and growth is not uniform.
   - Increased minimum size limit regulations are relatively easy to implement and enforce.

The Dungeness crab stock is also impacted by other fisheries including the recreational and bay commercial crab fisheries, and the nearshore groundfish trawl fishery. While crab mortality in these fisheries is estimated to be small relative to the ocean commercial fishery, they are likely to impact the stock in different ways (e.g., different size and sex selectivity). As part of the adaptive management response, management measures for these fisheries will also be considered.

VII. Evaluation of management tools

The management tools used in the Oregon Dungeness crab fishery are generally consistent with those employed in Washington and California, reflective of the interstate context of the fishery and Dungeness crab stock. Specific management tools currently employed in the Oregon Dungeness crab fishery are summarized in Table 6. These include input controls that limit inputs to the fishery (i.e., who is allowed to fish and where/when/how they are allowed to fish) and output controls which directly constrain catch (i.e., what is allowed to be harvested) (Morison, 2004).

Table 6. Overview of management tools used in the Oregon Dungeness crab fishery, by sector.

	Management tool	Fishery sector: Ocean comm.	Fishery sector: Bay comm.	Fishery sector: Rec.	Primary purpose
Output controls	Size limits	X	X	X	Allow crab to reach sexual maturity & reproduce; Recreational access
Output controls	Sex restrictions	X	X	X	Minimize impacts on reproductive capacity
Output controls	Daily bag limits			X	Provide access to a reasonable harvest
Output controls	Summer trip limits	X			Minimize impacts of fishing on softshell crab
Output controls	Summer quota	X			Minimize impacts of fishing on softshell crab
Input controls	Seasons	X	X	X[a]	Protect crab during molting season; Recreational access; Mitigate gear conflicts; Support enforcement
Input controls	Limited entry	X			Control fishing effort
Input controls	Gear/pot limits	X	X	X	Control fishing effort
Input controls	Area-based biotoxin & meat recovery management	X	X	X	Maintain a safe, quality product; Interstate coordination
Input controls	Gear regulations	X	X	X	Support enforcement; Maintain accountability; Minimize bycatch & impacts to other species/habitat; Recreational access; Mitigate gear conflicts

[a]Only in ocean

Size, sex, and season regulations in all fishery sectors protect the long-term reproductive capacity of the Dungeness crab population. In the ocean commercial fishery, the 3-S approach is combined with summer fishery regulations to protect crab during vulnerable periods and effort controls (i.e., limited entry, pot limits) to address concerns of overcapitalization in the fishery. Limits on the amount of gear in the bay commercial and recreational fisheries also serve to structure sustainable fishing activity. Various gear regulations (e.g., release mechanisms, escape ports, gear marking) are designed to minimize impacts to sublegal crab, other species, and habitat, while allowing for successful enforcement and administration of fishery rules.

While each fishery sector employs a 3-S management approach, separate regulations serve to address the unique objectives of each sector (Table 7). Commercial harvesters with a variety of business plans are able to deliver a safe, high quality product to consumers, whereas recreational harvesters have sustained access to crabbing opportunities and harvest. Collectively, these management tools are in service to the management goals and objectives defined for the fishery (see *Section B.I*).

Table 7. Relationship between management tools employed in the Oregon Dungeness crab fishery and the primary management objectives that they support (see *Section B.I.b* for full description of objectives).

Objectives	Size restrictions	Sex restrictions	Season restrictions	Bay commercial season	Pre-season testing	Gear setting	Barging	Hold inspections	Fair start provisions	Limited entry	LE 200	Vessel length restrictions	Pot limits	Gear marking	Bay fishery gear limit	Recreational bag limit	Summer fishery limits	Derelict gear removal	Marine reserves/closed area	Fish tickets and crab logbooks	Entanglement risk reduction	Biotoxin management	Potential LRP actions
Ecological objectives																							
1.1 Ensure crab productivity	×	×	×							×	×				×	×	×	×		×			×
1.2 Support ecosystem resilience													×		×			×	×		×		
1.3 Minimize impacts to habitat/other species			×							×	×		×	×	×		×	×	×	×	×		×
1.4 Utilize best available science	×	×	×		×									×			×		×	×	×	×	×
Social/cultural objectives																							
2.1 Provide regulatory stability	×	×	×	×		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×			
2.2 Consider cultural/aesthetic value																		×	×		×		
2.3 Support commercial business plan diversity				×		×	×	×	×	×	×	×	×				×				×	×	
2.4 Prioritize food safety/quality					×												×					×	
2.5 Provide access to sustainable recreational harvest	×			×											×	×						×	
Economic objectives																							
3.1 Optimize long-term harvest & minimize adverse economic impacts	×	×	×	×	×				×	×	×	×	×		×	×	×			×	×	×	×
3.2 Maintain commercial market quality	×		×		×												×					×	×
3.3 Maintain crabbing opportunities, consider non-consumptive value, & provide near-year-round product	×			×						×			×		×	×	×					×	

VIII. Recommended actions

Through this analysis of Oregon's Dungeness crab resource and harvest management strategy, several recommended actions have been identified which fall into two main categories: (1) actions to help resolve current issues related to the fishery, and (2) actions to maintain a resilient fishery in the face of changing climate and ocean conditions. In addition to these actions, efforts should be made to address the information gaps and research needs identified in *Section A.VII* allowing for informed management decisions to be made.

a. Actions to help resolve current issues

There are several potential management measures or tools that have been proposed as mechanisms for resolving issues in the crab fishery, including the prominent current issues described in *Section B.IV*. The purpose of this section is to document those measures, provide relevant background information, and identify primary barriers to implementation to support future decision-making processes. Most of these measures require significant additional development time before they are ready to be considered for implementation.

Accountability

Improved vessel accountability and near real-time access to crab harvest information is needed to help inform whale entanglement mitigation measures and improve the efficiency and effectiveness of biotoxin management.

Electronic monitoring

Along the West Coast, there is a recognized need for near-real-time collection of spatially and temporally explicit information on fishery effort to improve vessel accountability, strengthen crab traceability regulations, aid enforcement of season opening provisions, and inform management decision-making related to marine life entanglements (see *Sections B.IV.a* and *B.IV.b*).

In 2019, an initial step towards establishing automated electronic data collection systems was taken through adoption of a requirement for electronic fish tickets with harvest area information for all commercial crab landings (ODFW, 2019a). To continue improving data collection, ODFW is committed to working with industry to test electronic vessel monitoring systems (e.g., solar loggers) for operability within the crab fishery and developing procedures for how systems can be used to provide necessary fishery data in the near-term. There are various EM systems available on the market and testing of one or more EM systems within the fishery is a critical step for familiarizing fishery participants with the technology and defining data requirements, before requiring industry to invest in the equipment.

Additionally, ODFW is planning to pursue development of an electronic logbook to replace the current paper version that is in use. The development of an electronic logbook was recommended by the ODA and ODFW Dungeness Crab and Biotoxins Rules Advisory Committee to improve data collection, harvest area accountability, and enforcement (ODA and ODFW, 2017). An electronic logbook system will greatly improve the quality, speed, and usability of data received by ODFW, while lessening the recordkeeping burden for fishery participants. As of 2021, ODFW has begun taking steps to migrate past logbook data in preparation to receive EM data.

Before widespread adoption of either component is considered, a number of challenges must be resolved related to cost, design, enforceability, and multiple data issues (including transmission, processing, storage, and confidentiality).

Line marking

As described in *Section B.IV.a*, accurate fishery and state of origin information is critical for targeted fishery management that reduces the risk of marine life entanglements. Requiring specific marking of buoy lines that identifies the specific fishery and/or state, is one method that has been put forth for potentially improving attribution rates.

There was significant discussion among the Tri-State Committee in May 2020 about the rationale and goals for buoy line marking regulations. The Committee generally agreed that goals for current and future line marking regulations include that they are: (1) identifiable and accurate, (2) visible (primarily in photographs), (3) reasonable and cost-effective, (4) coordinated across West Coast Dungeness crab fisheries and potentially other fixed gear fisheries, and (5) environmentally friendly.

Although ocean commercial industry members have generally supported the concept of line marking to help identify the fishery source for entanglements, there is little consensus on how best to implement buoy line marking in Oregon. Significant concerns have been raised about the risk of false positive and false negative gear attributions with line marking schemes proposed to date.

As a first step and in support of a coordinated West Coast approach, the OFWC adopted a prohibition of buoy line markings used in other West Coast fisheries in September 2020 (ODFW, 2020b). ODFW plans to continue working with industry, NMFS, and the other West Coast states to develop a line marking scheme that can be recommended for implementation in the Oregon crab fishery.

Long-term effort reduction

Long-term fishery effort reduction is one tool for contributing to whale entanglement risk reduction and mitigating gear conflicts, as well as, addressing potential overcapitalization in the fishery. Due to the magnitude of the ocean commercial fishery sector, proposed effort reduction scenarios are focused on reducing the number of permits active in that fishery sector or limiting the number of pots that are able to be deployed. The measures described below represent potential mechanisms for achieving long-term effort reduction, although others exist and may be considered in the future.

Full season pot limit reduction

A full season pot limit reduction is a potential measure that would reduce vertical lines and the associated marine life entanglement risk throughout the entire season. Early in the season, whale species are less abundant but can still be present off Oregon when substantially more gear is deployed.

This measure would affect all permit holders and has the potential to affect the distribution of catch and revenue across the season and among participants. For example, with a reduced pot limit, some participants that typically exit the fishery early may choose to participate longer or opt to forego some revenue. However, the level of pot limit reduction that may significantly impact catch and revenue is not known at this time. An assessment of catch and revenue following the implementation of pot limits in 2006 indicates that the annual pounds landed did not decline and that ex-vessel value has increased to record levels since that time. Additionally, an analysis of landings and earnings suggests that the distribution among participants also did not significantly change (ODFW, 2009b).

While there is a small segment of the crab industry that support full season pot limit reduction, limited fleet support due to the potential impacts to the fishery remains the primary barrier to implementation at this time. A full season pot limit reduction may become a more viable option, if ongoing monitoring efforts indicate that gear deployed during the early season presents a greater entanglement threat than currently believed.

Permit stacking

Under current regulations, only one crab permit (with a single pot limit) can be attached to an individual vessel. Permit stacking is a potential future measure which would allow multiple permits to be assigned to the same vessel to achieve a higher combined pot limit, with some discount applied which reduces the overall number of pots fished. For example, two 500 pot permits on a single vessel may stack to allow for a discounted 750 total pots to be fished.

During the development and implementation of the pot limit system in Oregon, a permit/pot stacking program was considered as a way to aid individuals in adapting to pot limits and allow for continued growth in some business plans while simultaneously reducing the number of pots and permits in the fleet. At the time, development of a stacking program could not be pursued due to several constraints, including the absence of LE 200 regulations at the California-Oregon border (ODFW, 2006). At the request of the OFWC, ODFW worked with the crab fleet through a pot stacking subcommittee and the 2007 Crab Industry Summit to develop goals and potential options for a stacking plan.

Discussions continued through the three-year review of the pot limit program in 2009 with variable support and no consensus on the specific aspects of what a stacking program would include (ODFW, 2009b). A fleet-wide survey following the 2009 Crab Industry Summit indicated that 72% of respondents were not in favor of ODFW pursuing a pot stacking program at that time (ODFW, unpublished data), and plans for permit stacking were put on hold.

Today, while there is a portion of the crab industry that supports the concept of permit stacking, there is concern among others regarding consolidation that restructures the fishery toward larger operations (i.e., vessels, companies, processors). Additionally, the design of a permit stacking plan would have to address concerns about the potential reactivation of latent permits (i.e., some portion of vessel permits which do not actively make landings into Oregon every year) (see *Section B.III.g*). At this time, the challenge of designing a program that simultaneously meets conservation goals and addresses industry concerns remains a primary barrier to implementation. The specific details of any future permit stacking plan would need to be carefully developed with industry input to create incentives that support the goal of gear reduction.

License buyback program

A license buyback program would permanently reduce the total amount of gear allowed in the fishery by eliminating permits through a voluntary buyback option. A buyback may impact the fishery by reducing opportunities for new entrants due to the reduced availability and increased cost of the more limited number of permits (i.e., fleet consolidation). Additionally, as with a permit stacking measure, a license buyback may raise concerns about the potential reactivation of latent permits (see *Section B.III.g*). At this time, the primary barrier to implementing a license buyback is the need to identify an adequate funding mechanism that enables the purchase of enough permits to meaningfully reduce risk.

Late-season limited entry program

A late-season limited entry program is a potential future measure which would ensure that an increase in entanglement risk is avoided by capping potential effort in the late-season when whale species are more abundant off Oregon. Participation in a late-season limited entry program would be restricted to only those crabbers or vessels with a history of participating in the late-season. As it is currently being considered, this measure would prevent an increase in entanglement risk but would not necessarily reduce risk, unless it was specifically designed to do so.

A control date of August 14, 2018 was adopted by the OFWC in September 2019 for participation in a potential late-season limited entry program (ODFW, 2019a). In effect, this ensures that only landings prior to that date will be considered in qualifying criteria during development of any future limit on participation in the late-season. The action to establish a control date was taken as a signal to industry that fishing activity after that date would not be considered in qualifying criteria, in order to reduce the motivation for a “prospecting” response.

The development and details of a potential limited entry program are contentious, as such a program inevitably creates winners and losers in terms of who obtains a late-season permit. At this time, the primary barrier to implementation is the wide range of options that would need to be considered and decided upon in order to design an effective program.

Tri-State coastwide pot limit

A Tri-State (or bi-state) pot limit is a potential mechanism for reducing gear coastwide, and particularly in border areas (e.g., the Columbia River) where excessive gear and crowding concerns from dual-permitted vessels exist. This type of program would involve a limit on the total number of pots that can be fished on the West Coast, regardless of how many pots a permit holder is authorized to use in a particular state. Similar to permit stacking, a dual permit holder with a 500 pot limit in Oregon and a 500 pot limit in Washington might be limited to a total of 750 pots, for example, if they chose to fish in both states within a crab season.

Impacts to the fishery would be limited to vessels permitted in two or all three West Coast states and would likely impact the distribution of catch and revenue geographically and among participants. Importantly, a Tri-State or bi-state pot limit would require substantial coordination and agreement from the other West Coast states which may be a challenge due to the diversity of perspectives and business plans within the coastwide fishery.

Other potential entanglement risk reduction measures

In addition to the long-term effort reduction measures described above, there are other future potential measures that are being considered for evaluation, development, and implementation in order to reduce the risk of marine life entanglements in Dungeness crab gear from Oregon (see *Section B.IV.a*). As with the measures above, these tools are being considered for implementation in the ocean commercial fishery due to the sheer magnitude of fishing lines used in that sector relative to the bay commercial and recreational sectors.

Maximum surface gear allowance

A maximum surface gear allowance is currently planned for implementation in the ocean commercial fishery. This regulation will restrict the amount of surface gear (i.e., buoys and lines used to mark and retrieve pots) permitted to be used by crab fishery participants on each pot, in order to reduce entanglement risk. Although a forensic understanding of the factors that lead to an animal becoming entangled is limited, it is generally accepted that slack line between buoys, knots, and splices where lines are joined are all places where an animal is more likely to become entangled. By regulating the amount of surface gear, the number of entanglement points that a whale or sea turtle might encounter are reduced.

Potential impacts to the fishery from a maximum surface gear allowance include reduced visibility or retrievability of gear which could lead to increased pot loss. Additionally, there may be some time or cost involved with reconfiguring gear. At this time, implementation of a maximum surface gear allowance is largely dependent on solicitation of fleet input to develop reasonable and effective language that works to reduce entanglement risk, while still providing enough flexibility for industry to set up their gear to account for the wide variety of environmental conditions that may be encountered off Oregon. ODFW plans to work to solicit this input and pursue implementation of a maximum surface gear allowance in the near future.

Authorization of longlining/duplexing

Longlining is currently prohibited in the crab fishery as a result of a series of actions by the OFWC in the mid-1990s to address concerns about overcapitalization and incidence of gear conflicts with other users (e.g., single crab pots, trawl gear). Today, every crab pot is required to be marked by an individual buoy and crab pots are prohibited from being attached to one another by a groundline or any other means, which aids enforcement of pot limits (see *Section B.III.e*). However, authorization of longlining or duplexing (i.e., two crab pots connected to a single vertical line) has been proposed as a potential mechanism for significantly reducing the number of vertical lines to address marine life entanglement risk, while still allowing a higher number of pots to be fished.

At this time, potential gear conflicts and enforcement of pot limits remain the primary barriers to implementation. However, while the current prohibition on longlining ensures that crab and other fishers know the location of gear and can avoid gear setting conflicts, the authorization of longlining may also reduce conflicts stemming from the sheer number of single lines present (e.g., conflicts with commercial and recreational salmon trollers). Additionally, there are several information gaps related to longlining/duplexing which may have implications for entanglement incidence and severity. First, there is limited information about the entanglement risk posed by different groundline types, particularly for bottom feeding whale species (e.g., gray whales). Also, it is not known how longlining or duplexing might affect the severity and number of unreported entanglements if a whale becomes entangled with multiple pots which constrain their ability to move.

The challenges associated with authorization of longlining/duplexing may be partially addressed through a more targeted implementation approach. For example, implementation only in deeper water (e.g., outside 40 fathoms) and/or in the late-season (e.g., after May 1). If properly developed, longlining/duplexing could also potentially be implemented as an in-season adaptive response to elevated entanglement risk.

Hot spot closures

Hot spot closures (or zonal closures) are a potential measure for reducing entanglement risk through the targeted removal of gear from areas of higher whale abundance. The impact of hot spot closures on crab fishery participants are variable and dependent on when and where individuals are deploying gear.

The primary barrier to hot spot closures in Oregon is the expense of collecting ongoing, real-time information on whale species distribution. An additional concern related to hot spot closures is the potential of creating a “curtain” effect where gear is concentrated around the perimeter of a closed area. This phenomenon has been observed in logbook data that indicate crab fishing concentrated around the perimeter of marine reserve sites at certain times off Oregon (ODFW, unpublished data). A dense aggregation of gear around a hot spot could greatly increase entanglement risk when animals pass through to move in or out of the area.

Innovative gear technologies

Fishing gear innovations, such as ropeless or breakaway gear technology, represent a possible management measure for reducing entanglement risk. Ropeless gear broadly refers to technologies that partially or fully eliminate the vertical line that attaches fixed bottom fishing gear to a surface buoy. Breakaway gear involves lines that are specifically designed to break when a pot or trap entangles a whale.

There is not currently enough information to consider specific gear modifications, but it remains an active area of research. At this time, ropeless gear prototypes are very expensive and not operationally practical, but there have been recent efforts to explore different options on the East Coast (Shester, 2018). CDFW has recently encouraged at-sea testing of modified, legal fishing gear that considers the guidelines established by the California Dungeness Crab Fishing Gear Working Group for research and development of new gears (CDFW, 2019). The Oregon Whale Entanglement Working Group has recommended collaboration with working groups in Washington and California to facilitate this research (OSG, 2019).

ODFW currently has the ability to authorize testing of otherwise illegal gear configurations, such as pop-up gear, through an Experimental Gear Permit (EGP) authorized under OAR 635-006-0020. The application process is largely informal and typically initiated by an applicant making a request to ODFW. ODFW then works with the applicant to determine if the gear is likely to be successful in meeting ODFW's goals for the fishery and conservation of species and habitats, and specify terms and conditions for permit issuance. Gear testing under an EGP must comply with all other commercial fishing regulations such as closed seasons and license and permit requirements. ODFW can authorize such testing for research purposes outside of season, under a Scientific Take Permit, which requires a more formal application and review process.

b. Actions to address climate and ocean change

Fisheries around the world and in Oregon face numerous challenges under changing climate, ocean, and ecosystem conditions (see *Section A.V.e*). Oregon is involved in a number of initiatives to address climate and ocean change, and Dungeness crab resilience is a central theme behind much of this work. There are both direct impacts of climate and ocean change on Dungeness crab productivity (e.g., ocean acidification erosion of shells, hypoxia increased mortality) and indirect impacts (e.g., harmful algal bloom impacts on harvestability, fishery footprint adjustments to avoid entanglements). This section describes a few key initiatives that are shaping Oregon's climate and ocean change agenda and the implications for ODFW's management of Dungeness crab.

Initiative 1: OAH Council and Action Plan

In 2017, the Oregon Legislature created the Coordinating Council for Ocean Acidification and Hypoxia, tasked with providing recommendations and guidance for addressing ocean acidification and hypoxia (see *Section A.V.e*). Building on the OAH Council's 2018 Legislative report, Oregon's Ocean Acidification and Hypoxia Action Plan (OAH Action Plan) is the state's roadmap to tackle these two ocean stressors that pose risks to Oregon's Dungeness crab resources. The Action Plan is built around five key goals:

1) Advance scientific understanding of OAH
2) Reduce the causes of OAH
3) Promote adaptation and resilience to OAH
4) Raise awareness of OAH science, impacts, and solutions
5) Build a sustained framework and resources for tackling this global problem

To achieve these goals, the Action Plan identifies specific steps forward, including investment in OAH and biological monitoring, study of socioeconomic vulnerabilities to OAH, and research on biological responses to OAH. For Dungeness crab and the industries and communities that depend on them, these investments would provide essential information needed to assess vulnerabilities to OAH and inform ways to mitigate and adapt to adverse impacts. HB 3114 (2021) allocated $1.9 million in state funds to implement several priorities identified in the OAH Action Plan.

Initiative 2: ODFW Climate and Ocean Change Policy

In 2020, the OFWC adopted the Climate and Ocean Change Policy that provides high level direction to ODFW to evaluate the impacts of climate change on the resources under its stewardship and implement management practices that are protective of those resources and minimize impact to the communities that depend on them. As part of implementing this policy, ODFW has established fishery objectives through this FMP that prioritize the long-term sustainability of the Dungeness crab resource, fishery, and broader ecosystem in the face of the challenges of climate and ocean change.

Initiative 3: PFMC Climate and Communities Initiative

At the federal level, the Pacific Fishery Management Council's Fishery Ecosystem Plan (FEP) is the primary pathway for which the PFMC incorporates ecosystem science into its fishery management decisions. The FEP does not act primarily through regulating fisheries, instead it is implemented through topical ecosystem initiatives, the outcomes of which inform fisheries management. Recent initiatives include forage fish, the development of ecosystem indicators, and most recently the Climate and Communities Initiative (CCI) launched in 2017. The bulk of the work done in the CCI was a series of scenario planning workshops to explore and envision the potential effects of climate change on fishing communities. Under this initiative, PFMC brought together a range of stakeholders (including fishery participants, processors, fishing community members, fishery scientists, fishery managers, non-governmental organizations, and the public) to discuss and plan for the potential effects of climate variability and change on fish stocks, fisheries, and fishing communities in the California Current System. As part of the scenario planning process, stakeholders were asked to identify potential actions that could be taken now to prepare for different future conditions. Across all scenarios, several themes emerged which include, but are not limited to, building flexibility into management, providing support (e.g., financial, infrastructure) to fishing industries and communities, improving data, and fostering communication and collaboration between stakeholder groups.

Another product of this scenario planning process was the identification of pathways to incorporate climate and ecosystem information into the PFMC decision making process and identify potential actions to prepare West Coast fish stocks, fisheries habitat, and fishing communities for a variety of future effects of climate change. While the Dungeness crab fishery is not federally managed, this work will help to improve understanding of potential risks and opportunities for all West Coast fishing communities facing climate change impacts in the future.

Crab fishery management implications

Fishery management that is responsive to changing conditions is essential to Oregon's management strategy for Dungeness crab. This includes working with researchers and other partners to anticipate climate and ocean change impacts on the fishery and implementing management decisions that allow for flexibility to adapt to future scenarios. Oregon's crab fishery management structure already includes several mechanisms for adaptive management that will be increasingly important for responding to climate and ocean change. First, the ocean commercial fishery's limit reference point is a key tool for detecting and responding to sustained declines in the crab population off Oregon (see *Section B.VI.a*). In the event that the LRP is reached, ODFW has identified a suite of potential management actions that will be considered to determine and implement an appropriate response. Due to the relative size of the ocean commercial fishery, the LRP indices are specific to that sector; however, the LRP strategy also includes consideration and implementation of management responses in the bay commercial and recreational fishery sectors, if determined to be useful and appropriate.

Adaptive management is also a key component of ODFW's approach to addressing several current issues. For example, Oregon's biotoxin management strategy is designed to maintain flexibility through enhanced traceability that allows continued harvest during biotoxin events (see *Section B.IV.b*). Additionally, Oregon's approach to marine life entanglement mitigation includes the development of an explicit adaptive management plan for modifying Oregon's conservation strategy as conditions develop or new information suggests that changes may be warranted (see *Section B.IV.a*). This includes a strategy for responding to elevated entanglement risk through a variety of short-term management responses or adjustments to existing conservation measures, as well as a prioritized list of future potential measures that ODFW will be continuing to develop and consider for implementation over time.

Oregon has a long history of innovation and each of these tools are examples of Oregon applying creative solutions to fishery management challenges. This out-of-the-box thinking will be increasingly important moving forward.

C. Literature Cited

Ainsworth, J. C., Vance, M., Hunter, M. V., and Schindler, E. 2012. The Oregon recreational Dungeness crab fishery, 2007-2011. Oregon Department of Fish and Wildlife, Marine Resources Program, Information Report No. 2012-04. 62 pp.

Airriess, C. N., and McMahon, B. R. 1994. Cardiovascular adaptations enhance tolerance of environmental hypoxia in the crab *Cancer magister*. Journal of Experimental Biology, 190: 23–41.

Anderson, D. M., Burkholder, J. M., Cochlan, W. P., Glibert, P. M., Gobler, C. J., Heil, C. A., Kudela, R. M., *et al*. 2008. Harmful algal blooms and eutrophication: examining linkages from selected coastal regions of the United States. Harmful Algae, 8: 39–53.

Antonelis, K., Huppert, D., Velasquez, D., and June, J. 2011. Dungeness crab mortality due to lost traps and a cost-benefit analysis of trap removal in Washington State waters of the Salish Sea. North American Journal of Fisheries Management, 31: 880–893.

Armstrong, D. A., Buchanan, D. V., Mallon, M. H., Caldwell, R. S., and Millemann, R. E. 1976. Toxicity of the insecticide methoxychlor to the Dungeness crab *Cancer magister*. Marine Biology, 38(3): 239–252.

Armstrong, D. A., Burreson, E. M., and Sparks, A. K. 1981. A ciliate infection (*Paranophrys* sp.) in laboratory-held Dungeness crabs, *Cancer magister*. Journal of Invertebrate Pathology, 37: 201–209.

Armstrong, D. A., Stevens, B. G., and Hoeman, J. C. 1981. Distribution and abundance of Dungeness crab and Crangon shrimp, and dredging-related mortality of invertebrates and fish in Grays Harbor, Washington. School of Fisheries, University of Washington, 377 pp.

Armstrong, D. A., Wainwright, T. C., Orensanz, J., Dinnel, P. A., and Dumbauld, B. R. 1987. Model of dredging impact on Dungeness crab in Grays Harbor, Washington. Fisheries Research Institute, School of Fisheries, University of Washington, FRI-UW-8702, 178 pp.

Armstrong, J. L., Armstrong, D. A., and Mathews, S. B. 1995. Food habits of estuarine staghorn sculpin, *Leptocottus armatus*, with focus on consumption of juvenile Dungeness crab, *Cancer magister*. Fishery Bulletin, 93(3): 456–470.

Arthur, C., Sutton-Grier, A. E., Murphy, P., and Bamford, H. 2014. Out of sight but not out of mind: Harmful effects of derelict traps in selected U.S. coastal waters. Marine Pollution Bulletin, 86: 19–28.

Barber, J. S., and Cobb, J. S. 2007. Injury in trapped Dungeness crabs (*Cancer magister*). ICES Journal of Marine Science, 64: 464–472.

Barth, J. A., Fram, J. P., Dever, E. P., Risien, C. M., Wingard, C. E., Collier, R. W., and Kearney, T. D. 2018. Warm blobs, low-oxygen events, and an eclipse: the Ocean Observatories Initiative Endurance Array captures them all. Oceanography, 31(1): 90–97.

Bates, S. S., Bird, C. J., de Freitas, A. S. W., Foxall, R., Gilgan, M., Hanic, L. A., Johnson, G. R., *et al.* 1989. Pennate diatom *Nitzchia pungens* as the primary source of domoic acid, a toxin in shellfish from eastern Prince Edward Island, Canada. Canadian Journal of Fisheries and Aquatic Sciences, 46: 1203–1215.

Bednaršek, N., Feely, R. A., Beck, M. W., Alin, S. R., Siedlecki, S. A., Calosi, P., Norton, E. L., *et al.* 2020. Exoskeleton dissolution with mechanoreceptor damage in larval Dungeness crab related to severity of present-day ocean acidification vertical gradients. Science of the Total Environment, 716(136610): 1–12.

Behrens Yamada, S. 2001. Global Invader: The European Green Crab. Oregon Sea Grant, 123 pp.

Behrens Yamada, S., and Kaufmann, B. 2013. Status of the European green crab in Oregon and Washington estuaries in 2013. Pacific State Marine Fisheries Commission, 24 pp.

Behrens Yamada, S., Mathias Davidson, T., and Fisher, S. 2010. Claw morphology and feeding rates of introduced European green crabs (*Carcinus maenas* L, 1758) and native Dungeness crabs (*Cancer magister* Dana, 1852). Journal of Shellfish Research, 29(2): 471–477.

Bernatis, J. L., Gerstenberger, S. L., and McGaw, I. J. 2007. Behavioural responses of the Dungeness crab, *Cancer magister*, during feeding and digestion in hypoxic conditions. Marine Biology, 150: 941–951.

Botsford, L. W., Methot, R. D., Jr., and Wilen, J. E. 1982. Cyclic covariation in the California king salmon, *Oncorhynchus tshawytscha*, silver salmon, *O. kisutch*, and Dungeness crab, *Cancer magister*, fisheries. Fishery Bulletin, 80(4): 791–801.

Bradburn, M. J., Keller, A. A., and Horness, B. H. 2011. The 2003 to 2008 U.S. West Coast bottom trawl surveys of groundfish resources off Washington, Oregon, and California: Estimates of distribution, abundance, length, and age composition. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-NWFSC-114, 323 pp.

Breitburg, D. 2002. Effects of hypoxia, and the balance between hypoxia and enrichment, on coastal fishes and fisheries. Estuaries, 25(4b): 767–781.

Brierly, A. S., and Kingsford, M. J. 2009. Impacts of climate change on marine organisms and ecosystems. Current Biology, 19: R602–R614.

Buchanan, D. V., Millemann, R. E., and Stewart, N. E. 1970. Effects of the insecticide Sevin on various stages of the Dungeness crab, *Cancer magister*. Journal of the Fisheries Research Board of Canada, 27(1): 93–104.

Buckley, T. W., Tyler, G. E., Smith, D. M. and Livingston, P. A. 1999. Food habits of some commercially important groundfish off the coast of California, Oregon, Washington, and British Columbia. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-AFSC-102, 173 pp.

Butler, T. H. 1954. Food of the commercial crab in the Queen Charlotte Islands region. Fisheries Research Board of Canada, Pacific Biological Station, Progress Report No. 99, pp. 3–5.

Butler, T. H. 1956. The distribution and abundance of early post-larval stages of the British Columbia commercial crab. Fisheries Research Board of Canada, Progress Report No. 107. Biological Station, Nanaimo, B.C., pp. 22–23.

Butler, T. H. 1960. Maturity and breeding of the Pacific edible crab, *Cancer magister* Dana. Journal of the Fisheries Research Board of Canada, 17(5): 641–646.

Butler, T. H. 1961. Growth and age determination of the Pacific edible crab *Cancer magister* Dana. Journal of the Fisheries Research Board of Canada, 18(5): 873–891.

Caddy, J. F., and Mahon, R. 1995. Reference points for fisheries management. Food and Agriculture Organization of the United Nations, Fisheries Technical Paper No. 347, 83 pp.

Caldwell, R. S., Armstrong, D. A., Buchanan, D. V., Mallon, M. H., and Millemann, R. E. 1978. Toxicity of the fungicide Captan to the Dungeness crab *Cancer magister*. Marine Biology, 48: 11–17.

Caldwell, R. S., Buchanan, D. V., Armstrong, D. A., Mallon, M. H., and Millemann, R. E. 1979. Toxicity of the herbicides 2,4-D, DEF, Propanil, and Trifluralin to the Dungeness crab, *Cancer magister*. Archives of Environmental Contamination and Toxicology, 8(4): 383–396.

California Department of Fish and Wildlife (CDFW). 2019. Guidance for testing trap fishing gear modifications. 2 pp. Available at https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=169838&inline

California Ocean Science Trust. 2016. Frequently asked questions: harmful algal blooms and California fisheries, developed in response to the 2015-2016 domoic acid event. 28 pp.

Chan, F., Barth, J. A., Lubchenco, J., Kirincich, A., Weeks, H., Peterson, W. T., and Menge, B. A. 2008. Emergence of anoxia in the California Current large marine ecosystem. Science, 319: 920.

Checkley, D. M., Jr., and Barth, J. A. 2009. Patterns and processes in the California Current System. Progress in Oceanography, 83: 49–64.

Chesapeake Bay Stock Assessment Committee (CBSAC). 2018. Chesapeake Bay blue crab advisory report. 23 pp.

Childers, R. K., Reno, P. W., and Olson, R. E. 1996. Prevalence and geographic range of *Nadelspora canceri* (Microspora) in Dungeness crab *Cancer magister*. Diseases of Aquatic Organisms, 24: 135–142.

Cho, Y., Sim, W. J., Han, G. M., and Hong, S. H. 2019. Abundance and characteristics of microplastics in market bivalves from South Korea. Environmental Pollution, 245: 1107–1116.

Cleaver, F. C. 1949. Preliminary results of the coastal crab (*Cancer magister*) investigation. Washington Department of Fisheries, Biological Report No. 49A, pp. 47–82.

Collard, F., Gilbert, B., Compère, P., Eppe, G., Das, K., Jauniaux, T., and Parmentier, E. 2017. Microplastics in livers of European anchovies (*Engraulis encrasicolus*, L.). Environmental Pollution, 229: 1000–1005.

Croteau, G., and Zoller, E. 2011. Oregon crab fishing safety assessment. National Institute of Occupational Safety and Health Award #2 u50 OH07544, 79 pp. Available at https://deohs.washington.edu/sites/default/files/images/general/FINAL_Oregon_Crab_Fishing_Safety_Assess_with_cover.pdf

Daehler, C. C., and Strong, D. R. 1996. Status, prediction and prevention of introduced cordgrass *Spartina* spp. invasions in Pacific estuaries, USA. Biological Conservation, 78: 51–58.

Dahlstrom, W. A., and Wild, P. W. 1983. A history of Dungeness crab fisheries in California. *In* Life History, Environment, and Mariculture Studies of the Dungeness Crab, *Cancer magister*, With Emphasis on the Central California Fishery Resource, pp. 7–23. Ed. By P. W. Wild and R. N. Tasto. California Department of Fish and Game, Fish Bulletin 172, 352 pp.

Dana, J. D. 1852. Conspectus crustaceorum, conspectus of the crustacea of the exploring expedition under Capt. Wiles, U. S. N., including the Crustacea Cancroidea Corystoidea. Proceedings of the Academy of Natural Sciences of Philadelphia, 6: 73–86.

Darling, J. D., Keogh, K. E., and Steeves, T. E. 1998. Gray whale (*Eschrichtius robustus*) habitat utilization and prey species off Vancouver, B.C. Marine Mammal Science, 14(4): 692–720.

Davie, P. J. F., Guinot, D., and Ng, P. K. L. 2015. Anatomy and functional morphology of Brachyura. *In* Treatise on Zoology – Anatomy, Taxonomy, Biology, The Crustacea, 9(C-1), pp. 11–163. Ed. by P. Castro, P. Davie, D. Guinot, F. Schram, and C. von Vaupel Klein. Brill, Leiden.

Davis, S., Syvlia, G., Yochum, N., and Cusack, C. 2017. Oregon Dungeness crab fishery bioeconomic model: a fishery interactive simulator learning tool. Prepared by OSU Coastal Oregon Marine Experiment Station and The Research Group, LLC for the Oregon Dungeness Crab Commission. 125 pp.

Dean Runyan Associates. 2009. Fishing, Hunting, Wildlife Viewing, and Shellfishing in Oregon, 2008. Prepared for Oregon Department of Fish and Wildlife and Travel Oregon. 72 pp.

Demory, D. 1971. Abandoned crab pots near Cannon Beach, Oregon. Shellfish Investigation Information Report No. 70-6. Fish Commission of Oregon, Research Division, 6 pp.

Demory, D. 1978. Helicopter crabbing. Oregon Department of Fish and Wildlife, 1 pp.

Demory, D. 1984. An overview of Oregon Dungeness crab fishery with management concepts for the future. *In* Proceedings of the Symposium on Dungeness Crab Biology and Management, Report No. 85-3, pp. 27 – 32. Ed. by B. Melteff. Alaska Sea Grant, University of Alaska.

Demory, D. 1990. History and status of the Oregon Dungeness crab fishery. Oregon Department of Fish and Wildlife, Marine Region, 13 pp.

Demory, D. 1991. Oregon Dungeness crab fishery data report series, 1977-1990. Oregon Department of Fish and Wildlife, Marine Region, 157 pp.

Demory, D., and McCrae, J. 1991. Alsea Bay sport crab survey, 1988-89. Oregon Department of Fish and Wildlife, Marine Region, 42 pp.

Department of Land Conservation and Development (DLCD). 2010. Oregon's Statewide Planning Goals & Guidelines. Oregon Department of Land Conservation and Development, 84 pp. Available at https://www.oregon.gov/lcd/OP/Documents/compilation_of_statewide_planning_goals.pdf

Desforges, J-P. W., Galbraith, M., and Ross, P. S. 2015. Ingestion of microplastics by zooplankton in the Northeast Pacific Ocean. Archives of Environmental Contamination and Toxicology, 69: 320–330.

Didier, A. J., Jr. 2002. The Pacific coast Dungeness crab fishery. Submitted to the Committee on Commerce, Science, and Transportation of the United States Senate and Committee on Resources of the United States House of Representatives. The Pacific States Marine Fisheries Commission, 30 pp.

Dinnel, P. A., Armstrong, D. A., and McMillan, R. O. 1993. Evidence for multiple recruitment-cohorts of Puget Sound Dungeness crab, *Cancer magister*. Marine Biology, 115: 53–63.

Dunn, P. H., and Shanks, A. L. 2012. Mating success of female Dungeness crabs (*Cancer magister*) in Oregon coastal waters. Journal of Shellfish Research, 31(3): 835–839.

Dunn, P. H., and Young, C. M. 2014. Larval settlement of the nemertean egg predator *Carcinonemertes errans* on the Dungeness crab, *Metacarcinus magister*. Invertebrate Biology, 133(3): 201–212.

Dunn, P. H., and Young, C. M. 2015. Salinity and temperature tolerance of the nemertean worm *Carcinonemertes errans*, an egg predator of the Dungeness crab. Biological Bulletin, 228: 163–169.

Durham, C., and Hunter, M. 2008. 2004-2005 Columbia River recreational Dungeness crab pilot catch and effort study. Oregon Department of Fish and Wildlife, Marine Resources Program. 9 pp.

Durkin, J. T., Buchanan, K. D., and Blahm, T. H. 1984. Dungeness crab leg loss in the Columbia River Estuary. Marine Fisheries Review, 46(1): 22–24.

Eggleston, D. B., and Armstrong, D. A. 1995. Pre- and post-settlement determinants of estuarine Dungeness crab recruitment. Ecological Monographs, 65(2): 193–216.

Emmett, R. L., and Krutzikowsky, G. K. 2008. Nocturnal feeding of Pacific hake and jack mackerel off the mouth of the Columbia River, 1998-2004: Implications for juvenile salmon predation. Transactions of the American Fisheries Society, 137(3): 657–676.

Fernández, M. 1999. Cannibalism in Dungeness crab *Cancer magister*: effects of predator-prey size ratio, density, and habitat type. Marine Ecology Progress Series, 182: 221–230.

Fernández, M., Iribarne, O., and Armstrong, D. 1993. Habitat selection by young-of-the-year Dungeness crab *Cancer magister* and predation risk in intertidal habitats. Marine Ecology Progress Series, 92: 171–177.

Fields, S. A. 2016. Eyes on the seafloor: using video tools to monitor benthic communities at dredged material disposal sites at the mouth of the Columbia River. MS thesis, Oregon State University, Corvallis, OR.

Fisher, J. L. 2006. Seasonal timing and duration of brachyuran larvae in a high-latitude fjord. Marine Ecology Progress Series, 323: 213–222.

Fisher, R. B. 1972. A long-line (set-line) crab pot system. Circular of Information 630. Agricultural Experiment Station, Oregon State University, 8 pp.

Fisher, W. S. 1976. Relationships of epibiotic fouling and mortalities of eggs of the Dungeness crab (*Cancer magister*). Journal of the Fisheries Research Board of Canada, 33: 2849–2853.

Fisher, W. S., and Nelson, R. T. 1977. Therapeutic treatment for epibiotic fouling on Dungeness crab (*Cancer magister*) larvae reared in the laboratory. Journal of the Fisheries Research Board of Canada, 34: 432–436.

Fritz, L., Quilliam, M. A., and Wright, J. L. C. 1992. An outbreak of domoic acid poisoning attriabuted to the pennate diatom *Pseudonitzschia australis*. Journal of Phycology, 28: 439–442.

Froehlich, H. E., Essington, T. E., Beaudreau, A. H., and Levin, P. S. 2014. Movement patterns and distributional shifts of Dungeness crab (*Metacarcinus magister*) and English sole (*Parophrys vetulus*) during seasonal hypoxia. Estuaries and Coasts, 37: 449–460.

Fullerton, C., Donaldson, J., and Sandison, G. 1980. Memorandum of understanding relative to improvement management of the Pacific coast Dungeness crab fishery. 1 pp.

Gibbons, B., Fisher, R., and Turner, R. 1993. Memorandum of understanding regarding management of the Pacific coast Dungeness crab fishery. 4 pp.

Gobler, C. J., and Baumann, H. 2016. Hypoxia and acidification in ocean ecosystems: couple dynamics and effects on marine life. Biology Letters, 12: 1–8.

Goblirsch, G., and Theberge, S. 2008. Getting to know Oregon's commercial fisheries: Traps. Oregon Sea Grant, Oregon State University, ORESU-G-08-002. 2 pp.

Gotshall, D. W. 1977. Stomach contents of Northern California Dungeness crabs, *Cancer magister*. California Fish and Game, 63(1): 43–51.

Guzzetti, E., Sureda, A., Tejada, S., and Faggio, C. 2018. Microplastic in marine organism: Environmental and toxicological effects. Environmental Toxicology and Pharmacology, 64: 164–171.

Hauri, C., Gruber, N., Plattner, G.-K., Alin, S., Feeley, R. A., Hales, B., and Wheeler, P. A. 2009. Ocean acidification in the California Current system. Oceanography, 22(4): 60–71.

Haertel, L., and Osterberg, C. 1967. Ecology of zooplankton, benthos and fishes in the Columbia River estuary. Ecology, 48(3): 459–472.

Hankin, D. G., Diamond, N., Mohr, M. S., and Ianelli, J. 1989. Growth and reproductive dynamics of adult female Dungeness crabs (*Cancer magister*) in northern California. Journal du Conseil International pour l-Exploration de la Mer, 46: 94–108.

Hankin, D. G., Butler, T. H., Wild, P. W., and Xue, Q.-L. 1997. Does intense fishing on males impair mating success of female Dungeness crabs? Canadian Journal of Fisheries and Aquatic Sciences, 54: 655–669.

Hans, S., Fehsenfeld, S., Treberg, J. R., and Weihrauch, D. 2014. Acid-base regulation in the Dungeness crab (*Metacarcinus magister*). Marine Biology, 161: 1179–1193.

Hardin, D. 2010. Operation Safe Crab. Proceedings of the Marine Safety and Security Council, 67(4): 39–42.

Hatfield, S. 1983. Intermolt staging and distribution of Dungeness crab, *Cancer magister*, megalopae. *In* Life History, Environment, and Mariculture Studies of the Dungeness Crab, *Cancer magister*, With Emphasis on the Central California Fishery Resource, pp. 85–123. Ed. by P. W. Wild and R. N. Tasto. California Department of Fish and Game, Fish Bulletin 172, 352 pp.

Heppell, S. S., Thompson, K., and Price, C. 2009. Development of monitoring and assessment tools for the Dungeness crab fishery. Report to the Oregon Dungeness Crab Commission, 42 pp.

Hickey, B. M., and Banas, N. S. 2008. Why is the northern end of the California Current System so productive? Oceanography, 21(4): 90–107.

Hiebert, T. C., and Rasmuson, L. 2015. *Cancer magister*. *In* Oregon Estuarine Invertebrates: Rudys' Illustrated Guife to Common Species. 3rd ed. Ed. by T. C. Hiebert, B. A. Butler, and A. L. Shanks. University of Oregon Libraries and Oregon Institute of Marine Biology, Oregon.

Hildenbrand, K., Gladics, A., and Eder, B. 2011. Adult male Dungeness crab (*Metacarcinus magister*) movements near Reedsport, Oregon from a fisheries collaborative mark-recapture study. Oregon Wave Energy Trust and Oregon Dungeness Crab Commission, 21 pp.

Horn, D., Miller, M., Anderson, S., and Steele, C. 2019. Microplastics are ubiquitous on California beaches and enter the coastal food web through consumption by Pacific mole crabs. Marine Pollution Bulletin, 139: 231–237.

Howard, V., Pfauth, M., Sytsma, M., and Isaacson, D. 2007. Oregon *Spartina* Response Plan. Prepared for Oregon Department of Agriculture. Center for Lakes and Reservoirs, Portland State University, 70 pp.

Hunt, S. L., Mulligan, T. J., and Komori, K. 1999. Oceanic feeding habits of chinook salmon, *Oncorhynchus tshawytscha*, off northern California. Fishery Bulletin, 97(3): 717–721.

Jackson, T. M., Roegner, G. C., and O'Malley, K. G. 2017. Evidence for interannual variation in genetic structure of Dungeness crab (*Cancer magister*) along the California Current System. Molecular Ecology, 1–17.

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., *et al*. 2015. Plastic waste input from land into the ocean. Science, 347(6223) 768–771.

Jamieson, G. S., and Phillips, A. C. 1990. A natural source of megalopae for the culture of Dungeness crab, *Cancer magister* Dana. Aquaculture, 86: 7–18.

Jensen, G. C. 2014. Crab and Shrimps of the Pacific Coast: A Guide to Shallow-Water Decapods from Southeastern Alaska to the Mexican Border, 1st edn. MolaMarine, Washington. 240 pp.

Jensen, G. C., and Asplen, M. K. 1998. Omnivory in the diet of juvenile Dungeness crab, *Cancer magister* Dana. Journal of Experimental Marine Biology and Ecology, 226: 175–182.

Jensen, P. C., Orensanz, J. M., and Armstrong, D. A. 1996. Structure of the female reproductive tract in the Dungeness crab (*Cancer magister*) and implications for the mating system. Biological Bulletin, 190: 336–349.

Johnson, A. M. 1982. Status of Alaska sea otter populations and developing conflicts with fisheries. Transactions of the Forty-Seventh North American Wildlife and Natural Resources Conference, 293–299.

Juanes, F., and Hartwick, E. B. 1990. Prey size selection in Dungeness crabs: the effect of claw damage. Ecology, 71(2): 744–758.

Juanes, F., and Smith, L. D. 1995. The ecological consequences of limb damage and loss in decapod crustaceans: a review and prospectus. Journal of Experimental Marine Biology and Ecology, 193: 197–223.

Kahru, M., Kudela, R., Manzano-Sarabia, M., and Mitchell, B. G. 2009. Trends in primary production in the California Current detected with satellite data. Journal of Geophysical Research, 114(C02004): 1–7.

Keller, A. A., Simon, V., Chan, F., Wakefield, W. W., Clarke, M. E., Barth, J. A. Kamikawa, D. *et al*. 2010. Demersal fish and invertebrate biomass in relation to an offshore hypoxic zone along the US West Coast. Fisheries Oceanography, 19(1): 76–87.

Keller, A. A., Wallace, J. R., and Methot, R. D. 2017. The Northwest Fisheries Science Center's West Coast Groundfish Bottom Trawl Survey: History, design, and description. U.S. Department of Commerce, NOAA Technical Memorandum, NMFS-NWFSC-136, 38 pp.

Kellner, L. 2009. A toolbox for sustaining working waterfronts; assessing applications in Newport, Oregon. M.S. Thesis, Oregon State University, Corvallis, Oregon. 126 pp.

Klaoudatos, S. D., and Klaoudatos, D. S. 2008. Phylogeny biology and ecology of crustaceans (phylum Arthropoda; subphylum Crustacea). *In* Reproductive Biology of Crustaceans, Case Studies of Decapod Crustaceans, pp. 13–90. Ed. By E. Mente. Science Publishers, Enfield. 565 pp.

Kline, T. C., Jr. 2002. Relative trophic position of *Cancer magister* megalopae. *In* Crab in Cold Water Regions: Biology, Management, and Economics, pp. 645–649. Ed. By A. J. Paul, E. G. Dawe, R. Elner, G. S. Jamieson, G. H. Kruse, R. S. Otto, B. Saint-Marie, *et al*. Alaska Sea Grant College Program, University of Alaska Fairbanks. 876 pp.

LaRiviere, P. E., and Barry, S. T. 1998. Limited entry in the Washington coastal Dungeness crab (*Cancer magister*) fishery: the first step toward rationalizing an overcapitalized and chaotic fishery. *In* Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management, pp. 325–333. Ed. By G. S. Jamieson and A. Campbell. Canadian Special Publication of Fisheries and Aquatic Sciences, 125, 462 pp.

Le Quéré, C., Andrew, R. M., Canadell, J. G., Sitch, S., Korsbakken, J. I., Peters, G. P., Manning, A. C., *et al*. 2016. Global carbon budget 2016. Earth System Science Data, 8: 605–649.

Lewis, N. S., Young, D. R., Folger, C. L., and DeWitt, T. H. 2020. Assessing the relative importance of estuarine nursery habitats – a Dungeness crab (*Cancer magister*) case study. Estuaries Coast, 44(4): 1062–1073.

Long, J. B., and Horton, H. F. 1963. Recreational and commercial use pattern for the fish and wildlife resources of Yaquina Bay, Oregon. Oregon State University, Department of Fish and Game Management, 15 pp.

Lough, R. G. 1976. Larval dynamics of the Dungeness crab, *Cancer magister*, off the central Oregon coast, 1970-71. Fishery Bulletin, 74(2): 353–376.

Love, M. S., Yoklavich, M., and Thorsteinson, L. K. 2002. The Rockfishes of the Northeast Pacific. University of California Press, Berkeley. 404 pp.

Lusher, A. L., Hollman, P. C. H., and Mendoza-Hill, J. J. 2017. Microplastics in fisheries and aquaculture: status of knowledge on their occurrence and implications for aquatic organisms and food safety. FAO Fisheries and Aquaculture Technical Paper, No. 615, 147 pp.

MacKay, D. C. G. 1942. The Pacific edible crab, *Cancer magister*. Bulletin of the Fisheries Research Board of Canada, LXII: 1–32.

Marine debris removal project for the Oregon coast. 2006. Mailing, 28 September 2006. 2 pp.

Marshall, K. N., Kaplan, I. C., Hodgson, E. E., Hermann, A., Busch, D. S., McElhany, P., Essington, T. E., *et al*. 2017. Risks of ocean acidification in the California Current food web and fisheries: ecosystem model projections. Global Change Biology, 23: 1525–1539.

Martin, M., Osborn, K. E., Billig, P., and Gilckstein, N. 1981. Toxicities of ten metals to *Crassostrea gigas* and *Mytilus edulis* embryos and *Cancer magister* larvae. Marine Pollution Bulletin, 12(9): 305–308.

Maselko, J., Bishop, G., and Murphy, P. 2013. Ghost fishing in the Southeast Alaska commercial Dungeness crab fishery. North American Journal of Fisheries Management, 33: 422–431.

McDonald. P. S., Jensen, G. C., and Armstrong, D. A. 2001. The competitive and predatory impacts of the nonindigenous crab *Carcinus maenas* (L.) on early benthic phase Dungeness crab *Cancer magister* Dana. Journal of Experimental Marine Biology and Ecology, 258: 39–54.

McGaw, I. J. 2005. Does feeding limit cardiovascular modulation in the Dungeness crab *Cancer magister* during hypoxia? Journal of Experimental Biology, 208: 83–91.

McGaw, I. J. 2008. Gastric processing in the Dungeness crab, *Cancer magister*, during hypoxia. Comparative Biochemistry and Physiology, Part A, 150: 458–463.

McMillan, R. O., Armstrong, D. A., and Dinnel, P. A. 1995. Comparison of intertidal habitat use and growth rates of two Northern Puget Sound cohorts of 0+ age Dungeness crab, *Cancer magister*. Estuaries, 18(2): 390–398.

Methot, R. D., Jr., and Botsford, L. W. 1982. Estimates preseason abundance in the California Dungeness crab (*Cancer magister*) fisheries. Canadian Journal of Fisheries and Aquatic Sciences, 39(8): 1077–1083.

Miller, J. A., and Shanks, A. L. 2004. Ocean-estuary coupling in the Oregon upwelling region: abundance and transport of juvenile fish and of crab megalopae. Marine Ecology Progress Series, 271: 267–279.

Miller, J. J., Maher, M., Bohaboy, E., Friedman, C. S., and McElhany, P. 2016. Exposure to low pH reduces survival and delays development in early life stages of Dungeness crab (*Cancer magister*). Marine Biology, 163(118): 1–11.

Moloney, C. L., Botsford, L. W., and Largier, J. L. 1994. Development, survival and timing of metamorphosis of planktonic larvae in a variable environment: the Dungeness crab as an example. Marine Ecology Progress Series, 113: 61–79.

Morado, J. F. 2011. Protistan diseases of commercially important crabs: a review. Journal of Invertebrate Pathology, 106: 27–53.

Morado, J. F., Giesecke, R. H., and Syrjala, S. E. 1999. Molt related mortalities of the Dungeness crab *Cancer magister* caused by a marine facultative ciliate *Mesanophrys pugettensis*. Diseases of Aquatic Organisms, 38: 143–150.

Morgan, V. H., and Sytsma, M. D. 2013. Potential ocean dispersal of cordgrass (*Spartina* spp.) from core infestations. Invasive Plant Science and Management, 6: 250–259.

Morison, A. K. 2004. Input and output controls in fisheries management: a plea for more consistency in terminology. Management and Ecological Note. Fisheries Management and Ecology, 11: 411–413.

Murphy, M. C. 1995. Summary of the Dungeness Crab Management Workshop Held in Homer, Alaska, February 1–3, 1995. Alaska Department of Fish and Game, Regional Information Report No. 5J95-17, 24 pp.

National Oceanic and Atmospheric Administration (NOAA). 2017. Oregon Marine Debris Research Priorities Workshop proceedings. Marine Debris Program, 16 pp.

National Oceanic and Atmospheric Administration (NOAA). 2019. 2018 West Coast whale entanglement summary. National Marine Fisheries Service, 10 pp. Available at https://www.fisheries.noaa.gov/resource/document/2018-west-coast-whale-entanglement-summary

Natter, J. R. 2018. When pesticides change. Natter's Notes. Metro-area Master Gardener Newsletter, OSU Extension Service. Available at https://blogs.oregonstate.edu/mgmetro/2018/10/02/when-pesticides-change/

North Pacific Fishery Management Council (NPFMC). 2018. Stock assessment and fishery evaluation report for the king and Tanner crab fisheries of the Bering Sea and Aleutian Islands regions. Plan Team for the King and Tanner Crab Fisheries of the Bering Sea and Aleutian Islands, 41 pp.

Ocean Policy Advisory Council (OPAC). 1994. Oregon Territorial Sea Plan. Ocean Policy Advisory Council. Available at https://www.oregon.gov/lcd/OCMP/Pages/Territorial-Sea-Plan.aspx

Oh, S. J., and Hankin, D. G. 2004. The sperm plug is a reliable indicator of mating success in female Dungeness crabs, *Cancer magister*. Journal of Crustacean Biology, 24(2): 314–326.

O'Malley, K. G., Corbett, K., Beacham, T. D., Jacobson, D. P., Jackson, T. M., and Roegner, G. C. 2017. Genetic connectivity of the Dungeness crab (*Cancer magister*) across oceanographic regimes. Journal of Shellfish Research, 36(2): 453–464.

O'Malley, K., and Roegner, C. 2013. Evaluating the population genetic structure of Dungeness crab (*Cancer magister*) off the Oregon coast. Oregon Wave Energy Trust, 20 pp.

Oregon Department of Agriculture (ODA), and Oregon Department of Fish and Wildlife (ODFW). 2017. 2017 RAC recommendation summary. Dungeness Crab and Biotoxin Rules Advisory Committee, 3 pp. Available at https://www.dfw.state.or.us/MRP/shellfish/commercial/crab/docs/2018/FINAL_RACSummaryRecommendations.pdf

Oregon Department of Fish and Wildlife (ODFW). 1977a. The Dungeness Crab Fishery in Oregon Estuaries. Marine Region, 13 pp.

Oregon Department of Fish and Wildlife (ODFW). 1977b. Helicopter crabbing report – Update. Marine Region, 3 pp.

Oregon Department of Fish and Wildlife (ODFW). 1977c. Staff report on the use of helicopters in the Dungeness crab fishery in Oregon. Marine Region, 14 pp.

Oregon Department of Fish and Wildlife (ODFW). 1978. Escape port requirements on commercial crab pots. Fish Division, 1 pp.

Oregon Department of Fish and Wildlife (ODFW). 1982a. Staff statement on extending the Dungeness crab season for public hearing August 20, 1982. Exhibit C. Marine Region, 5 pp.

Oregon Department of Fish and Wildlife (ODFW). 1982b. Staff statement on destruct device for lost crab pots for public hearing August 20, 1982. Exhibit C. Marine Region, 3 pp.

Oregon Department of Fish and Wildlife (ODFW). 1983. Staff statement on preseason setting of crab pots and crab pot release mechanism for public hearing March 18, 1983. Exhibit E. Marine Region, 4 pp.

Oregon Department of Fish and Wildlife (ODFW). 1984a. Staff statement on commercial crab fishing in estuaries for public hearing February 16, 1984. Exhibit A. Marine Region, 4 pp.

Oregon Department of Fish and Wildlife (ODFW). 1984b. Staff statement on crab pot buoy identification for public hearing October 12, 1984. Marine Region, 2 pp.

Oregon Department of Fish and Wildlife (ODFW). 1984c. Oregon commercial fishing regulations, 1984 synopsis. 11 pp.

Oregon Department of Fish and Wildlife (ODFW). 1984d. Staff statement for public hearing Feb. 16, 1984 on summer Dungeness crab fishery. Oregon Fish and Wildlife Commission, 16 February 1984. Marine Region, 6 pp.

Oregon Department of Fish and Wildlife (ODFW). 1986a. Shellfish Investigations progress report, 1985. Marine Region, 20 pp.

Oregon Department of Fish and Wildlife (ODFW). 1986b. Misc. crab regulations. Oregon Fish and Wildlife Commission, Exhibit H. Marine Region, 7 pp.

Oregon Department of Fish and Wildlife (ODFW). 1987a. Commercial crab fishing in Oregon's estuaries. Technical Report, 23 pp.

Oregon Department of Fish and Wildlife (ODFW). 1987b. Oregon commercial fishing regulations, 1987 synopsis. 27 pp.

Oregon Department of Fish and Wildlife (ODFW). 1988a. Oregon commercial fishing regulations, 1988 synopsis. 30 pp.

Oregon Department of Fish and Wildlife (ODFW). 1988b. Shellfish Program annual report, 1986. Marine Region, 13 pp.

Oregon Department of Fish and Wildlife (ODFW). 1990. Staff statement on petition to permit a two week period for removal of crab gear after the close of the season. Oregon Fish and Wildlife Commission. 9 pp.

Oregon Department of Fish and Wildlife (ODFW). 1991a. The feasibility and desirability of harvesting female Dungeness crab. 6 pp.

Oregon Department of Fish and Wildlife (ODFW). 1991b. Staff report on recreational and commercial Dungeness crab fisheries. Oregon Fish and Wildlife Commission, 16 October 1991. 18 pp.

Oregon Department of Fish and Wildlife (ODFW). 1992a. Commercial Dungeness crab fishery. Oregon Fish and Wildlife Commission, 21 October 1992. Marine Region, 60 pp.

Oregon Department of Fish and Wildlife (ODFW). 1992b. Shellfish Program monthly reports. Marine Region, 54 pp.

Oregon Department of Fish and Wildlife (ODFW). 1993. September 1993 angling regulations Commission hearing: staff statement for sport crab regulation discussion. 3 pp.

Oregon Department of Fish and Wildlife (ODFW). 1994. Staff report on commercial Dungeness crab fisheries. Oregon Fish and Wildlife Commission, 19 October 1994, Exhibit D. 11 pp.

Oregon Department of Fish and Wildlife (ODFW). 1995a. Shellfish Program annual report, 1992. Marine Region, 14 pp.

Oregon Department of Fish and Wildlife (ODFW). 1995b. Shellfish and Marine Habitat Program annual report, 1993. Marine Region, 15 pp.

Oregon Department of Fish and Wildlife (ODFW). 1996. Shellfish and Marine Habitat Program annual report, 1994. Marine Region, 17 pp.

Oregon Department of Fish and Wildlife (ODFW). 1997a. Economic impact statement for the January 21, 1997 rulemaking involving the amendment of rules relating to the management of the commercial Dungeness crab fisheries. Oregon Fish and Wildlife commission, 21 January 1991. Marine Resources Program, 10 pp.

Oregon Department of Fish and Wildlife (ODFW). 1997b. Report to the Legislature on the Oregon ocean Dungeness crab fishery license limitation program. Marine Resources Program, 8 pp.

Oregon Department of Fish and Wildlife (ODFW). 1998a. Oregon commercial fishing regulations, 1998 synopsis. 35 pp.

Oregon Department of Fish and Wildlife (ODFW). 1998b. Dungeness crab season and permit rules. Oregon Fish and Wildlife Commission, 23 October 1998. Marine Resources Program, 37 pp.

Oregon Department of Fish and Wildlife (ODFW). 2000a. Oregon commercial Dungeness crab fishery status report. Oregon Fish and Wildlife Commission, 13 October 2000, Exhibit B. Marine Resources Program, 27 pp.

Oregon Department of Fish and Wildlife (ODFW). 2000b. Oregon commercial Dungeness crab fishery 1999-00 fishing season review and issues update. Presented to Oregon Dungeness Crab Commission. Marine Resources Program, 12 pp.

Oregon Department of Fish and Wildlife (ODFW). 2001. Oregon commercial Dungeness crab fishery status report. Oregon Fish and Wildlife Commission, 19 October 2001, Exhibit F. Marine Resources Program, 51 pp.

Oregon Department of Fish and Wildlife (ODFW). 2002a. Oregon commercial Dungeness crab fishery: pot limitation for the 2002-03 fishery. Oregon Fish and Wildlife Commission, 9 August 2002, Exhibit G. Marine Resources Program, 32 pp.

Oregon Department of Fish and Wildlife (ODFW). 2002b. Oregon commercial Dungeness crab fishery: a review of the fishery, fishing fleet profile and pot limitation approaches to supplement a discussion on the development of a pot limitation system for Oregon. Marine Resources Program, 79 pp.

Oregon Department of Fish and Wildlife (ODFW). 2002c. Oregon commercial Dungeness crab fishery. Oregon Fish and Wildlife Commission, Exhibit G, 12 April 2002. Marine Resources Program, 30 pp.

Oregon Department of Fish and Wildlife (ODFW). 2003. Oregon commercial fishing regulations, 2003 synopsis. 41 pp.

Oregon Department of Fish and Wildlife (ODFW). 2004. Briefing on Dungeness crab fishery management. Oregon Fish and Wildlife Commission, 12 November 2004, Exhibit G. 8 pp.

Oregon Department of Fish and Wildlife (ODFW). 2005a. Waivers for commercial Dungeness crab fishery permit transfers. Oregon Fish and Wildlife Commission, 4 November 2005, Exhibit E. Marine Resources Program, 2 pp.

Oregon Department of Fish and Wildlife (ODFW). 2005b. Commercial Dungeness crab briefing and 200 mile limited entry rules. Oregon Fish and Wildlife Commission, 7 October 2005, Exhibit D. Marine Resources Program, 24 pp.

Oregon Department of Fish and Wildlife (ODFW). 2006. Dungeness crab pot limits. Oregon Fish and Wildlife Commission, 9 June 2006, Exhibit H. Marine Resources Program, 26 pp.

Oregon Department of Fish and Wildlife (ODFW). 2007a. Modifications to the Dungeness crab pot limit program. Oregon Fish and Wildlife Commission, 12 October 2007, Exhibit E. Marine Resources Program, 11 pp. Available at https://www.dfw.state.or.us/agency/commission/minutes/07/october/E_1_Summary.pdf

Oregon Department of Fish and Wildlife (ODFW). 2007b. Commercial Dungeness crab newsletter. 10 pp. Available at https://www.dfw.state.or.us/MRP/shellfish/commercial/crab/docs/ODFWCrabNewsletter_2007.pdf

Oregon Department of Fish and Wildlife (ODFW). 2007c. Commercial Dungeness crab fishery rules. Oregon Fish and Wildlife Commission, 8 June 2007, Exhibit H. Marine Resources Program, 6 pp. Available at https://www.dfw.state.or.us/agency/commission/minutes/07/june/index.asp

Oregon Department of Fish and Wildlife (ODFW). 2008a. Commercial Dungeness crab newsletter. 6 pp. Available at https://www.dfw.state.or.us/MRP/shellfish/commercial/crab/docs/ODFWCrabNewsletter_2008.pdf

Oregon Department of Fish and Wildlife (ODFW). 2008b. Industry notice, 19 August 2008. Marine Resources Program, 1 pp.

Oregon Department of Fish and Wildlife (ODFW). 2009a. Oregon sport fishing regulations. 112 pp.

Oregon Department of Fish and Wildlife (ODFW). 2009b. Commercial Dungeness crab fishery management. Oregon Fish and Wildlife Commission, 2 October 2009, Exhibit C. Marine Resources Program, 14 pp. Available at https://www.dfw.state.or.us/agency/commission/minutes/09/10_october/index.asp

Oregon Department of Fish and Wildlife (ODFW). 2010a. Oregon Department of Fish and Wildlife Administrative Overview. 13 pp. Available at https://sos.oregon.gov/archives/Documents/recordsmgmt/sched/overview-fish-wildlife.pdf

Oregon Department of Fish and Wildlife (ODFW). 2010b. Commercial Dungeness crab gear requirements. Oregon Fish and Wildlife Commission, 6 August 2010, Exhibit J. Marine Resources

Program, 3 pp. Available at
https://www.dfw.state.or.us/agency/commission/minutes/10/08_aug/index.asp

Oregon Department of Fish and Wildlife (ODFW). 2011a. Commercial Ocean Dungeness Crab Fishery Logbook CPUE Preliminary Assessment. Marine Resources Program, 21 pp.

Oregon Department of Fish and Wildlife (ODFW). 2011b. 3rd annual ODFW Dungeness crab fishery newsletter. Marine Resources Program, 4 pp. Available at
https://www.dfw.state.or.us/MRP/shellfish/commercial/crab/docs/ODFWCrabNewsletter_2011.pdf

Oregon Department of Fish and Wildlife (ODFW) 2012. Technical Supplement to the Oregon Nearshore Strategy: Potential Impacts of Global Climate Change in Oregon's Nearshore Ocean. Marine Resources Program, 22 pp. Available at
https://www.dfw.state.or.us/conservationstrategy/docs/climate_change/Climate_Change_Supplemental_pdf_9_25_12.pdf

Oregon Department of Fish and Wildlife (ODFW). 2014a. Oregon Dungeness Crab Research and Monitoring Plan. Marine Resources Program, 25 pp. Available at
https://www.dfw.state.or.us/MRP/shellfish/commercial/crab/docs/2014/ODFW_DungenessCrabResearchMonitoringPlan_updated2014_Final_081414.pdf

Oregon Department of Fish and Wildlife (ODFW). 2014b. Commercial Ocean Dungeness Crab Fishery Logbook CPUE Preliminary Assessment – 3rd iteration. Marine Resources Program, 45 pp. Available at
https://dfw.state.or.us/agency/commission/minutes/14/08_august/Exhibit%20F_Attachment%2011_Commercial%20Ocean%20Dungeness%20Crab%20Fishery%20Logbook.pdf

Oregon Department of Fish and Wildlife (ODFW). 2014c. Commercial Dungeness crab fishery regulations and update on proposed limit reference point policy. Oregon Fish and Wildlife Commission, 1 August 2014, Exhibit F. Marine Resources Program. Available at
https://www.dfw.state.or.us/agency/commission/minutes/14/08_august/index.asp

Oregon Department of Fish and Wildlife (ODFW). 2014d. Industry notice, 8 August 2014. Marine Resources Program, 2 pp. Available at
https://www.dfw.state.or.us/MRP/shellfish/commercial/crab/docs/2014/2014_IndustryNotice.pdf

Oregon Department of Fish and Wildlife (ODFW). 2014e. Status of Oregon bay clam fisheries, stock assessment, and research. Marine Resources Program, Information Report No. 2014-09. 116 pp.

Oregon Department of Fish and Wildlife (ODFW). 2015a. Oregon Marine Fisheries Management Plan Framework. Marine Resources Program, 41 pp. Available at
https://www.dfw.state.or.us/MRP/publications/docs/MFMP%20Framework_01-09-15.pdf

Oregon Department of Fish and Wildlife (ODFW). 2015b. Commercial bay clamming rules and housekeeping for commercial Dungeness crab. Oregon Fish and Wildlife Commission, 9 September 2015, Exhibit C. Marine Resources Program. Available at https://www.dfw.state.or.us/agency/commission/minutes/15/09_september/index.asp

Oregon Department of Fish and Wildlife (ODFW). 2016. Oregon Nearshore Strategy. Marine Resources Program. Available at http://oregonconservationstrategy.org/oregon-nearshore-strategy/

Oregon Department of Fish and Wildlife (ODFW). 2017. 2017-19 Legislatively Adopted Budget (LAB). K. State Police Enforcement, pp. 861–874. Available at https://www.dfw.state.or.us/agency/budget/docs/17-19_LAB/K_State%20Police%20Enforcement.pdf

Oregon Department of Fish and Wildlife (ODFW). 2019a. Commercial and recreational fixed gear regulations. Oregon Fish and Wildlife Commission, 13 September 2019, Exhibit 2019. Marine Resources Program, 16 pp. Available at https://www.dfw.state.or.us/agency/commission/minutes/19/09_Sep/B/Attachment%201_Agenda%20Item%20Summary.pdf

Oregon Department of Fish and Wildlife (ODFW). 2019b. Industry notice, 5 July 2019. Marine Resources Program, 3 pp. Available at https://www.dfw.state.or.us/MRP/shellfish/commercial/crab/docs/2019/Industry%20Notice%20070519_FINALcom.pdf

Oregon Department of Fish and Wildlife (ODFW). 2019c. Oregon's commercial marine fisheries. Marine Resources Program, 11 pp. Available at https://www.dfw.state.or.us/MRP/docs/Backgrounder_Comm_Fishing.pdf

Oregon Department of Fish and Wildlife (ODFW). 2019d. Pounds and values of commercially caught fish and shellfish landed in Oregon, 2009 – 2018. Marine Resources Program, 11 pp. Available at https://www.dfw.state.or.us/fish/commercial/landing_stats/2018/10%20YEAR%20POUNDS%20AND%20VALUES.pdf

Oregon Department of Fish and Wildlife (ODFW). 2019e. Economic contributions of Oregon's commercial marine fisheries. Prepared for ODFW by ECONorthwest, 30 pp.

Oregon Department of Fish and Wildlife (ODFW). 2020a. 12th annual ODFW Dungeness crab fishery newsletter. Marine Resources Program, 10 pp. Available at https://www.dfw.state.or.us/mrp/shellfish/commercial/crab/docs/2020/Crab%20Newsletter_2020_FINAL.pdf

Oregon Department of Fish and Wildlife (ODFW). 2020b. Reducing risk of whale entanglement in commercial crab fishing gear. Oregon Fish and Wildlife Commission, 11 September 2020, Exhibit C. Marine Resources Program, 19 pp. Available at https://www.dfw.state.or.us/agency/commission/minutes/20/09_Sep/C/Exhibit%20C_Attachment%201_Agenda%20Item%20Summary.pdf

Oregon Department of Fish and Wildlife (ODFW). 2021a. 2021 synopsis - Oregon commercial fishing regulations. 56 pp. Available at https://www.dfw.state.or.us/fish/commercial/docs/2021_Commercial_Synopsis.pdf

Oregon Department of Fish and Wildlife (ODFW). 2021b. 2021 Oregon sport fishing regulations. 100 pp. Available at https://www.eregulations.com/assets/docs/guides/21ORFW-VLR.pdf

Oregon Department of Fish and Wildlife (ODFW). 2022. Recreational and commercial harvest of shellfish to address nearshore ecosystem conditions and management of fisheries, 18 March 2022, Exhibit F. Marine Resources Program, 10 pp. Available at https://www.dfw.state.or.us/agency/commission/minutes/22/03_Mar/F/Exhibit%20F_Attachment%201_Agenda%20Item%20Summary.pdf

Oregon Dungeness Crab Commission (ODCC). 2015. Minutes, 18 February 2015. 3 pp.

Oregon Dungeness Crab Commission (ODCC). 2018. The Dungeness dispatch, 3 April 2018. Volume 1, Issue 2, 6 pp. Available at http://oregondungeness.org/wp-content/uploads/2016/09/The-Dungeness-Dispatch-Vol.-1-Issue-2.pdf

Oregon Fish Commission (OFC). 1948a. Proposed regulations on the crab fishery of the state of Oregon. 4 pp.

Oregon Fish Commission (OFC). 1948b. Shellfish Investigation progress report No. 15. 25 pp.

Oregon Fish Commission (OFC). 1949. Shellfish Investigation progress report No. 17. 19 pp.

Oregon Fish Commission (OFC). 1962. Shellfish Investigations progress report No. 33, April 1, 1959 – March 31, 1961. Research Division, 21 pp.

Oregon Fish Commission (OFC). 1970. Shellfish Investigations progress report No. 39, April 1, 1967 – March 31, 1970. Research Division, 30 pp.

Oregon Fish and Wildlife Commission (OFWC). 2014. Minutes, 1 August 2014. 36 pp.

Oregon Legislative Assembly. 2009. 75th Oregon Legislative Assembly 2009 summary of legislation. Legislative Administration Committee Services, 214 pp. Available at https://www.oregonlegislature.gov/lpro/summleg/2009SummaryOfLegislation.pdf

Oregon Sea Grant (OSG). 2019. Oregon Whale Entanglement Working Group recommendations. 3 pp.

Pacific Fishery Management Council (PFMC). 1979. Draft Fishery Management Plan for the Dungeness Crab Fishery off Washington, Oregon and California. 93 pp.

Pacific Fishery Management Council (PFMC). 1997. Draft Pacific Fishery Management Council Analysis of Options for Dungeness Crab Management. PFMC September Meeting, Attachment G.1.a. 36 pp. Available at https://www.pcouncil.org//bb/1997/0997/G_DungenessCrab_Sept97_BB.pdf

Pacific Fishery Management Council (PFMC). 2016. Pacific groundfish fishery management plan for the California, Oregon, and Washington groundfish fishery. NOAA Award No. NA05NMF441008, 148 pp. Available at http://www.pcouncil.org/wp-content/uploads/2017/03/GF_FMP_FinalThruA27-Aug2016.pdf

Pacific Marine Fisheries Commission (PMFC). 1978. Dungeness Crab Project of the State-Federal Fisheries Management Program. 196 pp.

Pacific Marine Fisheries Commission (PMFC). 1981. 34th annual report of the Pacific Marine Fisheries Commission for the year 1981, to the Congress of the United States and to the governors and Legislatures of Washington, Oregon, California, Idaho, and Alaska. 48 pp. Available at https://www.psmfc.org/wp-content/uploads/2012/02/Resources_Publications__Annual_Reports_1981_PSMFC_Annual_Report.pdf

Pacific Marine Fisheries Commission (PMFC). 1982. 35th annual report of the Pacific Marine Fisheries Commission for the year 1982, to the Congress of the United States and to the governors and Legislatures of Washington, Oregon, California, Idaho, and Alaska. 48 pp. Available at https://www.psmfc.org/wp-content/uploads/2012/02/Resources_Publications__Annual_Reports_1982_PSMFC_Annual_Report.pdf

Pacific States Marine Fisheries Commission (PSMFC). 1993. A review of the California, Oregon, and Washington Dungeness crab fishery. Pursuant to National Oceanic and Atmospheric Administration Award No. NA89AA-D-IJ095, 80 pp.

Pacific States Marine Fisheries Commission (PSMFC). 2010. Compact document. 8 pp. Available at https://www.psmfc.org/wp-content/uploads/2012/02/Publications_PSMFC_Compact_2010_compact1.pdf

Paul, A. J. 1984. Mating frequency and viability of stored sperm in the Tanner crab *Chionoecetes bairdi* (Decapoda, Majidae). Journal of Crustacean Biology, 4(3): 375–381.

Pauley, G. B., Armstrong, D. A., and Heun, T. W. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest), Dungeness crab. U.S. Fish and Wildlife Service, Biological Report 82(11), 20 pp.

Pearson, W. H., Williams, G. D., and Skalski, J. R. 2003. Estimated entrainment of Dungeness crab during maintenance dredging of the mouth of the Columbia River, Summer 2002. Prepared for the U.S. Department of Energy under Contract DE-AC06-76RL01830. Pacific Northwest National Laboratory, PNNL-14190, 33 pp.

Pearson, W. H., Miller, M. C., Williams, G. D., Kohn, N. P., and Skalski, J. R. 2006. Preliminary assessment of potential impacts to Dungeness crabs from disposal of dredged materials from the Columbia River. Prepared for the U.S. Army Corps of Engineers under a Related Services Agreement with the U.S. Department of Energy, Contract DE-AC05-76RL01830. Pacific Northwest National Laboratory, PNNL-15477, 51 pp.

Phillips, J. B. 1935. The crab fishery of California. California Fish and Game, 21(1): 38–60.

Pickering, D. L. 2000. Site Weed Management Plan for Cox Island Preserve, Florence, Oregon for the Period 2000 – 2005. The Nature Conservancy, 9 pp.

Poole, R. L. 1966. A description of laboratory-reared zoeae of *Cancer magister* Dana, and megalopae taken under natural conditions (Decapoda Brachyura). Crustaceana, 11(1): 83–97.

Radcliffe, L. 1919. Fisheries of the Pacific coast states in 1915. *In* Fishery Industries of the United States: Report of the Division of Statistics and Methods for Fisheries for 1918, Appendix X, Bureau of Fisheries Document No. 875, pp. 49–167. United States Department of Commerce.

Rasmuson, L. K. 2013. The biology, ecology, and fishery of the Dungeness crab, *Cancer magister*. *In* Advances in Marine Biology, Vol. 65, pp. 95–148. Ed. By M. Lesser. Academic Press, Burlington. 176 pp.

Reed, P. H. 1969. Culture methods and effects of temperature and salinity on survival and growth of Dungeness crab (*Cancer magister*) larvae in the laboratory. Journal of the Fisheries Research Board of Canada, 26(2): 389–397.

Reilly, P. N. 1983a. Dynamics of Dungeness crab, *Cancer magister*, larvae off central and northern California. *In* Life History, Environment, and Mariculture Studies of the Dungeness Crab, *Cancer magister*, With Emphasis on the Central California Fishery Resource, pp. 57–84. Ed. By P. W. Wild and R. N. Tasto. California Department of Fish and Game, Fish Bulletin 172, 352 pp.

Reilly, P. N. 1983b. Predation on Dungeness crab, *Cancer magister*, in central California. *In* Life History, Environment, and Mariculture Studies of the Dungeness Crab, *Cancer magister*, With Emphasis on the Central California Fishery Resource, pp. 155–164. Ed. By P. W. Wild and R. N. Tasto. California Department of Fish and Game, Fish Bulletin 172, 352 pp.

The Research Group, LLC (TRG). 2021. Oregon commercial and recreational fishing industry economic activity coastwide and in proximity to marine reserve sites for years 2018 and 2019, executive summary. Prepared for Oregon Department of Fish and Wildlife, Marine Reserve Program and Marine Resources Program. 56 pp.

Richerson, K., Punt, A., E., and Holland, D. S. 2020. Nearly a half century of high but sustainable exploitation in the Dungeness crab (*Cancer magister*) fishery. Fisheries Research, 226(105528):1–11.

Roegner, G. C., Armstrong, D. A., and Shanks, A. L. 2007. Wind and tidal influences on larval crab recruitment to an Oregon estuary. Marine Ecology Progress Series, 351: 177–188.

Romsos, C. G. 2004. Mapping surficial geologic habitats of the Oregon continental margin using integrated interpretive GIS techniques. MS thesis, Oregon State University, Corvallis, OR.

Russell, V. 2013. A looking back at the Newport Crab Festival 1949. Coast Explorer Magazine. Available at https://www.coastexplorermagazine.com/features/looking-back-newport-crab-festival-1949

Saez, L., Lawson, D., DeAngelis, M., Petras, E., Wilkin, S., and Fahy, C. 2013. Understanding the co-occurrence of large whales and commercial fixed gear fisheries off the west coast of the United States. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Regional Office, NOAA-TM-NMFS-SWR-044, 102 pp.

Schindler, E. 2000. An evaluation of the ocean recreational Dungeness crab fishery on the Oregon coast, 1999 (draft). Oregon Department of Fish and Wildlife, Marine Resources Program, 6 pp.

Schindler, E., Freeman, M., and Wright, B. 2015. Sampling design of the Oregon Department of Fish and Wildlife's Ocean Recreational Boat Survey (ORBS). Appendix A. Oregon Department of Fish and Wildlife, Marine Resources Program, 27 pp.

Scientific Certification Systems (SCS). 2010. MSC Public Certification Report: Oregon Dungeness Crab Fishery. 119 pp.

SCS Global Services (SCS). 2014. 4th Annual Surveillance Audit Report: Oregon Dungeness Crab. Certificate No. SCS-MF-0024. 27 pp.

Shanks, A. L., and Roegner, G. c. 2007. Recruitment limitation in Dungeness crab populations is driven by variation in atmospheric forcing. Ecology, 88(7): 1726–1737.

Shanks, A. L., Roegner, G. C., and Miller, J. 2010. Using megalopae abundance to predict future commercial catches of Dungeness crabs (*Cancer magister*) in Oregon. California Cooperative Fisheries Investigations (CalCOFI) Report, 51: 1–13.

Shanks, A. L. 2013. Atmospheric forcing drives recruitment variation in the Dungeness crab (*Cancer magister*), revisited. Fisheries Oceanography, 22(4): 263–272.

Shanks, A. L. 2017. Report on the recruitment of Dungeness crab megalopae during the 2017 recruitment season. 5 pp. Available at http://oregondungeness.org/wp-content/uploads/2019/11/2017-Annual-report.pdf

Shanks, A. L. 2020. Report on the recruitment of Dungeness crab megalopae during the 2020 recruitment season. 5 pp. Available at https://oregondungeness.org/wp-content/uploads/2021/04/Annual-report-2020-A-Shanks.pdf

Shester, G. 2018. Initial trials exploring ropeless fishing technologies for the California Dungeness crab fishery. Update to the California Dungeness Crab Fishing Gear Working Group, 8 pp. Available at http://www.opc.ca.gov/webmaster/_media_library/2018/08/ropeless-trials-update7-30-18.pdf

Shields, J. D. 1991. The reproductive ecology and fecundity of *Cancer* crabs. *In* Crustacean Egg Production, pp. 193–213. Ed. By A. Wenner and A. Kuris. Crustacean Issues, 7, 403 pp.

Shirley, S. M., and Shirley, T. C. 1988. Appendage injury in Dungeness crabs, *Cancer magister*, in Southeastern Alaska. Fishery Bulletin, 86(1): 156–160.

Shirley, S. M., Shirley, T. C., and Rice, S. D. 1987. Latitudinal variation in the Dungeness crab, *Cancer magister*: zoeal morphology explained by incubation temperature. Marine Biology, 95(3): 371–376.

Small, H. J., Meyer, G. R., Stentiford, G. D., Dunham, J. S., Bateman, K. and Shields, J. D. 2014. *Ameson metacarcini* sp. nov. (Microsporidia) infecting the muscles of Dungeness crabs *Metacarcinus magister* from British Columbia, Canada. Diseases of Aquatic Organisms, 110: 213–225.

Smith, B. D., and Jamieson, G. S. 1989. Exploitation and mortality of male Dungeness crabs (*Cancer magister*) near Tofino, British Columbia. Canadian Journal of Fisheries and Aquatic Sciences, 46: 1609–1614.

Smith, B. D., and Jamieson, G. S. 1991. Possible consequences of intensive fishing for males on the mating opportunities of Dungeness crabs. Transactions of the American Fisheries Society, 120: 650–653.

Smith, M., Love, D. C., Rochman, C. M., and Neff, R. A. 2018. Microplastics in seafood and the implications for human health. Current Environmental Health Reports, 5: 375–386.

Snohomish County Marine Resource Advisory Committee (MRC). 2003. Proposed Dungeness crab stewardship plan for Snohomish County. Dungeness Crab Sub-committee, 45 pp. Available at https://snohomishcountywa.gov/ArchiveCenter/ViewFile/Item/2094

Snow, C. D. 1960. Oregon crab seasons and their effect on the quality and quantity of crabs landed. Oregon Fish Commission, Research Division, 6 pp.

Snow, C. D. 1962. Oregon crab seasons. Oregon Fish Commission, Research Division, 10 pp.

Snow, C. D. 1963. Oregon crab management. Oregon Fish Commission, 14 pp.

Snow, C. D. 1984. Why are all the crabs dying? Oregon Wildlife, 39(6): 10–11.

Snow, C. D., and Neilsen, J. R. 1966. Premating and mating behavior of the Dungeness crab (*Cancer magister* Dana). Journal of the Fisheries Research Board of Canada, 23(9): 1319–1323.

Snow, C. D., Stewart, N. E., Dahlstrom, W., and Tegelberg, H. 1975. Criteria for coastwide crab condition sampling. Prepared for the State/Federal Dungeness Crab Management Program, Dungeness Crab Scientific Committee Sub-Committee on Crab Condition Studies, 4 pp.

Somers, K. A., Jannot, J., Tuttle, V., Riley, N. B., and McVeigh, J. 2017. Estimated discard and catch of groundfish species in the 2016 US West Coast fisheries. U.S. Department of Commerce, NOAA Fisheries, NWFSC Observer Program, 95 pp.

Sparks, A. K., Hibbits, J., and Fegley, J. C. 1982. Observations on the histopathology of a systemic ciliate (*Paranophrya* sp.?) disease in the Dungeness crab, *Cancer magister*. Journal of Invertebrate Pathology, 39: 219–228.

Sparks, A. K., Morado, J. F., and Hawkes, J. W. 1985. A systemic microbial disease in the Dungeness crab, *Cancer magister*, caused by a *Chlamydia*-like organism. Journal of Invertebrate Pathology, 45: 204–217.

State of Oregon. 1908. Annual report of the Department of Fisheries of the State of Oregon for the years 1907-1908 to the twenty-fifth Legislative Assembly. 155 pp.

Stevens, B. G., Armstrong, D. A., and Cusimano, R. 1982. Feeding habits of the Dungeness crab *Cancer magister* as determined by the Index of Relative Importance. Marine Biology, 72: 135–145.

Stewart, N. E. 1974. The Dungeness crab sport fishery in Washington, Oregon, and California. Pacific Marine Fisheries Commission, State/Federal Dungeness Crab Management Program, 11 pp.

Stone, R. P., and O'Clair, C. E. 2001. Seasonal movements and distribution of Dungeness crabs *Cancer magister* in a glacial southeastern Alaska estuary. Marine Ecology Progress Series, 214: 167–176.

Sulkin, S., Lehto, J., Strom, S., and Hutchinson, D. 1998. Nutritional role of protists in the diet of first stage larvae of the Dungeness crab *Cancer magister*. Marine Ecology Progress Series, 169: 237–242.

Sulkin, S. D., and McKeen, G. L. 1989. Laboratory study of survival and duration of individual zoeal stages as a function of temperature in the brachyuran crab *Cancer magister*. Marine Biology, 103: 31–37.

Swiney, K. M., and Shirley, T. C. 2001. Gonad development of Southeastern Alaskan Dungeness crab, *Cancer magister*, under laboratory conditions. Journal of Crustacean Biology, 21(4): 897–904.

Swiney, K. M., Shirley, T. C., Taggart, S. J., and O'Clair, C. E. 2003. Dungeness crab, *Cancer magister*, do not extrude eggs annually in southeastern Alaska: an *in situ* study. Journal of Crustacen Biology, 23(2): 280–288.

Tegelberg, H. C. 1970. Condition, yield, and handling mortality studies on Dungeness crabs during the 1969 and 1970 seasons. 23rd Annual Report of the Pacific Marine Fisheries Commission for the Year 1970, pp. 42–47.

Toyofuku, H. 2006. Joint FAO/WHO/IOC activities to provide scientific advice on marine biotoxins (research report). Marine Pollution Bulletin, 52: 1735–1745.

United States Bureau of Labor Statistics. 2021. CPI for all urban consumers (CPI-U). All items in U.S. city average, all urban consumers, not seasonally adjusted. Retrieved on 13 May 2021 from https://beta.bls.gov/dataViewer/view/timeseries/CUUR0000SA0

United States Coast Guard (USCG). 2001. Operation Safe Crab 2000. Proceedings of the Marine Safety Council, 58(2): 28–29.

United State Coast Guard (USCG). 2019. 2018 report to the Pacific Fishery Management Council. USCG Report 1, Agenda Item E.1.a, 27 pp. Available at https://www.pcouncil.org/wp-content/uploads/2019/05/E1a_USCG_RPT1_2018Rpt_JUN2019.pdf

United States Food and Drug Administration (USFDA). 1993. Domoic acid in Dungeness crab. Center for Food Safety and Applied Nutrition, Office of Seafood, memo. 4 pp.

United States House of Representatives. 1998. Report 105–674 to accompany H.R. 3498 the Dungeness Crab Conservation and Management Act. 105th Congress, 2nd Session, 10 pp.

Vavrinec, J., Pearson, W. H., Kohn, N. P., Skalski, J. R., Lee, C., Hall, K. D., Romano, B. A., *et al*. 2007. Laboratory assessment of potential impacts to Dungeness crabs from disposal of dredged material from the Columbia River. Prepared for the U.S. Army Corps of Engineers under a Related Services Agreement with the U.S. Department of Energy, Contract DE-AC05-76RL01830. Pacific Northwest National Laboratory, PNNL-16482, 64 pp.

Waldron, K. D. 1958. The fishery and biology of the Dungeness crab (*Cancer magister* Dana) in Oregon waters. Fish Commission of Oregon, Report No. 24, 45 pp.

Washington Department of Fish and Wildlife (WDFW). 2001. Coastal Dungeness crab even flow harvest management plan. 26 pp. Available at https://wdfw.wa.gov/sites/default/files/publications/00976/wdfw00976.pdf

Washington Department of Health (WA DOH). 1991. Fact sheet on Amnesic Shellfish Poisoning (ASP). Office of Shellfish Programs, 3 pp.

Washington State University (WSU). 2014. Pesticide linked to three generations of disease" methoxychlor causes epigenetic changes. ScienceDaily. Available at https://www.sciencedaily.com/releases/2014/07/140724144253.htm

Watts, A. J. R., Lewis, C., Goodhead, R. M., Beckett, S. J., Moger, J., Tyler, C. R., and Galloway, T. S. 2014. Uptake and retention of microplastics by the shore crab *Carcinus maenas*. Environmental Science and Technology, 48: 8823–8830.

Watts, A. J. R., Urbina, M. A., Corr, S., Lewis, C., and Galloway, T. S. 2015. Ingestion of plastic microfibers by the crab *Carcinus maenas* and its effect on food consumption and energy balance. Environmental Science and Technology, 49: 14597–14604.

Welden, N. a. C., and Cowie, P. R. 2016. Long-term microplastic retention causes reduced body condition in the langoustine, *Naphrops norvegicus*. Environmental Pollution, 218: 895–900.

Wickham, D. E. 1979. Predation by the nemertean *Carcinonemertes errans* on eggs of the Dungeness crab *Cancer magister*. Marine Biology, 55: 45–53.

Wickham, D. E. 1980. Aspects of the life history of *Carcinonemertes errans* (Nemertea: Carcinonemertidae), an egg predator of the crab *Cancer magister*. Biological Bulletin, 159: 247–257.

Wilcox, W. A. 1902. Notes on the fisheries of the Pacific coast in 1899. *In* Report of the Commissioner for the Year Ending June 30, 1901, Part XXVII, pp. 501–574. United States Commission of Fish and Fisheries.

Wild, P. W. 1980. Effects of seawater temperature on spawning, egg development, hatching success, and population fluctuations of the Dungeness crab, *Cancer magister*. CalCOFI Report, 21: 115–120.

Yochum, N., Stoner, A. W., Sampson, D. B., and Rose, C. 2018. A comparison of laboratory-holding and tag-return methods for evaluating delayed mortality of Dungeness crab (*Cancer magister*) discarded in Oregon fisheries. Fishery Bulletin, 116(2): 126–141.

Yochum, N., Stoner, A. W., Sampson, D. B., Rose, C., Pazar, A., and Eder, R. 2017. Utilizing reflex impairment to assess the role discard mortality in “Size, Sex, and Season” management for Oregon Dungeness crab (*Cancer magister*) fisheries. Canadian Journal of Fisheries and Aquatic Sciences, 74: 739–750.

Youde, J. G., and Wix, J. R. 1967. Economics of the Dungeness crab industry. Oregon State University, Corvallis Agricultural Experiment Station, Circular of Information 627. 24 pp.

Zhang, Z., Hajas, W., Phillips, A., and Boutillier, J. A. 2004. Use of length-based models to estimate biological parameters and conduct yield analyses for male Dungeness crab (*Cancer magister*). Canadian Journal of Fisheries and Aquatic Sciences, 61: 2126–2134.

Appendix A: Oregon ocean commercial Dungeness crab fishery seasons

Season dates, delays, and closures for the ocean commercial Dungeness crab fishery in Oregon. Coastwide dates refer only to the Oregon coast, so timing may differ south of the OR/CA border or north of the OR/WA border.

Season	Regulatory season date(s) in Oregon	Notes
1947-48	Aug. 26 south of Cascade Head; Oct. 10 north of Cascade Head[a]	First seasonal closure[a]
1948-49	Closed Aug. 15 south of Cascade Head; Sept. 15 north of Cascade Head[b]	Season opened when <10% of legal-sized male crab were softshelled (exact dates unknown)[a]
1949-50	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[b]	
1950-51	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1951-52	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1952-53	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1953-54	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1954-55	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1955-56	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1956-57	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1957-58	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1958-59	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1959-60	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1960-61	Nov. 15 to Aug. 15 south of Cascade Head; Dec. 15 to Sept. 15 north of Cascade Head[c]	
1961-62	Dec. 1 to Aug. 15 south of Cascade Head; Jan. 1 to Sept. 15 north of Cascade Head[c]	
1962-63	Dec. 1 to Aug. 15 south of Cascade Head; Jan. 1 to Sept. 15 north of Cascade Head[c]	
1963-64	Dec. 1 to Aug. 15 coastwide[c]	
1964-65	Dec. 1 to Aug. 15 coastwide[c]	
1965-66	Dec. 1 to Aug. 15 coastwide[c]	

1966-67	Dec. 1 to Aug. 15 coastwide[c]	
1967-68	Dec. 1 to Aug. 15 coastwide[c]	
1968-69	Dec. 1 to Aug. 15 coastwide[c]	
1969-70	Dec. 1 to Sept. 15 coastwide[c]	
1970-71	Dec. 1 to Sept. 15 coastwide[c]	
1971-72	Dec. 1 to Sept. 15 south of Cascade Head; Dec. 1 to Aug. 15 north of Cascade Head[c]	
1972-73	Dec. 1 to Aug. 31 south of Cascade Head; Dec. 1 to Aug. 15 north of Cascade Head[c]	
1973-74	Dec. 1 to Aug. 15 coastwide[c]	
1974-75	Dec. 1 to Aug. 15 coastwide[c]	
1975-76	Dec. 1 to Aug. 15 coastwide[c]	
1976-77	Dec. 1 to Sept. 15 coastwide[c]	
1977-78	Dec. 1 to Sept. 15 coastwide[c]	
1978-79	Dec. 1 to Sept. 15 coastwide[c]	
1979-80	Dec. 1 to Sept. 15 coastwide[c]	
1980-81	Dec. 1 to Sept. 15 coastwide[c]	
1981-82	Dec. 1 to Oct. 15 coastwide[c]	
1982-83	Dec. 1 to Sept. 15 coastwide[c]	Staff requested an early season closure due to projections of poor crab condition; Fishers requested a season extension to Oct.; Both requests were denied[d]
1983-84	Dec. 1 to Sept. 1 coastwide[c]	Commission took action to end the season two weeks sooner than scheduled due to increased effort late in the season resulting in the landing of marginal crab[e]
1984-85	Dec. 1 to Aug. 14 coastwide[c]	Commission moved the closing date back to Aug. 15 due to increased effort and poor crab grade late in the season[e]
1985-86	Dec. 1 to Aug. 14 coastwide[c]	
1986-87	Dec. 1 to Aug. 14 coastwide[c]	
1987-88	Dec. 1 to Aug. 14 coastwide[c]	
1988-89	Dec. 1 to Aug. 14 coastwide[c]	
1989-90	Dec. 1 to Aug. 14 coastwide[c]	
1990-91	Dec. 1 to Aug. 14 coastwide[c]	
1991-92	Dec. 1 to Aug. 14 coastwide[c]	Industry-sponsored closure from Dec. 11 – 21 due to fear of consumer panic surrounding elevated domoic acid levels in crab viscera[f]
1992-93	Dec. 1 to Aug. 14 coastwide[c]	
1993-94	Dec. 1 to Aug. 14 coastwide[c]	
1994-95	Dec. 1 to Aug. 14 south of Cape Falcon; Dec. 16 to Aug. 14 north of Cape Falcon[c]	Season delay due to low meat recovery[c]
1995-96	Dec. 1 to Aug. 14 south of Cape Falcon; Jan. 1 to Aug. 14 north of Cape Falcon[g]	Season delay due to low meat recovery[c]; Industry delays over price in both areas[g]

1996-97	Dec. 1 to Aug. 14 coastwide[c]	
1997-98	Dec. 1 to Aug. 14 coastwide[c]	
1998-99	Dec. 1 to Aug. 14 coastwide[c]	
1999-00	Dec. 1 to Aug. 14 coastwide[c]	Industry-led season delay due to low meat recovery and weather for a varying number of days (Dec. 3–10)[h]
2000-01	Dec. 1 to Aug. 14 south of Cape Lookout; Dec. 16 to Aug. 14 north of Cape Lookout[i]	Season delay due to due to low meat recovery[c]; Industry delay in the north until Dec. 21 over price[g]
2001-02	Dec. 1 to Aug. 14 coastwide[j]	Industry delay until Dec. 10 over price[j]
2002-03	Dec. 1 to Aug. 14 south of Floras Creek; Dec. 10 to Aug. 14 north of Floras Creek[i]	Industry delay through Dec. 20 over price along most of coast[g]
2003-04	Dec. 1 to Aug. 14 coastwide[i]	In-season evisceration order between Cape Lookout and Cape Blanco[k]
2004-05	Dec. 1 to Aug. 14 south of Cape Falcon; Jan. 15 to Aug. 14 north of Cape Falcon[l]	Season delay due to low meat recovery[l]
2005-06	Dec. 31 to Aug. 14 coastwide[m]	Season delay due to low meat recovery[m]; Industry delay until Jan. 7 over price, weather was also a factor[g]
2006-07	Dec. 1 to Aug. 14 coastwide[n]	Industry delay until Dec. 10, except Garibaldi[i]
2007-08	Dec. 1 to Aug. 14 coastwide[o]	
2008-09	Dec. 1 to Aug. 14 coastwide[p]	
2009-10	Dec. 1 to Aug. 14 coastwide[q]	
2010-11	Dec. 1 to Aug. 14 coastwide[r]	In-season closure from Cape Blanco to the Rogue River mouth from Dec. 10 – Jan. 15 due to low meat recovery [s]; Industry delay through Dec. 12 over price[t]
2011-12	Dec. 15 to Aug. 14 north of Gold Beach; Jan. 15 to Aug. 14 south of Gold Beach[u]	Season delay due to low meat recovery[v]
2012-13	Dec. 31 to Aug. 14 coastwide[w]	Season delay due to low meat recovery[w]
2013-14	Dec. 16 to Aug. 14 coastwide[x]	Season delay due to low meat recovery[x]
2014-15	Dec. 1 to Aug. 14 coastwide[y]	
2015-16	Jan. 4 to Aug. 14 coastwide[z]	Season delay due to elevated levels of domoic acid[z]
2016-17	Dec. 18 to Aug. 14 south of Cape Blanco[aa] Jan. 1 to Aug. 14 north of Cape Blanco[ab]	Season delays due to elevated domic acid levels[aa,ab]; Industry delay from Jan. 1–9 over pricei; In-season domoic acid evisceration order from Coos Bay North Jetty to Heceta Head in Feb[ac]

2017-18	Jan. 15 to Aug. 14 north of Cape Blanco; Feb. 7 to Aug. 14 south of Cape Blanco[ad]	Season delay north of Cape Blanco due to low meat recovery, plus industry delay of another seven days for price negotiations; Season delay south of Cape Blanco due to combined low meat recovery and elevated levels of domoic acid[ad]; In-season evisceration order in harvest areas K and L in Feb[ae]
2018-19	Jan. 4 to Aug. 14 north of Cape Arago[af]; Feb. 1 to Aug. 14 south of Cape Arago[ag]	Initial season delays due to low meat recovery[af]; Southern opener further delayed due to elevated levels of domoic acid and eventually opened under an evisceration order[ag]; In-season evisceration order in harvest areas J, K, and L in Feb/Mar[ah]; In-season evisceration order in harvest areas K and L in May[k]
2019-20	Dec. 31 to Aug. 14 coastwide[ai]	Season delay due to low meat recovery[ai]
2020-21	Dec. 16 to Aug. 14 south of Cape Falcon[aj]; Feb. 15 to Aug. 14 north of Cape Falcon[ak]	Initial season delays due to low meat recovery[aj]; Northern opener further delayed due to elevated levels of domoic acid detected in WA and efforts to coordinate with WA's coastal fishery[ak]

[a]OFC. 1949. Shellfish Investigation progress report no. 17, soft-shell crab season and regulation review.
[b]Waldron, K.D. 1958. The fishery and biology of the Dungeness crab (*Cancer magister* Dana) in Oregon waters. OFC Report No. 24.
[c]Didier, A.J., Jr. 2002. The Pacific coast Dungeness crab fishery. PSMFC.
[d]ODFW. 1984. Shellfish Investigations progress report, 1975–1983.
[e]ODFW. 1985. Shellfish Investigations progress report, 1984.
[f]ODFW. 1995. Shellfish Program annual report, 1992.
[g]Furman, N. 2006. Market information notes, 1994 – 2006. ODCC.
[h]ODFW. 2000. Oregon commercial Dungeness crab fishery status report. OFWC, Exhibit B.
[i]Inferred from ODFW Fish Tickets.
[j]Kingman, A. 2002. Dungeness derby. National Fisherman.
[k]ODFW, unpublished data
[l]ODFW Industry Notice, Dec. 21, 2004.
[m]ODFW Industry Notice, Dec. 9, 2005.
[n]ODFW Industry Notice, Nov. 22, 2006.
[o]ODFW. 2008. Commercial Dungeness crab newsletter.
[p]ODA New Release, Nov. 25, 2008.
[q]ODFW News Release, Nov. 23, 2009.
[r]ODFW News Release, Nov. 22, 2010.
[s]ODFW Industry Notice, Dec. 9, 2010.
[t]Johnson, C.S. 2011. Prices set as crabbers kick off promising Dungie season. National Fisherman.
[u]ODFW. 2010. 4th annual ODFW Dungeness crab fishery newsletter.
[v]ODFW News Release, Nov. 10, 2011.
[w]ODFW Industry Notice, Dec. 10, 2012.
[x]ODFW. 2014. 6th annual ODFW Dungeness crab fishery newsletter.
[y]ODFW. 2015. 7th annual ODFW Dungeness crab fishery newsletter.
[z]ODFW Industry Notice, Dec. 22, 2015.
[aa]ODFW Industry Notice, Dec. 9, 2016.
[ab]ODFW Industry Notice, Dec. 21, 2016.
[ac]ODFW Industry Notice, Feb. 2, 2017.
[ad]ODFW. 2018. 10th annual ODFW Dungeness crab fishery newsletter.
[ae]ODFW News Release, Feb. 16, 2018.
[af]ODFW Industry Notice, Dec. 29, 2018.
[ag]ODFW Industry Notice, Jan. 24, 2019.
[ah]ODFW News Release, Feb. 14, 2019.
[ai]ODFW Industry Notice, Dec. 20, 2019.
[aj]ODFW Industry Notice, Dec. 8, 2020.
[ak]ODFW Industry Notice, Feb. 8, 2021.

Appendix B: Oregon Dungeness crab FMP implementing rules

The vast majority of the crab fishery management measures described throughout this FMP were already included in permanent rule at the time of writing; however, several additional minor management measures were recommended by ODFW and adopted into rule by the OFWC in October 2021 in order to implement this FMP. These measures are described throughout the FMP and include:

- A bay commercial crab logbook requirement (see *Section A.III.b*)
- A change to the definition of fishing gear relative to Marine Reserves to include surface buoys (see *Section B.III*)
- An extension of the time allowed to attach late-season buoy tags (see *Gear marking* in Section *B.III.e*)
- A prohibition on landing crab by those not participating in the late-season tag program (see *Gear marking* in *Section B.III.e*)
- An update of the Dungeness crab harvest area map to include finer scale areas in Washington (see *Domoic acid monitoring and response* in *Section B.IV.b*)
- Provisions to allow landing of crab into Oregon for evisceration if they are from an area in another state that is under an evisceration order (see *Domoic acid monitoring and response* in *Section B.IV.b*)