Dungeness crab

Metacarcinus magister

Image © Monterey Bay Aquarium

British Columbia and United States

Pot

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Neosha Kashef, Independent Research Analyst

About Seafood Watch®

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from www.seafoodwatch.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices," "Good Alternatives" or "Avoid." The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Guiding Principles

Seafood Watch defines sustainable seafood as originating from sources, whether fished[1] or farmed, that can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems.

Based on this principle, Seafood Watch had developed four sustainability **criteria** for evaluating wild-catch fisheries for consumers and businesses. These criteria are:

- How does fishing affect the species under assessment?
- How does the fishing affect other, target and non-target species?
- How effective is the fishery's management?
- How does the fishing affect habitats and the stability of the ecosystem?

Each criterion includes:

- Factors to evaluate and score
- Guidelines for integrating these factors to produce a numerical score and **rating**

Once a rating has been assigned to each criterion, we develop an overall recommendation. Criteria ratings and the overall recommendation are color coded to correspond to the categories on the Seafood Watch pocket guide and the Safina Center's online guide:

Best Choice/Green: Are well managed and caught in ways that cause little harm to habitats or other wildlife.

Good Alternative/Yellow: Buy, but be aware there are concerns with how they're caught.

Avoid/Red: Take a pass on these for now. These items are overfished or caught in ways that harm other marine life or the environment.

Scores range from zero to five where zero indicates very poor performance and five indicates the fishing operations have no significant impact.

Final Score = geometric mean of the four Scores (Criterion 1, Criterion 2, Criterion 3, Criterion 4).

1 "Fish" is used throughout this document to refer to finfish, shellfish and other invertebrates.

Summary

This report provides recommendations for Dungeness crab (*Metacarcinus magister* a.k.a. *Cancer magister*) caught commercially by pot/trap in the Northeast Pacific Ocean, ranging from Alaska to California. The assessment is divided into five groups based upon management region: Alaska, British Columbia, Washington, Oregon and California

Dungeness crab has a low inherent vulnerability due to its early age at reproductive maturity, high fecundity, and short life span, compared to fish and shellfish stocks worldwide. There is low conservation concern because landings data indicate that targeted stocks are not overfished; however, stock abundance is uncertain. British Columbia has a regionally limited stock assessment but the United States has no formal, fishery-independent stock assessment program. Fishing is restricted through a 3-S management strategy that limits harvest by size, sex, and season. Although landings are thought to reflect the legal-sized male crab abundance (which fluctuates cyclically), information is lacking on the abundance of females and the population size structure.

Fishing mortality is of moderate concern due to high exploitation and uncertainty over future sustainability (as a result of insufficient data). Legal-sized males are considered to be fully fished annually, which leaves the fishery dependent on annual recruitment. There is concern that increased spatial effort may remove portions of the population that could act as a buffer during poor environmental conditions. Despite these issues, the fishery has historically maintained stable average landings, with fluctuations attributed to environmental factors.

Bycatch in the fishery is not quantified but considered to be low, due to passive fishing and high selectivity of gear. Female and male softshell crabs caught as bycatch may experience handling mortality, although closed seasons reduce encounters with softshell crabs and the discard rate is estimated to be low, based on similar fisheries. Humpback whales (*Megaptera novaeangliae*), an endangered species, are sometimes (albeit rarely) entangled in pot line, which may lead to injury or mortality. Concern is rated low because the cumulative fisheries mortality does not exceed half of Potential Biological Removal. Discarding in Dungeness crab fisheries is relatively low with dead discards representing 35% of landings, although bait use is approximately 16%–23% of landings.

The management of harvest strategy is moderately effective in British Columbia and Washington/California. Research is limited and there is a need for increased precaution to address stock uncertainty and handling mortality of female and softshell crab. Management improvement is needed in Alaska due to historic regional stock declines, which failed to recover despite fishery closures. Bycatch strategy is considered well managed in all regions; however, gear regulations could be improved to further reduce ghostfishing.

Seafood Watch considers pot gear used in the fishery to be of low conservation concern for seafloor habitat. Pot limits and size restrictions further mitigate gear impacts. There is a moderate conservation concern regarding the effects of Dungeness crab removal on ecosystem functioning. More research is necessary to determine the implications of fishing to community structure.

Table of Conservation Concerns and Overall Recommendations

Stock / Fishery	Impacts on the Stock	Impacts on other Spp.	Management	Habitat and Ecosystem	Overall Recommendation
Dungeness crab Alaska Northeast Pacific - Pot	Yellow (2.64)	Yellow (2.99)	Green (3.46)	Yellow (3.12)	**Good Alternative (3.040)**
Dungeness crab British Columbia Northeast Pacific - Pot	Yellow (3.05)	Yellow (2.99)	Green (3.46)	Yellow (3.12)	**Good Alternative (3.151)**
Dungeness crab Washington Northeast Pacific - Pot	Yellow (3.05)	Red (2.01)	Green (3.46)	Yellow (3.12)	**Good Alternative (2.855)**
Dungeness crab Oregon Northeast Pacific - Pot	Yellow (3.05)	Red (2.01)	Green (4.00)	Yellow (3.12)	**Good Alternative (2.960)**
Dungeness crab California Northeast Pacific - Pot	Yellow (3.05)	Red (1.72)	Green (3.46)	Yellow (3.12)	**Good Alternative (2.747)**

Scoring Guide

Scores range from zero to five where zero indicates very poor performance and five indicates the fishing operations have no significant impact.

Final Score = geometric mean of the four Scores (Criterion 1, Criterion 2, Criterion 3, Criterion 4).

- **Best Choice/Green** = Final Score >3.2, **and** no Red Criteria, **and** no Critical scores

- **Good Alternative/Yellow** = Final score >2.2-3.2, **and** neither Harvest Strategy (Factor 3.1) nor Bycatch Management Strategy (Factor 3.2) are Very High Concern[2], **and** no more than one Red Criterion, **and** no Critical scores
- **Avoid/Red** = Final Score <=2.2, **or** either Harvest Strategy (Factor 3.1) or Bycatch Management Strategy (Factor 3.2) is Very High Concern **or** two or more Red Criteria, **or** one or more Critical scores.

[2] Because effective management is an essential component of sustainable fisheries, Seafood Watch issues an Avoid recommendation for any fishery scored as a Very High Concern for either factor under Management (Criterion 3).

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Introduction

Scope of the analysis and ensuing recommendation

This report includes recommendations for Dungeness crab (*Metacarcinus magister* a.k.a. *Cancer magister*) caught by pot/trap in the Northeastern Pacific Ocean ranging from Alaska to California. Both *Metacarcinus magister* and *Cancer magister* may be used to describe this species because there is no current consensus on nomenclature; however, this report will refer to the former scientific name because it is officially recognized by the FDA. The assessment is divided into five groups based upon management region: Alaska, British Columbia, Washington, Oregon and California.

Overview of the species and management bodies

Dungeness crab is a Brachyuran true crab occupying nearshore coastal environments from the Aleutian Islands, Alaska to Santa Barbara, California (Garth & Abbott 1980). It occurs subtidally to a depth of 230 m, but is most commonly found shallower than 90 m in mud and silt habitats. This species is the largest edible true crab on the Pacific coast of North America, with males growing larger than females. It has a hard exoskeleton and must undergo molting for growth, which generally occurs for females in the spring and males in the summer. Timing of molting varies by latitude, with molting occurring later in the season further north. During the molting and mating season, Dungeness crabs move inshore (Diamond & Hankin 1985). Female crabs mate immediately after molting; however, they can store sperm for up to 2.5 years and may skip egg extrusion in some years (Swiney et al. 2003) (Jensen & Bentzen 2012). Fertilized eggs are carried under an abdominal flap until hatching as pelagic larvae. Larvae metamorphose through six stages, disperse, and return to nearshore habitat in 3–5 months through larval behavior, physical transport and, occasionally, by riding on jellies and the by-the-wind sailor (*Velella velella*) (Wickham 1979). Juveniles settle in nearshore and estuarian habitats, which serve as nursery grounds (Armstrong et al. 2003). Dungeness crab are carnivorous scavengers and predators, feeding primarily on crustaceans and clams when juveniles and including shrimp and fishes into their diet as they get older (Stevens et al. 1982).

The Dungeness crab fishery ranked seventh in value among United States commercial fisheries in 2013, reaching 253 million dollars (NOAA 2015). The U.S. fishery is managed at a state level: in Alaska by the Alaska Department of Fish & Game; and in Washington, Oregon, and California by their respective Fish & Wildlife agencies, which consult through a Tri-state Dungeness Crab Committee (U.S. Congress 1998). Management in British Columbia is overseen by the Department of Fisheries & Oceans. The commercial fishery originated in 1848 in San Francisco, CA and expanded northward along the West Coast of the United States and Canada by the early 1900s (Demory 1990) (ADFG 1994) (Hankin & Warner 2001) (DFO 2013a). Despite historic regional declines in Alaska and California, Dungeness crab populations are generally considered healthy.

Production Statistics

The United States and Canada are the exclusive producers of Dungeness crab. The West Coast of the United States produces the greatest quantity of crab, with Washington (34%) leading in 2013 followed by Oregon (32%), California (21%), and Alaska (3%, Figure 1). In 2013, British Columbia contributed 10% to global production, which reached 36,992 metric tons (NOAA 2015).

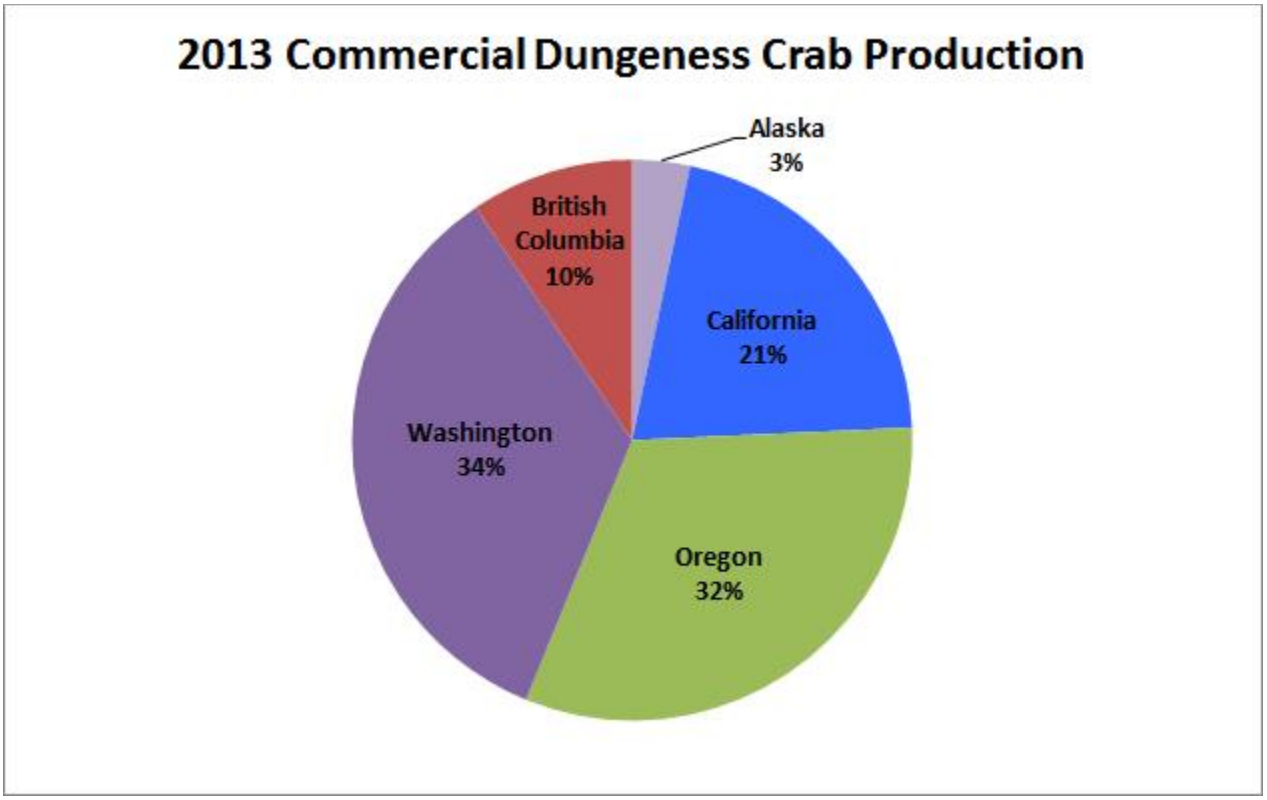

Figure 1: Commercial Dungeness crab production. Percent reflects relative contribution to landings by weight in 2013 (data source: NOAA 2015a).

Landings fluctuate, but stable means have been maintained over time in each management area (Figures 2–6). In Alaska, landings in recent decades have been reduced due to historical regional fishery collapse and closure (Figure 2).

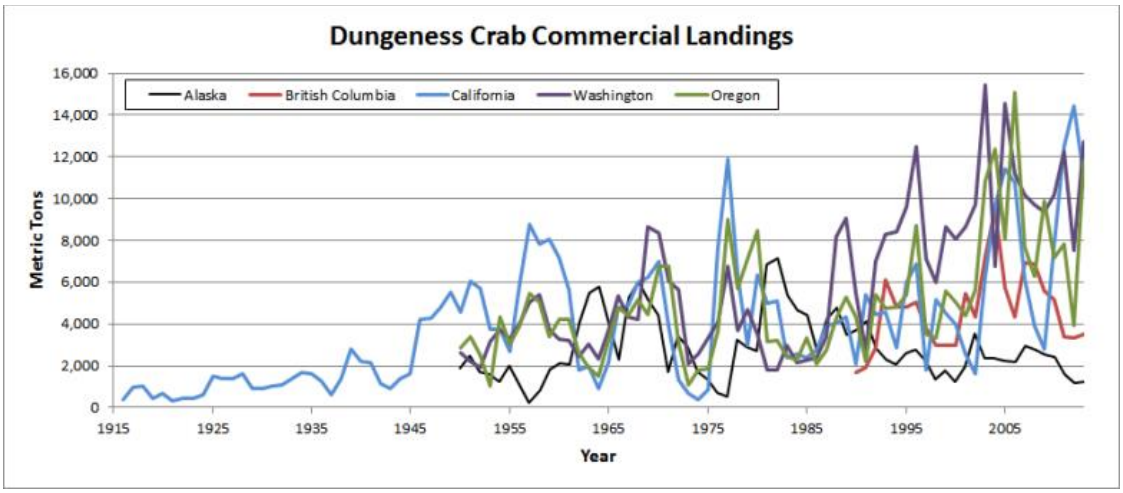

Figure 2: Annual Dungeness crab commercial fishery landings 1950–2013 (DFG 2012a, NOAA 2015a, DFO 2013b).

Importance to the U.S./North American market

Although Dungeness crab is not produced outside of North America, it is sometimes processed overseas and imported into the United States. In 2014, 9 metric tons were imported from China (61%) and Canada (39%) (Figure 3) (NOAA 2015b).

In recent years, Dungeness exports have increased due to the demand for live crab in China (Figure 4). In 2014, exports reached 2,180 metric tons, with the majority sent to China (71%) and Canada (15%) (Figure 3) (NOAA 2015b). South Korea and Vietnam each imported 6%, Australia imported 2%, and Japan and Jamaica each imported ≤ 1%.

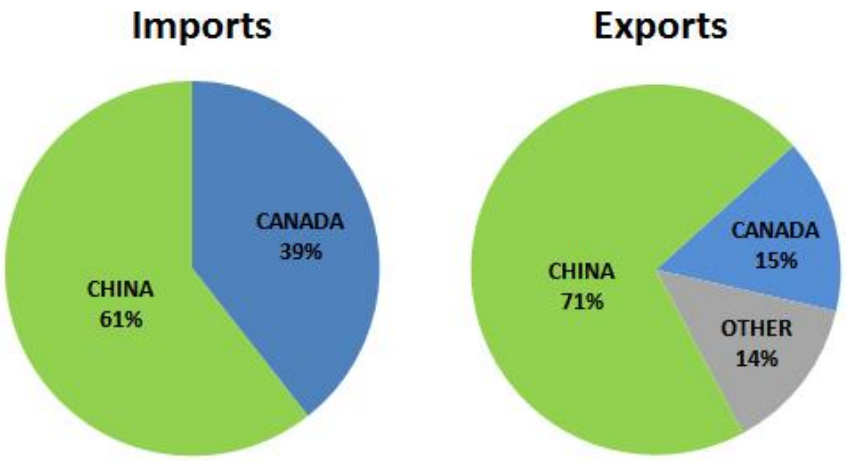

Figure 3: Commercial Dungeness crab trade in 2014. Percent reflects relative contribution by weight (all product forms combined, data source: NOAA 2015b).

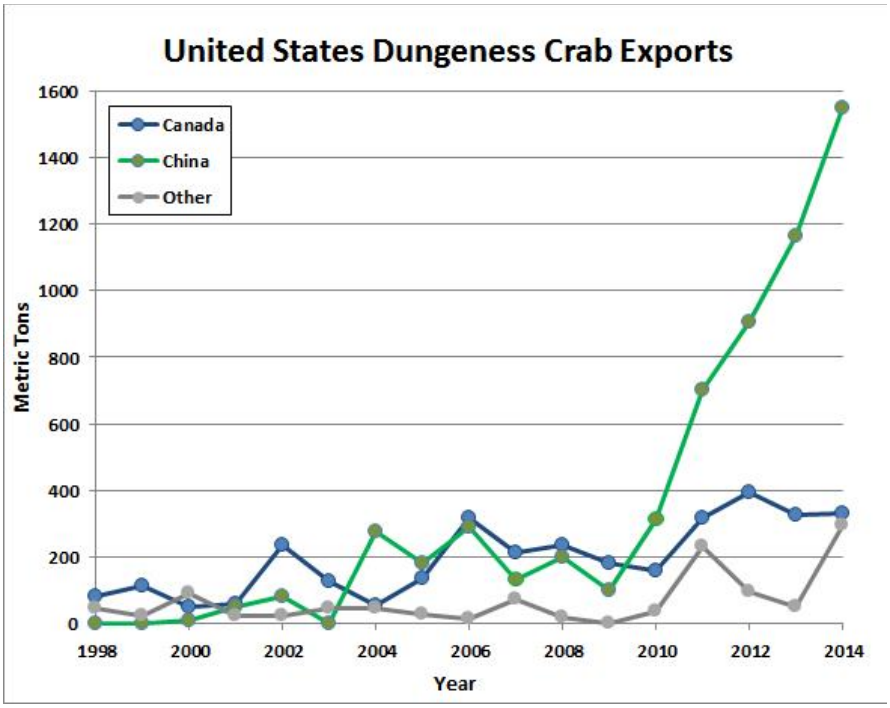

Figure 4: United States commercial Dungeness crab exports since 1998 by weight (all product forms combined, data source: NOAA 2015b).

Common and market names

Commercial crab, Dungeness crab, edible crab, market crab, Pacific edible crab, San Francisco crab

Primary product forms

Dungeness crab is sold live or cooked. Cooked crab are offered fresh and frozen whole, as legs in sections or as singles, and as picked meat. Meat is also available in pasteurized canned form and legs are sometimes pre-cracked and marketed as “snap-n-eats” for ease of opening (Seafood Business 2013).

Assessment

This section assesses the sustainability of the fishery(s) relative to the Seafood Watch Criteria for Fisheries, available at http://www.seafoodwatch.org.

Criterion 1: Stock for which you want a recommendation

This criterion evaluates the impact of fishing mortality on the species, given its current abundance. The inherent vulnerability to fishing rating influences how abundance is scored, when abundance is unknown. The final Criterion 1 score is determined by taking the geometric mean of the abundance and fishing mortality scores. The Criterion 1 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and <=3.2=Yellow or Moderate Concern*
- *Score <=2.2=Red or High Concern*
  Rating is Critical if Factor 1.3 (Fishing Mortality) is Critical.

Criterion 1 Summary

DUNGENESS CRAB				
Region / Method	**Inherent Vulnerability**	**Stock Status**	**Fishing Mortality**	**Subscore**
Alaska Northeast Pacific Pot	3.00:Low	3.00:Moderate Concern	2.33:Moderate Concern	**Yellow (2.644)**
British Columbia Northeast Pacific Pot	3.00:Low	4.00:Low Concern	2.33:Moderate Concern	**Yellow (3.053)**
California Northeast Pacific Pot	3.00:Low	4.00:Low Concern	2.33:Moderate Concern	**Yellow (3.053)**
Oregon Northeast Pacific Pot	3.00:Low	4.00:Low Concern	2.33:Moderate Concern	**Yellow (3.053)**
Washington Northeast Pacific Pot	3.00:Low	4.00:Low Concern	2.33:Moderate Concern	**Yellow (3.053)**

Criterion 1 Assessment

DUNGENESS CRAB

Factor 1.1 - Inherent Vulnerability

Scoring Guidelines

- *Low—The FishBase vulnerability score for species is 0-35, OR species exhibits life history characteristics that make it resilient to fishing, (e.g., early maturing (*

- *Medium—The FishBase vulnerability score for species is 36-55, OR species exhibits life history characteristics that make it neither particularly vulnerable nor resilient to fishing, (e.g., moderate age at sexual maturity (5-15 years), moderate maximum age (10-25 years), moderate maximum size, and middle of food chain).*
- *High—The FishBase vulnerability score for species is 56-100, OR species exhibits life history characteristics that make is particularly vulnerable to fishing, (e.g., long-lived (>25 years), late maturing (>15 years), low reproduction rate, large body size, and top-predator).*
  Note: The FishBase vulnerability scores is an index of the inherent vulnerability of marine fishes to fishing based on life history parameters: maximum length, age at first maturity, longevity, growth rate, natural mortality rate, fecundity, spatial behaviors (e.g., schooling, aggregating for breeding, or consistently returning to the same sites for feeding or reproduction) and geographic range.

Alaska Northeast Pacific, Pot

Low

Dungeness crab has a low inherent vulnerability (score of 2.67) due to its early age at sexual maturity, high fecundity, and short lifespan. In Alaska, sexual maturity is reached at 2 years for females and 3 years for males (Hoopes 1973), and maximum lifespan is 8–13 years (ADFG 1994).

Rationale:

Factor	Alaska	British Columbia	California, Oregon & Washington	Score	Sources
Average age at maturity	2-3 years	2 years	2 years	3	Hoopes 1973, Butler 1961, Tasto 1983,
Average maximum age (or range if unavailable)	8-13 years	8 years	6-8 years	3	ADFG 1994, Hankin & Warner 2001
Reproductive Strategy	egg brooder	egg brooder	egg brooder	2	Pauley et al. 1989
Density dependence	unknown	unknown	unknown	-	-
Average Score:				**2.67**	

Table 1: Life-history characteristics for Dungeness crab in the Northeast Pacific.

British Columbia Northeast Pacific, Pot

Low

Dungeness crab has a low inherent vulnerability (score of 2.67) due to its early age at sexual maturity, high fecundity, and short lifespan. In British Columbia, sexual maturity is reached at 2 years of age and the maximum lifespan is approximately 8 years (Butler 1961).

Rationale:

See Table 1 above.

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Low

Dungeness crab has a low inherent vulnerability (score of 2.67) due to its early age at sexual maturity, high fecundity, and short lifespan (Hankin & Warner 2001). Along the U.S. West Coast, sexual maturity is reached at 2 years of age and maximum lifespan is 6–8 years (Tasto 1983) (Hankin & Warner 2001).

Rationale:

See Table 1 above.

Factor 1.2 - Stock Status

Scoring Guidelines

- *5 (Very Low Concern)—Strong evidence exists that the population is above target abundance level (e.g., biomass at maximum sustainable yield, BMSY) or near virgin biomass.*
- *4 (Low Concern)—Population may be below target abundance level, but it is considered not overfished*
- *3 (Moderate Concern) —Abundance level is unknown and the species has a low or medium inherent vulnerability to fishing.*
- *2 (High Concern)—Population is overfished, depleted, or a species of concern, OR abundance is unknown and the species has a high inherent vulnerability to fishing.*
- *1 (Very High Concern)—Population is listed as threatened or endangered.*

Alaska Northeast Pacific, Pot

Moderate Concern

There is no active Dungeness crab stock assessment program in Alaska (Messmer et al. 2011) (Stratman et al. 2014). Some regions have experienced historic population collapse and have been closed to fishing for several years without rebounding. It is unknown if these stocks are genetically distinct from currently fished stocks. In areas of active commercial fishing, management does not consider the stock to be overfished, based on landings data. Current fishery-independent information is lacking. Pot surveys have revealed high spatial and temporal variability in life-history timing, which complicates assessment (Bishop et al. 2010).

British Columbia Northeast Pacific, Pot

Low Concern

Dungeness crab stock assessment in British Columbia is based on catch per unit effort (CPUE) from pot surveys (DFO 2013a) (DFO 2014). Populations fluctuate cyclically, with periods of higher abundance followed by periods of lower abundance; these are likely influenced by fluctuations in annual recruitment due to environmental conditions. In the Fraser River delta, relative abundance indices from standardized catch rates (CPUEs) indicate an increase in legal crab abundance between 1991 and 2003, followed by a decrease from 2004–2010 (Zhang & Dunham 2013). Female abundance has been stable since 1994, but sublegal crab abundance has declined since 2005 (Zhang & Dunham 2013). The population of Dungeness crab in British Columbia is not considered to be overfished by the Canadian Department of Fisheries and Oceans.

California Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Low Concern

There is no active Dungeness crab stock assessment program in California or Washington. Dungeness populations are fully exploited for legal-sized males, so annual catch is considered to be a proxy for population size. Management considers the stock healthy, with annual landings that fluctuate around a fairly stable long-term mean (Figures 4 & 5 in Hankin & Warner 2001) (CDFW 2015) (NOAA 2015)). Landings reached a record high in California in 2011—the largest catch by weight over the last 100 years—but have decreased in recent years to around the 10-year average (DFG 2012c). Little is known about female abundance and population size structure.

Oregon Northeast Pacific, Pot

Low Concern

The Oregon fishery lacks an active stock assessment based on fishery independent data; however, management does not consider the stock to be overfished, based on landings. Annual landings fluctuate around a fairly stable mean (SCS Global Services 2014). Although legal-sized males in the population are fully exploited, female mating success does not appear to be impaired (Dunn & Shanks 2014). There is no evidence of decreased genetic diversity or population substructure of Dungeness crab sampled off the Oregon coast (O'Malley & Roegner 2014).

Factor 1.3 - Fishing Mortality

Scoring Guidelines

- *5 (Very Low Concern)—Highly likely that fishing mortality is below a sustainable level (e.g., below fishing mortality at maximum sustainable yield, FMSY), OR fishery does not target species and its contribution to the mortality of species is negligible (≤ 5% of a sustainable level of fishing mortality).*
- *3.67 (Low Concern)—Probable (>50%) chance that fishing mortality is at or below a sustainable level, but some uncertainty exists, OR fishery does not target species and does not adversely affect species, but its contribution to mortality is not negligible, OR fishing mortality is unknown, but the population is healthy and the species has a low susceptibility to the fishery (low chance of being caught).*
- *2.33 (Moderate Concern)—Fishing mortality is fluctuating around sustainable levels, OR fishing mortality is unknown and species has a moderate-high susceptibility to the fishery and, if species is depleted, reasonable management is in place.*
- *1 (High Concern)—Overfishing is occurring, but management is in place to curtail overfishing, OR fishing mortality is unknown, species is depleted, and no management is in place.*
- *0 (Critical)—Overfishing is known to be occurring and no reasonable management is in place to curtail overfishing.*

Alaska Northeast Pacific, Pot

Moderate Concern

The maximum sustainable yield (MSY) for Dungeness stocks is unknown because population abundance is uncertain. Fishery mortality is ranked as "moderate" concern due to high exploitation rates that result in dependence on annual recruitment for population persistence since the 1980s (Orensanz et al. 1998). A fishery-independent survey conducted in Southeast Alaska from 2000 to 2004 found exploitation rates ranging from 83%–99% that varied with location and gear type (Bishop et al. 2010). Although fishery mortality is assumed to be high in all regions, exploitation rates are presumed acceptable due to a

management strategy that restricts landings based on size, sex, and season. Landings in Alaska fluctuate cyclically but have been stable overall, with recent declines since 2007 (NOAA 2015) (Kelley et al. 2011).

Rationale:

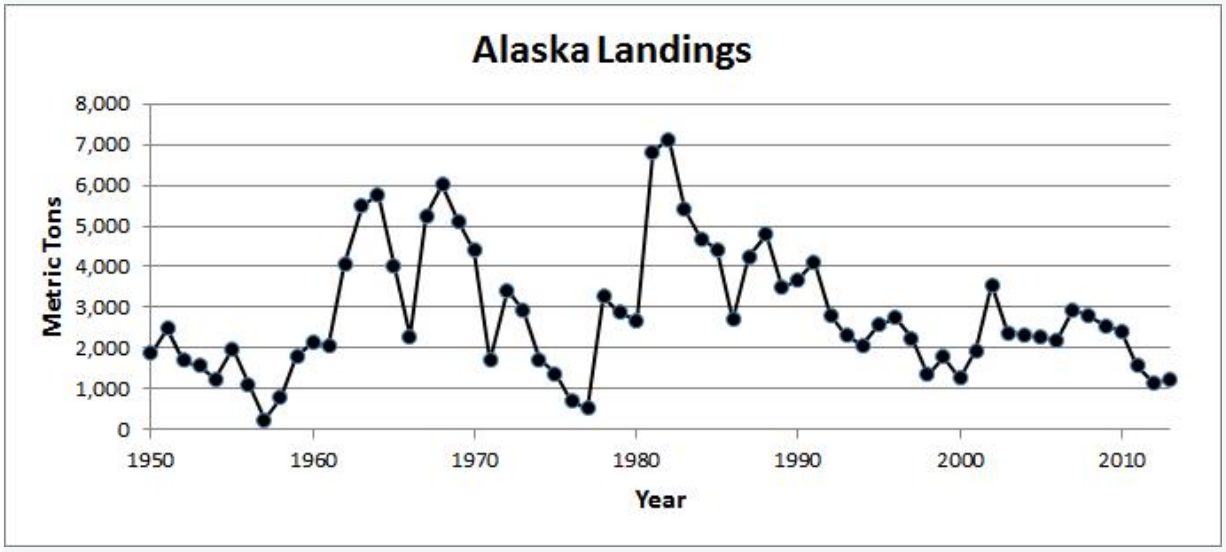

Figure 5. Annual Dungeness crab commercial fishery landings in Alaska (NOAA 2015).

California Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Moderate Concern

Legal-sized male Dungeness populations in California and Washington are fully exploited, with 80%–90% estimated fishery capture, but are not considered overfished (Hankin & Warner 2001). Intense harvest does not appear to impair mating success (Hankin et al. 1997) (Oh & Hankin 2004). Fishery mortality is ranked as “moderate” concern due to high exploitation rates that result in dependence on annual recruitment for population persistence. Landings in Washington and California fluctuate but have had a stable long-term mean overall (CDFW 2015) (NOAA 2015). Fishery effort has increased, as have landings, with California reaching record highs in 2011 and 2012; however, the most recent landings for both states are comparable to the 10-year average. Fishery mortality is regulated through management regulations limiting collection by size, sex, and season; however, adequate data are not available to determine maximum sustainable yield.

Rationale:

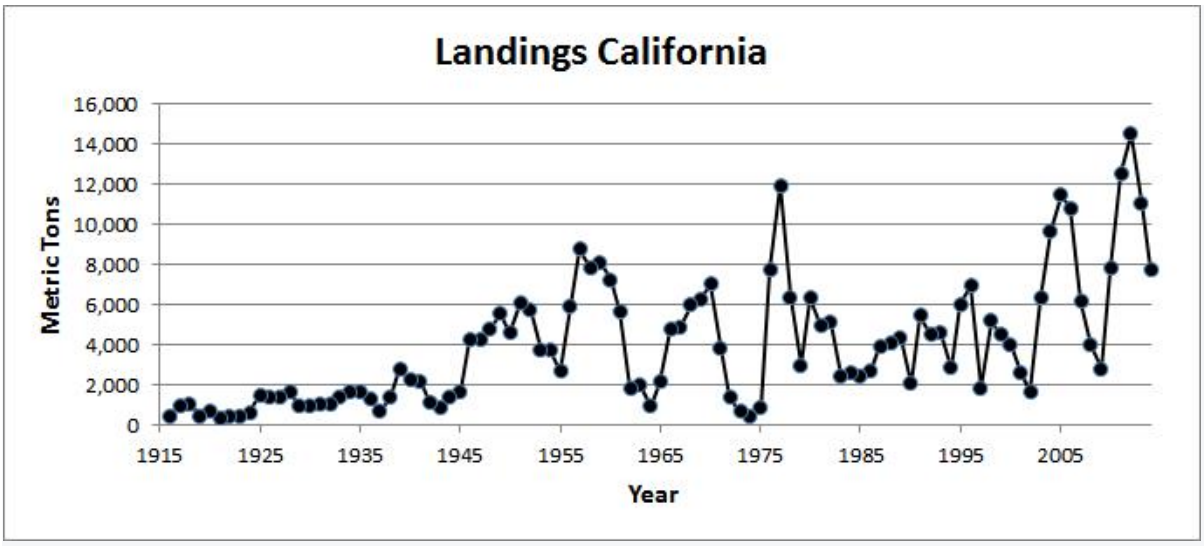

Figure 6. Seasonal Dungeness crab commercial fishery landings in California (CDFG 2015).

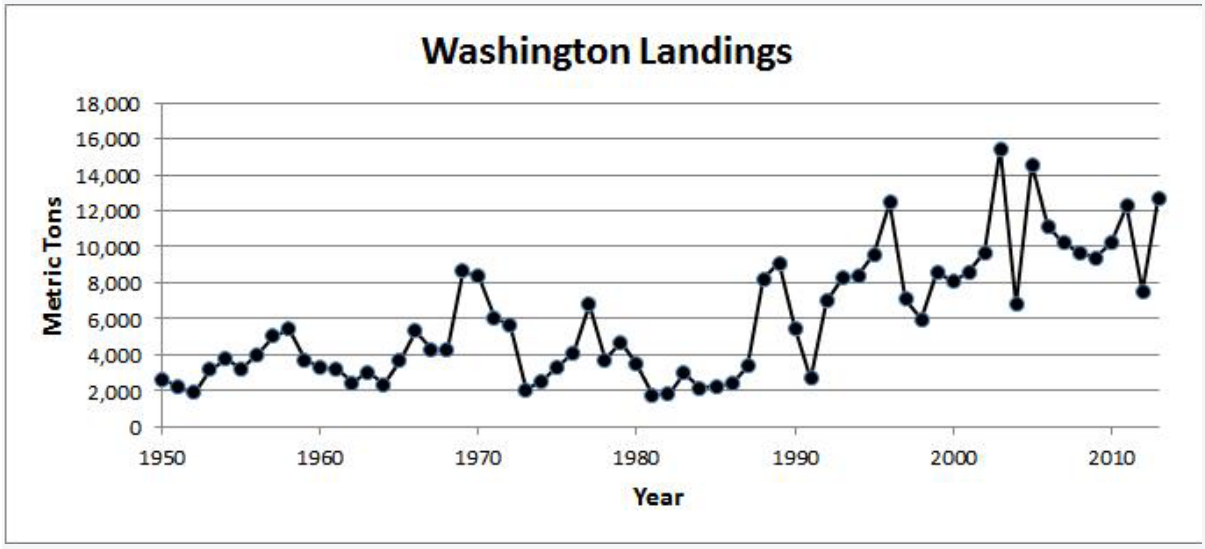

Figure 7. Annual Dungeness crab commercial fishery landings in Washington (NOAA 2015).

British Columbia Northeast Pacific, Pot

Moderate Concern

Adequate data are not available to determine maximum sustainable yield. Fishery mortality is managed through regulations limiting collection by size, sex, and season rather than quota. Exploitation rates have historically been high, reaching near 100% in some regions (Smith & Jamieson 1989). Despite an intense harvest, annual fishery landings fluctuate cyclically around a relatively stable mean, a pattern thought to be tied to environmental variability (Figure 3) (DFO 2013a) (DFO 2013b). Fishery mortality is ranked as “moderate” concern due to high exploitation rates that result in dependence on annual recruitment for population persistence.

Landings decreased from 2008–2011 but have been stable for the past three seasons. Although regulations limit collection by size, sex, and season, there is growing concern about the extent of mortality to undersize, female, and soft-shell crab due to handling. A comparison of female relative abundance indices from standardizing catch rates (CPUEs) both before and after the commercial fishing season has shown post-season declines since 1990, which implies increased female mortality (Zhang & Dunham 2013).

Rationale:

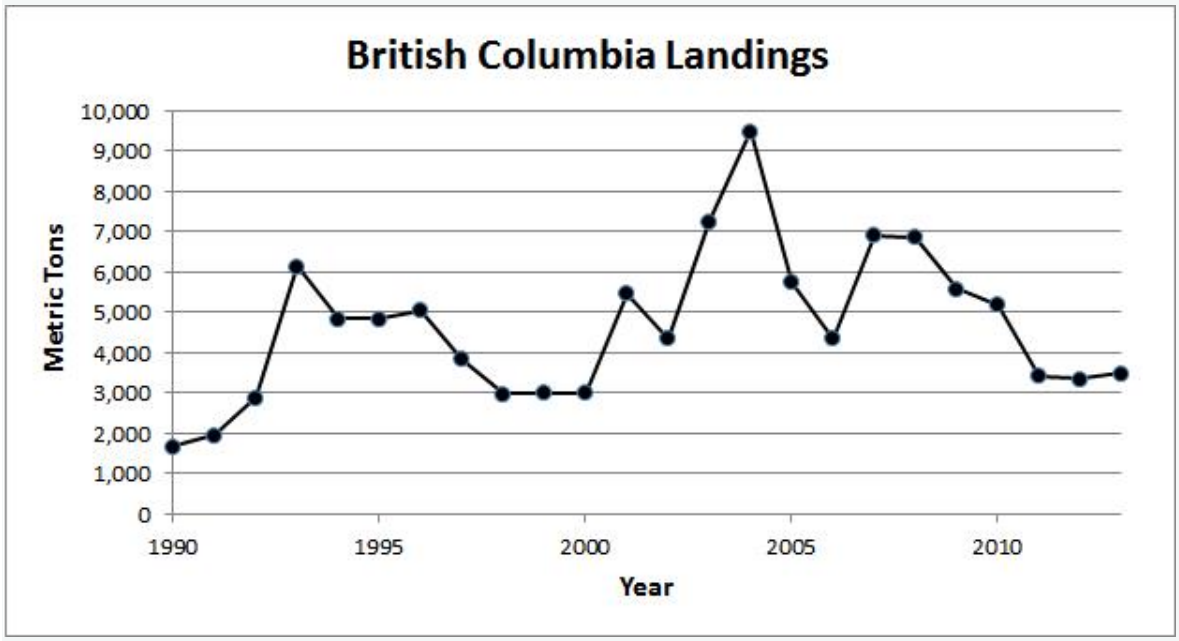

Figure 8. Annual Dungeness crab commercial fishery landings in British Columbia.

Oregon Northeast Pacific, Pot

Moderate Concern

Commercial fishery landings in Oregon fluctuate around a generally increasing 10-year mean. Fishery mortality is regulated through management regulations that limit collection by size, sex, and season; however, adequate data on fishing effort, size structure, and female spawning stock biomass are currently unavailable to determine maximum sustainable yield. The Oregon Department of Fish & Wildlife and the Oregon Dungeness Crab Commission have developed a Limit Reference Point (LRP) harvest policy, based on information from landings and logbooks, and an adaptive management framework to respond to breaches of the LRP (ODFW 2014). The proposed LRP will be reached if landings decline for three consecutive seasons and are projected to continue declining in the fourth season to below 20% of the 20-year average, or if the logbook CPUE falls below the average range from

the 1980–1981 to 1986–1987 seasons. Four consecutive declining years would equate to approximately one generation time. If the LRP is reached, management intervention will vary after evaluation of the cause of decline, and may include seasonal closure, reduced pot limits, trip limits, area closure, and/or increasing minimum size limits. The LRP has yet to be evaluated by a scientific panel. Due to the uncertainty surrounding the suitability of this reference point, fisheries mortality is ranked as "moderate" concern.

Rationale:

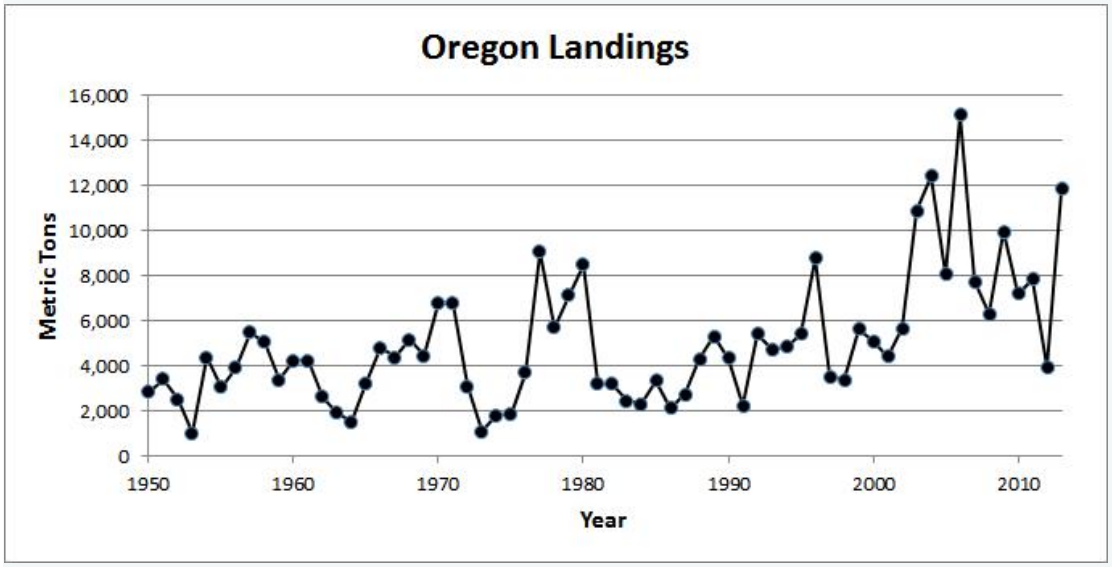

Figure 9. Annual Dungeness crab commercial fishery landings in Oregon (NOAA 2015).

Criterion 2: Impacts on Other Species

All main retained and bycatch species in the fishery are evaluated in the same way as the species under assessment were evaluated in Criterion 1. Seafood Watch® defines bycatch as all fisheries-related mortality or injury to species other than the retained catch. Examples include discards, endangered or threatened species catch, and ghostfishing. To determine the final Criterion 2 score, the score for the lowest scoring retained/bycatch species is multiplied by the discard rate score (ranges from 0-1), which evaluates the amount of non-retained catch (discards) and bait use relative to the retained catch. The Criterion 2 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and <=3.2=Yellow or Moderate Concern*
- *Score <=2.2=Red or High Concern*
  Rating is Critical if Factor 2.3 (Fishing Mortality) is Critical.

Criterion 2 Summary

Dungeness crab: Alaska Northeast Pacific, Pot

Subscore:: 3.318 **Discard Rate: 0.90** **C2 Rate: 2.986**

Species	Inherent Vulnerability	Stock Status	Fishing Mortality	Subscore
DUNGENESS CRAB	Low	3.00: Moderate Concern	2.33: Moderate Concern	**2.644**
BENTHIC INVERTS	Medium	3.00: Moderate Concern	3.67: Low Concern	**3.318**
FINFISH	Medium	3.00: Moderate Concern	3.67: Low Concern	**3.318**

Dungeness crab: British Columbia Northeast Pacific, Pot

Subscore:: 3.318 **Discard Rate: 0.90** **C2 Rate: 2.986**

Species	Inherent Vulnerability	Stock Status	Fishing Mortality	Subscore
DUNGENESS CRAB	Low	4.00: Low Concern	2.33: Moderate Concern	**3.053**
BENTHIC INVERTS	Medium	3.00: Moderate Concern	3.67: Low Concern	**3.318**

FINFISH	Medium	3.00: Moderate Concern	3.67: Low Concern	**3.318**

Dungeness crab: California Northeast Pacific, Pot

Subscore:: **1.916** **Discard Rate:** **0.90** **C2 Rate:** **1.724**

Species	Inherent Vulnerability	Stock Status	Fishing Mortality	Subscore
HUMPBACK WHALE: CALIFORNIA/OREGON/WASHINGTON	High	1.00: Very High Concern	3.67: Low Concern	**1.916**
DUNGENESS CRAB	Low	4.00: Low Concern	2.33: Moderate Concern	**3.053**
BENTHIC INVERTS	Medium	3.00: Moderate Concern	3.67: Low Concern	**3.318**
FINFISH	Medium	3.00: Moderate Concern	3.67: Low Concern	**3.318**

Dungeness crab: Oregon Northeast Pacific, Pot

Subscore:: **2.236** **Discard Rate:** **0.90** **C2 Rate:** **2.012**

Species	Inherent Vulnerability	Stock Status	Fishing Mortality	Subscore
HUMPBACK WHALE: CALIFORNIA/OREGON/WASHINGTON	High	1.00: Very High Concern	5.00: Very Low Concern	**2.236**
DUNGENESS CRAB	Low	4.00: Low Concern	2.33: Moderate Concern	**3.053**
BENTHIC INVERTS	Medium	3.00: Moderate Concern	3.67: Low Concern	**3.318**
FINFISH	Medium	3.00: Moderate Concern	3.67: Low Concern	**3.318**

Dungeness crab: Washington Northeast Pacific, Pot

Subscore:: **2.236** **Discard Rate:** **0.90** **C2 Rate:** **2.012**

Species	Inherent Vulnerability	Stock Status	Fishing Mortality	Subscore
HUMPBACK WHALE:	High	1.00: Very	5.00: Very	**2.236**

CALIFORNIA/OREGON/WASHINGTON		High Concern	Low Concern	
DUNGENESS CRAB	Low	4.00: Low Concern	2.33: Moderate Concern	**3.053**
BENTHIC INVERTS	Medium	3.00: Moderate Concern	3.67: Low Concern	**3.318**
FINFISH	Medium	3.00: Moderate Concern	3.67: Low Concern	**3.318**

Little information is available on the bycatch associated with Dungeness crab traps. Therefore the unknown bycatch matrix was used and it identified finfish and benthic invertebrates as likely to be caught alongside the target species. Interactions with humpback whales and gray whales are known to occur in the Dungeness crab fisheries. These interactions are rare and in Alaska, and in British Columbia they are believed to be at a negligible level. But in California, Oregon, and Washington, the Dungeness crab fishery is listed as a Category II fishery according to NOAA due to interactions with humpback whales in the region. Therefore, Seafood Watch has considered these interactions as part of the assessment for this fishery.

Criterion 2 Assessment

BENTHIC INVERTS

Factor 2.1 - Inherent Vulnerability

Scoring Guidelines (same as Factor 1.1 above)

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Medium

Invertebrates have a “medium” inherent vulnerability according to Seafood Watch criteria (SFW 2012).

Factor 2.2 - Stock Status

Scoring Guidelines (same as Factor 1.2 above)

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Moderate Concern

Stock status is scored as “moderate” concern using Seafood Watch criteria (SFW 2012).

Factor 2.3 - Fishing Mortality

Scoring Guidelines (same as Factor 1.3 above)

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Low Concern

Fishing mortality is scored as “low” concern under Seafood Watch criteria for invertebrates caught as bycatch via the pot fishery (SFW 2012).

Factor 2.4 - Discard Rate

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

40-60%

Discards are estimated to be 143 crab for every 100 crab kept, or 143% of landings (SCS Global Services 2014). The Dungeness crab mortality rate is 1%–4% for undersize crab, 12%–25% for soft-shell crab, and 8% for females (Alverson et al. 1994) (SCS Global Services 2014). Limited research has been conducted on bycatch mortality. The most precautionary value for mortality rate was used for scoring because there is potential for the mortality rate to vary temporally and with stressors of repeated capture and varied handling time. Using an estimated conservative mortality rate of 25% for all discards, the net dead discard rate is estimated to be 35.75%.

Information on bait use is lacking because it is not quantified in the fishery. The best available estimate is 4.3–6.3 lbs of crab landed for every pound of bait used in Oregon: approximately a 16%–23% bait-to-landing ratio (pers. comm., ODFW 2015). This is considered an appropriate estimate for the Alaskan region (pers. comm. 2015, Forrest Bowers ADFG).

FINFISH

Factor 2.1 - Inherent Vulnerability

Scoring Guidelines (same as Factor 1.1 above)

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Medium

Finfishes have a “medium” inherent vulnerability under Seafood Watch criteria (SFW 2012).

Factor 2.2 - Stock Status

Scoring Guidelines (same as Factor 1.2 above)

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Moderate Concern

Stock status is scored as “moderate” concern using Seafood Watch criteria (SFW 2012).

Factor 2.3 - Fishing Mortality

Scoring Guidelines (same as Factor 1.3 above)

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Low Concern

Fishing mortality is scored as “low” concern under Seafood Watch criteria for finfishes caught as bycatch via the pot fishery (SFW 2012).

Factor 2.4 - Discard Rate

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

40-60%

Discards are estimated to be 143 crab for every 100 crab kept, or 143% of landings (SCS Global Services 2014). The Dungeness crab mortality rate is 1%–4% for undersize crab, 12%–25% for soft-shell crab, and

8% for females (Alverson et al. 1994) (SCS Global Services 2014). Limited research has been conducted on bycatch mortality. The most precautionary value for mortality rate was used for scoring because there is potential for the mortality rate to vary temporally and with stressors of repeated capture and varied handling time. Using an estimated conservative mortality rate of 25% for all discards, the net dead discard rate is estimated to be 35.75%.

Information on bait use is lacking because it is not quantified in the fishery. The best available estimate is 4.3–6.3 lbs of crab landed for every pound of bait used in Oregon: approximately a 16%–23% bait-to-landing ratio (pers. comm., ODFW 2015). This is considered an appropriate estimate for the Alaskan region (pers. comm. 2015, Forrest Bowers ADFG).

HUMPBACK WHALE: CALIFORNIA/OREGON/WASHINGTON

Factor 2.1 - Inherent Vulnerability

Scoring Guidelines (same as Factor 1.1 above)

California/Northeast Pacific, Pot

Oregon/Northeast Pacific, Pot

Washington Northeast Pacific, Pot

High

As a marine mammal, this species has high inherent vulnerability under Seafood Watch criteria (SFW 2012).

Factor 2.2 - Stock Status

Scoring Guidelines (same as Factor 1.2 above)

California/Northeast Pacific, Pot

Oregon/Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Very High Concern

Humpback whales are designated as endangered in their entire range under the Endangered Species Conservation Act (NOAA 2011a). The minimum population estimate is 1,876 with the population

growing at a rate of approximately 7% per year (NOAA 2014).

Factor 2.3 - Fishing Mortality

Scoring Guidelines (same as Factor 1.3 above)

Oregon/Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Very Low Concern

Whales in the California/Oregon/Washington humpback stock are occasionally entangled in gear from the crab fishery, resulting in incidental mortality or serious injury (NOAA 2012). In this region, the Dungeness fishery is listed as a Category II fishery. Interaction between the crab fishery and humpback whales is limited temporally, with the majority of crab fishing occurring prior to humpback whale migration to the region (Hankin & Warner 2001) (NOAA 2014). Although many fishers cease fishing early in the season and there are less pots actively fishing by the time whales migrate north to feed, gear remains in the water and poses an entanglement threat to whales. The percent of Potential Biological Removal (PBR) (11 whales per year) due to entanglement in pot, trap, or unidentified fishery rope (omitting net fishery interactions) is 8.6% for Washington and 5.0% for Oregon (NOAA 2014) (Carretta et al. 2013). The exact contribution of the Dungeness crab fishery to these percentages is unknown because not all gear is identifiable to its source fishery. The cumulative fisheries mortality does not exceed PBR, so fishery mortality is ranked as “very low” concern.

California/Northeast Pacific, Pot

Low Concern

Whales in the California/Oregon/Washington humpback stock are occasionally entangled in gear from the crab fishery resulting in incidental mortality or serious injury (NOAA 2012). In this region the Dungeness fishery is listed as a Category II fishery. Interaction between the crab fishery and humpback whales is limited temporally with the majority of crab fishing occurring prior to humpback whale migration to the region (Hankin & Warner 2001), (NOAA 2014)). Although many fishers cease fishing early in the season and there are less pots actively fishing by the time whales migrate north to feed, gear remains in the water posing an entanglement threat to whales. The percent of Potential Biological Removal (PBR, 11 whales per year) due to entanglement in pot, trap or unidentified fishery rope (omitting net fishery interactions) is 14.5% for CA (NOAA 2014)(Carretta et al. 2013). The exact contribution from the Dungeness crab fishery is unknown as not all gear is identifiable to source fishery. Cumulative fisheries mortality does not exceed PBR therefore fishery mortality is ranked as low.

Factor 2.4 - Discard Rate

Washington Northeast Pacific, Pot

40-60%

Discards are estimated to be 143 crab for every 100 crab kept, or 143% of landings (SCS Global Services 2014). The Dungeness crab mortality rate is 1%–4% for undersize crab, 12%–25% for soft-shell crab, and 8% for females (Alverson et al. 1994) (SCS Global Services 2014). Limited research has been conducted on bycatch mortality. The most precautionary value for mortality rate was used for scoring because there is potential for the mortality rate to vary temporally and with stressors of repeated capture and varied handling time. Using an estimated conservative mortality rate of 25% for all discards, the net dead discard rate is estimated to be 35.75%.

Information on bait use is lacking because it is not quantified in the fishery. The best available estimate is 4.3–6.3 lbs of crab landed for every pound of bait used in Oregon: approximately a 16%–23% bait-to-landing ratio (pers. comm., ODFW 2015). This is considered an appropriate estimate for the Alaskan region (pers. comm. 2015, Forrest Bowers ADFG).

Criterion 3: Management effectiveness

Management is separated into management of retained species (harvest strategy) and management of non-retained species (bycatch strategy).

The final score for this criterion is the geometric mean of the two scores. The Criterion 3 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and <=3.2=Yellow or Moderate Concern*
- *Score <=2.2 or either the Harvest Strategy (Factor 3.1) or Bycatch Management Strategy (Factor 3.2) is Very High Concern = Red or High Concern*
  Rating is Critical if either or both of Harvest Strategy (Factor 3.1) and Bycatch Management Strategy (Factor 3.2) ratings are Critical.

Criterion 3 Summary

Region / Method	Management of Retained Species	Management of Non-Retained Species	Overall Recommendation
Alaska Northeast Pacific Pot	3.000	4.000	Green(3.464)
British Columbia Northeast Pacific Pot	3.000	4.000	Green(3.464)
California Northeast Pacific Pot	3.000	4.000	Green(3.464)
Oregon Northeast Pacific Pot	4.000	4.000	Green(4.000)
Washington Northeast Pacific Pot	3.000	4.000	Green(3.464)

Factor 3.1: Harvest Strategy

Scoring Guidelines

Seven subfactors are evaluated: Management Strategy, Recovery of Species of Concern, Scientific Research/Monitoring, Following of Scientific Advice, Enforcement of Regulations, Management Track Record, and Inclusion of Stakeholders. Each is rated as 'ineffective,' 'moderately effective,' or 'highly effective.'

- *5 (Very Low Concern)—Rated as 'highly effective' for all seven subfactors considered.*
- *4 (Low Concern)—Management Strategy and Recovery of Species of Concern rated 'highly effective' and all other subfactors rated at least 'moderately effective.'*

- *3 (Moderate Concern)—All subfactors rated at least 'moderately effective.'*
- *2 (High Concern)—At minimum, meets standards for 'moderately effective' for Management Strategy and Recovery of Species of Concern, but at least one other subfactor rated 'ineffective.'*
- *1 (Very High Concern)—Management exists, but Management Strategy and/or Recovery of Species of Concern rated 'ineffective.'*
- *0 (Critical)—No management exists when there is a clear need for management (i.e., fishery catches threatened, endangered, or high concern species), OR there is a high level of Illegal, unregulated, and unreported fishing occurring.*

Factor 3.1 Summary

Factor 3.1: Management of fishing impacts on retained species							
Region / Method	**Strategy**	**Recovery**	**Research**	**Advice**	**Enforce**	**Track**	**Inclusion**
Alaska Northeast Pacific Pot	Moderately Effective	Moderately Effective	Moderately Effective	Highly Effective	Highly Effective	Moderately Effective	Highly Effective
British Columbia Northeast Pacific Pot	Moderately Effective	N/A	Moderately Effective	Highly Effective	Highly Effective	Highly Effective	Highly Effective
California Northeast Pacific Pot	Moderately Effective	N/A	Moderately Effective	Highly Effective	Highly Effective	Highly Effective	Highly Effective
Oregon Northeast Pacific Pot	Highly Effective	N/A	Moderately Effective	Highly Effective	Highly Effective	Highly Effective	Highly Effective
Washington Northeast Pacific Pot	Moderately Effective	N/A	Moderately Effective	Highly Effective	Highly Effective	Highly Effective	Highly Effective

Subfactor 3.1.1 – Management Strategy and Implementation

Considerations: What type of management measures are in place? Are there appropriate management goals, and is there evidence that management goals are being met? To achieve a highly effective rating, there must be appropriate management goals, and evidence that the measures in place have been successful at maintaining/rebuilding species.

Alaska Northeast Pacific, Pot

Moderately Effective

The Alaska Department of Fish and Game manages the fishery utilizing a 3-S strategy with a minimum size limit of 165 mm carapace width, restricted to male harvest with seasonal closures (Messmer et al. 2011) (Stratman et al. 2014). In contrast to seasonal management in other regions of North America, collection in some Alaskan regions is permitted during the summer, which allows for harvest

during the molting period. This results in removal of males prior to the mating season and increased handling mortality of soft-shell crab, which are concerns to future sustainability. Seasonal closures in Alaska vary between management regions; however, in most areas harvest closures are implemented during the peak molting period from mid-August to the end of September. The fishery is limited-entry with gear requirements including maximum pot size, escape rings, and pot limits in some regions. The viability of the historical passive management plan is uncertain (Kelley et al. 2011). This passive management strategy has failed in the Cook Inlet, Yakutat, and Prince William Sound regions, where Dungeness crab population collapses have led to fishery closures (Trowbridge & Goldman 2006) (Messmer et al. 2011) (Wessel et al. 2012). As a precaution, the Southeast Alaska region has implemented provisions for reductions in season length if predicted harvests do not meet prescribed thresholds (Messmer et al. 2011). Due to increased exploitation in recent years, all areas are fully fished such that the population lacks a buffer to environmental variability and the fishery is dependent on annual recruitment. Implementation of harvest guidelines could result in more effective future fishery management. This factor is rated “moderately effective.”

British Columbia Northeast Pacific, Pot

Moderately Effective

Management strategy in British Columbia includes size, sex, and hardness harvest restrictions, seasonal closures, limited licensing, trap limits, gear requirements, and limits on soak time and weekly haul (DFO 2013a). This strategy has been successful in maintaining crab productivity, based on stability of annual landings on a decadal average. There is growing concern about the effects of increased fisheries effort in recent years and the resulting increased handling mortality of discarded crab. Management is ranked “moderately effective” due to a lack of biological reference points for precautionary population monitoring.

California Northeast Pacific, Pot

Moderately Effective

The California and Washington Departments of Fish and Wildlife manage the fishery using a 3-S strategy, including size, sex, season, and hardness harvest restrictions (WAC 2012a) (WAC 2012b) (CDFW 2014). The fishery is limited-entry and employs pot limits and gear restrictions, including size and escape mechanism requirements. Management is ranked as “moderately effective” due to a lack of biological data to determine stock abundance and its resilience to recent increased fishing effort and to future environmental fluctuations.

Oregon Northeast Pacific, Pot

Highly Effective

The fishery is managed using a 3-S strategy with limits on size, sex, and season (ODFW 2015) (ODFW 2014). The fishery is limited-entry, employing gear restrictions and pot limits. Logbooks are required and must be completed prior to each landing. The season opening date is based on crab quality testing coordinated by the Tri-State Dungeness Crab Committee. Management is adaptive and continuously improving, most recently adopting Limit Reference Points (LRP) in 2014. The LRP is reached when landings have decreased for three consecutive seasons, landings are projected to continue declining in the fourth season to below 20% of the 20-year average, and logbook CPUE falls below the average for the 1980–1981 through 1986–1987 seasons. The LRP will be evaluated within 8 weeks of the season opening. Management has committed to respond by seasonal closure, reduction in pot or trip limits, area closures, or increasing minimum size limits if the LRP is reached. Management is ranked as "highly effective."

Washington Northeast Pacific, Pot

Moderately Effective

The California and Washington Departments of Fish and Wildlife manage the fishery using a 3-S strategy, including size, sex, season, and hardness harvest restrictions (WAC 2012a) (WAC 2012b) (CDFW 2014). The fishery is limited-entry and employs pot limits and gear restrictions, including size and escape mechanism requirements. Management is ranked as "moderately effective" due to a lack of biological data to determine stock abundance and its resilience to recent increased fishing effort and to future environmental fluctuations.

Subfactor 3.1.2 – Recovery of Species of Concern

Considerations: When needed, are recovery strategies/management measures in place to rebuild overfished/threatened/ endangered species or to limit fishery's impact on these species and what is their likelihood of success? To achieve a rating of Highly Effective, rebuilding strategies that have a high likelihood of success in an appropriate timeframe must be in place when needed, as well as measures to minimize mortality for any overfished/threatened/endangered species.

Alaska Northeast Pacific, Pot

Moderately Effective

There are currently no overfished, depleted, endangered, or threatened species targeted or retained in

the fishery. The Alaska Department of Fish & Game (ADF&G) has maintained regional closures in the Prince William Sound (PWS), Yakutat, and Cook Inlet areas where crab populations historically collapsed (Trowbridge & Goldman 2006) (Messmer et al. 2011) (Wessel et al. 2012). Depletion of these stocks was likely due to a synergistic effect of environmental fluctuations, otter predation, and spatial expansion of fishing effort that all led to serial depletion of fishing grounds (Orensanz et al. 1998). The Cook Inlet region has been closed to commercial fishing since 1991, Yakutat since 2000, and PWS in its entirety since 2000 (Copper River region of PWS since 1992, and Orca Inlet since 1980). Despite long-term closures, population abundance remains depressed. Recovery failure is likely due to a variety of factors including sea otter predation, loss as bycatch in other trawl fisheries, recruitment variability, and environmental fluctuations. These regions are near the northern limit of the Dungeness crab range, which may further contribute to their vulnerability. ADF&G intends to protect depleted regions until populations recover and stock assessment and management plans are developed for sustainability. Recovery is scored as “moderately effective” because closures have not generated population recovery and further intervention may be necessary.

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

N/A

There are currently no overfished, depleted, endangered, or threatened species targeted or retained in the fishery.

Subfactor 3.1.3 – Scientific Research and Monitoring

Considerations: How much and what types of data are collected to evaluate the health of the population and the fishery’s impact on the species? To achieve a Highly Effective rating, population assessments must be conducted regularly and they must be robust enough to reliably determine the population status.

Alaska Northeast Pacific, Pot

Moderately Effective

Data are collected to assess stock health and to evaluate population age and size composition through comprehensive fish ticket reporting and dockside sampling (Messmer et al. 2011) (Stratman et al. 2014). Sampling occurs occasionally via onboard observer and on-the-ground surveys, but sampling is not

spatially or temporally comprehensive and life-history timing is uncertain. Research is ranked "moderately effective" due to incomplete coverage because Dungeness crab displays high spatial and temporal variability in life-history timing (Bishop et al. 2010). Due to insufficient resources, management lacks a fishery-independent stock assessment program.

British Columbia Northeast Pacific, Pot

Moderately Effective

Fishery-independent stock assessments are conducted twice annually in two of seven designated fishing areas (Areas I and J) (DFO 2013a). Research surveys are performed in additional regions, on an inconsistent basis, to target specific scientific questions including stock composition, molt timing, and injury. Additional biological data are obtained through electronic monitoring programs, harvest logs, and biological sampling. The DFO acknowledges that existing biological information is insufficient for implementing future ecosystem-based management and has plans underway to begin monthly fishery-independent surveys in additional fishing areas (DFO 2013a). This factor is rated "moderately effective."

California Northeast Pacific, Pot

Moderately Effective

There is limited data availability for the California and Washington fisheries, and no formal stock assessments have been conducted (Hankin & Warner 2001). Pre-season testing for meat fill occurs annually in both states, and data are collected from required logbooks in Washington (PSMFC 2012) (WAC 2007). More research is needed to determine the long-term effects of the fishery's increasing spatial footprint on stock abundance. This factor is rated "moderately effective."

Oregon Northeast Pacific, Pot

Moderately Effective

There is no regular stock assessment for Dungeness crab in Oregon. Monitoring programs are in place to assess mating success, population genetic structure, and size structure and to estimate discard mortality (ODFW 2014). Stock health and bycatch composition are assessed through fish ticket reporting and dockside and at-sea sampling, while CPUE data are obtained from logbook records. Monitoring is considered "moderately effective" due to the limited amount of fishery-independent data, which prevents a score of highly effective from being achieved.

Washington Northeast Pacific, Pot

Moderately Effective

There is limited data availability for the California and Washington fisheries and no formal stock assessments have been conducted (Hankin & Warner 2001). Pre-season testing for meat fill occurs annually in both states and data are collected from required logbooks in Washington (PSMFC 2012) (WAC 2007). More research is needed to determine the long-term effects of the fishery's increasing spatial footprint on stock abundance. This factor is rated "moderately effective."

Subfactor 3.1.4 – Management Record of Following Scientific Advice

Considerations: How often (always, sometimes, rarely) do managers of the fishery follow scientific recommendations/advice (e.g. do they set catch limits at recommended levels)? A Highly Effective rating is given if managers nearly always follow scientific advice.

Alaska Northeast Pacific, Pot

Highly Effective

Management follows scientific advice by modifying and implementing regulations in response to research findings; however, research on stock abundance is extremely limited.

British Columbia Northeast Pacific, Pot

Highly Effective

Management follows scientific advice by modifying and implementing regulations in response to research findings; however, research on stock abundance is extremely limited. A move toward precautionary management of crab populations through development of biological reference points to indicate stock status has been recommended (Zhang & Dunham 2013). Fisheries and Oceans Canada intends to base future management of the crab fishery on biological information (DFO 2013a).

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Highly Effective

Management follows scientific advice by modifying and implementing regulations in response to research findings; however, research on stock abundance is extremely limited.

Subfactor 3.1.5 – Enforcement of Management Regulations

Considerations: Do fishermen comply with regulations, and how is this monitored? To achieve a Highly Effective rating, there must be regular enforcement of regulations and verification of compliance.

Alaska Northeast Pacific, Pot

Highly Effective

Fishery vessels are subject to inspection, and dockside sampling occurs in some regions (ADF&G 2012). Alaska Wildlife troopers patrol fishing waters, monitoring for proper gear and licensing and inspecting buoy tags to enforce pot limits.

British Columbia Northeast Pacific, Pot

Highly Effective

The DFO conducts enforcement activities to survey closed areas for illegal activity; to check gear requirement compliance; to investigate landings of undersize, female, and soft-shell crab; and to investigate fraudulent crab landing reporting (DFO 2013a). The enforcement program includes dockside monitoring, vessel inspection, electronic vessel monitoring, and fishery patrol via vessel and air surveillance.

California Northeast Pacific, Pot

Highly Effective

The California and Washington Departments of Fish and Wildlife conduct monitoring and enforcement via land and at-sea patrols (Spear & Babich 2001) (IACP 2008). Efforts include license, catch, gear, and vessel inspection.

Oregon Northeast Pacific, Pot

Highly Effective

The Oregon State Police (OSP) Fish and Wildlife Division troopers patrol for violations, ensure fishers are licensed and maintain log books, monitor crab pots for compliance in size and escape mechanisms, and enforce size limits. The OSP works cooperatively with the Oregon Department of Fish and Wildlife in planning enforcement priorities (OSP 2015).

Washington Northeast Pacific, Pot

Highly Effective

The California and Washington Departments of Fish and Wildlife conduct monitoring and enforcement via land and at-sea patrols (Spear & Babich 2001) (IACP 2008). Efforts include license, catch, gear, and vessel inspection.

Subfactor 3.1.6 – Management Track Record

Considerations: Does management have a history of successfully maintaining populations at sustainable levels or a history of failing to maintain populations at sustainable levels? A Highly Effective rating is given if measures enacted by management have been shown to result in the long-term maintenance of species overtime.

Alaska Northeast Pacific, Pot

Moderately Effective

Management measures currently in place have resulted in regional stock collapses in the Cook Inlet, Yakutat, and Prince William Sound areas, which have since failed to recover despite closures (Trowbridge & Goldman 2006) (Messmer et al. 2011) (Wessel et al. 2012). This may be due to a number of factors including complex predator-prey relationships.

British Columbia Northeast Pacific, Pot

Highly Effective

Based on annual landings data, management of the crab fishery has resulted in long-term maintenance of average stock abundance and ecosystem integrity (DFO 2013a).

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Highly Effective

Stock abundance, based on annual landings, fluctuates cyclically (Hankin & Warner 2001). The mechanisms underlying interannual variability in recruitment success are uncertain. Larval survival appears to be impacted by environmental factors (the Pacific Decadal Oscillation, the El Niño Southern Oscillation, timing of the spring transition, and upwelling intesity) that influence biological productivity and larval transport (Botsford 2001) (Shanks 2013). The central California fishery experienced a dramatic decline in the 1950s, presumably due to warming water temperatures and late timing of the spring transition (Hankin & Warner 2001) (Shanks & Roegner 2007). But measures enacted by management have resulted in long-term maintenance of average stock abundance.

Subfactor 3.1.7 – Stakeholder Inclusion

Considerations: Are stakeholders involved/included in the decision-making process? Stakeholders are individuals/groups/organizations that have an interest in the fishery or that may be affected by the management of the fishery (e.g., fishermen, conservation groups, etc.). A Highly Effective rating is given if the management process is transparent and includes stakeholder input.

Alaska Northeast Pacific, Pot

Highly Effective

The Southeast Alaska Commercial Dungeness Task Force, comprised of ten commercial fishers, serves as an industry advisory group to management (ADF&G 2000). Public comment is also welcome at Alaska Board of Fisheries meetings.

British Columbia Northeast Pacific, Pot

Highly Effective

The crab fishery management process is inclusive of stakeholder groups (DFO 2013a). Fishery planning involves an annual consultative process through a Crab Sectoral Committee comprised of representatives from DFO, commercial license holders, and processors.

California Northeast Pacific, Pot

Highly Effective

The California and Washington Departments of Fish & Wildlife solicit input on fishery management from the public and industry advisory groups: the California Dungeness Crab Task Force and Washington Coastal Dungeness Crab Advisory Board (DCTF 2012) (WADFW 2013).

Oregon Northeast Pacific, Pot

Highly Effective

The Oregon Department of Fish & Wildlife solicits stakeholder input on management issues from the Oregon Dungeness Crab Advisory Committee, the Oregon Dungeness Crab Commission, and the public (ODFW 2014). Agency, industry, and the public are involved in making management decisions through surveys, workshops, and public meetings. ODFW distributes a crab fishery annual newsletter to keep stakeholders informed.

Washington Northeast Pacific, Pot

Highly Effective

The California and Washington Departments of Fish & Wildlife solicit input on fishery management from the public and industry advisory groups: the California Dungeness Crab Task Force and Washington Coastal Dungeness Crab Advisory Board (DCTF 2012) (WADFW 2013).

Bycatch Strategy

Factor 3.2: Management of fishing impacts on bycatch species						
Region / Method	**All Kept**	**Critical**	**Strategy**	**Research**	**Advice**	**Enforce**
Alaska Northeast Pacific Pot	No	No	Highly Effective	Moderately Effective	Highly Effective	Moderately Effective
British Columbia Northeast Pacific Pot	No	No	Highly Effective	Moderately Effective	Highly Effective	Moderately Effective
California Northeast Pacific Pot	No	No	Highly Effective	Moderately Effective	Highly Effective	Moderately Effective
Oregon Northeast Pacific Pot	No	No	Highly Effective	Moderately Effective	Highly Effective	Moderately Effective
Washington Northeast Pacific Pot	No	No	Highly Effective	Moderately Effective	Highly Effective	Moderately Effective

Subfactor 3.2.1 – Management Strategy and Implementation

Considerations: What type of management strategy/measures are in place to reduce the impacts of the fishery on bycatch species and how successful are these management measures? To achieve a Highly Effective rating, the primary bycatch species must be known and there must be clear goals and measures in place to minimize the impacts on bycatch species (e.g., catch limits, use of proven mitigation measures, etc.).

Alaska Northeast Pacific, Pot

Highly Effective

Management mitigates impacts of the fishery on bycatch through gear requirements. Traps must have two 4⅜-inch diameter escape rings to allow for escape of undersize crab and females (Messmer et al. 2011). An escape panel secured with biodegradable twine acts to reduce effects of ghostfishing when pots are lost at sea. This escape mechanism could use improvement because the current design is vulnerable to unsuccessful lid release due to metal fatigue and biofouling (Maselko et al. 2013). The use of single trap gear and pot limits minimizes whale entanglement through reduction of gear in the water.

British Columbia Northeast Pacific, Pot

Highly Effective

Management mitigates impacts of the fishery on bycatch through gear requirements. Traps must have two 105-mm diameter escape rings to allow for escape of undersize crab and females (DFO 2013a). To reduce handling mortality, hanging bait and bait cups have been banned and managers may implement in-season closures if a great frequency of soft-shell capture is observed. The gear must be equipped with rot cord that serves as a biodegradable escape mechanism to reduce effects of ghostfishing when pots are lost at sea. The use of single trap gear and pot limits minimizes whale entanglement through reduction of gear in the water.

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Highly Effective

Management mitigates impacts of the fishery on bycatch through gear requirements, limitations on soak time, and a specified final trap-retrieval day at the end of each season. Traps must have two 4¼-inch diameter escape rings in the upper half of the pot to allow for escape of undersize and female crab (WAC 2012b) (DFG 2012b) (ODFW 2015). Gear must be equipped with rot cord that serves as a biodegradable escape mechanism to reduce effects of ghostfishing when pots are lost at sea.

Researchers have recommended reducing cord diameter to increase effectiveness, because it takes 126 days for this cord to decompose at sea (Antonelis et al. 2011). The use of single trap gear, pot limits, and limited-entry permits minimizes whale entanglement through reduction of gear in the water. Derelict gear removal efforts have helped to mitigate effects of ghostfishing (ODFW 2012) (ODFW 2014).

Subfactor 3.2.2 – Scientific Research and Monitoring

Considerations: Is bycatch in the fishery recorded/documented and is there adequate monitoring of bycatch to measure fishery's impact on bycatch species? To achieve a Highly Effective rating, assessments must be conducted to determine the impact of the fishery on species of concern, and an adequate bycatch data collection program must be in place to ensure bycatch management goals are being met.

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Moderately Effective

Scientific research exists on the fishery's impacts on sublegal and female crab, but data are limited and more comprehensive information is necessary regarding the magnitude of bycatch collected, handling effects, and mortality. Based on co-occurrence, the Dungeness crab trap fishery has the highest whale entanglement risk among commercial fixed-gear fisheries off the U.S. West Coast (Saez et al. 2013). Despite entanglement concerns, much is unknown about the fishery's effect on whales, including frequency of entanglement and mortality (Neilson et al. 2009). In southeast Alaska, the majority of humpback whales have been non-lethally entangled, as determined from scarring. But more research is necessary to determine the prevalence in other regions and the magnitude attributed specifically to the Dungeness crab fishery. Some research is available on the effects of bycatch due to lost gear; however, the impact of lost traps is still poorly understood. It is estimated that 10%–20% of traps are lost at sea annually, with 7.5%–32.5% of lost pots actively ghostfishing that results in bycatch mortality (Breen 1990) (ODFW 2012). Ghostfishing presents a serious concern because derelict pots can fish effectively for at least 7 years in some regions (Maselko et al. 2013). More information is needed to identify and quantify species that are affected by lost Dungeness crab pots.

Subfactor 3.2.3 – Management Record of Following Scientific Advice

Considerations: How often (always, sometimes, rarely) do managers of the fishery follow scientific recommendations/advice (e.g., do they set catch limits at recommended levels)? A Highly Effective rating is given if managers nearly always follow scientific advice.

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Highly Effective

There is no evidence that advice is followed differently for bycatch species.

Subfactor 3.2.4 – Enforcement of Management Regulations

Considerations: Is there a monitoring/enforcement system in place to ensure fishermen follow management regulations and what is the level of fishermen's compliance with regulations? To achieve a Highly Effective rating, there must be consistent enforcement of regulations and verification of compliance.

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Moderately Effective

Pots without proper rot cord have been observed ghostfishing, which suggests that further enforcement of gear requirements is necessary (NRC 2006) (NSF & NRC 2011) (Maselko et al. 2013).

Criterion 4: Impacts on the habitat and ecosystem

This Criterion assesses the impact of the fishery on seafloor habitats, and increases that base score if there are measures in place to mitigate any impacts. The fishery's overall impact on the ecosystem and food web and the use of ecosystem-based fisheries management (EBFM) principles is also evaluated. Ecosystem-based fisheries management aims to consider the interconnections among species and all natural and human stressors on the environment.

The final score is the geometric mean of the impact of fishing gear on habitat score (plus the mitigation of gear impacts score) and the ecosystem-based fishery management score. The Criterion 2 rating is determined as follows:

- *Score >3.2=Green or Low Concern*
- *Score >2.2 and <=3.2=Yellow or Moderate Concern*
- *Score <=2.2=Red or High Concern*
  Rating cannot be Critical for Criterion 4.

Criterion 4 Summary

Region / Method	Gear Type and Substrate	Mitigation of Gear Impacts	EBFM	Overall Recomm.
Alaska Northeast Pacific Pot	3.00:Low Concern	0.25:Minimal Mitigation	3.00:Moderate Concern	**Yellow (3.123)**
British Columbia Northeast Pacific Pot	3.00:Low Concern	0.25:Minimal Mitigation	3.00:Moderate Concern	**Yellow (3.123)**
California Northeast Pacific Pot	3.00:Low Concern	0.25:Minimal Mitigation	3.00:Moderate Concern	**Yellow (3.123)**
Oregon Northeast Pacific Pot	3.00:Low Concern	0.25:Minimal Mitigation	3.00:Moderate Concern	**Yellow (3.123)**
Washington Northeast Pacific Pot	3.00:Low Concern	0.25:Minimal Mitigation	3.00:Moderate Concern	**Yellow (3.123)**

Justification of Ranking

Factor 4.1 – Impact of Fishing Gear on the Habitat/Substrate

Scoring Guidelines

- *5 (None)—Fishing gear does not contact the bottom*
- *4 (Very Low)—Vertical line gear*
- *3 (Low)—Gears that contacts the bottom, but is not dragged along the bottom (e.g. gillnet, bottom longline, trap) and is not fished on sensitive habitats. Bottom seine on resilient mud/sand habitats. Midwater trawl that is known to contact bottom occasionally.*

- *2 (Moderate)—Bottom dragging gears (dredge, trawl) fished on resilient mud/sand habitats. Gillnet, trap, or bottom longline fished on sensitive boulder or coral reef habitat. Bottom seine except on mud/sand*
- *1 (High)—Hydraulic clam dredge. Dredge or trawl gear fished on moderately sensitive habitats (e.g., cobble or boulder)*
- *0 (Very High)—Dredge or trawl fished on biogenic habitat, (e.g., deep-sea corals, eelgrass and maerl)*
  Note: When multiple habitat types are commonly encountered, and/or the habitat classification is uncertain, the score will be based on the most sensitive, plausible habitat type.

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Low Concern

The fishery uses pot/trap gear that contacts the bottom (via a vertical line) primarily in mud and sand habitats. Traps have the potential to crush and scour biogenic structures (DFO 2013a), but have minimal impact to benthic habitats compared to other types of fishing gear.

Factor 4.2 – Mitigation of Gear Impacts

Scoring Guidelines

- *+1 (Strong Mitigation)—Examples include large proportion of habitat protected from fishing (>50%) with gear, fishing intensity low/limited, gear specifically modified to reduce damage to seafloor and modifications shown to be effective at reducing damage, or an effective combination of 'moderate' mitigation measures.*
- *+0.5 (Moderate Mitigation)—20% of habitat protected from fishing with gear or other measures in place to limit fishing effort, fishing intensity, and spatial footprint of damage caused from fishing.*
- *+0.25 (Low Mitigation)—A few measures are in place (e.g., vulnerable habitats protected but other habitats not protected); there are some limits on fishing effort/intensity, but not actively being reduced.*

- *0 (No Mitigation)—No effective measures are in place to limit gear impacts on habitats.*

Alaska Northeast Pacific, Pot

Minimal Mitigation

Fishing effort and spatial footprint are reduced via pot limits and gear size restrictions (Messmer et al. 2011). The magnitude of the spatial footprint is uncertain because pots are deployed several times within the season and may drag across the seafloor during storm events. Fishing is closed in Glacier Bay National Park and Preserve and the Prince William Sound, Yakutat, and Cook Inlet areas (Trowbridge & Goldman 2006) (Messmer et al. 2011) (Wessel et al. 2012).

British Columbia Northeast Pacific, Pot

Minimal Mitigation

Fishing is prohibited within the Endeavour and Bowie Seamount Marine Protected Areas and in regions of the Hecate Strait/Queen Charlotte Sound Glass Sponge Reefs to protect vulnerable cloud sponges (DFO 2013a). Fishery effort is regulated with pot limits; however, some fishers have compensated for this limitation by increasing the frequency of haul—effectively increasing spatial footprint. In the 2013 season, new regulations were implemented in some regions that restrict haul frequency to once per day. The spatial footprint is further reduced through limits on maximum trap size.

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Minimal Mitigation

Damage to the seafloor is mitigated through maximum trap size and pot limits (WAC 2012b) (DFG 2012b) (ODFW 2015). There are no-take Marine Protected Areas in each state, but they represent less than 20% of Dungeness crab habitat.

Factor 4.3 – Ecosystem-Based Fisheries Management

Scoring Guidelines

- *5 (Very Low Concern)—Substantial efforts have been made to protect species' ecological roles and ensure fishing practices do not have negative ecological effects (e.g., large*

proportion of fishery area is protected with marine reserves, and abundance is maintained at sufficient levels to provide food to predators).

- *4 (Low Concern)—Studies are underway to assess the ecological role of species and measures are in place to protect the ecological role of any species that plays an exceptionally large role in the ecosystem. Measures are in place to minimize potentially negative ecological effect if hatchery supplementation or fish aggregating devices (FADs) are used.*
- *3 (Moderate Concern)—Fishery does not catch species that play an exceptionally large role in the ecosystem, or if it does, studies are underway to determine how to protect the ecological role of these species, OR negative ecological effects from hatchery supplementation or FADs are possible and management is not place to mitigate these impacts.*
- *2 (High Concern)—Fishery catches species that play an exceptionally large role in the ecosystem and no efforts are being made to incorporate their ecological role into management.*
- *1 (Very High Concern)—Use of hatchery supplementation or fish aggregating devices (FADs) in the fishery is having serious negative ecological or genetic consequences, OR fishery has resulted in trophic cascades or other detrimental impacts to the food web.*

Alaska Northeast Pacific, Pot

British Columbia Northeast Pacific, Pot

California Northeast Pacific, Pot

Oregon Northeast Pacific, Pot

Washington Northeast Pacific, Pot

Moderate Concern

Dungeness crab play important roles in trophic interactions both as predator and prey (Pauley et al. 1989). But there is no evidence that they play a disproportionate role in the ecosystem relative to their biomass. No formal assessments of ecosystem impacts of Dungeness crab fishing activity have been conducted. Although removal of large quantities of crab will have some impact on benthic coastal species diversity, abundance, and community structure, the effects are currently unknown.

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