Oregon Dungeness Crab Research and Monitoring Plan

Oregon Department of Fish and Wildlife

Marine Resources Program

Updated August, 2014

Table of Contents

A. Executive Summary

This document is a strategic research and monitoring plan for the Oregon Dungeness crab resource (*Cancer magister/ syn. Metacarcinus magister*) that synthesizes historical and on-going biological, ecological and economic research and monitoring efforts conducted by the Oregon Department of Fish and Wildlife (ODFW), pertaining to Dungeness crab. The plan identifies research gaps and plans for addressing a number of those gaps with internal resources. Additional research in each of these categories that would be of value to the management of the fishery but are unlikely to be conducted by ODFW due to resource limitations are also identified.

B. Background

B.1. Agency Structure and Funding

The lead agency responsible for overseeing all of Oregon's Dungeness crab resources is ODFW. The marine fisheries management group is within ODFW's Marine Resources Program (MRP), which is authorized by the State Legislature in statute and the Oregon Fish and Wildlife Commission (OFWC) in administrative rule, to administer the regulation, harvest and management of commercial and recreational fisheries in Oregon.

The bulk of research and monitoring efforts described throughout this strategic plan are conducted by various work groups within MRP. These work groups are funded largely by commercial fishing fees and recreational shellfish license sales. Each is currently part of the permanent budget for MRP and has dedicated funds for research and monitoring of Dungeness crab.

B.2. Guiding Documents

Management of the Oregon Dungeness crab resource is guided by four overarching policy documents: Food Fish Management Policy (Oregon Revised Statute § 506.109), Wildlife Policy (Oregon Revised Statute 496.012), the Native Fish Conservation Policy (Oregon Administrative Rules 635-007-0502 through 0509), and the Oregon Nearshore Strategy (ODFW 2006). At the statewide level, the intent of the Food Fish Management and Wildlife policies is to manage fish and shellfish in order to provide optimum economic, recreational and aesthetic benefits. Key elements to the Native Fish Conservation Policy include maintaining and restoring sustainable native species, along with optimizing recreational, commercial, cultural, aesthetic and ecological benefits of these species. The Oregon Nearshore Strategy was developed to promote collaborative efforts to sustainably manage and conserve nearshore resources.

B.3. Existing Management Structure

Oregon has very active commercial and recreational fisheries that target Dungeness crab. The amended Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSA) granted states the interim authority to manage Dungeness crab in the Exclusive Economic Zone (EEZ; 3-200 nautical miles offshore) until 2016 (MSA P.L. 109-479, § 302(e)). Oregon's crab fisheries are governed by a series of Oregon Revised Statues (ORS§508.921 through 941 and 509.415) and Oregon Administrative Rules (OARs 635-007-0502 through 0509, 635-005-0500 through 0515 and 635-039-0080 through 0090). The ORSs are adopted or modified through legislation and contain regulations and requirements related to fees, licensing, gear and limited entry. The OARs are adopted or modified by the OFWC and pertain to season, gear and operation within the fisheries. Implementation of ORSs and OARs is overseen by ODFW with enforcement functions carried out by the Oregon State Police (OSP).

Oregon has three targeted fisheries for Dungeness crab: the ocean commercial crab fishery, the bay commercial crab fishery, and the recreational crab fishery (which occurs in both the ocean and estuaries). Although minor commercial and recreational fisheries exist for other crab species in Oregon, for the purposes of this report the term "crab fishery" refers to a fishery targeting Dungeness crab. For over sixty years, these fisheries have been managed under a '3-S' system—sex, size, and season. Retention of female Dungeness crab is prohibited. Fishery participants must comply with a minimum carapace size limit for retained males (6.25 inch commercial, 5.75 inch recreational), which is intended to allow 1-2 years of reproduction before recruitment into the fishery. Furthermore, the ocean commercial crab fishery is either limited or closed during sensitive molting periods (summer and fall). These basic, conservative, biological management restrictions are in place in all three of the targeted Dungeness crab fisheries to maintain productivity of the species and manage for the long-term sustainability of the resource.

The ocean commercial crab fishery is considered the most valuable single species commercial fishery in Oregon, harvesting a long-term average (25 years) of 14.7 million pounds of crab per season as of the 2012-13 crab season. Since 1995, this fishery has operated under a limited entry permit system which capped the number of vessels allowed to participate in the fishery (initially 433 permits, however, due to non-renewal, the number has subsequently dropped to 425 permits as of June, 2014). The second measure to control effort in the fishery was the implementation of pot limits in late 2006, which designated the amount of gear each permitted vessel could use (three tiers of 200, 300 or 500 pots). These socio-economic management policies were in part designed to reduce overcapitalization and excess effort in the fishery.

Due to the economic importance of the ocean commercial crab fishery to Oregon, the geographic scale, and the numerous participants, ODFW incorporates a large degree of agency, industry and public involvement when making management decisions. Coast wide recommendations are considered through the Tri-State Dungeness Crab Committee which is comprised of industry participants and state agency representatives from Washington, Oregon and California. To address Tri-State issues, along with more localized issues, the Oregon Dungeness Crab Advisory Committee (ODCAC) was formed to help foster industry input to inform management issues and decisions. The ODCAC is comprised of harvesters and processors from all of the major crabbing ports in Oregon. On major management issues ODFW also disseminates information and gathers a further degree of input from the crab industry (all permit holders, processors, and interested parties) through industry public meetings, surveys, workshops, mailings and a crab fishery annual newsletter. An additional source of industry input is provided through the Oregon Dungeness Crab Commission (ODCC), which was initiated through the Commodity Commission Act of 1977 (ORS §576.051 through §576.455; §576.911(2),(3))**.**

The ODCC is an industry-funded marketing and promotion commodity commission that also participates as a voice for the crab industry in fishery related regulatory and policy processes. The ocean commercial crab fishery was certified as sustainable by the Marine Stewardship Council (MSC) in December 2010, a 5-year certification that was pursued by the Oregon Dungeness Crab Commission (SCS, 2010). The MSC certification is a science-based environmental standard that offers fisheries a way to confirm sustainability, using a credible, independent, third-party assessment process. ODFW assisted in the fishery maintaining certification through development of this strategic plan and reference points for the fishery which were in line with the resource management goals of the agency.

Relative to the ocean commercial crab fishery, the bay commercial crab fishery is much smaller, in terms of both the number of participants (20-30 boats on average) and total harvest (15,000-

30,000 pounds annually; Ainsworth *et al.* 2012). The fishery is restricted to a 3-4 month season (September through December), harvesting is not permitted on holidays or on weekends, and no more than 15 rings per vessel may be used.

Oregon's recreational crab fishermen target Dungeness crab in the ocean and within the state's many bays. Participation and harvest in the recreational crab fishery peaks in the summer months and is estimated to harvest an average of five and half percent of the total targeted harvest of Dungeness crab statewide (average from 2010 and 2011 estimates to compare seasons of the same length (Dec-Oct.15)) (Ainsworth *et al.* 2012). Fishery participants are restricted to utilizing three pieces of gear per licensed angler (with a choice of gear including pots, rings, and snares, or a combination of these) to harvest crab and a daily bag limit of 12 male crabs. Harvest is allowed in the bays year-round and in the ocean from December through October.

C. ODFW Research and Monitoring

This section outlines ODFW's historical and on-going biological, ecological and economic research and monitoring efforts on the Dungeness crab resource in Oregon (appendix Table 1).

C.1. Biological

C.1.a. Total Fishery Mortality

ODFW currently does not conduct annual stock assessments for Dungeness crab, however, ODFW has historically implemented a conservative biological management strategy that relies on size, sex and season restrictions (see section B.3.). To avoid overfishing this management system relies on low levels of mortality of both females and sublegal males in order to sustain the fishery. In order to fully assess the effectiveness of current management it is necessary to quantify the fishery related total mortality of all Dungeness crab, including discarded catch (e.g. females and sublegal males).

Components of fishery related crab mortality include targeted and non-targeted Dungeness crab catch. Like many commercial fisheries, not all catch is retained, and all females and sublegal males must be discarded. Targeted Dungeness crab catch occurs in the commercial and recreational fisheries, as well as a small amount in research efforts conducted on Dungeness crab. Non-targeted catch of Dungeness crab occurs as bycatch in other commercial fisheries (e.g., the trawl fisheries) and in various non-crab targeted research efforts. Both types of crab catch (targeted and non-targeted) are further defined and methods for monitoring are described throughout this section. The term mortality within this section refers to a total amount of crab rather than a rate, unless specified otherwise.

Ocean and Bay Commercial Catch

Two targeted commercial Dungeness crab fisheries in Oregon contribute to the total mortality of crab: the ocean commercial crab fishery and, to a lesser extent, the bay commercial crab fishery. All targeted, commercially caught Dungeness crab have been tracked through various methods since 1896. Oregon commercial fish landings, including Dungeness crab, are recorded in state summary reports from the late 1800's and Fisheries Statistics of the United States annual reports (1927-77). From 1969 onward ODFW landing receipts ("fish tickets") form the basis of catch statistics. In recent years, ODFW in-season crab landings data have been monitored and reported on a monthly basis.

Ocean Commercial Crab Bycatch

During regular ocean commercial crab fishing operations, female and sublegal male crabs are caught and discarded (crab bycatch). Crab bycatch mortality may occur as a result of crab being caught in fishing gear and removed from the bottom, handled during removal from fishing gear, and discarded back into the marine environment. Amounts of crab bycatch and bycatch composition data for the ocean commercial crab fishery were collected intermittently from 1976-1990 (Demory 1991). Currently, ODFW is collecting crab bycatch data from the ocean commercial crab fishery during its annual preseason testing program and through voluntary at-sea observer trips aboard commercial crabbing vessels.

Preseason testing is conducted in collaboration with the ocean commercial crab fleet and the ODCC, and is used to determine crab season opening date(s), relative to post-molt crab condition. This testing involves an average of two at-sea observation trips in each major crabbing port per year during November and December, aboard commercial Dungeness crab boats. The voluntary observer trips are sought opportunistically by ODFW and allow for the assessment and quantification of bycatch caught during normal commercial Dungeness crab fishing operations. Fleet participation in the ODFW at-sea observer program is voluntary and the success is dependent on sufficient industry involvement. Collection of this bycatch data will continue in conjunction with ODFW's commercial crab program and will be regularly reported as resources allow.

Recreational Catch

Oregon's recreational crab fishery has been monitored intermittently over the past four decades. In 1971, a study of recreational angler activities in 16 Oregon estuaries generated statewide recreational estimates of effort and catch in the estuarine crab fishery. In the late 1980s, effort and catch in the Alsea Bay recreational crab fishery were documented more extensively. Additionally, over the past few decades, the ODFW Oregon Recreational Boat Survey (ORBS) has collected catch and effort information on recreationally caught crab in the ocean and catch information on recreationally caught crab in the estuaries.

Currently, ODFW has dockside sampling programs that collect information to estimate recreational Dungeness crab effort and catch in the ocean and estuaries. These data are obtained through multiple creel-type surveys including ORBS, an estuary crab fishery survey, and a survey of the Lower Columbia River crab fishery (Ainsworth *et al.* 2012). These surveys account for the majority of the effort and catch in Oregon's recreational Dungeness crab fisheries. Continuation of these surveys is dependent on future budget allocations and funding from recreational shellfish license sales. Recreational crab effort and catch data in several less-utilized estuaries is being collected, and data collected from the recreational fishery on public piers and docks is being analyzed.

Recreational Bycatch

Similar to the commercial fishery, during recreational crab fishing operations, female and sublegal male crabs are caught and discarded (crab bycatch). Crab bycatch mortality may occur as a result of crab being caught in fishing gear and removed from the bottom, handled during removal from fishing gear, and discarded back into the marine environment. Since 2012, ODFW observers aboard chartered recreational groundfish vessels that concurrently participate in the recreational crab fishery have recorded the amount and composition of bycatch from crab gear. This data will allow for the assessment and quantification of bycatch caught during chartered recreational Dungeness crab fishing

operations. Collection of this recreational bycatch data will continue and be reported as resources allow.

Bycatch in Other Fisheries

Dungeness crab caught in Oregon's non-crab commercial fisheries must be discarded. The National Marine Fisheries Service's (NMFS) West Coast Groundfish Observer Program (WCGOP) collects annual data in all fisheries likely to catch Dungeness crab, including the limited entry groundfish trawl, nearshore groundfish fixed-gear, pink shrimp, sablefish fixed-gear and whiting fisheries (Bellman et al. 2012). This data is reported annually for the region in NMFS WCGOP reports. Oregon specific crab bycatch estimates are received by ODFW annually as well.

In the whiting fishery, from 2001 to 2010 federal regulations required vessels targeting Pacific whiting with midwater trawl gear to land unsorted catch (U.S. West Coast Groundfish FMP Amendment 13; 65 FR 99898; November 2000). Although catch of Dungeness crab with pelagic midwater trawl gear is negligible, full retention of catch increased crab mortality in this fishery during the nine years that the regulation was in place. With the inception of the trawl Individual Fishing Quota (IFQ) program, 100% at-sea observer coverage was required on all trawl vessels. From 2011 onward, Dungeness crab bycatch data in the trawl fisheries, including whiting, will be collected by the WCGOP program and requested annually by ODFW.

Research Related Catch

Research conducted on Dungeness crab (and research that is conducted on other species but has potential to take Dungeness crab) contribute to a small amount of crab mortality annually. The direct and indirect scientific take of Dungeness crab is monitored and tracked by ODFW through its scientific take permitting system (ORS 508.111).

Future Work: Total Fishery Mortality

Dungeness crab mortality due to bycatch in both targeted (female and sublegal male crab) and non-targeted (all crab) commercial fisheries likely represents the largest component of total fishery mortality for which ODFW has not yet obtained reliable estimates. Estimating discard mortality requires information on both bycatch rates (proportion of total catch that is discarded) and discard mortality rates (the proportion of discarded crabs that die).

To assess crab bycatch in the recreational crab fishery ODFW plans to evaluate its various current recreational fishery sampling and research programs. Evaluation may include an assessment of existing data to determine what information can be gleaned from these programs, and what minor modifications could be made to these programs to aid in collecting more specific recreational crab bycatch data (ex. include adding bycatch questions to angler interviews).

In addition, research on Dungeness crab bycatch and discard mortality was recently initiated by a graduate student at Oregon State University (OSU PhD candidate, Noelle Yochum). Ms. Yochum is currently attempting to assess mortality rates of discarded crab (females and sublegal males) in the commercial and recreational crab fisheries, along with crab discard mortality rates in the commercial groundfish trawl fisheries. The current anticipated completion of this study is October 2014. When the results of this research become available, ODFW will use the results as appropriate to complement and/or augment crab discard mortality estimates.

Another portion of Dungeness crab mortality is attributed to derelict gear on the bottom that continues capture and kill crab. Mortality related to derelict gear is estimated to be as high as

7% of annual catch, and 4.5% of the harvest value in the Dungeness crab fisheries of British Columbia and Salish Sea (Breen 1987; Antonelis *et al.* 2011). In Oregon, lost crabbing gear is tracked by ODFW through replacement buoy tags issued each year and the commercial crab logbook program. Since the inception of pot limits as a management tool in Oregon, an average of 3,668 replacement buoy tags have been issued annually, which is a rough indicator of annual pot loss. The current logbook program also collects some information on pot loss; fishermen are required to record the total number of pots lost, however, the current format of the logbook forms inhibits fishermen from accurately attributing lost gear to specific fishing trips. ODFW plans to re-format the logbook to obtain more accurate and geographically precise gear loss estimates.

By utilizing all of the information sources listed above, it will be possible to develop an annual report of Dungeness crab total mortality. This report could identify and provide estimates for each type of fishery-related Dungeness crab mortality, from Oregon waters, in order to generate total mortality estimates for the species. Development and regular updating of this type of report will be conducted by ODFW as resources allow.

C.1.b. Population Dynamics

Monitoring Size Distribution

In the commercial and recreational fisheries, the size distributions of Dungeness crab populations are monitored using methods and protocols that record width of the crab carapace.

Ocean Crab Carapace Width Data

From 1976-1990 ODFW regularly collected dockside sampling information on carapace widths for male crabs retained in the commercial fishery (Demory 1991), and sporadically from 1993-2005. In an effort to continue this long-term dataset and to monitor the fishery during the season, ODFW re-initiated the crab dockside sampling program beginning in the 2012-13 crab season. The objectives for sampling the fishery include: comparing current data to historical data to look for stock trends; investigating year class structure of harvest, recruitment trends and relative abundance; evaluating the success of current and future management measures; and facilitating crab related information channels between ODFW, industry and enforcement.

Additional sources of carapace width data from commercial fisheries include the ODFW annual preseason testing program, voluntary at-sea observer trips (see section *C.1.a. Total Fishery Mortality: Ocean Commercial Crab Bycatch*) and the WCGOP (see section *C.1.a. Total Fishery Mortality: Bycatch in Other Fisheries*). Since 2010, ODFW has collected carapace width data on a subset of the crab caught during the preseason tests, including legal males, females and sublegal males. Beginning in 2013, ODFW has collected carapace width data on a subset of the crab caught during observer trips aboard commercial crabbing vessels, including legal males, females and sublegal males. Carapace width data of crab caught as bycatch in other fisheries is provided to ODFW by the WCGOP annually.

Estuary Crab Carapace Width Data

ODFW's recreational crab fishery creel surveys (see section C.1.a. *Total Fishery Mortality: Recreational Catch*) in five major estuaries and the Lower Columbia River also collect carapace width data on crab retained in the recreational crab fishery (Ainsworth *et al.* 2012). Subsamples of crab are measured for carapace width during the angler interview portion of the surveys to collect harvest information. The crab populations in Yaquina and Alsea bays are periodically sampled using modified recreational crab pots in areas where the recreational fishery occurs. Carapace width data

is collected on crab captured during sampling periods of this project (see section C.1.b. *Population Dynamics: Characterization and Assessment of Oregon's Estuary Crab Populations* for further explanation of the objectives and methods of this project).

Future work: Monitoring Size Distribution

ODFW plans to continue collecting carapace width data in all of these programs listed above, and report on this data as resources allow.

Relative Abundance

Logbook catch-per-unit-effort (CPUE) data are analyzed annually by ODFW to assess the relative abundance of crab over time. Historically, ODFW has relied on total season landings to track the relative abundance of crab populations over time. However, landings based metrics may be influenced by factors other than crab abundance such as regulatory changes or market forces, while metrics that include a measure of effort such as logbook CPUE are less likely to be influenced by such factors. This analysis is also a required component of evaluating the Limit Reference Point for the commercial Dungeness crab fishery (see section *C.1.d Reference Points and Management Responses*). Three reports have been produced by ODFW which evaluate the use of logbook data as an index of abundance for crab (ODFW 2011a, ODFW 2013, ODFW 2014).

NMFS conducts an annual fishery independent survey that provides indices of relative abundance of groundfish species off the U.S. west coast (West Coast Groundfish Slope/Shelf Combination Bottom Trawl Survey). Although not targeted, Dungeness crab catch is recorded, providing quantifiable data on crab distribution and abundance. Oregon specific data is requested periodically by ODFW. Investigation of this data as a source for relative Dungeness crab abundance and distribution information will be made by ODFW as resources allow. Future data requests of this type will be made as needed by ODFW.

Female Mating Success and Fertilization Rates

Female mating success and fertilization rates influence crab population dynamics. Suppressed mating success and poor fertilization could lead to decreased larval production and recruitment, followed by a reduction in legal male stock size four years later. Various researchers have raised concerns that intensive male only crab fisheries could lead to reduced female mating success and poor fertilization rates if there are not enough large mature males to fertilize all reproductive females (e.g, Paul 1984, Smith and Jaimieson 1991). It is estimated that each year, the majority all legal male crabs are harvested from the population (Gotshall 1978, Methot and Botsford 1982).

Research by Dunn and Shanks (2009) examined female mating success in relation to carapace width and shell hardness and found that mature female Dungeness crabs are mating successfully, regardless of size. This research concluded that under the current management system, female mating success is probably not an important limiting factor affecting this fishery. Following mating, sperm are stored internally by the female crabs for several months until spawning when the eggs are fertilized as they pass through the reproductive tract and are extruded through paired ovipores on the crab's sternum. It is presumed that sperm remain viable over the 3-4 month period of storage by the females, and that fertilization rates are high. However, research to examine female fertilization rates is spatially and temporally limited (e.g., Hankin and Butler 1997, Oh and Hankin 2004, Dunn and Shanks 2009), and the degree to which fertilization rates may vary over time or between areas is not well understood. Annual estimates of female mating success and fertilization rates, combined with improved information on mortality of discarded

females, may ultimately prove useful for developing target and limit reference points that more directly consider the mechanisms likely to lead to recruitment overfishing in a male only fishery.

Future work: Female Mating Success
Beginning in 2012, ODFW has conducted sampling to monitor female mating success and plans to summarize this research in the future. ODFW plans to continue to monitor Dungeness crab female mating success, as resources allow.

Characterization and Assessment of Oregon's Estuarine Crab Populations
The crab populations in Yaquina and Alsea estuaries are sampled periodically by ODFW using modified recreational crab pots in areas where the recreational fishery occurs. This ongoing study (started in 2007) quantifies seasonal trends and annual variations in several attributes of the estuary crab population. Sampling has occurred as frequently as semimonthly but currently occurs bimonthly. The entire lower estuary is sampled, beginning near the mouth of each estuary and continuing to the upriver extent of the recreational crab fishery grounds.

Data collected from all crab captured include: species, carapace width, weight, sex, missing appendages, shell hardness, epifaunal growth or barnacles on carapace, parasite presence, and evidence of pitting (injuries). This long-term project has yielded insights into the use of the estuaries as habitat by adult Dungeness crab. The estuarine crab population varies in abundance, sex ratio, and size frequency in seasonal cycles observed annually.

Future Work: Characterization and Assessment of Oregon's Estuarine Crab Populations
The sampling programs to quantify seasonal trends and annual variations of several estuarine crab populations are planned to continue as resources allow.

C.1.c. Stock Structure

Population Genetics
Dungeness crabs are managed separately by each state, although, from a biological perspective are thought of as a single continuous population. However, the possibility of subpopulations exists (Rasmuson 2013). Selective harvest of subpopulations can cause genetic changes within a population, which can result in reduced productivity of a stock (Allendorf *et al*. 2008). An understanding of stock genetic components is necessary in order to sustainably manage a fishery. Although there is limited genetic information about Dungeness crab populations, a microsatellite study conducted in British Columbia found genetic differences among eight populations in study area extending from the Queen Charlotte Islands to the southern edge of Vancouver Island, which equates to a distance of approximately 500 miles of coastline (Beacham *et al.* 2008). Preliminary work by a graduate student at San Jose State University analyzed the Dungeness crab genetic structure along the west coast, including samples from California to Alaska (Lardy 2006, *unpublished*). This work suggests an absence of population structure and high level of gene flow among populations across this range.

Oregon State University's (OSU), Dr. Kathleen O'Malley, and three west coast state's fish and wildlife agencies (WDFW, ODFW and CDFW) have initiated a collaborative project to further examine the population genetic structure of Dungeness crab off the west coast. This research plans to provide a higher degree of spatial and genetic resolution by utilizing higher sample sizes, more sample site specificity and more genetic markers, in relation to the work by Lardy (2006). In 2011, during the first year of the study, genotypic data was obtained from 800 samples, which were collected during ODFW pre-season testing (see section C.1.a. *Total Fishery Mortality: Ocean Commercial Crab Bycatch*). Results from the first year of the study showed little evidence for population structuring or decreased genetic diversity within the samples

collected along the Oregon coast (O'Malley and Roegner 2013). During the second year of the study (2012), over 4,000 additional samples were collected for genetic testing off of WA, OR and CA from their state agency's crab preseason testing programs. The additional samples from a broader area will help evaluate the genetic diversity and population structure off the entire west coast.

Future Work: Population Genetics
Continued collection of Dungeness crab samples, in conjunction with ODFW's preseason testing program, for genetic analysis is planned as needed by ODFW to further this research.

C.1.d. Reference Points and Management Responses
Reference points are measureable criteria that represent the state of a fishery or population, and are believed to be useful for management of an exploited stock. A Limit Reference Point (LRP) indicates a state which is considered undesirable and which management should aim to avoid, or to recover from if reached (Caddy and Mahon, 1995). A management response is an action or set of actions that is specified by the managing agency in the event that a reference point is reached. This section defines a LRP for the Oregon Dungeness crab stock, and proposes a suite of management actions, termed the Adaptive Management Response, that may be taken in the event that the LRP is reached.

Oregon Commercial Ocean Dungeness Crab Fishery Limit Reference Point Definition
The LRP will be evaluated each season within about eight weeks of the season opening. The LRP will be considered to have been reached when all of the following conditions are met in the commercial ocean Dungeness crab fishery:

1) Landings (as determined by the Department from fish receiving tickets) have declined for three consecutive seasons; and
2) Landings are projected to decline for a fourth consecutive season based early season landings in the fourth season; and
3) Landings in the fourth season of a decline are projected to fall below 20% of the 20 year average based on early season landings; and
4) Logbook Catch-Per-Unit-Effort (as determined by the Department from submitted commercial crab fishery logbooks) falls below the average level predicted to have occurred over the 1980-81 through 1986-87 seasons.

Adaptive Management Response
If the LRP is reached, The Department will attempt to determine the primary causes of the observed stock decline through analysis of available fishery and research data, interaction with industry, and/or directed research. Based on the results of these investigations the Department will implement an Adaptive Management Response for the Oregon Dungeness crab stock through taking one or more management actions in the commercial ocean Dungeness crab fishery as described below.

1) Season closure
   Early closure of the season in the fourth year of a decline (e.g. by April 1) may benefit a depressed crab population in a number of ways, although the bulk of legal male crab would likely be taken before a closure could be implemented. This action would reduce fishery mortality on residual legal males, leaving more large crab available for mating. It would reduce catch and release mortality on female and sub-legal male crab, which may be particularly important during their respective molting seasons (spring for females, summer for males). It would reduce disturbance during mating, which is dependent on females molting.

Alternative structures for season closures include closing the fishery only during the female molting/mating period, closing the fishery only during the male molting period, or closing the fishery earlier than April 1 in order to further reduce fishery mortality on all stock components. Seasonal closures are relatively easy to implement and enforce at any time during the season.

2) Reduce pot limits
Reductions in the number of pots allowed to be fished by each vessel would reduce overall effort in the fishery directly, by further limiting the number pots each individual vessel could fish, and potentially indirectly if traditional participants chose not to fish due to reduced limits. Pot limit reductions would likely have to be severe to significantly reduce fishery mortality on any stock component, as fishers may fish their available gear more intensely. Pot limit reductions would be easiest to implement when the buoy tags used to track and enforce limits are issued, which is just prior to the season start.

3) Trip limits
Trip limits are limits on the amount of crab that a vessel may land in a given time period. Currently, vessels are limited to landing no more than 1200 pounds per week from the second Monday in June through the end of the season. Extending the current trip limit timeframe, reducing trip limits, or some combination of both may limit effort and fishery mortality on various stock components depending on the timing and level of such limits. Trip limits are easily implemented and enforced for all or any part of a season.

4) Area closure
Closures of specific areas to fishing may protect all components of the crab stock existing in that area from fishery mortality, depending on the size and duration of the closure. Such protection may provide a "brood-stock" to seed outlying areas, contributing to population recovery. Alternative structures for area closures may include closing a depth zone to fishing for certain times of the year. For example, an area closure might be structured to avoid fishing in a particular depth zone and during a time that female bycatch rates are high, to the extent such determinations can be made. Area closures are easily implemented for all or any part of a season, however enforcement difficulty varies with the number, size, and location of closed areas.

5) Increase minimum size limit
The current minimum size limit (6 ¼ inches carapace width) is designed to allow male crabs one or two seasons of reproduction before becoming susceptible to harvest. However, crab growth and morphology is not uniform, and crabs of a given age have some variation in carapace width. Increasing the minimum size limit would leave a higher proportion of male crab larger than 6 ¼ inches available for mating. Changes to the minimum size limit are easily implemented and enforced for all or any part of a season.

Immediate actions (i.e., within the fourth season of a decline) may be implemented through temporary rule if the Department finds that failure to act would result in serious prejudice to the public interest. Subsequent actions or extension of any immediate actions beyond six months would be implemented through the Oregon Fish and Wildlife Commission's standard rulemaking process. Any management actions taken in response to reaching the LRP could be continued in subsequent seasons until there is evidence that the population is recovering or has recovered. Recovery criteria are likely to be dependent on the management action taken, and would be established at the time

management actions are implemented. For example, total landings in a season closing April 1 would not be comparable to total landings during a season extending to August 15 (the current closing date).

Fisheries other than the commercial ocean crab fishery also impact the Dungeness crab stock, primarily the recreational crab fishery, the commercial bay crab fishery, and the nearshore groundfish trawl fishery (described in section C.1.a). Although total crab mortality in these fisheries is thought to be small relative to the commercial ocean fishery, they are likely to have different size and sex selectivity, and therefore may impact the stock in different ways. Management measures for these fisheries will also be considered as part of the Adaptive Management Response.

C.2. Ecological

C.2.a. Non-crab Bycatch

Throughout the targeted ocean commercial crab fishery non-crab bycatch is also brought to the surface and discarded during normal fishing operations. To begin documentation of this bycatch and to assess potential impacts of the crab fishery on other species, ODFW has collected bycatch amounts and composition of non-crab species in conjunction with preseason testing and on voluntary observer trips aboard commercial crab vessels (see section C.1.a. *Total Fishery Mortality: Ocean Commercial Crab Bycatch*).

C.2.b. Marine Mammal Interactions

Marine mammals have been documented to occasionally become entangled fishing gear, including but not limited to crab pot lines, at times causing serious injury or mortality. Since marine mammals are federally protected under the Marine Mammal Protection Act (MMPA) these entanglements are tracked and assessed by NOAA. In recent years, ODFW provided aggregated location and depth information from ocean commercial crab logbook data and participated in a workshop to assist NOAA in investigating the overlap of crab fishing and whale distributions throughout the season (Saez, et al. 2013 and NMFS 2014). Working under the assumption that it is possible to decrease interactions between mammals and fishing gear through decreasing the amount of fishing gear in the water at one time, ODFW has made efforts through various management measures. Additionally, ODFW has worked with NOAA and ODCC to quantify and reduce derelict crab gear through research and clean-up efforts. See section D.3. for more information on ODFW's regulations, research and efforts to limit and reduce derelict crab gear.

Future Work: Marine Mammal Interactions

Assessments will be conducted by ODFW on an as-needed basis to provide spatially explicit fisheries data to assist NOAA in assessing marine mammal interactions with crab gear. Additionally, ODFW plans to continue to support industry initiatives to develop sustainable solutions for cleaning up derelict crab gear left in the ocean.

C.3. Socio-Economic

C.3.a. Socio-Economic Summaries and Reports

Monthly ocean commercial crab landing summaries are produced by ODFW to monitor the fishery in-season, which includes ex-vessel value and price per pound by month. These reports are distributed at ODCC quarterly meetings and similar information is disseminated to all industry participants at the season end through the ODFW annual crab newsletter. Additionally, ODFW is required to produce and provide fiscal and economic impact statements to the OFWC for any proposed regulation changes. These impact statements briefly describe the regulation

change(s) and report on any anticipated impact they may have on state agency resources, units of local government or the public.

In addition to the internal economic summaries and impact statements, ODFW has regularly contracted with natural resource economics consultants to further investigate the economic contributions and significance of Oregon's commercial and recreational fisheries. The Research Group has been contracted biennially to report on the economic contributions of commercial fisheries in Oregon, work done by Shannon Davis (The Research Group, LLC 2013 A). These reports include landings volume, harvest value, processor production, participant characteristics, and fishing industry economic contribution estimates on an annual basis. In 2009, ODFW contracted with Dean Runyan and Associates to investigate the state-wide economic significance of its recreational opportunities (including fishing, shellfishing and wildlife viewing), in terms of participants and expenditures on the activity (Dean Runyan and Associates 2009). The report divides the shellfishing activity into percent expenditures spent on specific shellfish fisheries, including recreational crabbing. In 2013, The Research Group was contracted to further investigate the economic contributions of Oregon's recreational fisheries (The Research Group, LLC 2013 B).

Future Work: Socio-economic Summaries and Reports

The internally produced economic data summaries, combined with contracted reports of economic contributions of the fisheries ODFW manages provide ODFW with information on potential socio-economic impacts, when making management decisions. The agency plans to continue to produce and receive these reports on a regular basis.

C.3.b. Spatial Planning

Marine Spatial Planning (MSP) or "ocean zoning" is a topic that has garnered much attention at the local, state, and federal level in recent years, and is likely to continue to do so for several more. In Oregon, the recent establishment of marine reserves and interest from ocean renewable energy developers (for both nearshore wave and offshore wind energy) have resulted in legislative and commission actions to define how the state's territorial sea (shoreline to 3 nautical miles offshore) is allocated. In a cooperative effort by several state agencies, Oregon completed and adopted Territorial Sea Plan Part 5 (State of Oregon 2013), to identify areas within the territorial sea which are most suitable for consideration by interested renewable energy project developers. The plan also establishes standards for evaluating impacts to existing uses and resources as part of a permit review process. The statewide planning goal 19 (which addresses marine resources) provides the policy framework for how the protections and standards work. ODFW was a key player in the public processes underlying these efforts, defining how fish and wildlife resources are protected within this plan. The federal government is also currently undertaking a Coastal and Marine Spatial Planning (CMSP) effort that extends to the outer limit of the EEZ (3-200 nautical miles offshore) which will address offshore development in the energy and aquaculture sectors (National Ocean Council 2012).

For the Territorial Sea planning process specifically, ODFW developed many spatially explicit ecological datasets on marine resources, including using commercial fishery logbook data (ocean commercial crab was one of several) in a Marxan analysis. Collectively, the Marxan analysis products, and other ecological datasets comprise the Nearshore Ecological Data Atlas (or NEDA), the purpose of which is to provide spatial information to support the state's evaluation of ocean development proposals and potential adverse impacts on marine resources. For the establishment and continued monitoring of socio-economic impacts of marine reserves ODFW contracted with The Research Group to develop a bio-economic model. This model utilizes spatially explicit commercial fishery logbook data summaries (including the ocean commercial

crab logbook summaries) among other datasets for analysis of the socio-economic impacts of Oregon's marine reserves (The Research Group, LLC and Golden Marine Consulting 2012).

ODFW is working with the Oregon Department of Land Conservation and Development to develop a Geographic Location Description (GLD) under provisions of the Coastal Zone Management Act (CZMA P.L. 109-58). A GLD will allow the state to review federal permit and license activities for ocean energy development in a defined area of Federal waters for consistency with the state's enforceable policies within their Coastal Zone Management Program. ODFW's role in these processes centers on providing marine ecological and fisheries data and associated policy recommendations. During this early phase of GLD development, staff has focused on compiling existing information on fisheries and marine fish, birds, mammals and habitat off of Oregon for incorporation into the GLD proposal to NOAA. These data will be used to help demonstrate Oregon's interest in Federal waters off its coast, a key step in justifying the need for the GLD to NOAA.

Future Work: Spatial Planning

Within the territorial sea, where the broader planning process is nearly complete, it is anticipated that socio-economic data and analysis will be required when specific proposals are brought forth by developers. The federal process for CMSP is still in the early stages, so specific needs for data and analysis to support socio-economic and ecological impacts analysis are not known at this point.

C.3.c. Interactions with Other Fisheries

Management changes to one fishery can influence the degree of effort allocated to another fishery. In 2011, the west coast groundfish bottom and midwater trawl fisheries transitioned to an IFQ program. Prior to IFQ, the trawl fisheries were constrained by trip limits and participants were required to fish during specific management windows, which limited the amount of effort that trawl fishery participants could spend harvesting in other fisheries. With the inception of IFQ, participants have more flexibility to fish in other fisheries, which ultimately may result in effort shift, or spillover. Effort shifts were explored through the analysis of Dungeness crab and pink shrimp effort and landings data. Based on this preliminary analysis, some degree of effort shifted into the pink shrimp fishery, but a minimal amount shifted in the ocean commercial crab fishery. However, because the IFQ program is relatively new, the full effects of effort shift may not be realized until effort in the IFQ program stabilizes. In order to document and monitor the IFQ program, along with potential effort shifts into other fisheries, ODFW produced multiple reports that tracked trends in each fishery, relative to historical data (ODFW 2011b, ODFW 2011c, ODFW 2012b, and ODFW 2012c).

The commercial and recreational crab fisheries (both in the ocean and estuaries) interact in seasons, spatial locations for harvests, and in the populations that are targeted. At times these interactions have been contentious. ODFW has implemented multiple management measures to mitigate these conflicts such as allowing a smaller minimum size limit for recreational harvest, extending the season for recreational harvest of crab in the ocean beyond the commercial season, and restricting commercial harvest of crabs in the estuaries to specific times of the year and days of the week. Additionally, the ocean crab fisheries are conducted in the same areas as many other fisheries that utilize different types of gear such as troll lines and trawl nets. Usually, it is fairly easy for other fisheries to avoid actively fished crab gear since it is generally in strings (lines) and buoys are clean and visible. Crab gear that has been lost or abandoned ("derelict gear") is less avoidable since it is usually scattered randomly about the fishing grounds and the buoys may be less visible or submerged due to bio-fouling or drifting into deeper waters. Troll lines can be snapped off and trawl gear can be damaged or tangled when they interact with this

crab gear, which generally results in lost gear and is costly for all parties involved. See section D.3. *Marine Debris* for ODFW's regulations, research and efforts to reduce derelict crab gear.

Future Work: Interactions with Other Fisheries
Monitoring and assessment of the inter-specific and intra-specific fishery interactions will continue on an as-needed basis, by ODFW. Improved information on lost gear and derelict gear recoveries resulting from reformatting of logbooks should improve ODFW's ability to quantitatively assess the spatial overlap of lost and derelict commercial crab gear with effort in other fisheries.

D. Information Gaps

Additional research in a number of the areas identified in the above sections, that would be of value to the management of the fishery but are unlikely to be conducted by ODFW due to resource limitations at this time, are identified in the following section. The types of research are listed in order of relative value and importance to managers of the Dungeness crab resource.

D.1. *Recruitment Studies*

A considerable amount of research, both historical and ongoing, has explored recruitment dynamics in Dungeness crab populations off Oregon. Both abiotic and biotic factors influence annual abundance of larval crab, as reviewed by Rasmuson (2013). Shanks *et al.* (2007 and 2010) determined that the timing of the spring transition (a well-documented seasonal change in ocean currents along the west coast) is one driving factor for successful crab recruitment in the California Current ecosystem. This research is, to some degree, indicative of future populations and harvest levels, although other factors likely affect larval recruitment as well. Previous research suggests that food availability, cannibalism, competition and ocean temperatures are some of the other factors likely influencing recruitment levels (Rasmuson 2013). Offshore of the California Current ecosystem, information is lacking pertaining to metapopulation larval exchange in the open ocean (e.g., transport with the Davidson Current to the Alaska Current) and among populations within enclosed waters (e.g., Puget Sound, Alaska Fjords; reviewed in Rasmuson 2013). After transport, via currents or by upwellings, larvae must ultimately return to the nearshore environment (e.g., continental shelf and estuaries), and develop into adults. The majority of research on juvenile settlement patterns pertains to the estuarine environment (Rasmuson 2013). Understanding what factors (e.g., abiotic/biotic and estuarine/ocean) influence recruitment into the fishery is an important facet of fisheries management.

Research on the post-larval to pre-recruit (up to 3 years old) life stages of Dungeness crab has been minimal. Assessment of the data collected through pre-season testing (see section *C.1.a. Total Fishery Mortality: Ocean Commercial Crab Bycatch*) for "pre-recruit" signals that may be indicative of future stock abundance will be conducted by ODFW as resources allow. Due to current sampling methodologies and the limited scope of preseason testing at this time, any insights from this evaluation will likely be limited. More targeted direct pre-recruit surveys might provide better predictive modeling of recruitment in the adult Dungeness crab stock.

D.2. Gear Studies

Understanding the efficiency and selectivity of fishing gear is an important aspect of fisheries management. Making inferences about populations from fisheries catch and size data often requires some knowledge or assumptions about the selectivity of the gear used. See sections C.2 and D.3 for information related to the ecological impacts of crab gear and derelict gear.

Regulations in most west coast Dungeness crab fisheries require trap designs that allow escapement of female and sublegal male crabs. The most common requirement is for permanent "escape ports" of some minimum diameter. In the ocean commercial crab fishery, the requirement is for a minimum of two circular escape ports at least 4.25 inches in diameter, which must be located on the top or upper half of the side of the trap. Rasmuson (2013) identified a handful of studies that attempted to directly assess the selectivity of Dungeness crab gear with and without escape ports of varying sizes (e.g., High 1976, Breen 1987). While these and other studies (Jaimieson 1983, Muir and Durkin 1984) provide some insight into crab trap selectivity most were conducted under conditions (e.g., in inland waters, at low crab densities, using un-baited traps) that are not reflective of conditions under which the vast majority of crab catch and effort occurs in Oregon.

Studies which investigate the selectivity of crab traps in Oregon's commercial fishery could contribute valuable information to ODFW's management of the fishery. In particular, studies which quantify the effects of crab population density, type and amount of bait, soak time, within-trap crab density, and the interactions between these factors would be useful. Ultimately, such studies are likely to improve the ability of ODFW and other researchers to make inferences about crab populations using fishery catch and size data. In addition, since ODFW's pre-season testing program (see section C.1.a. *Total Fishery Mortality: Ocean Commercial Crab Bycatch)* utilizes commercial crab traps, the interpretation of catch and size data obtained during preseason testing would be improved by a better understanding of the processes and factors affecting selectivity of crab traps.

D.3. Marine Debris

Prior to the implementation of pot limits in the Dungeness crab fishery, an estimated 150,000 commercial crab pots were fished annually off the Oregon coast during the heaviest fishing times. Since pot limits (implemented in 2006-07 crab season) an estimated average of 100,000 pots are utilized at the peak of the each season. Due to mostly uncontrollable circumstances (e.g., rough weather, ocean conditions, gear entanglements) an estimated 10% crab pots (ODFW 2012a) are often lost and become derelict contributing to an estimated annual deposition of 10,000 commercial crab pots to marine debris. Derelict crab pots are known to contribute to gear conflicts, navigation hazards, crab mortality from ghostfishing (Rasmuson 2013) and marine mammal entanglements.

ODFW has implemented multiple regulations to reduce the amount and impact of derelict crab gear. Regulations that reduce the amount of derelict gear include: 1) limitation of the number of participants in the fishery, 2) limitation of the amount of gear allowed in the fishery, 3) requirement of active use of gear throughout the season, 4) specification of a final retrieval day at the end of each season, 5) implementation of summer weekly landing limits, 6) allowing sale of crab caught in derelict gear to further incentivize retrieval and 7) out of season permit program that allows permitted vessels to keep or sell retrieved gear. Regulations that reduce the potential impacts of derelict crab gear on the crab stock include: 1) requirements that every pot must have two escape ports, which allow unrestricted exit of smaller crabs, and 2) a destruct mechanism that disintegrates after a period of time that allows unrestricted exit of all size crabs.

ODFW has initiated two derelict crab gear research and retrieval programs. The first project, conducted in 2007, was a pilot effort that explored the cost and effectiveness of different retrieval methods, along with some derelict pot removal in high concentration areas. Building on this pilot effort, from 2009-2010 ODFW conducted a derelict gear research and retrieval program, in collaboration with NOAA and the crab industry. This program retrieved derelict

crab gear, assessed the magnitude of crab gear loss off Oregon, investigated effective methods for detecting and quantifying gear with buoys cut off, and provided a model for an on-going, industry-driven initiative for derelict gear removal (ODFW 2012a). Since the completion of this program ODCC has sponsored multiple derelict gear clean-up programs which reimburse fishermen for derelict gear they retrieve and report. Industry-driven initiatives will continue to be supported by ODFW to develop additional creative and sustainable tools for cleaning up derelict crab gear left in the ocean.

Additional research on the biological and ecological impacts of derelict crab gear would assist ODFW in evaluating the effectiveness of current management measures and programs designed to minimize the amount and impact of derelict crab gear. Studies that would fall under this category include, but are not limited to, regionally specific mortality estimates from ghostfishing, and impacts of cut-off derelict gear in various habitats.

D.4. Climate Change

Many nearshore species and habitats in Oregon's waters may be affected by a changing climate and/or ocean acidification, however what those specific effects will be and the degree of impact they will have on Oregon's nearshore resources are uncertain at this time (ODFW 2012d). Changing climatic conditions have the potential to affect the distribution and productivity of Dungeness crab in Oregon. Rasmuson (2013) reports that current research on Dungeness crab indicates the high thermal and salinity tolerance of the species will likely substantially reduce the effects of a changing climate, such as global warming. However, research to develop quantitative estimates of the impacts of climate change on Dungeness crab populations would help ODFW plan for mitigation of impacts to Oregon's crab resource. In some shell-forming organisms increased acidic ocean conditions may reduce individual size and decrease populations (ODFW, 2012d). Additional research to develop quantitative estimates of the impacts of ocean acidification specifically on Dungeness crab growth, shell condition and mortality throughout all life stages would help ODFW plan for mitigation of impacts to Oregon's crab resource.

D.5. Movement Studies

Immigration and emigration are key components of population dynamics, and ultimately of stock structure. Currently, it is known that adult crabs move significant distances in their habitat but the details of that movement are not well understood. Distance, rate, migration corridors, seasonality and other metrics of adult Dungeness crab movement in Oregon would aid management of the resource. In 2010, adult Dungeness crab movement was assessed by Oregon SeaGrant, through a collaborative mark-recapture study near Reedsport, Oregon, utilizing the commercial crab fleet (Hildenbrand *et al.* 2010). This study, and other similar studies, demonstrated that the majority (approximately 65%) of adult crabs in the area traveled less than 20 kilometers in one season (December–September), and predominately migrated parallel to the shore, along the continental shelf (as reviewed in Rasmuson 2013).

Larval crab movement is less well understood. Roegner *et al.* (2007) used light traps in Coos Bay to track larval crab recruitment, in relation to environmental parameters (e.g., temperature, tidal range, and wind stress). They found a positive correlation with the spring neap tidal cycle, and estuarine larval crab recruitment.

Both of these research projects help explain juvenile and adult movement patterns, and each was carried out in southern Oregon waters. Additional research regarding migration patterns throughout the range of this species would be beneficial to better understand population

dynamics. Rasmuson (2013) reviewed numerous studies looking at larval movement at the regional and population level. It is thought that some degree of connectivity occurs among larval populations in the Alaska and California Currents (Park *et al*. 2007), although data gaps exist on large scale dispersal patterns.

D.6. Gear and Habitat Interactions

The ocean commercial crab fishery utilizes thousands of individually buoyed crab pots to harvest crab. Each of those pots rests on the ocean floor for a period of time before harvest. Although thought to be minimal due to the relative short time crab pots are on the bottom and relatively small footprint of the gear, the impacts of crab pots on habitat is not well known or documented (Rasmuson 2013).

Research on the extent of habitat disruption caused by fishing individually buoyed pots, and the potential impacts of this disruption on other fish and invertebrate populations, would be valuable to ODFW in assessing the overall ecological impact of crab fishing in Oregon.

D.7. Connections Between Estuary and Ocean Populations

All life stages of Dungeness crab are found in the open ocean and in estuaries, and movement between these water bodies occurs throughout all crab life stages. It is clear that larval zoea and megalopa stages are dispersed widely within the nearshore and offshore Pacific waters during the extended planktonic larval period prior to settlement in the nearshore or in estuaries. Research has been less prevalent and holistic in terms of the extent of migration and mixing between the ocean and estuarine habitats, and little is known regarding the levels of dependency on each environment by Dungeness crab at each of its larval, pre-adult, and adult life stages.

E. Literature Cited

Ainsworth, J.C., M. Vance, M.V. Hunter, and E. Schindler. 2012. The Oregon recreational Dungeness crab fishery, 2007-2011. Oregon Department of Fish and Wildlife, Informational Report Series, No. 2007-05. 62 p. (https://nrimp.dfw.state.or.us/CRL/Reports/Info/2012-04.pdf)

Allendorf, F.W, England, P.R., Luikart, G., Ritchie, P.A., and N. Ryman. 2008. Genetic effects of harvest on wild animal populations. Trends in Ecology and Evolution 23: 327-337.

Antonelis, K., D. Huppert, and D. Velaszuez. 2010. Mortality of Dungeness crabs (*Cancer magister*) due to lost traps and the cost benefit of removal in Washington State waters of the Salish Sea. Report submitted to the National Fish and Wildlife Foundation.

Beacham, T.D., Supernault, J., and K.M. Miller. 2008. Population structure of Dungeness crab in British Columbia. Journal of Shellfish Research 27: 901-906.

Bellman, M.A., A.W. Al-Humaidhi, J. Jannot, and J. Majewski. 2012. Estimated discard and catch of groundfish species in the 2011 U.S. West Coast fisheries. West Coast Groundfish Observer Program. National Marine Fisheries Service. Seattle, WA.

Breen, P. A. 1987. Mortality of Dungeness crabs caused by lost traps in the Fraser River Estuary, British Columbia. North American Journal of Fisheries Management 7(3): 429-435.

Caddy, J.F. and Mahon R. 1995. Reference points for fisheries management. FAO Fisheries Technical Paper No. 347: 1-83. Rome, FAO.

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

Demory D. 1991. *Unpublished*. Ocean Dungeness crab fishery data report series 1977-1990. The Oregon Department of Fish and Wildlife, Marine Resources Program. Newport, OR.

Dunn, P. and A. Shanks. 2009. Mating success of female Dungeness crabs (*Cancer magister*) in Oregon Coastal Waters. Journal of Shellfish Research 31(3): 1-5.

Gotshall, D. W. 1978. Northern California Dungeness crab, *Cancer magister*, movements as shown by tagging. California Department of Fish and Game 64: 234-248.

Hankin, D. G. and T. H. Butler. 1997. "Does intense fishing on males impair mating success of female Dungeness crabs." Canadian Journal of Fisheries and Aquatic Sciences 54(3): 655-669.

High, W. L. 1976. Escape of Dungeness crabs from pots. Marine Fisheries Review 38(4): 19-23.

Hildenbrand, K., Gladics A.J. and B. Eder. 2010. Adult male Dungeness crab (*Metacarcinus magister*) movements near Reedsport, Oregon from a fisheries collaborative mark-recapture study. Report submitted to the Oregon Dungeness Crab Commission. Oregon Sea Grant, Newport , Oregon.

Jaimieson, G. 1985. 1983 and 1984 Invertebrate management advice, Pacific Region. Canadian manuscript report of fisheries and aquatic sciences. Canada Department of Fisheries and Oceans. 1848: 21-39.

Lardy, C. 2006. Biogeographical genetic variation of the Dungeness crab (*Cancer magister*). MS Thesis, San Jose State University. San Jose, CA.

Methot, R. D. J. and L.W. Botsford. 1982. Estimated preseason abundance in the California Dungeness crab (*Cancer magister*) fisheries. Canadian Journal of Fisheries and Aquatic Sciences 54:655-669.

Muir, W. D., and J. T. Durkin 1984. Escape of captured Dungeness crabs from commercial crab pots in the Columbia River estuary. North American Journal of Fisheries Management 4(4B): 552-555.

National Marine Fisheries Service, West Coast Regional Office. 2014. U.S. west coast large whale entanglement information sharing workshop report. Portland, OR. November 13-14, 2013.

National Ocean Council, 2012. Draft National Ocean Policy Implementation Plan (http://www.whitehouse.gov/sites/default/files/microsites/ceq/national_ocean_policy_draft_implementation_plan_01-12-12.pdf)

ODFW. 2006. Oregon Nearshore Strategy. Oregon Department of Fish and Wildlife, Marine Resources Program. Newport, OR. (http://www.dfw.state.or.us/MRP/nearshore/document.asp)

ODFW. 2011a. Commercial Ocean Dungeness Crab Fishery Logbook CPUE Preliminary Assessment. The Oregon Department of Fish and Wildlife, Marine Resources Program. Newport, OR.

ODFW. 2011b. Oregon Department of Fish and Wildlife report on the shorebased Individual Fishing Quota Program off Oregon, submitted to the June 2011 Pacific Fisheries Management Council Meeting (www.pcouncil.org).

ODFW. 2011c. Oregon Department of Fish and Wildlife report on the shorebased Individual Fishing Quota Program off Oregon, submitted to the September 2011 Pacific Fisheries Management Council Meeting (www.pcouncil.org).

ODFW. 2012a. Final Report on the Oregon Fishing Industry Partnership to Restore Marine Habitat. Submitted to NOAA Fisheries Habitat Conservation Program Office upon completion of Grant Award: NA09NMF4630325.

ODFW. 2012b. Oregon Department of Fish and Wildlife report on the Individual Fishing Quota (IFQ) Program off Oregon, June 2012 Pacific Fisheries Management Council Meeting (www.pcouncil.org).

ODFW. 2012c. Oregon Department of Fish and Wildlife report on the Individual Fishing Quota (IFQ) Program off Oregon, September 2012 Pacific Fisheries Management Council Meeting (www.pcouncil.org).

ODFW. 2012d. Technical Supplement to the Oregon Nearshore Strategy: Potential Impacts of Global Climate Change in Oregon's Nearshore Ocean. Oregon Department of Fish and Wildlife,

Marine Resources Program. Newport, OR. (http://www.dfw.state.or.us/conservationstrategy/docs/climate_change/Climate_Change_Supplemental_pdf_9_25_12.pdf)

ODFW. 2013 Commercial Ocean Dungeness Crab Fishery Logbook CPUE Preliminary Assessment – 2nd iteration. The Oregon Department of Fish and Wildlife, Marine Resources Program. Newport, OR.

ODFW. 2014. Commercial Ocean Dungeness Crab Fishery Logbook CPUE Preliminary Assessment – 3rd iteration. The Oregon Department of Fish and Wildlife, Marine Resources Program. Newport, OR.

Oh, S. J. and D. G. Hankin. 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. and Roegner, C. 2013. Evaluating the population genetic structure of Dungeness crab (*Cancer magister*) off the Oregon coast. Oregon Wave Energy Trust.

Park, W., Douglas, D., and T. Shirley. 2007. North to Alaska: Evidence for conveyor belt transport of Dungeness crab larvae along the west coast of the United States and Canada. Limnology and Oceanography 52(1): 248-256.

Paul, A. 1984. Mating frequency and viability of stored sperm in the Tanner crab *Chionoecetes bairdi* (Decapoda Majidae). Journal of Crustacean Biology: 375-381.

Rasmuson, L. 2013. The Biology, Ecology and Fishery of the Dungeness crab, *Cancer magister*. Advances in Marine Biology, 65: 95-148.

Roegner, C.G., Armstrong DA, and A. Shanks. 2007. Wind and tidal influence on larval crab recruitment to an Oregon estuary. Marine Ecology Process Series, Vol. 351: 177-188, 2007.

Saez, L., Lawson, D., DeAngleis, M., Petras, E., Wilkin, S., Fahy, C. 2013. Understanding the co-occurrence of large whales and commercial fixed gear fisheries off the west coast of the United States. NOAA Technical Memorandum NMFS. NOAA-TM-NMFS-SWR-0444. Long Beach, CA.

SCS Scientific Certification Systems. 2010. MSC Public Certification Report: Oregon Dungeness Crab Fishery. Emeryville, CA.

Shanks, A. and Roegner, G. 2007 Recruitment limitation in Dungeness crab populations is driven by variation in atmospheric forcing. Ecology, 88(7): 1726-1737.
Shanks, A., Roegner, G., and J. Miller. 2010. Using megalopae abundance to predict future commercial catches of Dungeness crab (*Cancer magister*) in Oregon. CalCOFI Rep. 51: 1-13.

Smith, B. D. and G. S. Jamieson. 1991. Notes: Possible Consequences of Intensive Fishing for Males on the Mating Opportunities of Dungeness crabs. Transactions of the American Fisheries Society 120(5): 650-653.

State of Oregon. 2013. Oregon Territorial Sea Plan, Part Five: Use of the Territorial Sea for the Development of Renewable Energy Facilities or other Related Structures, Equipment or Facilities. Salem, OR: Department of Land Conservation and Development. 55 pp.

The Research Group, LLC and Golden Marine Consulting. 2012. Using Spatial Analysis of Fisheries Habitat Data to Evaluate Economic Effects of Oregon Marine Reserve Sites. Prepared for the Oregon Department of Fish and Wildlife. Covallis, OR.

The Research Group, LLC. 2013 A. Oregon's Commercial Fishing Industry: Year 2011 and 2012 Review. Version 1.5. Prepared for the Oregon Department of Fish and Wildlife and Oregon Coastal Zone Management Association. Corvallis, OR.

The Research Group, LLC. 2013 B. Oregon Marine Recreational Fisheries Economic Contributions in 2011 and 2012. Revision 2.1. Prepared for the Oregon Department of Fish and Wildlife and Oregon Coastal Zone Management Association. Corvallis, OR.

APPENDIX

Table 1. Historical and ongoing research and monitoring efforts pertaining to the Oregon Dungeness crab resource.

Timeframe	*Source*	*Category of Research or Monitoring Activity*	*Relevant Data*	*Fishery*
1896-present	ODFW fish tickets and state/federal reports	Total mortality Socio-economic reports	Landings records In-season economic summaries	Commercial crab: ocean and estuary
2012-present	ODFW current dockside and at-sea sampling	Total mortality Population dynamics Ecological	Dungeness crab bycatch amounts and composition Carapace width: market and at-sea samples Non-crab bycatch amounts and composition	Commercial crab:ocean
1976-2005	ODFW historical dockside sampling	Population dynamics	Carapace width: market sample	Commercial crab:ocean
2010-present	ODFW preseason testing	Total mortality Population dynamics Ecological	Dungeness crab bycatch amounts and composition Carapace width: at-sea samples Non-crab bycatch amounts and composition	Commercial crab:ocean
2001-present	ODFW ORBS	Total mortality	Catch and effort estimates	Recreational crab:ocean
2013-present	ODFW charter boat observer sampling	Total mortality Ecological	Dungeness crab bycatch amounts and composition Non-crab bycatch amounts and composition	Recreational crab:ocean
2007-present	ODFW creel surveys	Total mortality Population dynamics	Catch and effort estimates Carapace width: dockside samples	Recreational crab: estuary
2007-present	ODFW estuary surveys	Population dynamics	Carapace width: estuary samples	Fishery independent
2007-present	ODFW logbooks	Population dynamics Ecological	Relative Abundance: CPUE Spatial data: marine mammal interactions	Commercial crab:ocean
2012-present	ODFW	Population dynamics	Female mating success	Fishery independent
2012-present	ODFW	Ecological	Geographic location Description	Multi-fishery
As needed	ODFW	Socio-economic	Economic impact statements	Multi-fishery
As needed	ODFW scientific take permits	Total mortality	Mortality estimates	Fishery independent
2011-2012	ODFW	Socio-economic	Fishery significance reports	Multi-fishery
2012-present	OSU and ODFW	Stock structure	Genetic data	Fishery independent
2003-present	NMFS trawl surveys	Population dynamics	Population dynamics Relative abundance	Fishery independent
2004-present	NMFS WCGOP	Total mortality Population dynamics	Harvest estimates Carapace width: at-sea samples	Multi-commercial fisheries (non-crab)
1988-present 2010- as needed	Economic consultants	Socio-economic	Economic significance reports Bio-economic model	Multi-fishery