2 Dungeness crab, *Metacarcinus magister*

Dungeness crabs, *Metacarcinus magister*, in a crab trap caught near Bodega Bay, California. Photo credit: J Newman.

History of the Fishery

The Dungeness crab, *Metacarcinus magister* (formerly *Cancer magister*), fishery is one of the oldest commercial fisheries in California. It began in San Francisco Bay around the time of the Gold Rush and expanded as population increased in the region. Presently, Dungeness crab are taken in waters of the state from Crescent City to the Morro Bay-Avila area.

The fishery has been regulated by the California State Legislature since 1895 when reports filed by the State Board of Fish Commissioners described the subsequent effects of decreasing catch from previously fished areas, as fishermen were traveling greater distances to meet the increasing demand for crab, and suggested the Legislature oversee and restore the fishery. In 1897, the first legislative statute for the fishery was passed that prohibited the take and sale of females. In 1903, a season closure was instituted and in 1905 a minimum size limit was set at 6 inches (15.2 centimeters) across the back of the crab. Until recently, these regulations continued to be the only tools to manage the west coast states' crab fisheries and are known as the 3-S principle, which refers to sex, size, and season limits. Currently, only male crabs that are greater than 6.25 inches (15.9 centimeters) across the widest part of their carapace (CW) can be landed and the fishery is closed during the time of year when legal-sized crabs are molting and mating.

The Sonoma-Mendocino county line demarcates the central and northern management areas of California. These two distinct regions have different seasons, the central management area opens November 15 and continues through June 30, whereas the northern management area opens conditionally on December 1, provided the muscle

tissue in post-molt males has adequately filled out the newly formed shell, and continues through July 15.

The recreational seasons for these two areas begin on the first Saturday of November, allowing recreational anglers an opportunity to place traps in the water a few weeks before the commercial season begins. The recreationally caught Dungeness crab size limit is lower than that for commercially caught crab, at 5.75 inches CW (14.6 centimeters) and anglers can take 10 crab of either sex per day, unless fishing from a commercial passenger fishing vessel from Sonoma to Monterey counties, where anglers are only allowed 6 crab that are 6 inches CW (15.2 centimeters) or greater. These regulations give recreational anglers a greater opportunity to fish crabs before they are subject to being caught by the commercial fishery.

Dungeness crab are primarily fished with baited traps, also referred to as crab pots. They were introduced to the Crescent City-Eureka area in 1938 and by the mid to late 1940s had replaced the hoop net as the primary method of take. The traps are made from 2 circular iron frames 3 to 3.5 feet (0.9-1.1 meters) in diameter that are connected with spokes on the outer edges. The frame is wrapped with strips of rubber and the entire frame is enmeshed with stainless steel wire. Two entrance tunnels fitted with trigger bars prevent escapement of larger crabs and every trap must contain at least two escape ports with openings not less than 4.25 inches (10.8 centimeters) for the purpose of decreasing the likelihood of catching and retaining the generally smaller females and sublegal males. In the event the trap is not recovered, traps are equipped with a destruct device to allow the eventual escape of all crabs. New legislation in 2009 now permits the incidental commercial take of other rock crab species in Dungeness crab traps and Dungeness crab in rock crab traps, provided that all crabs retained are in season and fishermen possess the proper licenses and permits.

Dungeness crab landings for both management areas have been recorded since the 1915-1916 season (November 15 through June 30 of the following year) with the passing of a legislative statute requiring all wholesale fish dealers to submit landing receipts for all fish (FGC §8043). The larger fishing grounds and more productive waters of the northern management area have generally yielded greater landings than the central area since the 1945-46 season (Figure 2-1). Central California landings peaked during the 1956-57 season at 9.3 million pounds (4200 metric tons) and subsequently declined while remaining depressed until this past decade when landings finally surpassed 5.0 million pounds (2300 metric tons), yields not landed since the late 1950s (Figure 2-1).

Total statewide Dungeness crab landings have averaged, for the past 50 seasons 10.3 million pounds (4700 metric tons), for the past 20 seasons 12.7 million pounds (5800 metric tons), and for the past 10 seasons 16.0 million pounds (7300 metric tons). Four of the top five record seasons have occurred in the past ten years. A new statewide record of 27.5 million pounds (12,500 metric tons) landed in 2010-11, the most recent season in the time series, broke the previous record of 26.3 million pounds (11,900

metric tons) landed during the 1976-77 season. A total of 98 percent of the 1976-77 catch was landed in the northern management area, however, the 2010-11 season was not only a record breaking season for total landings statewide, but central California landings totaled 19.1 million pounds (8700 metric tons), which were more than twice those in the north at 8.4 million pounds (3800 metric tons) (Figure 2-1).

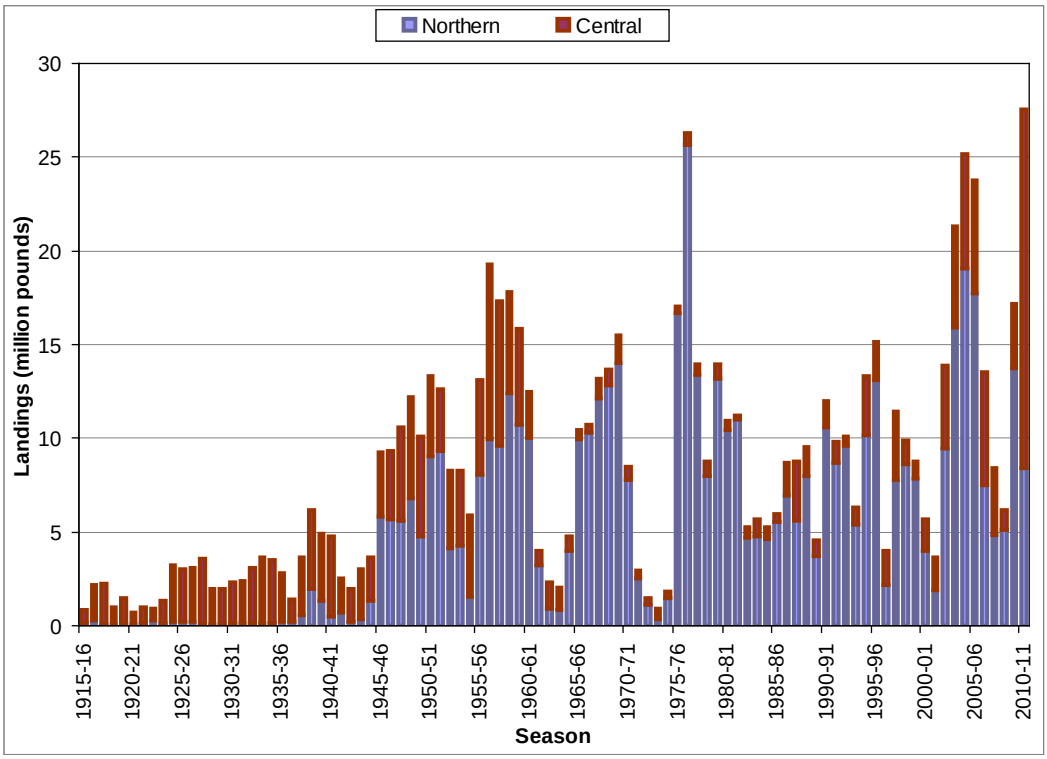

Figure 2-1. Dungeness crab commercial landings by season (November 15-July 15), 1915-2011. Data source: Department catch bulletins (1915-1986) and Commercial Fisheries Information System (CFIS) (1986-2011), all gear types combined.

Ex-vessel value during the past 10 seasons has averaged $30.4 million, maintaining Dungeness crab as one of the most valuable fisheries in California. For the past 10 years Dungeness crab has ranked first compared to all other commercial fisheries in ex-vessel value for the following years: 2003, 2004, and 2006, and second after market squid for all other years. The 2010-11 catch was valued at $56.8 million ex-vessel value, a record for Dungeness crab (Figure 2-2).

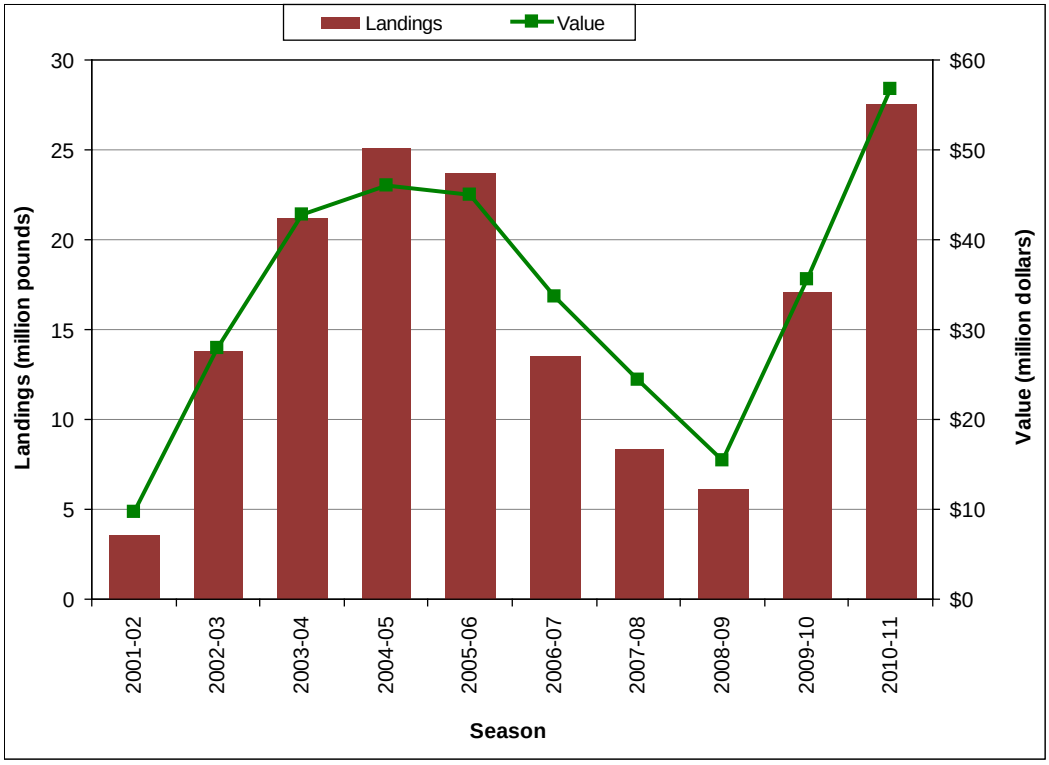

Figure 2-2. Dungeness crab commercial landings and ex-vessel value by season (November 15-July 15), 2001-2011. Data source: CFIS, all gear types combined. Ex-vessel values were adjusted for inflation and reflect 2011 values.

Historically, the sport catch was informally estimated at about one percent of commercial catch. Recently, the California Recreational Fisheries Sampling program began opportunistic sampling of the Dungeness crab catch for CPUE, size and sex ratios beginning with the 2009-10 season. However, due to funding restrictions the sampling is not rigorous enough to create reliable estimates of catch and effort at this time.

The Legislature enacted a limited entry permit system for the Dungeness crab fishery beginning in 1995, with the provision that most permits are transferable. Currently, there are less than 600 permits, and about 435 of those recorded landings in the 2010-11 season. This includes both resident and nonresident vessel permit holders. However, there is a concern that an increase in the use of the ”latent permits”, those that typically do not make landings, could cause overfishing and worsen overcrowding on crab fishing grounds. Such an increase could be triggered by the recent increase in demand and price of Dungeness crab, for example.

California, Oregon, and Washington share many Dungeness crab fishery management concerns and coordinate on interstate issues through the Tri-State Dungeness Crab Committee, which is overseen by the Pacific States Marine Fisheries Commission. One outcome of this concerted effort is the implementation of the pre-season crab quality

test to ensure crabs are ready for harvest on the target opening date. Commencing with the 1995-96 season, the State Legislature authorized an industry-funded crab quality test for California's northern management area that is conducted concurrently with tests in Washington and Oregon. The states then mutually decide, through the Tri-state Dungeness Crab Committee, whether to delay the opening of the season in order to let the crabs accumulate more body meat weight. In the case of a northern California season delay, "fair start" statutes mandate that anyone fishing in the central California area must wait 30 days after the delayed northern season opener to fish in those northern waters.

The recent decade of high landings has also increased the exportation of Dungeness crab products overseas, particularly to China. According to U.S. foreign trade figures gathered by the National Oceanic and Atmospheric Administration, the two California ports of Los Angeles and San Francisco exported a total of 53,000 pounds (24 metric tons) of Dungeness crab to China in 2009, 540,000 pounds (245 metric tons) in 2010 and 1.3 million pounds (590 metric tons) in 2011. This growing demand from China has contributed to a higher ex-vessel value for crab as processors supply crab product overseas.

Status of Biological Knowledge

Dungeness crab are highly motile, benthic crustaceans residing on sandy to sand-mud substrate of bays, estuaries and the open coast, usually found at depths less than 750 feet (230 meters). Juveniles also prefer eel grass habitat in bays and estuaries due to the availability of prey items and for protection. Dungeness crabs are reported from Amchitka Island in the Aleutians, Alaska to Point Conception, California, but are less common south of Morro Bay. The following details of the Dungeness crab reproductive cycle are specific to the California coast as time periods are longer and later further northward in its geographic range.

The mating period of Dungeness crabs occurs in coastal waters between February and June when pre-molt female crabs are located by adult males, possibly through pheromone detection. The male holds the female in a premating embrace for up to 7 days prior to her molting, and approximately one hour after the female molts, the male gonopods are inserted into the female spermothecae and the spermatophores are deposited (Figure 2-3). Females then store these spermatophores and fertilization occurs from October to December when the eggs are finally extruded (Figure 2-4). However, females that skip a molting period and, therefore, cannot mate are able to fertilize eggs from the stored

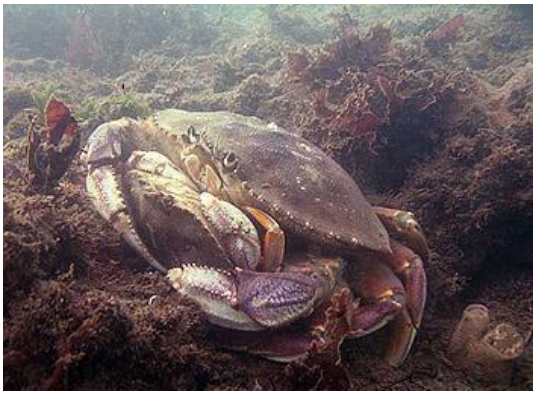

Figure 2-3. Larger male Dungeness crab in mating embrace with smaller female crab. Photo credit: S. Groth, ODFW.

spermatophores of the previous season. Females have been observed to store viable sperm for up to 2.5 years. It is estimated that smaller females produce on average 0.5 million eggs while larger females produce 1.5-2.0 million eggs.

During November to February the fertilized eggs hatch in to the first of five zoeal stages. Larvae are pelagic, consuming both zooplankton and phytoplankton, and make vertical diel migrations in the water column as a potential means to forage at night in surface waters, while avoiding predation during the day at depths of 45-75 feet (14-23 meters). Late stage zoea are also found further offshore as they may be transported seaward and alongshore when they migrate to surface waters. They finally develop into megalopae larvae after 80-95 days as zoea.

Figure 2-4. Female Dungeness crab with extruded, fertilized eggs. Photo credit: S. Groth, Oregon Department of Fish and Wildlife.

Dungeness crab megalopae (Figure 2-5) are pelagic and found offshore in central California around March, at which time they move further inshore and can also be found in bays and estuaries. An ongoing California Department of Fish and Wildlife (Department) study utilizing light traps to attract megalopae at night, and monitored daily, has captured megalopae in Bodega Bay, Fort Bragg's Noyo Harbor, and in Humboldt Bay from about mid-March to July. The mechanism by which shoreward transport of megalopae occurs during spring months of intense upwelling has been discussed in a University of Oregon study using similar light traps at two sites in Coos Bay, Oregon; one on the outer coast and the other in the estuary. Researchers found megalopae abundance peaked during spring tides at the outer coast site, in between spring and neap tides at the estuary site, and was significantly correlated with upwelling, favorable winds, and colder waters at both sites. Both upwelling and favorable, or southward winds, cause the net flow of the surface Ekman layer offshore, allowing denser subsurface water to rise and replace the surface waters. Organisms, such as Dungeness crab megalopae found below the Ekman layer, or greater than 60 feet (18 meters), would then be transported upward and during the strong spring tidal influxes would move toward the coast, promoting estuarine ingress.

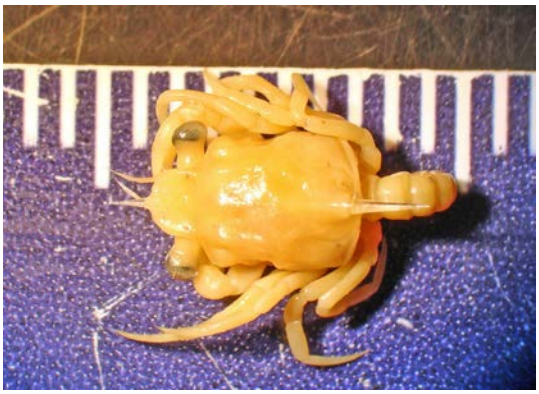

Figure 2-5. Dungeness crab megalope collected from Bodega harbor. Length is 0.3 inches from tip of rostrum to back of the carapace. Photo credit: R Dondanville.

After 25-30 days, megalopae larvae finally settle out into the benthic environment and metamorphose into the first juvenile crab instar phase, for a total of 105-125 days spent

as larvae. Growth occurs through a series of molts and the rate at which these occur are proportional to ocean temperature. Growth rates are slower and molting cycles are later in colder waters of northern latitudes, hence contributing to the different fishing season start dates in the central and northern management areas in California.

The majority of juveniles are reared nearshore in open coastal waters, but juveniles also reside in bays and estuaries. A Department study in the late 1970s found that juveniles in San Francisco Bay reach sexual maturity at about 1 year of age and enter the fishery at 3 years of age, almost an entire year before open coast juvenile crabs. This faster growth may be attributed to more frequent molts in the warmer waters of the estuary. Size at sexual maturity is about 4 inches CW (10 centimeters) for females and about 4.5 inches CW (11 centimeters) for males. At this size, crabs in estuaries will then move towards the open coast at the start of the mating period.

While Dungeness crab larvae are a food source for planktivores, megalopae have been found in the gut contents of Coho and Chinook salmon. A wide range of fish from starry flounder, rock sole, lingcod, cabezon, copper rockfish, and wolf eels, as well as octopus are known predators of juvenile instars. Cannibalism is common among juvenile size classes that are less than 2.4 inches CW (6 centimeters) who feed on recently molted smaller crabs of the same year class. This within-year-class cannibalism may play a role in the recruitment failure of megalopae later in the settlement season where it has been observed that first and second juvenile instars prey upon cohorts of settling megalopae larvae.

Adult crabs are non-specific feeders that generally feed on clams and other soft-sediment organisms. They also shift feeding behavior the larger they grow, eating bivalves the first year, shifting to shrimp the second year, and to teleost fish the third year. Cannibalism also occurs in adult populations and it has been proposed that density-dependent cannibalism between year classes may be responsible for the population fluctuations of the Dungeness crab fishery in California although no studies have been conducted to test this hypothesis.

The maximum life span of Dungeness crab is about 8-10 years of age where male crabs can grow up to a length of 8.6 inches CW (22 centimeters) while females can grow to 6.3 inches CW (16 centimeters), although crabs attaining these ages and sizes are not common.

Status of the Population

The pattern of statewide Dungeness crab landings over the past 60 years has been highly cyclic but with an irregular amplitude. An explanation for the decadal fluctuations of high landings followed by years of reduced landings, particularly in central California, may be explained by the Pacific Decadal Oscillation (PDO), a climate-based index derived from sea surface temperature data resulting from the periodic shifting of warm and cool ocean water regimes of the northeastern Pacific Ocean. These periods of warm and cool regimes result from the winter wind patterns in the North Pacific.

This index has been shown to be correlated with salmon landings from Alaska. Dungeness crab larval abundance has been correlated with lower water temperatures and on average, larvae will enter the commercial fishery within three years. Dungeness crab landings from the 1925-26 to 2010-11 seasons, when deviated from the season median, and then lagged three years and plotted within the warm and cold regimes of the PDO index, suggest higher than average larval abundance during the colder regime cycles of the PDO (Figure 2-6).

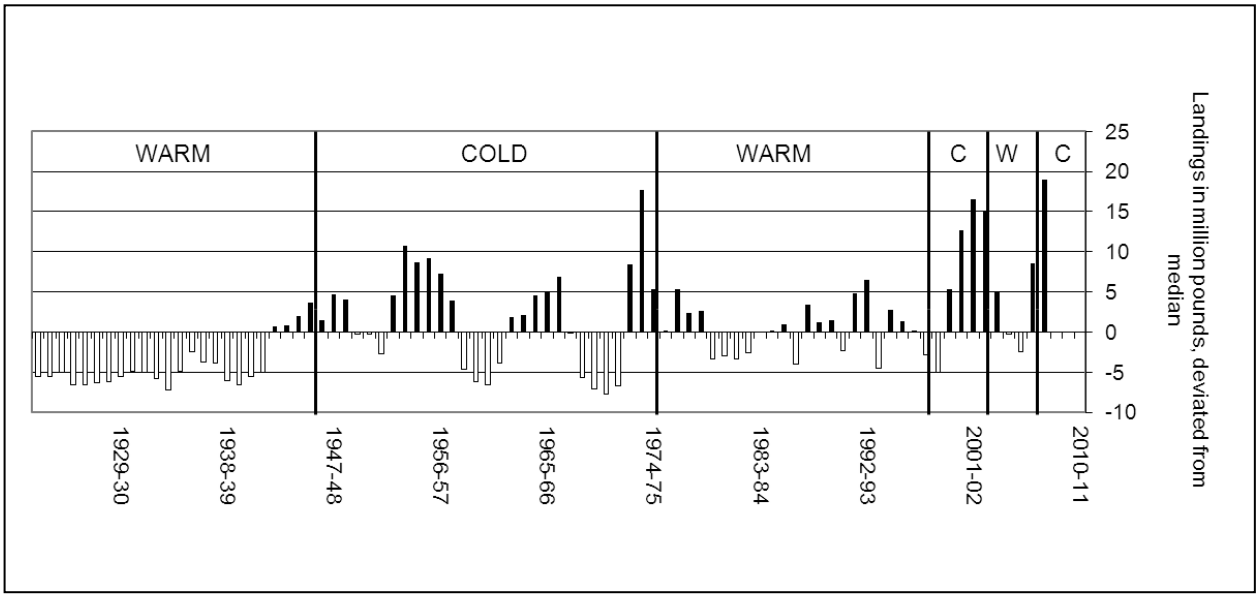

Figure 2-6. Dungeness crab commercial landings, deviated from the season median with a three year lag, as an index of larval abundance during warm and cold water regimes of the Pacific Decadal Oscillation. Data source: Department Fish Bulletins (1925-1986) and CFIS (1986-2011), all gear types combined. Warm and cold regime years were found at: http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/ca-pdo.cfm.

The Dungeness crab fisheries along the coastal western states are considered sustainable due in part to the combination of crab life history and a simple but effective fishery management scheme. Dungeness crab reach sexual maturity in a relatively short period of time and only the larger older males are removed from the population. The consensus among fishery managers based on research from northern California is that while the fishery removes most of the legal males each year, enough sublegal males remain that virtually every female is fertilized. The wide fluctuations in catch appear to be directly related to crab abundance which in turn seems to be a function of ocean conditions.

Management Considerations

Management of the Dungeness crab fishery currently relies on the limits imposed by the 3-S principle (size, sex, season). It is estimated that 80-90 percent of legal sized males

are removed by the fishery each season and so landings data are a relatively accurate index of crab abundance.

Dungeness Crab Task Force and Trap Limit Program

In 2008, Dungeness crab commercial fishermen began working on a cooperative approach to managing their fishery. Their efforts resulted in legislation which mandated the Ocean Protection Council facilitate a limited-term Dungeness Crab Task Force (task force) from 2009 through 2011. The task force is composed of Dungeness crab fishermen from ports between Morro Bay and Crescent City and crab processors, as well as non-voting members from the Department, Sea Grant, and non-governmental organizations. The task force objective was to make recommendations on management measures such as trap limits, fleet size reduction, and season opening date changes, among others, to the Legislature's Joint Committee on Fisheries and Aquaculture, the Department, and the California Fish and Game Commission (Commission) by January 2010. Through the efforts of the task force, new legislation was passed in 2011, which re-established the task force and implemented trap limits on Dungeness crab vessel permit holders.

The trap limit program is scheduled to take effect by the 2013-14 season. Permit holders are ranked into one of seven tiers based on their total California landings from a prescribed, 5-season window period. The highest tier is set at a maximum of 500 traps while the lowest tier is set at 175 traps. Permit holders will also be required to purchase a biennial trap limit permit along with all the Department-issued trap tags for each trap in their tier. If they fail to purchase all tags, their commercial permit will no longer be valid, potentially removing latent permits from the fishery.

The task force is expected to generate recommendations addressing the need for a permanent task force; the economic impact of the trap limit program; the cost of the program to the Department, including enforcement costs; refining commercial and sport Dungeness crab management; and the need for statutory changes to accomplish task force objectives. These initial recommendations will then be reported to the Joint Committee on Fisheries and Aquaculture, the Department, and the Commission by January 2015 with final recommendations due by January 2017. The extension of the task force and trap limit program will ultimately be decided by the State Legislature before April 1, 2019.

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Further Reading

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Dungeness crab commercial landings (pounds) by season (November 15-July 15), 1915-16 to 2010-11.

Season	Northern	Central	Statewide	Season	Northern	Central	Statewide
1915-16	107,016	748,632	855,648	**1963-64**	814,997	1,183,338	1,998,335
1916-17	289,464	1,880,952	2,170,416	**1964-65**	3,978,997	770,569	4,749,566
1917-18	99,552	2,164,824	2,264,376	**1965-66**	9,985,618	456,159	10,441,777
1918-19	55,032	940,536	995,568	**1966-67**	10,299,169	406,251	10,705,420
1919-20	71,184	1,376,280	1,447,464	**1967-68**	12,142,853	1,016,472	13,159,325
1920-21	66,792	665,544	732,336	**1968-69**	12,829,375	836,588	13,665,963
1921-22	141,312	832,864	974,176	**1969-70**	13,987,990	1,480,404	15,468,394
1922-23	263,328	633,552	896,880	**1970-71**	7,812,747	662,513	8,475,260
1923-24	165,792	1,149,024	1,314,816	**1971-72**	2,540,163	405,593	2,945,756
1924-25	183,768	3,074,112	3,257,880	**1972-73**	1,144,345	345,616	1,489,961
1925-26	207,960	2,802,120	3,010,080	**1973-74**	354,282	526,400	880,682
1926-27	177,792	2,885,520	3,063,312	**1974-75**	1,474,485	356,700	1,831,185
1927-28	95,928	3,448,656	3,544,584	**1975-76**	16,686,970	354,000	17,040,970
1928-29	62,880	1,920,624	1,983,504	**1976-77**	25,631,936	635,700	26,267,636
1929-30	99,168	1,891,632	1,990,800	**1977-78**	13,389,555	589,203	13,978,758
1930-31	110,896	2,173,524	2,284,420	**1978-79**	7,991,382	759,565	8,750,947
1931-32	113,878	2,234,741	2,348,619	**1979-80**	13,204,565	736,980	13,941,545
1932-33	126,428	2,934,670	3,061,098	**1980-81**	10,420,824	541,471	10,962,295

Dungeness crab commercial landings (pounds) by season (November 15-July 15), 1915-16 to 2010-11.							
Season	**Northern**	**Central**	**Statewide**	**Season**	**Northern**	**Central**	**Statewide**
1933-34	113,775	3,535,566	3,649,341	**1981-82**	10,996,936	217,981	11,214,917
1934-35	152,366	3,367,496	3,519,862	**1982-83**	4,702,531	573,275	5,275,806
1935-36	231,684	2,567,392	2,799,076	**1983-84**	4,731,961	916,697	5,648,658
1936-37	180,504	1,230,959	1,411,463	**1984-85**	4,616,243	635,265	5,251,508
1937-38	528,108	3,109,564	3,637,672	**1985-86**	5,558,362	431,329	5,989,691
1938-39	1,993,633	4,139,612	6,133,245	**1986-87**	6,969,837	1,701,559	8,671,396
1939-40	1,299,142	3,590,072	4,889,214	**1987-88**	5,627,938	3,119,823	8,747,761
1940-41	477,718	4,298,574	4,776,292	**1988-89**	7,974,503	1,580,158	9,554,661
1941-42	688,386	1,845,952	2,534,338	**1989-90**	3,715,949	834,475	4,550,424
1942-43	232,372	1,721,234	1,953,606	**1990-91**	10,592,045	1,364,255	11,956,300
1943-44	340,400	2,696,398	3,036,798	**1991-92**	8,678,034	1,154,905	9,832,939
1944-45	1,340,717	2,269,873	3,610,590	**1992-93**	9,607,833	466,025	10,073,858
1945-46	5,812,574	3,448,224	9,260,798	**1993-94**	5,362,162	915,943	6,278,105
1946-47	5,653,754	3,694,312	9,348,066	**1994-95**	10,175,284	3,170,183	13,345,467
1947-48	5,619,089	4,934,919	10,554,008	**1995-96**	13,084,053	2,042,519	15,126,572
1948-49	6,764,248	5,454,396	12,218,644	**1996-97**	2,202,960	1,805,651	4,008,611
1949-50	4,772,314	5,295,485	10,067,799	**1997-98**	7,795,745	3,605,434	11,401,179
1950-51	9,066,177	4,242,052	13,308,229	**1998-99**	8,594,637	1,295,967	9,890,604
1951-52	9,292,763	3,316,645	12,609,408	**1999-00**	7,841,311	946,385	8,787,696
1952-53	4,118,754	4,158,171	8,276,925	**2000-01**	4,024,677	1,674,664	5,699,341
1953-54	4,309,220	3,956,529	8,265,749	**2001-02**	1,897,992	1,720,141	3,618,133
1954-55	1,524,511	4,329,138	5,853,649	**2002-03**	9,493,499	4,364,853	13,858,352
1955-56	8,063,261	5,019,852	13,083,113	**2003-04**	15,925,301	5,349,415	21,274,716
1956-57	9,980,254	9,299,151	19,279,405	**2004-05**	19,061,375	6,115,401	25,176,776
1957-58	9,610,277	7,677,359	17,287,636	**2005-06**	17,763,180	5,984,892	23,748,072
1958-59	12,377,569	5,408,104	17,785,673	**2006-07**	7,533,829	5,974,679	13,508,508
1959-60	10,728,132	5,137,053	15,865,185	**2007-08**	4,802,296	3,575,389	8,377,685
1960-61	10,042,841	2,403,196	12,446,037	**2008-09**	5,089,209	1,098,313	6,187,521
1961-62	3,251,318	735,371	3,986,689	**2009-10**	13,771,393	3,392,026	17,163,419
1962-63	900,733	1,440,955	2,341,688	**2010-11**	8,435,195	19,105,841	27,541,037

Data source: Department catch bulletins (1915-1986) and CFIS data (1986-2011), all gear types combined.

Dungeness crab commercial landings and value by season (November 15-July 30), 1991-2011.					
Season	**Pounds**	**Value**	**Season**	**Pounds**	**Value**
1991-92	9,832,939	$20,782,593	**2001-02**	3,618,133	$9,700,577
1992-93	10,073,858	$17,710,520	**2002-03**	13,858,352	$27,917,563
1993-94	6,278,105	$11,872,642	**2003-04**	21,274,716	$42,837,655
1994-95	13,345,467	$31,218,272	**2004-05**	25,176,776	$45,987,156
1995-96	15,126,572	$29,065,534	**2005-06**	23,748,072	$44,945,658
1996-97	4,008,611	$12,084,233	**2006-07**	13,508,508	$33,615,740
1997-98	11,401,179	$30,665,666	**2007-08**	8,377,685	$24,422,852
1998-99	9,890,604	$23,837,780	**2008-09**	6,187,521	$15,368,841
1999-00	8,787,696	$23,681,678	**2009-10**	17,163,419	$35,583,120
2000-01	5,699,341	$16,390,483	**2010-11**	27,541,037	$56,810,465

Data Source: CFIS data, all gear types combined. Values were adjusted for inflation and reflect 2011 values.