Biological Report 82 (11.63)
August 1986

TR EL-82-4

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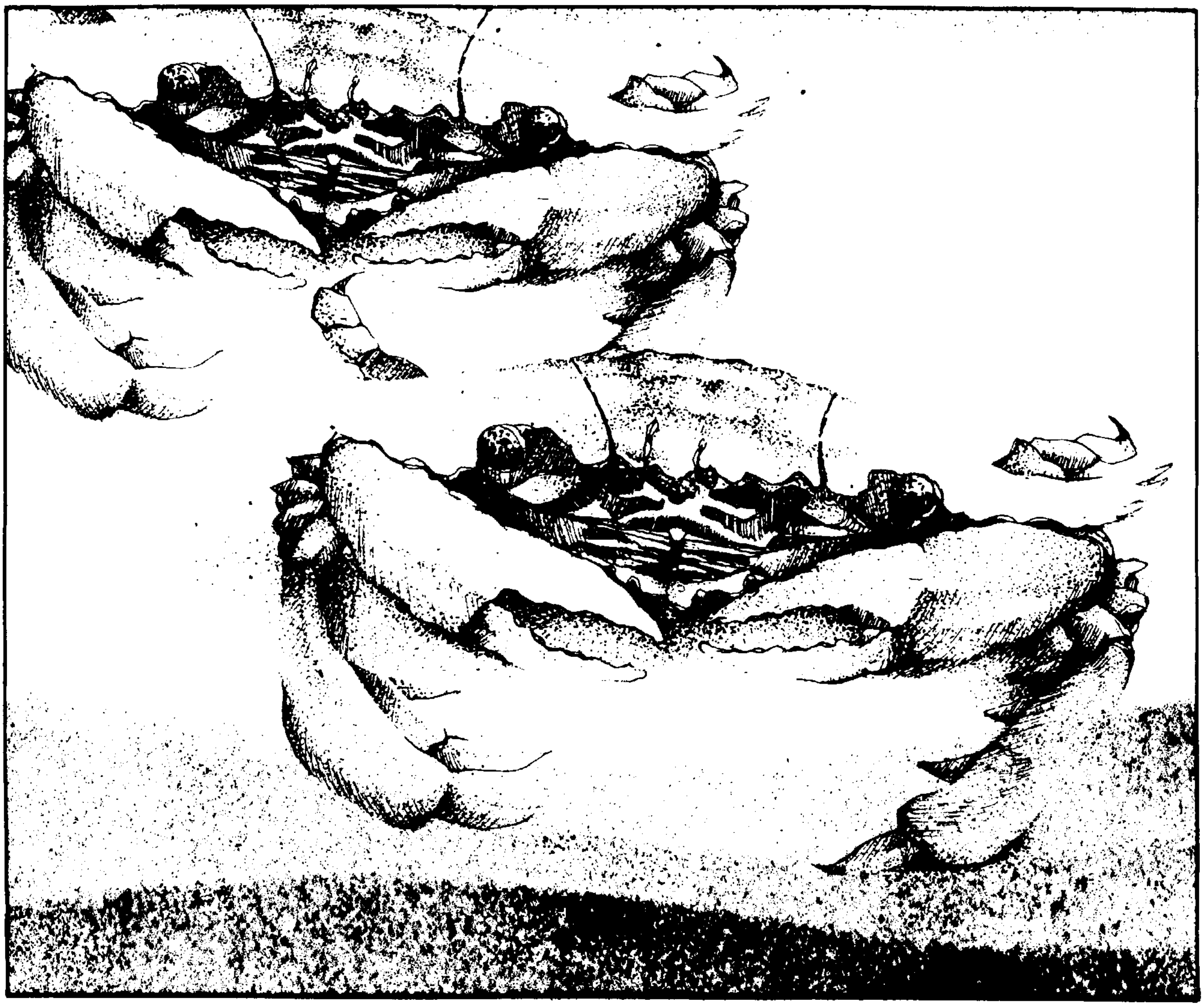

Fish and Wildlife Service
U.S. Department of the Interior

Coastal Ecology Group
Waterways Experiment Station
U.S. Army Corps of Engineers

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Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest)

DUNGENESS CRAB

by

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U.S. Army Corps of Engineers
Vicksburg, MS 39180

and

National Wetlands Research Center
Research and Development
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

This series may be referenced as follows:

U.S. Fish and Wildlife Service. 1983-19__. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates. U.S. Fish Wildl. Serv. Biol. Rep. 82(11). U.S. Army Corps of Engineers, TR EL-82-4.

This profile should be cited as follows:

Pauley, G.B., D.A. Armstrong, and T.W. Heun. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Northwest)--Dungeness crab. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.63). U.S. Army Corps of Engineers, TR EL-82-4. 20 pp.

PREFACE

This species profile is one of a series on coastal aquatic organisms, principally fish, of sport, commercial, or ecological importance. The profiles are designed to provide coastal managers, engineers, and biologists with a brief comprehensive sketch of the biological characteristics and environmental requirements of the species and to describe how populations of the species may be expected to react to environmental changes caused by coastal development. Each profile has sections on taxonomy, life history, ecological role, environmental requirements, and economic importance, if applicable. A three-ring binder is used for this series so that new profiles can be added as they are prepared. This project is jointly planned and financed by the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service.

Suggestions or questions regarding this report should be directed to one of the following addresses.

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CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
acres	0.4047	hectares
square miles (mi^2)	2.590	square kilometers
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees	0.5556(°F - 32)	Celsius degrees

CONTENTS

FIGURES

ACKNOWLEDGMENTS

We gratefully acknowledge the reviews of this manuscript by David Somerton, National Marine Fisheries Service, Seattle, and Paul Dinnel, Fisheries Research Institute, University of Washington, Seattle. We thank Vali Frank for her assistance with the graphics. Partial support for David Armstrong to acquire and analyze some of the original data in this report was provided by Washington Sea Grant.

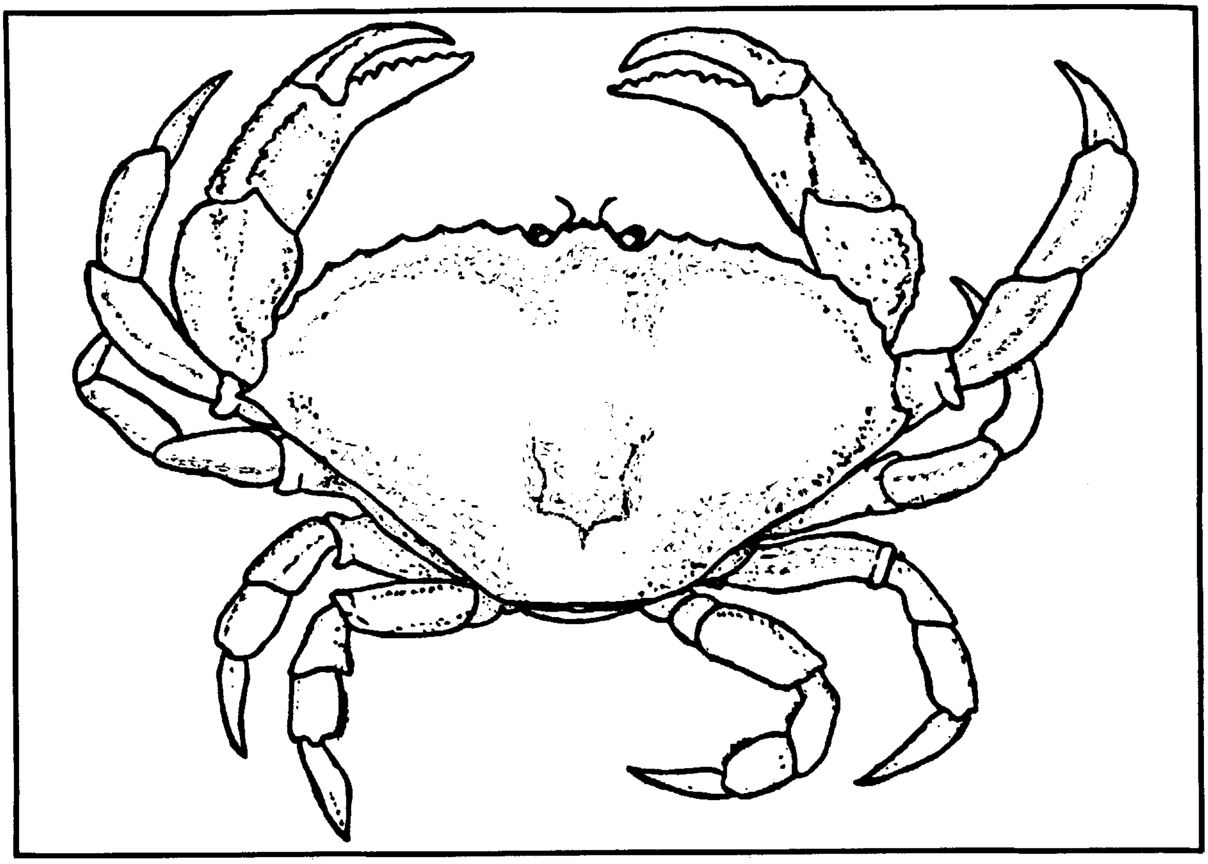

Figure 1. Dungeness crab.

DUNGENESS CRAB

NOMENCLATURE/TAXONOMY/RANGE

Scientific name . . . *Cancer magister* Dana
Preferred common name . . . Dungeness crab (Figure 1)
Other common names . . . Pacific edible crab, edible crab, market crab, commercial crab
Class . . . . Crustacea
Order . . . . Decapoda
Infraorder . . . . Brachyura
Family . . . . Cancridae

Geographic range: Coastal waters along the west coast of North American from Unalaska Island in the north to Mexico in the south (Schmitt 1921; MacKay 1943; Butler 1961a; Mayer 1973). The species ranges from the intertidal zone to a depth of at least 98 fathoms and inhabits substrates of mud, mud with eelgrass (*Zostera* sp.) and sand (Schmitt 1921; Butler 1956; Butler 1961a; Stevens 1982). The distribution of the Dungeness crab in the Pacific Northwest and the ports of major commercial landings are shown in Figure 2.

MORPHOLOGY/IDENTIFICATION AIDS

Dorsal and ventral anatomy of a *Cancer* crab is shown in Warner (1977).

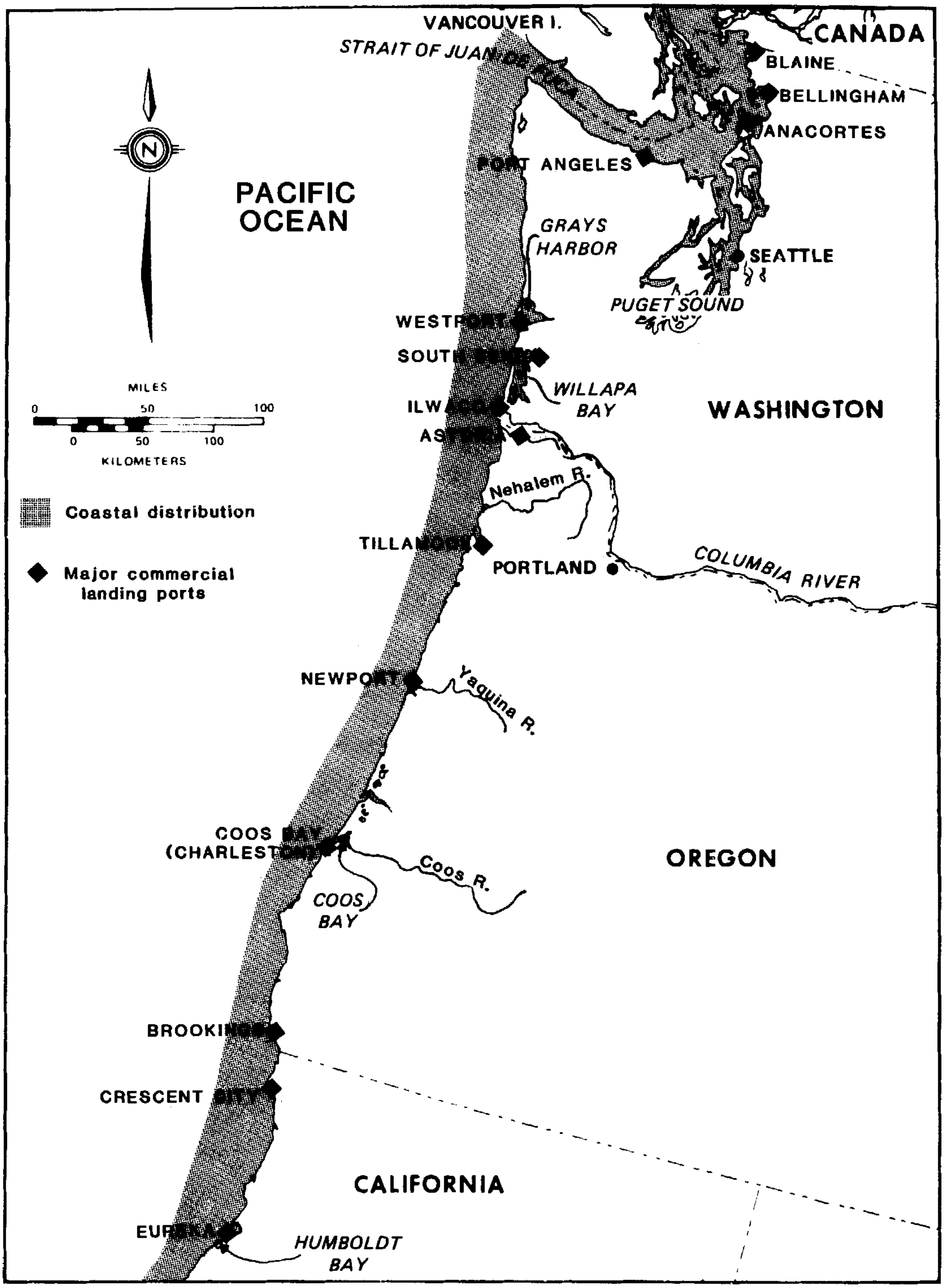

Figure 2. Distribution of the Dungeness crab in the Pacific Northwest.

The following morphology and identification aids were taken from Rudy and Rudy (1979). Size (type specimen): carapace 120.7 mm long x 177.8 mm wide. Color: beige to light brown with blue trim and hue, darkest anteriorly, often light orange below, sometimes light gray-purple below; inner sides of anterior feet and hands crimson, fingers not dark. Eyes: eyestalks short, orbits small. Antennae: antennules folded lengthwise: antennal flagella short, more or less hairy. Carapace: broadly oval, uneven but not highly sculptured; granular. Widest at 10th tooth, no rostrum. Frontal area: narrow with five unequal teeth, not markedly produced beyond outer orbital angles; middle tooth largest, more advanced than outer pair; outer pair form inner angles of orbit. Teeth: (antero-lateral) ten, counting orbital tooth; widest at 10th tooth, which is large and projecting; all teeth pointed, with anterior separations. Postero-lateral margins: unbroken, entire, without teeth, meets antero-lateral margin with distinct angle. Abdomen: narrow in male, broad in female (Figure 3). Chelipeds: fingers not dark; dactyl spinous on upper surface; fixed finger much deflexed; hand (propodus) with six carineae on upper outer surface; wrist (carpus) with strong inner spine. Walking legs: rough above; broad and flat (especially propodus and dactylus of last pair).

Juveniles: antero-lateral and postero-lateral margins meet at a distinct angle; carapace widest at 10th tooth; postero-lateral margin entire; carpus of cheliped with single spine above, fingers light colored; carapace not as broad as adults.

The red rock crab, _Cancer productus_, also has 10 antero-lateral teeth; frontal teeth are subequal (not equal) and the frontal area is markedly pronounced beyond outer orbital angles. Cheliped fingers are black; carapace is widest at eighth antero-lateral tooth.

The rock crab, _Cancer antennarius_, like _C. productus_, is dark red with black-tipped chelae, is widest at the eighth tooth, but is red-spotted on its ventral surface. _Cancer oregonensis_ (Oregon _Cancer_

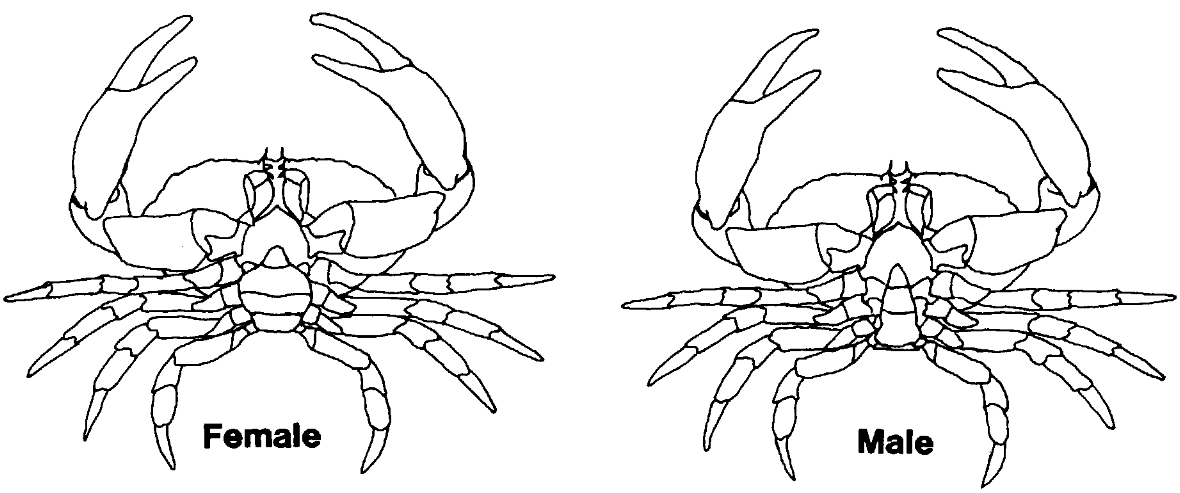

Figure 3. Abdominal differences between female (left) and male (right) Dungeness crabs. Only males, which possess a slender abdomen, may be kept by sport and commercial crabbers.

crab) is a small, oval crab with 12 teeth. Both Cancer gracilis and Cancer jordani, two rather uncommon species, have nine teeth. Identification keys to the genus Cancer were prepared by Kozloff (1974) and Carlton and Kuris (1975).

REASON FOR INCLUSION IN SERIES

The Dungeness crab supports a valuable commercial and sport fishery along the west coast of the United States. It occupies ecological niches in both marine and estuarine waters and is important as both predator and prey at all life stages. Recent studies on the environmental consequences of dredging in estuaries have established a strong probability that the Dungeness crab population is likely to be seriously reduced by habitat alteration from dredging unless proper precautions are taken to reduce losses (Armstrong et al. 1982; Stevens and Armstrong 1984). The loss of vital estuarine habitat could significantly reduce recruitment to the offshore fishery (Armstrong and Gunderson 1985).

LIFE HISTORY

Mating

Dungeness crabs mate from April to September in British Columbia (MacKay 1942; Butler 1956), mostly in March and April (David Armstrong, University of Washington, pers. comm.) but sometimes in May and June in Washington (Cleaver 1949), and March to July in California (Poole and Gotshall 1965). Mating usually occurs in offshore locations. Premolt female crabs are located by adult males for mating, possibly through a pheromonal homing system similar to those used by other crab species (Knudsen 1964; Edwards 1966; Hartnoll 1969). The female is held by the male in a premating embrace up to 7 days prior to her molting (Snow and Neilsen 1966). Approximately 1 h after molting of the female is completed, mating between the hardshell male and softshell female occurs. Mating involves the insertion of the male gonopods into the spermathecae of the female and the deposition of spermatophores. Following copulation, the female may be embraced again by the male for a period of up to 2 days. Both pre- and postmating embraces may serve to protect the female from predation, while insuring the mating success of the male by guarding the female against other males (Snow and Neilsen 1966). The spermatophores deposited by the male in the spermathecae contain sperm that are viable for many months (MacKay 1942), and which may remain viable through molting until a second egg extrusion (Orcutt 1978). Eggs are not fertilized until extrusion, at which time they are attached to the female pleopod setae and are carried beneath the abdominal flap (MacKay 1942; Wild 1983; Stevens 1982). Eggs hatch in 60 to 120 days.

Eggs and Fecundity

Eggs are extruded from September to February in British Columbia (MacKay 1942; Butler 1956), October to December in Washington (Cleaver 1949; Mayer 1973), October to March in Oregon (Waldrom 1958), and September to November in California (Orcutt et al. 1976; Wild 1983). An egg mass may contain from one to two million eggs (Wild 1983), and a female may produce up to five million eggs in three or four broods during her lifetime (MacKay 1942). Eggs are pale white to orange at extrusion, becoming progressively darker in color as they develop (MacKay 1942; Cleaver 1949).

Water temperatures and changes in water temperatures have considerable influence on the rate of egg development and mortality after fertilization and spawning. When temperatures rise, the rate of egg development also rises, but so does the rate of mortality. In laboratory tests (Wild 1983) eggs held at 9.4 °C hatched in 123 days and at 16.7 °C they hatched in 64 days. At 10 °C, 685,000 larvae were produced per egg mass, whereas at 16.7 °C, 14,000 larvae were produced per egg mass. In Similk Bay, Washington, egg mortality at 15 °C was serious; a major increase in mortalities was triggered by a water temperature increase from 10 °C to 12 °C (Mayer 1973).

Epibiotic fouling of Dungeness crab eggs has been linked to increased egg mortality because of mechanical interference with hatching and oxygen consumption (Fisher 1976; Fisher and Wickham 1976, 1977). Waters with high and rising nutrient levels caused increased fouling. Egg predation by a nemertean worm, *Carcinonemertes errans*, is thought to enhance the fouling of eggs through the liberation of yolk during feeding and by its own defecation (Wickham 1979a, 1979b). In coastal waters near San Francisco, the estimated average annual mortality caused by predation of the worm on Dungeness crab was over 55% in 1974-79 when worm densities were about 14 per 1,000 eggs (Wickham 1979b).

Eggs mature in about 2 to 3 months (Cleaver 1949; Orcutt 1978; Wild 1983). The hatching season commonly shortens from north to south along the Pacific coast. Eggs hatch in coastal waters from December to June in British Columbia (but considerably later in Queen Charlotte Islands) (MacKay 1942; Butler 1956), January to April in Washington (Cleaver 1949; Armstrong et al. 1981), December to April in Oregon (Reed 1969; Lough 1976), January to early March in northern California (Wild 1983), and late December to early February in central California (Wild 1983).

Larvae

Larvae emerge as prezoeae and molt to zoeae within about 1 h (Buchanan and Milleman 1969). The duration of the prezoeal period and the transformation to zoeae vary with salinity (Buchanan and Milleman 1969).

The larvae progress through five zoeal stages before molting into megalopae (Figure 4; Poole 1966; Reed 1969; Lough 1976). Zoeae first appear within a distance of 5-16 km from shore (Lough 1976; Orcutt 1977; Reilly 1983a). Offshore movement and distribution of larvae probably is regulated by a variety of factors including depth, latitude, temperature, salinity and ocean currents (Reilly 1983a, 1985). Using multiple regression, the most important independent variable that distribution offshore is correlated with is depth (Reilly 1983a, 1985). Distribution is dependent upon the larval stage and the larvae show a diel pattern of vertical distribution; they are near the surface at night (Reilly 1983a, 1985). There is considerable offshore movement of larvae that occurs during the zoeal stages; the larvae appear to be transported seaward from the onset of hatching (Reilly 1983a).

The megalops (advanced) stage of the Dungeness crab is found from May to September off the coast of British Columbia. In Washington waters, the megalops first appear in April; abundance peaks in May through June. In Oregon waters, they are most abundant in April and May (MacKay 1942; Cleaver 1949; Butler 1956; Lough 1976; Stevens 1982). This trend of abundance indicates larval development begins later proceeding from south to north. Off Oregon, megalops are carried within 1 km of shore by tidal currents and by self-propulsion (Lough 1976). Megalopae often are abundant on the hydrozoan *Velella velella*, when they are scarce or absent elsewhere in the water column (Wickham 1979c; Stevens and Armstrong 1985). Wickham (1979c) suggested that *V. velella* aids in the movement and distribution of megalops, and possibly provides a food source and protection from predation.

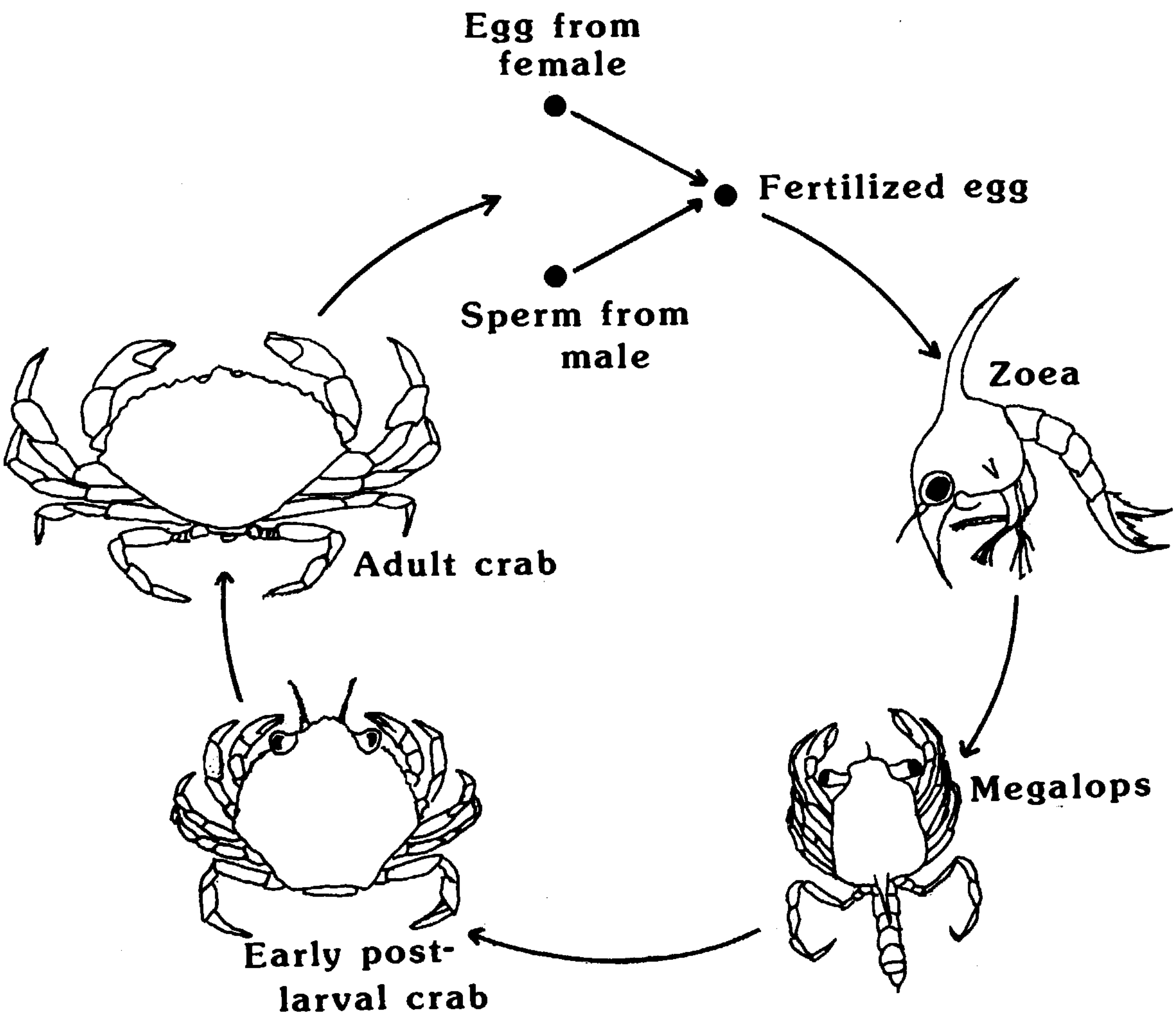

Figure 4. Life cycle stages of the Dungeness crab: zoea, megolops, postlarva (juvenile), and adult.

Larvae eat both zooplankton and phytoplankton, but zooplankton is most important (Lough 1976). The larvae capture food items with the natatory hairs of their maxillipeds, and size of food is a selection factor (Lough 1976; Armstrong et al. 1981).

Information on larval predators and predation rates is scarce. Zoeae are thought to be consumed by numerous types of planktivores (Stevens 1982); megalopae are preyed upon by many fishes, including coho salmon (Oncorhynchus kisutch) and chinook salmon (O. tshawytscha), according to Orcutt et al. (1976) and Reilly (1983b). Heavy predation by salmon may have caused the decline of the Dungeness crab catch in the San Francisco Bay area (Reilly 1983b). There appears to be a direct relationship between coho salmon hatchery production in Oregon and the magnitude of predation on the megalopae in California waters (Reilly (1983b). In a study of food habits, the combined stomachs of eight coho salmon contained 1,061 megalops (Orcutt 1977); in a separate study

(MacKay 1942) up to 1,500 megalopae were reportedly removed from a single fish. Prince and Gotshall (1976) found Dungeness crab megalops and instars, the stages between postlarval molts, to be the most important food items of copper rockfish (Sebastes caurinus) in northern California's Humboldt Bay.

The abundance of a year class depends primarily on larval survival to metamorphosis (Peterson 1973; Wickham et al. 1976; McKelvey et al. 1980). Natural larval mortality is probably high because of a combination of predation, excessively high or low water temperatures and fluctuations, a scarcity or low quality of food, and currents affecting distribution (Lough 1976; Armstrong 1983).

Juveniles

Most megalopae molt into juveniles in August off the coast of British Columbia (Figure 4; MacKay 1942; Butler 1956), and in April-May off the coasts of both Oregon (Lough 1976) and Washington (Stevens 1982). After molting, the juveniles are found in shallow coastal waters and estuaries, and large numbers live among eelgrass (Zostera sp.) or other aquatic vegetation that provides protection and substrate, and harbors food organisms for early instars (Butler 1956; Orcutt et al. 1975; Stevens and Armstrong 1984, 1985). Recently, shells of bivalves such as Mya arenaria and Crassostrea gigas have been documented as very important habitat for young Dungeness crabs (Armstrong and Gunderson 1985). In central California there is evidence that movement of postlarval Dungeness crabs into the estuaries takes place in May and June via bottom currents, where they stay for 11-15 months (Tasto 1983). Juveniles are common in estuaries, while subadults and adults are common offshore. The importance of estuaries to juvenile Dungeness crabs has been discussed in detail by Armstrong and Gunderson (1985) and Stevens and Armstrong (1985). Dungeness crab tag recovery data in California show a regular pattern of movement of juvenile crabs out of estuaries and a random movement of adult crabs in the ocean (Collier 1983). Stevens and Armstrong (1985) noted that although mating may occur in the estuary, spawning takes place offshore, which would be a major reason for adults' moving out of the estuary.

Juveniles molt 11 or 12 times prior to sexual maturity (Butler 1960, 1961b). Carapace width at the first instar varies from about 5 mm to greater than 8.5 mm (Cleaver 1949; Waldrom 1958; Butler 1960, 1961b; Poole 1967). After 1 year of growth beyond hatching, most crabs in Bodega Bay, California, are in their 8th, 9th, or 10th instar (Poole 1967). By comparison, crabs from Grays Harbor, Washington, only attain the sixth or seventh instar by the end of their first year of life (Stevens and Armstrong 1984). Carapace width (CW) after the first year averages 44 mm in Grays Harbor, while the range is 63-94 mm in Bodega Bay (Poole 1967; Stevens et al. 1982). The crabs mature after about 2 years (Butler 1961b) at carapace widths of about 116 mm for males and 100 mm for females (Butler 1960).

The diet of juvenile crabs consists largely of fish, mollusks, and crustaceans (Butler 1954; Gotshall 1977; Stevens 1982). In Grays Harbor, Washington, first-year juveniles $\leq$60 mm CW feed primarily on small mollusks and crustaceans. Second-year crabs, 61-100 mm CW, feed on fish and prefer shrimp (Crangon spp.; Stevens et al. 1982). Fish also are important to northern California crabs $<$ 100 mm CW according to Gotshall (1977), but Butler (1954) reported that crustaceans were the primary food among crabs of this size in the Queen Charlotte Islands, British Columbia. Cannibalism among Dungeness crabs has been noted by various authors (MacKay

1942; Butler 1954; Tegelberg 1972; Gotshall 1977; Stevens 1982; Stevens et al. 1982). Cannibalism was most prevalent among crabs < 60 mm CW which fed on smaller crabs of the same year class, probably during molting (Stevens 1982; Stevens et al. 1982). Cannibalism is cited as a possible cause of the dramatic population cycles characteristic of the Dungeness crab fishery (Botsford and Wickham 1978).

Juveniles are captured by a variety of demersal fishes in the nearshore area with various flatfishes (starry flounder, Platichthys stellatus; English sole, Parophrys vetulus; and rock sole, Lepidopsetta bilineata) being the most important (Reilly 1983b). Other predators on juvenile crabs are lingcod (Ophiodon elongatus), cabezon (Scorpaenichthys marmoratus), wolf-eels (Anarrhichthys ocellatus), rockfish (Sebastes spp.), and octopus (Octopus dofleini) according to Waldrom (1958) and Orcutt (1977). Predation on Dungeness crabs may be seasonal in nature, as observed in white sturgeons, Acipenser transmontanus (McKechnie and Fenner 1971). Predation on Dungeness crabs may have a devastating impact as in the case of sea otters (Enhydra lutris) in Orca Inlet, Alaska (Kimker 1985b).

Adults

At about 4 years old, most adult Dungeness males in the coastal waters of Washington are of marketable size (> 159 mm) (Cleaver 1949; Williams 1979). Marketable crabs usually only molt once a year (MacKay 1942). The maximum lifespan of Dungeness crabs is 8 to 10 years. The maximum size attained is about 218 mm CW in males and 160 mm CW in females at the 16th instar (MacKay 1942; Butler 1961b).

Adult Dungeness crabs are found primarily in the ocean but are also abundant in the inland waters of Washington and British Columbia. Along the coast of northern California, legal-sized and large sublegal-sized male crabs probably move offshore (often to the south or north) in late summer, sometimes through early winter; sometime in winter the direction of movement is probably reversed and the crabs return inshore. Interannual variation in the predominant direction of movement is considerable (Gotshall 1978). Recently, Collier (1983) has shown a random movement of adult crabs in the ocean. Many adult female crabs tagged off the coast of northern California moved relatively little (about 2 km) after 1 year (Diamond and Hankin 1985). Along the coast of southern Washington, legal-sized males generally moved inshore and toward the estuaries in fall (Barry 1985).

Clams are the most important food of adult Dungeness crabs ≥ 151 mm CW in northern California (Gotshall 1977) and ≥ 166 mm CW in British Columbia (Butler 1954). Crustaceans and fish are valuable foods of the adult Dungeness crabs from both Similk Bay and Grays Harbor, Washington (Mayer 1973; Stevens et al. 1982). Dungeness crab populations are apparently not limited by the abundance or scarcity of particular foods; they are somewhat nonspecific feeders which readily adjust to various foods (Gotshall 1977). They have developed an evolutionary niche for feeding on mud-sand substrate (Lawton and Elner 1985).

Crabs of different ages or sizes tend to eat different sizes or kinds of food (Stevens 1982; Stevens et al. 1982). According to Stevens et al. (1982), crabs progress from eating bivalves their first year, to eating shrimp (Crangon spp.) their second year, and finally to eating juvenile teleost fish in the third year; these shifts may be caused purely by changes in mechanisms of food handling, or they may have evolved to reduce competition among age groups of crabs. Crabs display a definite diel activity; they are more abundant by day in the subtidal area and more abundant at night in the intertidal area; the response is positively correlated with food availability (Stevens et al. 1984). Cannibalism is common among adults, but no correlations have been made between the rate of cannibalism and abundance (Stevens 1982; Stevens et al. 1982).

GROWTH CHARACTERISTICS

In Dungeness crabs, like other crustaceans, growth proceeds in steps through a series of molts. The general process of crustacean growth has been described by Barnes (1974) and Warner (1977). The number of molts that a crab undergoes before becoming mature depends upon the increment at each molt and the frequency of molting, both of which vary among crabs at different locations. Dungeness crabs grow in carapace size at molt and gain weight between molts. In older crabs the growth, as measured by the percent change in carapace width, declines as the frequency of molting slows down, but the rate of weight gain of the crabs increases over time. The probability of annual molting in female Dungeness crabs declines from about 1.0 for crabs of 130-135 mm CW to 0.0 for crabs of 155 mm CW and larger (Hankin et al. 1985).

Among possible attributes of estuarine residence suggested by Stevens and Armstrong (1984) is an enhanced growth rate compared to that of siblings of a year class that settle offshore. Size attained by juvenile crabs within certain periods after metamorphosis seems to be somewhat dependent on latitude and on time of settlement. Extreme estimates of age at sexual maturity range from as long as 4-5 years in British Columbia (MacKay and Weymouth 1935) to 1 year in San Francisco Bay, where the crabs reach a carapace width of 100 mm which is usually associated with sexual maturity (Tasto 1983). More generally, crabs are predicted to reach maturity at the end of their second year after metamorphosis or in their third growing season over much of the coast (Butler 1961b; Cleaver 1949). While age and size at sexual maturity may not differ substantially along the coasts, estimates of growth rates of newly settled 0+ crabs do.

Several studies of juvenile growth rates indicate the process is accelerated in estuaries or within nearshore coastal embayments where water temperatures are relatively high. Stevens and Armstrong (1984) studied growth of 0+ and 1+ juveniles in Grays Harbor and found that 6 months after metamorphosis (May to October) 0+ crab averaged 40 mm in carapace width and by 1 year were 50 mm. Crabs aged 0+ in Washington coastal estuaries may molt six to eight times in the first summer growing season after which the frequency apparently declines with the onset of winter and larger size. A dramatic indication of seasonal growth was demonstrated where growth was based on change in dry weight over time; rapid growth of the 0+ crabs in Grays Harbor resulted in a 280-fold increase in 14 months, and the growth rate of all age classes declined beginning in late summer of 1980. Rapid growth in early summer and midsummer of 1980 was not repeated in summer of 1981 (Figure 5).

Populations of 0+ crabs that settle directly offshore, as well as 1+ nearshore crabs, grow significantly slower than those in the estuary (Armstrong and Gunderson 1985). Young-of-the-year crabs in Grays Harbor grew from a first instar size of 7 mm in May to a mean carapace width of 38.3 mm (sixth instar) by October; 0+ crabs offshore had only reached a mean width of 18.9 mm in November when they were a mixture of third and fourth instars. Mean bottom water temperatures in the estuary were 15-16 °C during this time, while those offshore were 8.5-10 °C,

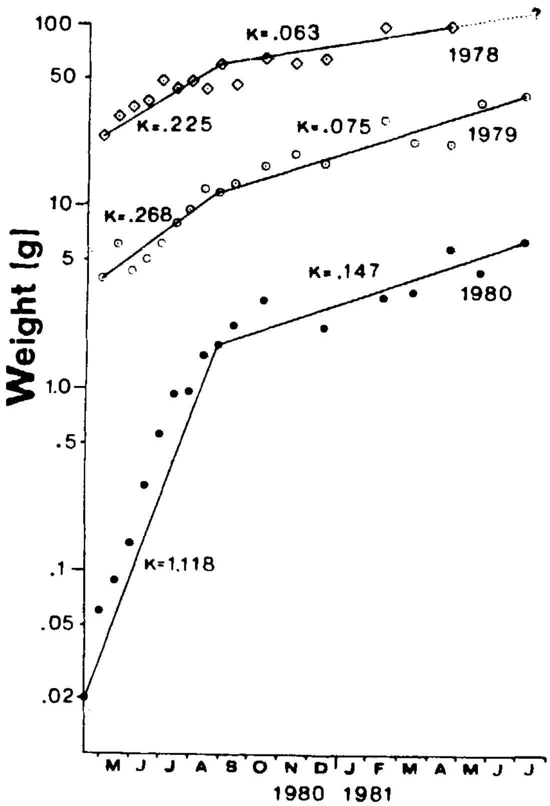

Figure 5. Changes in dry weight over time of three year classes (1978, 1979, and 1980) of Dungeness crabs in Grays Harbor, Washington. Growth rates (= k) are expressed as g/g dry weight per unit time. Note the rapid growth of 0+ in the summer of 1980 and the decline in growth of all year classes in the fall of 1980 (Stevens and Armstrong 1985).

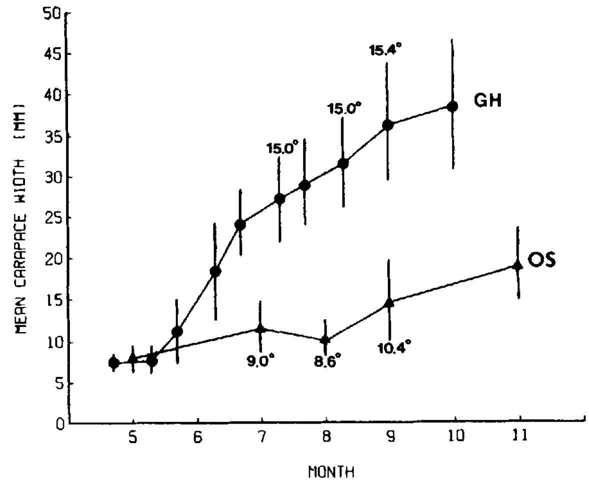

Figure 6. Growth, based on mean carapace width, of 0+ crabs from settlement as 7-mm first instars in May through November. Bar = ± 1 SD. Grays Harbor population shown as circles (GH). Offshore population shown as triangles (OS). Mean bottom water temperatures at the time of sampling are also shown for some samples (Armstrong and Gunderson 1985).

which may account for the growth difference (Figure 6). Young-of-the-year juveniles offshore of San Francisco Bay in the Gulf of the Farallones also grow substantially slower than estuarine crabs (Tasto 1983): the data show 0+ crabs at about 28-30mm, while in the estuary a good proportion of this age group were up to 60 mm in width.

Dungeness crab growth is quite variable along the Pacific coast. However, in general, it is somewhat slower in the northern part of the range (Washington and British Columbia) when compared to the southern part of the range (California).

THE FISHERY

Commercial Fishery

Commercial landings of Dungeness crab on the Pacific coast have fluctuated widely, almost cyclically, over the past 30 years (Figure 7) and have been reviewed by Armstrong (1983). According to Peterson (1973), commercial landings were highest 1.5 years after a period of strong upwelling in California and Oregon, and 6 months following a strong upwelling in Washington, although the biological sense of this conclusion is much in doubt. Botsford and Wickham

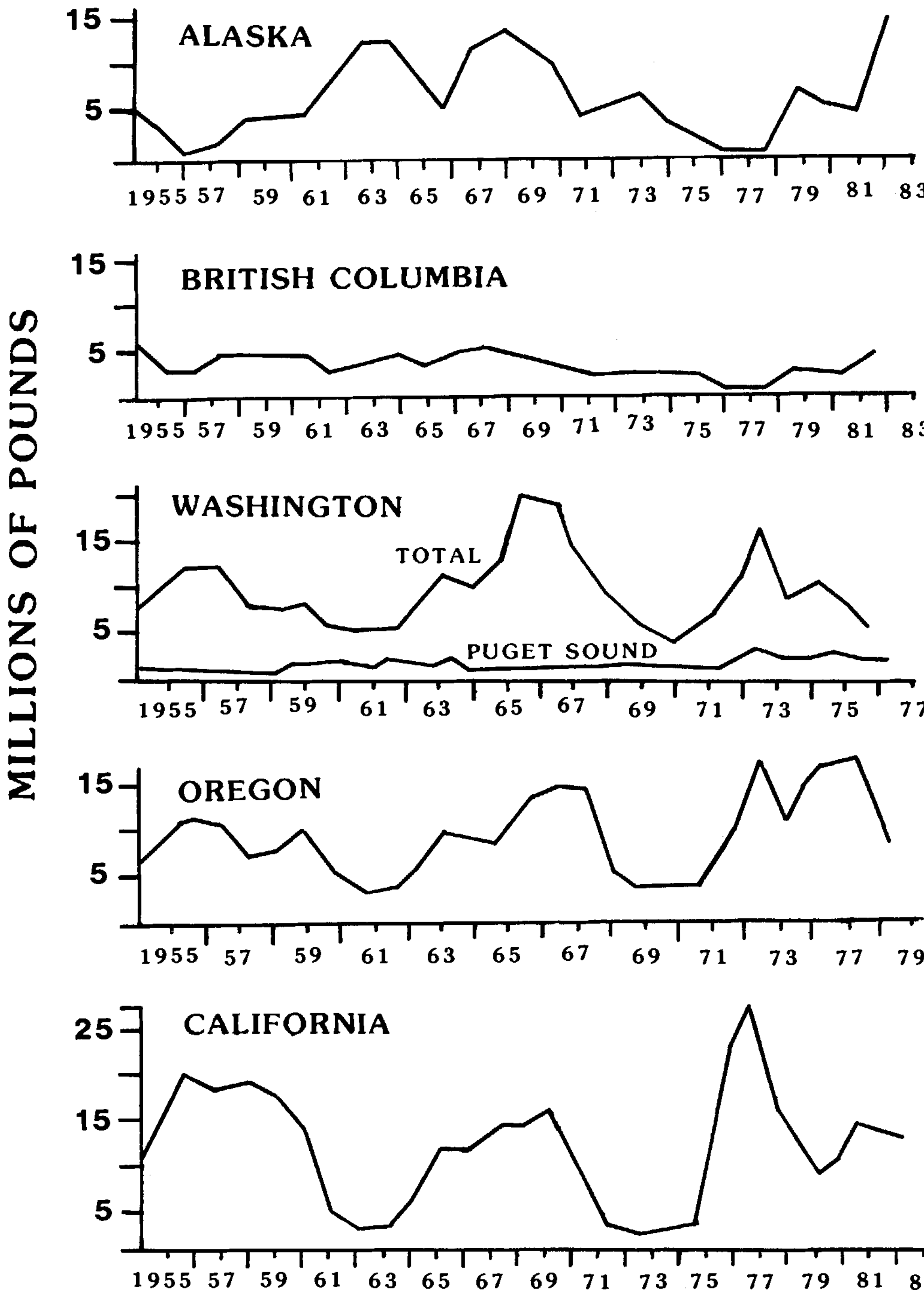

Figure 7. Dungeness crab landings by season for individual Pacific Coast States and the Province of British Columbia, 1955-83 (Pacific Marine Fisheries Commission 1983).

(1975) challenged this conclusion by using auto correlation to show that commercial landings are cyclic but upwelling is not.

Another theory to explain catch fluctuations suggests that periods of high levels of cannibalism and/or interspecific competition may cause a decline in the fishery 3 or 4 years later (Botsford and Wickham 1978). In a model predicting recruitment, McKelvey et al.(1980) discounted cannibalism as a factor and contended that changes in egg and larval survival have regulated population success. Larval survival may be seriously altered by a combination of environmental factors that can cause increased mortality if unfavorable for even short periods of time (Lough 1976). Stevens and Armstrong (1981) indicate that diseases caused by various organisms (bacteria, Protozoa, or fungi) may be responsible for mass mortalities of adult crabs.

Predation may have a profound impact on the Dungeness crab commercial fishery in certain geographic areas (Kimker 1985b). Reilly (1983b) theorizes that hatchery released coho salmon from the Columbia River continue to suppress the Dungeness crab fishery through extensive predation.

Landings of Dungeness crab from 1954 to 1983 are broken down by State and Province in Figure 7. In general, the landings in Washington (except for Puget Sound), Oregon, and California follow similar trends. Landings from Puget Sound and British Columbia are lower but show less annual variation. Alaska landings bear little relation to other areas of the Pacific Northwest. The Alaska catch of 15.6 million pounds in 1981 was a record for Alaska, but Washington coastal crab landings of 2.6 million pounds in the same year were the lowest in 30 years (Demory 1982). Recent reviews of the commercial Dungeness crab fishery have been published for Alaska (Eaton 1985; Kimker 1985b; Koeneman 1985; Merritt 1985), British Columbia (Jamieson 1985), Washington (Barry 1985), Oregon (Demory 1985), and California (Dahlstrom and Wild 1983; Warner 1985).

Sport Fishery

Sport catch data are scarce and according to Barry (1985) the Washington sport fishery on Dungeness crabs amounts to less than one percent of the annual commercial harvest. Most of the available sport catch data are from a survey reported by Williams (1979). He revealed that from April through August 1974, 471 crabs were taken intertidally at Mission Beach, Washington, by 735 sport crabbers. April, May, and June produced the best sport catches with the highest average catches occurring on low tides that ranged from -0.60 to -0.74 m. Aerial surveys made over Puget Sound beaches using Williams' (1979) survey data estimated that the beaches of Washington State probably supported about 20,000 crabbers during those months in 1974. In 1975, the sport crab pot fishery alone (other sport catch methods are ring nets, dip nets, and hook and line) accounted for the harvest of about 300,000 Dungeness crabs (Tegelberg 1976). Only male crabs may be taken in the sport fishery (Figure 3). In Washington there is a minimum size of 6 or 6.25 inches carapace width (depending on the area), measured directly in front of the 10th anteriolateral spines. In Oregon the minimum size is 6.25 inches, measured similarly. The sport catch is primarily found in Hood Canal, Puget Sound, and the major Pacific coast estuaries.

The State of Oregon has sought to limit the conflict between sport and commercial crabbers by restricting commercial crabbing to the middle of the week and to the use of sport gear (Demory 1985).

ECOLOGICAL ROLE

Dungeness crabs consume a wide variety of food organisms and are prey to numerous predators. Crabs contribute to several trophic levels as they progress through successive life stages. The larvae largely consume plankton (Lough 1976) and are preyed upon by numerous fishes. Adults and juveniles are preyed upon by sea otters, fishes, and octopuses (Butler 1954; Waldrom 1958; Stevens 1982; Reilly 1983b; Kimker 1985b). Cannibalism is common and probably exercises some control over abundance. In their various life stages, Dungeness crabs feed on a variety of mollusks, crustaceans, and fish species (Stevens et al. 1982). Other information on the ecological role of each life stage is given in the life history section.

ENVIRONMENTAL REQUIREMENTS

Temperature

The temperature preferences of adult crabs are different among seasons (Mayer 1973). They are somewhat tolerant of abrupt temperature and salinity fluctuations (Cleaver 1949), and water temperatures from 3 to 19 °C were listed as normal for the Dungeness crab (Cleaver 1949).

Dungeness crabs have different optimal water temperatures at different stages. In the laboratory, Des Voigne (1973) reported that optimal water temperatures for mating ranged from 12 to 16 °C during long photoperiods. Wild (1973) noted an apparent trend towards crabs mating later in colder water in his laboratory experiments, but noted that mating took place between 10 and 17 °C. In Washington coastal waters, where Dungeness crabs usually mate in early spring, the bottom temperatures are between 8 and 10 °C (Armstrong, pers. comm.). According to Wild (1983), the egg brooding periods varied inversely with seawater temperatures of 9 to 17 °C (Figure 8). Prolonged egg brooding periods in colder water are consistent with prolonged occurrences of ovigerous crabs and cooler ocean temperatures as you move progressively northward along the Pacific coast (Wild 1983). Hatching success, considered as the number of larvae that hatch from an egg mass, decreased as the temperature increased from 10 to 17 °C (Wild 1983). Mayer (1973) found a similar correlation between egg mortality and temperature with 20% mortality at 10 °C and 100% mortality at 20 °C.

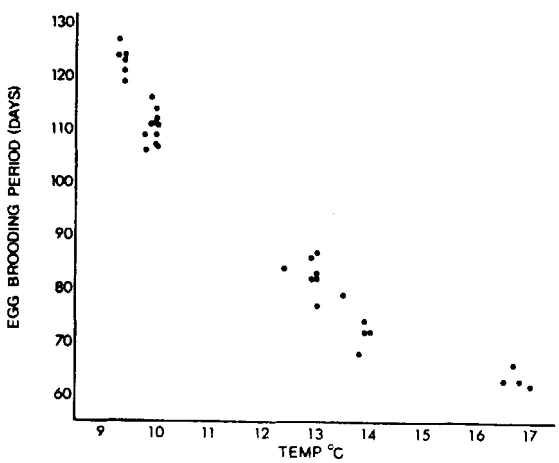

Figure 8. Dungeness crab egg brooding periods at various laboratory seawater temperatures (Wild 1983).

Optimal temperatures for larvae are 10 to 14 °C. Juvenile crabs, 80 mm wide and acclimated to 10.0 °C, have been exposed to water temperatures up to 25.0 °C for 7 days with little or no mortality (Des Voigne 1973); however, an increase of 2.5 °C above 25 °C was fatal to 100% of all crabs tested. In the laboratory, adult crabs had a maximum tolerable temperature of 25 °C during long photoperiods, which decreased to 20 °C when exposed to short photoperiods

(Des Voigne 1973). With adult crabs held for 8 months, Wild (1983) observed that mortality increased with temperature from 17% at 10 °C to 58% at 13 °C and to 80% at 17 °C, although laboratory stress probably exacerbated the effect of high temperatures.

Salinity

Tolerance to salinity varies among the life stages of the Dungeness crab. In general, salinity is not as important as temperature to egg development and hatching, but the larvae are highly sensitive to changes in salinity (Buchanan and Milleman 1969). The percentage of eggs hatching was optimum at 15 ppt, but hatching occurred to some degree over a wide range of salinities between 10 ppt and 32 ppt (Buchanan and Milleman 1969). When salinity was increased from 15 ppt to 32 ppt, the average prezoeal period was reduced from about 60 min to less than 11 min. At a salinity of 10 ppt, no prezoeae molted to zoeaea, but 100% molted at 30 ppt (Buchanan and Milleman 1969). The highest survival for larvae was between salinities from 25 ppt and 30 ppt (Reed 1969). Survival decreased with salinity and was poorest at salinities of 15 ppt (Reed 1969). No juvenile or adult tolerance levels are available in the literature at this time.

Temperature-Salinity Interactions

Salinity and temperature are both related to larval survival. Significant interaction exists between these two factors with salinity buffering temperature. At favorable temperatures, unfavorable salinities resulted in complete mortality, but favorable salinities at unfavorable temperatures allowed some survival (Reed 1969). The most obvious effect on growth rate occurred at temperatures that resulted in the best survival. Salinities that favored survival generally had little effect on zoeal growth. Survival of zoeae is optimal between the water temperatures of 10.0 and 13.0 °C and salinities of 25 and 30 ppt (Reed 1969). The significant interaction between temperature and salinity dictates caution when making statements about either variable independent of the other one. The effects of temperature or salinity alone on C. magister zoeae do not appear to cause large fluctuations in zoeal survival in the ocean (Reed 1969; Lough 1976).

Substrate

Adult crabs are found living over several substrate types (Schmitt 1921; Cleaver 1949; Butler 1956), but they prefer sandy-mud bottoms (Karpov 1982). Early juveniles prefer beds of eelgrass, shell, or sandy mud (Stevens and Armstrong 1984). This preference may stem from an abundance of food organisms on such substrates or perhaps the crabs find shelter from predation there (Stevens 1982). Older crabs seem less dependent on epibenthic cover and can be found over more exposed substrates. Most crabs remain in the subtidal environment, but may venture into littoral areas at high tide (Stevens et al. 1984). This behavior is enhanced by the presence of preferred food items and decreased during low salinities following heavy rains.

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50272-101

REPORT DOCUMENTATION PAGE	1. REPORT NO. Biological Report 82(11.63)*	2.	3. Recipient's Accession No.

4. Title and Subtitle
Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest)--Dungeness crab

5. Report Date
August 1986

6.

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10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.
(C)
(G)

12. Sponsoring Organization Name and Address
National Wetlands Research Center
Fish and Wildlife Service
U.S. Department of the Interior
Washington, DC 20240

U.S. Army Corps of Engineers
Waterways Experiment Station
P.O. Box 631
Vicksburg, MS 39180

13. Type of Report & Period Covered

14.

15. Supplementary Notes
*U.S. Army Corps of Engineers Report No. TR EL-82-4

16. Abstract (Limit: 200 words)

Species profiles are literature summaries of the taxonomy, morphology, range, life history, and environmental requirements of coastal aquatic species. They are designed to assist in environmental impact assessment. The Dungeness crab (Cancer magister) is found off the coasts of Washington, Oregon, and southern British Columbia, as well as in the estuarine waters of this geographic area. It is a shellfish highly prized and sought after by both commercial and sport fishermen. In Washington and Oregon, only male crabs may be retained by sport and commercial fishermen. Commercial crab catches are highly variable from year to year, but the catches from Washington and Oregon follow a very similar pattern. The highest sport catches take place on low tides ranging from -0.60 to -0.74 m. Dungeness crab go through a life cycle that involves several metamorphic stages: zoea, megalops, postlarval crab, and adult crab. Hatching success decreases as water temperature increases from 10 to 17 °C; the optimal temperature for larval crabs is between 10 and 14 °C. Salinity is not as important to egg development and hatching as temperature, but optimum hatching occurs at about 15 ppt.

17. Document Analysis a. Descriptors
Temperature
Estuaries
Shellfish
Salinity
Feeding habits
Crabs
Life cycles
Temperature

b. Identifiers/Open-Ended Terms
Dungeness crab
Cancer magister Dana
Life history
Ecological role
Environmental requirements

c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited	Unclassified	20
	20. Security Class (This Page) Unclassified	22. Price

(See ANSI-Z39.18)

OPTIONAL FORM 272 (4-77)
(Formerly NTIS-35)
Department of Commerce

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DEPARTMENT OF THE INTERIOR

U.S. FISH AND WILDLIFE SERVICE

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