

# Late-Holocene Dungeness crab (*Cancer magister*) harvest at an Oregon coast estuary

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## Abstract

Coastal peoples worldwide harvested and consumed a wide variety of shellfish. Most archaeological analyses of shellfish remains tend to focus on bivalves such as clams and mussels while other shellfish such as gastropods, barnacles, and crabs have received much less attention. Here we examine the use of Dungeness crabs (*Cancer magister*) at a late-Holocene village on Netarts Bay, northern Oregon Coast. Ethnographic and ethnohistoric records suggest that crabs were both individually hunted as well as gathered, often en masse. We employ allometric scaling of Dungeness claws (propal fingers) recovered from several household middens to estimate crab body size and age. These data indicate that while a wide age range of crabs were collected, most harvesting efforts focused on juveniles and young adults. This suggests that most Dungeness crabs at the site were gathered (not individually hunted) in Netarts Bay, most likely in shallow subtidal areas where cockles (*Clinocardium nuttalli*) were also being regularly taken. As such, Dungeness crabs were part of a foraging strategy that involved the efficient mass harvest of small prey using minimal technology.

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## 1. Introduction

The use of shellfish among native peoples is an important topic on the Northwest Coast of North America [4,5,7,11,17,26,42,44,55,64] and on coastlines worldwide [6,9,10,13,14,16,21,33,41,47,49,63]. As Jerardino and Navarro [32] have argued though, crustaceans have been largely ignored in most zooarchaeological literature concerning shellfish (but see [12,27,35,39,54]). Zooarchaeological research on Northwest Coast shellfish use follows a similar pattern. Most investigations of the role of shellfish in the region's ancient economies have focused on a few genera of bivalves that tend to be recovered in abundance from shell middens (e.g., *Mytilus*, *Tresus*, *Saxidomus*, *Clinocardium*) and those used as

ornaments or currency (notably *Haliotis*, *Olivella*, and *Dentalium*).

Ethnographic and ethnohistoric data show native peoples of the Northwest Coast used a wide variety of shellfish including bivalves (mussels, clams), gastropods (snails, limpets, abalones), crustaceans (barnacles, shrimp, crabs), echinoderms (urchins), cephalopods (octopi, squid), and others [58]. The dearth of discussion in the archaeological literature on the use of some of these shellfish is expected given that some (e.g., octopi, squid) have few or no hard body parts that could be expected to survive in most archaeological burial environments. Others though have many hard body parts that are often recovered through standard archaeological recovery techniques but yet remain little studied and often unidentified or unquantified, especially in comparison to most bivalves. One such group of often-ignored shellfish is the crabs, several species of which are commonly found in Northwest Coast intertidal and subtidal habitats.

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Here we explore the use of Dungeness crabs (*Cancer magister*) at a late-Holocene village on the northern Oregon Coast. While crab remains have been recovered from many Oregon Coast archaeological sites [1–3,23,43,60], little is known about native people's crab harvest methods, which habitats crabs were harvested from, or crabs' dietary and economic importance. Where these small animals individually hunted? Or, where crabs harvested en masse using nets or other high-investment technology? Was their mass harvest possible with only minimal technology? Resolving these issues is important if we are to better understand foraging strategies, prey ranking systems, settlement patterns, and subsistence technologies [39,40,57]. We begin here by briefly reviewing archaeological excavations at 35-TI-1 on Netarts Bay and discuss the recovery and identification of crab remains from the site. Following this, we present ethnographic and ethnohistoric data on crab use on the southern Northwest Coast, which indicates crabs were both individually hunted as well as collected, sometimes en masse. Finally, we employ allometric scaling to estimate the size range and mortality pattern of crabs at 35-TI-1. These data indicate that a wide size range of Dungeness were being harvested, including many juvenile crabs, suggesting that most of these crabs were collected in Netarts Bay, perhaps while also gathering cockles using rake-like implements.

## 2. 35-TI-1 and Netarts Bay

The Netarts Sandspit Village (35-TI-1) is situated on a narrow forested sandspit separating Netarts Bay from the Pacific Ocean on the Northern Oregon Coast (Fig. 1). Netarts Bay is a shallow saline lagoon that receives very little freshwater input from the small streams along its eastern margin. Tidal range in the bay is approximately 2.1 m and about 75% of the bay's water drains with each tidal cycle, exposing roughly 6.1 km<sup>2</sup> of tidelands cut by shallow (1–3 m) subtidal channels, especially in the lower two-thirds of the bay [38,50]. The bay is bracketed by steep basaltic headlands to the north and south and its eastern shore is composed of more gently sloping marine and aeolian deposits.

The bay is home to one of the most prolific and diverse estuarine invertebrate faunas on the Oregon Coast. For example, during a survey of the recreational fishery at Netarts Bay conducted from March through October of 1971, over 261,500 invertebrates were harvested [20]. Around 89% of these were the bivalves *Tresus capax*, *Clinocardium nuttalli*, *Saxidomus gigantea*, *Protothaca staminea*, and *Mya arenaria* (an introduced species), all of which inhabit intertidal and subtidal soft sediments. Also harvested during the recreational fishery were 19,000 Dungeness crabs, 4600

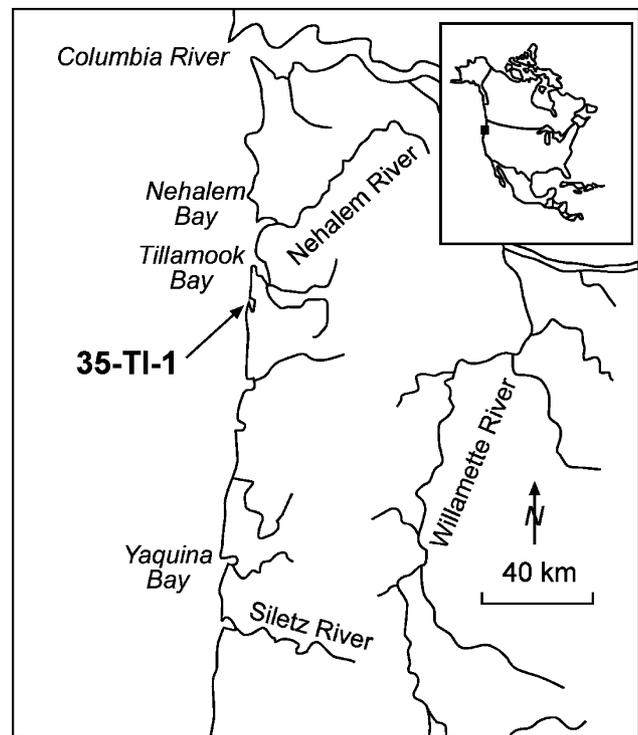


Fig. 1. Map of Netarts Bay, northern Oregon Coast, showing location of Netarts Sandspit Village.

red rock crabs (*Cancer productus*), 100 shore (*Hemigrapsus oregonensis* and *Hemigrapsus nudus*) and hermit crabs (*Pagurus* sp.), and nearly 25,700 mud and ghost shrimps (*Upogebia pugettensis* and *Callinassa californiensis*). During the same year, nearly 22,000 pounds (number unspecified) of Dungeness crabs also were taken in the commercial fishery at the bay [20].

The first excavation of the Netarts Sandspit Village was undertaken by Lloyd Collins in 1952. More extensive excavations were conducted at the site from 1956 to 1958 with Thomas Newman, working under Luther Cressman, acting as field director. The results of this work were reported as part of Newman's [45] dissertation. The site was reexamined in 1999–2001 as part of Losey's work investigating the impacts of a large earthquake and tsunami in AD 1700 on the site inhabitants and local environment [36].

Excavations at the site revealed that it consists of two rows of oblong depressions, with 11 depressions in the western-most row and two in the eastern-most row fronting Netarts Bay [36]. Collins excavated a large trench through depression 2, while Newman excavated most of depressions 1, 12, and 13 and smaller portions of several others. Within depressions 5, 12, and 13, Newman [45] identified the remains of semisubterranean rectangular wood plank houses, and he also found evidence for a fourth structure in depression 10. Dense shell midden deposits up to 2 m deep were found around the periphery of all four of these house pits. All the other

depressions at the site contained hearths, midden debris, and other occupation debris, but no clear evidence of structures. Neither Collins nor Newman systematically collected shellfish remains during their work at the site but did collect around 5100 vertebrate specimens (discussed below).

In 1999, Losey began work at the site, focusing on establishing the general stratigraphy of the site, refining the chronology of occupation, recovering faunal remains, and gaining an understanding of landscape changes associated with the AD 1700 earthquake and tsunami. Test pits were excavated in the middens fronting housepits 5, 12, and 13. Excavation was undertaken with trowels following the natural stratigraphy and 5 cm arbitrary levels were employed where necessary. All excavated sediment was screened over 3.35 mm (0.132 in.) mesh sieves. Midden deposits fronting depression 12 extended about 130 cm below surface while those fronting depressions 5 and 13 reached over 220 cm below surface. A total of 20 radiocarbon dates suggest that the site was occupied from around AD 1300 until the mid to late 1700s [36,45]. Just over 62,000 vertebrate specimens were recovered from the three test pits, and combined with the 5100 specimens recovered by Newman and Collins, represent the largest analyzed vertebrate assemblage from the Oregon Coast. At least 59 vertebrate species were identified, including 36 birds, 9 fishes, 8 sea mammals, 5 terrestrial mammals, and 1 freshwater mammal [36]. Of the aquatic species identified, nearly all could have been taken in Netarts Bay or in adjacent near-shore waters. The invertebrate remains from the site are dominated by four taxa of bivalves (see below), all of which commonly inhabit sheltered saltwater (estuarine) habitats [36].

### 3. Crab remains at 35-TI-1

Immediately upon beginning work at the site in 1999, excavators and field screeners noticed a large number of crab claws (propals and dactyls) and small unidentifiable crab carapace fragments in the midden deposits. In an effort to quantify the crab remains in the midden, the decision was made to collect all crab claw fragments encountered during field screening. From the approximate 4.07 m<sup>3</sup> of sediment excavated from the site during Losey's excavations, 14,111 propal and dactyl fragments were recovered (3467 per m<sup>3</sup>). In addition, 48 bulk samples of approximately 2 l each were taken from the test unit profiles for quantification of faunal remains. Bulk samples were air dried in the lab and then dry screened over a set of graded nested sieves (25 mm, 12.5 mm, 6.3 mm, 3.35 mm, and 2 mm), with the fine fraction retained. All invertebrate remains retained in the 3.35 mm and larger sieves were then sorted and identified to the most specific taxonomic category

possible. These samples produced a total of 274.65 g of crab remains<sup>1</sup>.

Crab remains were identified using the University of Oregon, Department of Anthropology comparative shellfish collection. The only recognizable portions (i.e. portions of the exoskeleton that could be identified to element) of crab exoskeleton present were the fixed finger of the propodus (the lower claw, hereafter referred to simply as the propodus), dactylus (the moveable upper claw), and the distal maxilla (recovered in the bulk samples only) (see Fig. 3). The rest of the exoskeleton was so badly crushed and deteriorated that elements were impossible to recognize. In general, those areas of crab exoskeletons most exposed to abrasion and wear are also the most calcified [62]. The chelipeds or claws, used for manipulating food and in battles with other crabs, and the maxillae, employed for sweeping bits of food into the mouth, are undoubtedly subject to much wear and abrasion and are likely more calcified than most of the rest of the crab exoskeleton. This, and the fact that it is not necessary to break open this portion of the crab exoskeleton to remove the flesh (it can be easily removed by breaking open the palm of the propodus) may account for their tendency to differentially preserve at 35-TI-1.

After much examination, the maxillae of the *Cancer* crabs were found to be too similar in morphology to be differentiated and all further efforts at identification were then focused on the propodus and dactyl. To prevent double counting of specimens when calculating minimum number of individuals (MNI), only those specimens judged to be more than 50% complete were ultimate subject to identification<sup>2</sup>. Note that we considered a propodus 'complete' when the whole fixed finger with all its molars (the teeth-like projections on the gripping surface of the finger) was intact—the palm of the propodus was never recovered intact. While this counting method clearly results in underestimation of crab MNI, it does ensure that only the more complete specimens are identified to species, thereby reducing the chances of misidentification. Dungeness crabs were found to constitute around 96% of identified crabs by

<sup>1</sup> NISP figures for the bulk samples are not available. Weight in grams and MNI were the only quantification measured used for all invertebrate remains recovered in bulk samples at 35-TI-1 [36]. MNI values for the crab remains recovered in the bulk sample are: Dungeness crabs, 134; red rock crabs, 4; shield backed crabs, 3; undifferentiated crabs, 14.

<sup>2</sup> The decision to only identify propal and dactyls judged to be over 50% complete was based on two factors. First, smaller fragments of *Cancer* spp. propals and dactyls are extremely difficult to identify to species. Identifying only those over 50% complete should greatly reduce the number of identification errors. Second, the task of identifying over 14,000 propal and dactyl fragments was extremely time consuming and we thus chose to conserve time by only identifying those fragments judged to be over 50% complete.

MNI (1274 of 1319 total MNI) from 35-TI-1, but red rock crab (1.7%, 23 MNI), lined shore crab (*Pachygrapsus crassipes*; 1.4%, 19 MNI), and shield back crab (*Pugettia productus*; 0.2%, 3 MNI) were also present in small numbers.

Dungeness propals and dactyls are fairly distinct and are unlikely to be confused with those of other common Northwest Coast edible crabs. The most distinct feature of the Dungeness dactyl is the set of often more than 10 sharp ‘teeth’ extending down the crest of the dorsal surface (Figs. 2 and 3). The Northwest Coast crab with the most similar dactyls is the slender crab (*Cancer gracilis*), a much smaller (rarely larger than 7.5 cm across carapace) and slightly more gracile crab than the Dungeness (rarely found in Oregon). The dorsal crest of its dactyls is marked by a ridge bearing only two or three irregular rounded ‘teeth’ instead of the multiple pointed ‘teeth’ seen on *C. magister*. The dactyls of the other crabs identified at 35-TI-1 completely lack such ‘teeth’ and were easily distinguished from those of Dungeness. The propal fingers of Dungeness are also fairly distinct being triangular in lateral outline and having a rounded ridge extending lengthwise down the center of the medial face marking its widest point. The propals of *C. gracilis* can be differentiated from those of Dungeness by noting that the ‘teeth’ are slightly smaller relative to the rest of the finger, and the finger is slightly taller relative to length where it meets the palm.

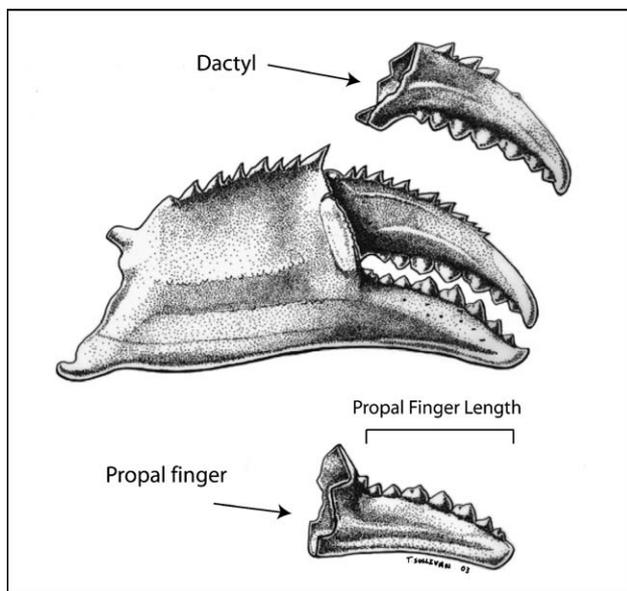


Fig. 2. Dungeness crab left cheliped of modern comparative specimen (center) and left dactyl and propal finger of archaeological specimens (upper and lower items, respectively). The length dimension measured on the propal fingers is indicated. Note that both archaeological samples are eroded and worn, likely from both post-depositional erosion and from being harvested long after initially molting.

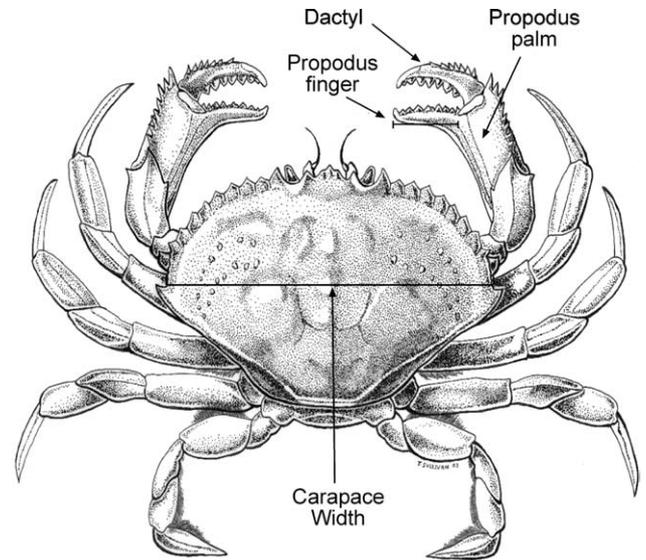


Fig. 3. Dorsal view of a Dungeness crab with carapace width measurement used in this study is indicated.

#### 4. Ethnographic and ethnohistoric accounts of crab use

Few detailed ethnographic or ethnohistoric accounts of crab harvest and use are available from the southern Northwest Coast. Some early explorers and settlers report use of crabs by the region's native peoples [19,59,61], but specifics on species harvested are rarely if ever provided. Two general methods of crab harvest are reported: hunting individual crabs and gathering crabs, often en masse. For example, Nehalem Tillamook men of the northern Oregon Coast hunted crabs in estuaries using long poles to stab them [29]. Presumably this harvest method would have been focused on larger crabs that were easier to spot and strike than smaller individuals. The mortality profile for a population of crabs harvested solely in this manner would likely have few small individuals (juveniles) and instead would consist largely of large, fully adult crabs.

Swan [59] also reports that the Chinook of Willapa Bay in Washington State waded for crabs of “large size” in pools left on the tidal flats during low tides. He also states that only the claws were kept and that the remainder of the body discarded. Based on our few measurements of the distribution of edible flesh in Dungeness crabs, this seems an unlikely harvest practice, as it would result in the discard of the majority of a Dungeness crab's edible meat (see Table 1). We suggest instead that all portions of the body were likely retained and that the claws may have been removed in order to eliminate the chances of being pinched while being handled. Dungeness crabs can inflict serious damage with their claws, and when sold alive today often have their claws rendered immobile with small rubber bands to prevent injury to

Table 1  
Distribution of meat weight for two Dungeness crabs (carapace width of crab 1 is 18.9 cm and for crab 2 is 18.3 cm; both crabs were purchased after steaming at the Pike Place Market, Seattle, in April of 2001)

Element	Meat Wt. (g)	Element	Meat Wt. (g)
<b>Dungeness crab #1</b>			
L 1st leg	38.7	R 1st leg	40.2
L 2nd leg	25.4	R 2nd leg	25.9
L 3rd leg	22.4	R 3rd leg	19.8
L 4th leg	14.2	R 4th leg	14.6
L 5th leg	10.1	R 5th leg	9.8
Subtotals for legs	110.8		110.3
Main body cavity	139.2		
Total meat weight	360.3		
Total exoskeleton weight	262.5		
<b>Dungeness crab #2</b>			
L 1st leg	35.3	R 1st leg	32.8
L 2nd leg	23.9	R 2nd leg	22.4
L 3rd leg	19.7	R 3rd leg	21.8
L 4th leg	12.8	R 4th leg	13.1
L 5th leg	7.9	R 5th leg	**
Subtotals for legs	99.6		90.1
Main body cavity	143.3		
Total meat weight	333.0		
Total exoskeleton weight	252.9		

\*\*Element not present.

handlers. Swan [59] also reports that “small crab(s)” were taken in “great quantities” in “creeks” entering Willapa Bay and were later boiled and eaten whole (including the exoskeleton). The mortality profile of crabs harvested largely through gathering or some sort of mass harvesting would likely include individuals of a wide size range, and smaller individuals (juveniles) would likely be more prevalent than when solely taken by hunters. This would be especially true if the gathering or mass harvesting was carried out in shallow estuarine subtidal areas, a preferred habitat of juvenile Dungeness crabs.

The Nehalem reportedly cooked crabs by steaming them in pits filled with rocks and hot coals covered with mats [19]. On the central Oregon coast, crabs were steamed on a bed of rocks, coals, and seaweed on the ground surface [61]. Neither of these cooking techniques would likely result in the burning of crabs’ carapaces. Some oral tradition of the northern Oregon coast indicates that crabs were considered a public resource and were “not to be fenced in for just one person” [30].

## 5. Dungeness crabs

*C. magister* is one of the larger crabs in the northeastern Pacific, attaining typical and maximum carapace widths of 180 and 230 mm, respectively (Table 2). The species ranges from the Pribilof Islands in Alaska to Santa Barbara, California and can be found from the

Table 2  
Life history characteristics for Dungeness crabs (data compiled from Pauley et al. [48]; CW denotes carapace width)

Season of mating	March–June
Season of egg production	October–March
Season of hatching	December–April
Settling time of larvae	April–May
Age at sexual maturity	2–3 years
Size at sexual maturity	100 mm females, 116 mm males
CW by end of first summer in estuary	~40–50 mm
CW by end of second summer in estuary	~100 mm
CW for legally harvested males in Oregon	146.1 mm (5 $\frac{3}{4}$ inches)
Maximum life span	Around 8 years

intertidal zone to depths of 230 m [31]. Growth of *C. magister* varies with water temperature and thus the life history patterns vary annually and regionally. Age of sexual maturity and life span are typically lower in California than in Alaska and lower in near-shore coastal waters than in estuaries [48]. While mating occurs in shallow water, female crabs migrate offshore to brood and hatch their eggs. The early larval stages feed and rear in the water column but the final larval stage migrates back to shore and settles in shallow coastal and estuarine habitats. When the final larval stage molts, it transforms into the first crab stage with a carapace width of 5–8.5 mm. The highest densities of juvenile Dungeness crabs are found in estuaries, which provide warm water temperatures, high biological productivity, and protection from predation, especially compared to adjacent near-shore areas [15,28]. Sand substrate and eelgrass (*Zostera marina*) beds are preferred habitat for these crabs, which bury themselves in the sand or hide in the grasses to escape predation [25,46,51,53].

Dungeness crabs, like all arthropods, grow by molting their exoskeleton. After the larval stages, crabs typically molt 11 to 12 times to reach sexual maturity at a carapace width of about 115 mm for males and 100 mm for females. Mature crabs usually molt once a year. Those crabs that attain the maximum size of 230 mm will have molted about 15 times [48]. The molting process starts once a crab has experienced a critical minimum amount of tissue growth and environmental conditions are favorable. As calcium is being absorbed from the old exoskeleton, the sutures, or seams, between the skeletal plates become visibly thinner. About 12 h later, the sutures on the side of the body start to split and the new cuticle becomes visible beneath. Soon after, the crab stops moving and begins to ingest large volumes of seawater. The body swells and when the internal pressure becomes great enough, the old exoskeleton splits along suture lines except at the mouth region, which acts as a hinge between the upper

and lower plates of the carapace. The crab then backs out of its old skin using rhythmic muscle contractions of its appendages. After molting, the skeleton is totally soft and the crab can move only in water. During this time the crab ingests more water to increase its volume. The initial hardening process lasts one to two days and progresses at different rates in the different body regions. The cuticle is further strengthened through the addition of calcium salts and chitin. The duration of hardening depends on temperature and crab size and takes from four days to a few weeks to complete.

Dungeness feed on clams, mussels, oysters, small crustaceans, shrimp, segmented worms, fish, and decaying animal matter [48]. Its meat is an excellent source of protein, containing all the essential amino acids as well as important minerals such as zinc, copper, calcium, magnesium and iron [24]. Currently, around 25,000 metric tons of Dungeness crabs are landed annually in west coast ports, representing a commercial value of around \$130 million [18].

## 6. Mortality profiles and crab harvest

The construction of mortality profiles has proven to be a powerful tool in examining past human subsistence patterns and foraging strategies [22,34,37,56,57]. To estimate the size and age of Dungeness crabs at the site and the possible harvest method(s) used to procure them, we employ allometric scaling to relate propal finger length to carapace width. The data sets used for this analysis are 56 Dungeness crabs curated in the Department of Systematic Biology, National Museum of Natural History, Smithsonian Institution, and 20 Dungeness crabs collected from Yaquina Bay, Oregon specifically for this study. The Smithsonian sample contains Dungeness from throughout their current range (central California to Alaska), from estuaries and offshore habitats, and roughly equal numbers of males and females (where sex could be determined). The crabs collected from Yaquina Bay were trapped during the summer of 2003 and were predominantly male.

Propal finger length is here defined as the length from the tip of the propal to the back edge of the last large molar on the gripping surface of the finger (Fig. 2). The propal finger was chosen for measurement because it is essentially straight in outline and could be more consistently measured with precision than the more arched dactyl. It should be noted that the tip of the propal (and dactyl) wears down during course of each molting cycle as it is exposed to abrasion. Dungeness crabs harvested soon after molting will have slightly longer propal fingers in relation to carapace width than those harvested long after molting. We estimate that this loss in propal finger length is probably no more than 1–2 mm for an adult crab. As such, our method of estimating

carapace width slightly underestimates the size of crabs harvested in the latter portion of their molting cycle. Carapace width is here defined as the straight line width across the back immediately anterior of the lateral spines (points) (Fig. 3). This is the standard width measurement used by Dungeness recreational and commercial harvesters.

Fig. 4 illustrates the strong correlation ( $r = 0.9832$ ) between Dungeness propal finger length and carapace width for the comparative data set. The slope of the trend line for the data scatter plot is obtained by the formula:

$$y = 6.1431x + 0.3778$$

This equation, where variable  $x$  is the propal finger length in cm and variable  $y$  the carapace width in cm, allows for estimation of Dungeness crab size to be made from measurements of archaeological propal fingers with a high degree of accuracy ( $R^2 = 0.9666$ ). Because Dungeness carapace width is closely correlated to age, mortality patterns of the archaeological crabs can also be estimated from these measurements.

Overall, a wide size and age range of crabs appear to have been harvested at 35-TI-1, from juveniles to full-sized adults (Fig. 5). Nearly 90% of the crabs are estimated to have had carapace widths ranging between 6 and 15 cm. Based on the growth profile for Dungeness crabs presented in Table 2, it is reasonably safe to assume that all crabs with projected carapace widths of less than 10 cm are juveniles. Roughly 56% of the crabs fall into this juvenile subgroup. The remaining 44% or so are likely of adult age, but less than 6% of the total is large enough to meet Oregon's current minimum

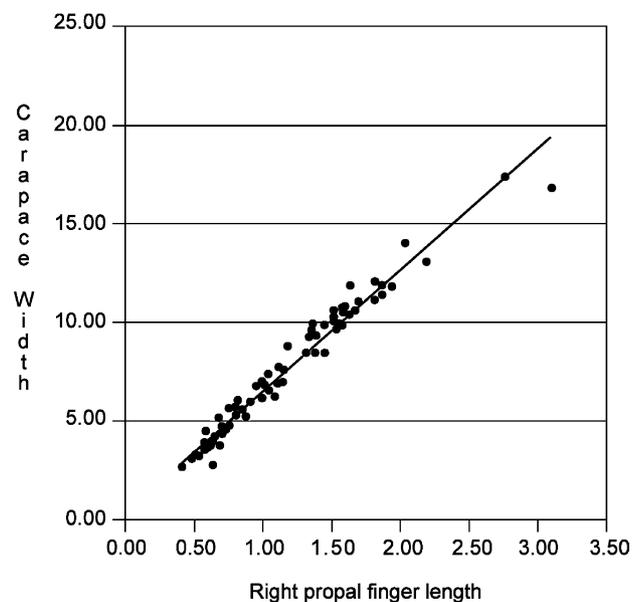


Fig. 4. Linear relationship between propal finger length and carapace width for Dungeness crabs in the comparative data set ( $r = 0.9832$ ). Trend line is shown.

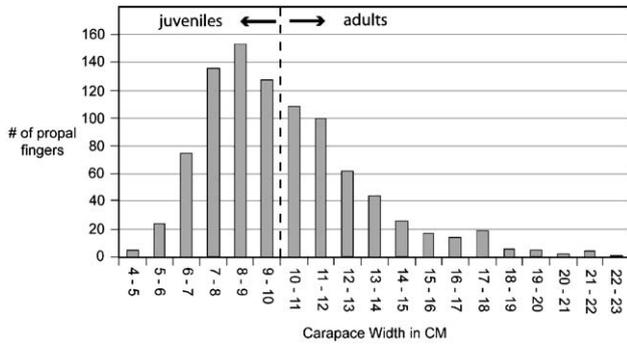


Fig. 5. Mortality profile for archaeological Dungeness crabs based on allometric scaling of propal finger length to carapace width. Profile is based on measurements taken on 931 propal fingers.

size for harvest (14.6 cm carapace width). Given the dearth of large adult individuals in the sample, we believe that individual hunting of crabs is very unlikely to have been the sole harvest strategy in use. Most of the crabs are simply too small to have been efficiently harvested in this manner. Collecting or mass harvesting of crabs, perhaps using nets, traps, or rakes, seems a more probable approach, although some individual hunting cannot be completely ruled out. Mass harvesting using a net or trap would allow for the efficient harvest of a wide size range of crabs, and if employed in an estuarine setting, would result in the taking of many juvenile Dungeness crabs. Initial costs in terms of net or trap construction, though would be fairly high. Raking of shallow subtidal estuarine sandy habitat or eelgrass beds and even gathering of crabs by hand might produce a similar mortality profile, and would require less initial time and material input when compared to net or trap use. At the same time, hand gathering and raking would have required somewhat more search time and a slower rate of return<sup>3</sup>.

The mortality profile of the crabs and other shellfish remains recovered from the site provide some indication of the habitats from which the crabs were harvested. As stated earlier, the highest density of juvenile Dungeness crabs is found in the region's estuaries. The site's location on the Netarts Bay sandspit provided immediate walking access to the sandy subtidal substrate and eelgrass beds of the bay. Offshore areas, on the other hand, would have had proportionally greater numbers of adult crabs and would generally have required more effort (paddling watercraft on the open Pacific Ocean) and considerable technology (boats and traps or nets fitted with lengthy ropes) to exploit. While such efforts and technology were not beyond the capabilities of the

region's native peoples, they seem fairly unlikely when crabs could be much more easily accessed in the sheltered waters of estuaries. The relatively small proportion of larger adult crabs in the sample also supports the interpretation that they were largely harvested from the estuary.

The other shellfish remains recovered from the village middens also suggest Dungeness crabs were procured from the estuary. Four species of bivalves dominate the other shellfish remains at the site: bay mussels (*Mytilus edulis*), gaper clams (*Tresus* spp.), butter clams (*Saxidomus giganteus*), and cockles (*C. nuttalli*). All of these bivalves are common estuarine inhabitants and are found in Netarts Bay today [20], suggesting estuarine habitats similar to those of present were in place during the occupation of the village. The only truly outer-coast shellfish species identified was California mussel (*Mytilus californianus*), but it constituted a very small portion of the total shellfish assemblage (<1% by MNI or weight). Of the estuarine bivalves, bay mussels are the ones that require hard substrate such as rock or wood for attachment. The three other taxa of bivalves live buried in softer sediments with only the tips of their siphons reaching the surface, and all can be found in intertidal and subtidal areas. Therefore, Dungeness crabs and these estuarine bivalves have overlapping habitats, particularly in subtidal areas.

Notably though, gaper clams and butter clams can usually only be harvested (by hand) through digging, as they are often buried fairly deep (10–60 cm) in the substrate [51]. As a result, these bivalves cannot be effectively harvested from areas with standing water (subtidal or flooded intertidal areas). Their siphons would be difficult to locate, the holes excavated by harvesters would collapse, and the surrounding water would quickly become murky making visibility a problem. The people of Netarts Sandspit village then would likely not have been harvesting gaper clams and butter clams from the areas where most Dungeness crabs were procured, in other words from flooded portions of the estuary.

Cockles on the other hand, can be harvested from subtidal and flooded intertidal areas. Cockles are among the most active bivalves on the Northwest Coast, having a strong muscular foot that allows them to quickly flip themselves over, dig into the sand, and even spring through the water several feet if pursued by predators [51]. These clams can live completely exposed on the surface, and even when buried are usually found within a few centimeters of the surface [51]. As a result, cockles and juvenile Dungeness crabs often would be found in the same estuarine habitat. Today, many cockles are harvested from Netarts Bay and nearby estuaries by individuals wading in shallow subtidal channels who use garden rakes and similar implements to pull them from the sand or flooded bay surface. While raking for cockles, many juvenile Dungeness crabs also are often

<sup>3</sup> While no evidence of rakes, nets, or traps has been recovered at 35-TI-1, several wood stake fishing weirs have been identified in Netarts Bay [8]. Rake-like implements of whale bone have been recovered a short distance away at Tillamook Bay by artifact collectors [52].

found tightly clinging to rakes, likely in a defensive response to their being suddenly swept from their hiding places. We suggest that many of the Dungeness crabs from Netarts Sandspit Village were harvested using a similar implement, and perhaps being collected concurrently with cockles.

## 7. Discussion and conclusions

The people of Netarts Sandspit Village were harvesting a wide size range of Dungeness crabs, including many juveniles, most likely from Netarts Bay. Hunting (spearing) seems an unlikely strategy for taking such a wide size and age range of crabs, as the smaller individuals would be difficult to efficiently spot and strike. Collecting using technologies such as traps, nets, or rakes seems more likely and would allow for the efficient harvest of even small individuals. If rake-like implements were employed, Dungeness crabs easily could have been harvested at the same time cockles were being gathered due to significant overlap in the habitat of these two species. As such, Dungeness crabs would have fit into a foraging strategy at Netarts Bay that allowed all of the major shellfish species present in the middens to be harvested during a single tidal cycle. Bay mussels could have been plucked from the upper intertidal zone as the tide first receded, butter and gaper clams dug from the mud and sand flats as the tide continued to fall, and cockles and crabs raked from the shallow subtidal channels adjacent to the flats. The technology needed to efficiently harvest Dungeness crabs may have been nothing more than a rake-like implement that would allow people to brush through the upper few centimeters of subtidal sediment. Given that the crucial elements involved in the use of small fauna have been argued to include relatively small material investment in mass harvesting technology, abundant and dense prey, and low search time [27,39,40,57], it is little surprise that Dungeness crabs were readily used at the Netarts Sandspit village.

One question that arises is that if Dungeness crabs were relatively easily taken and perhaps part of a regular round of shellfish harvesting at Netarts Bay, why are they not found in abundance in other sites in the region? We suspect several factors are at work. First, the 35-TI-1 assemblage is relatively young—all excavated samples appear to be 700 years old or less. The propal fingers and dactyls of Dungeness, let alone the rest of the carapace, are structurally thin and relatively fragile. As such, crab remains may suffer more attrition over time than the somewhat denser bivalve shells. The abundance of crab remains in the site may therefore relate somewhat to its relatively young age.

Second, we also suspect sampling methods and bias toward the study of bivalves and vertebrate fauna to be

at issue. Shellfish remains on the Northwest Coast are typically sampled either through “grab samples” that involve arbitrarily selecting whole or interesting specimens during field screening or through the use of ‘bulk sampling’ which consists of collecting a given volume of midden sediment for detailed analysis. In our experience, grab sampling usually focuses on the recovery of bivalve and gastropod shells, not crab carapace fragments. At the same time, efforts are usually also made to recover *all* bone during field screening, leaving crab remains largely unaccounted for. Bulk sampling might rectify this bias, but crab remains recovered in these samples often are not identified, or alternatively identified only as *Cancer* sp. Added to this is that even when bulk samples are employed (as at 35-TI-1) only crab propals, dactyls, and occasionally distal portions of the mandibles might be recovered. The inability to recover most of crabs’ carapaces complicates efforts at determining the contribution of crabs to the overall meat diet, especially when such calculations are made using bone/shell weight to meat weight conversions. This issue is difficult to remedy but might be lessened by collecting crab propals and dactyls during field screening in the same way that bone is typically recovered and then making meat weight conversions on MNI values.

Fully understanding the role of crabs in the broader region’s ancient economies awaits similar studies on assemblages from other areas and time periods. The relationship between Dungeness propal finger length and carapace width demonstrated in this paper should be of use to those interested in evaluating crab mortality patterns and harvest methods elsewhere on the world’s coastlines. It is hoped that this project will inspire similar projects on other understudied fauna on the Northwest Coast and elsewhere, and that the analyses of shellfish will expand even further beyond the study of bivalves.

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