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APPENDAGE INJURY IN DUNGENESS CRABS, *CANCER MAGISTER*, IN SOUTHEASTERN ALASKA

The Dungeness crab, *Cancer magister*, is commercially important along the western coast of the United States. Like many decapod crustaceans, it can autotomize and regenerate appendages to heal wounds and limit injury.

Studies of appendage injury may be useful in assessing the physical condition of crustacean populations and the impact of fishing on commercially important species. Incidences of appendage loss in the field have been reported for species of crabs other than *C. magister* (McVean 1976; McVean and Findlay 1979; Needham 1953). Appendage loss was studied in adult Dungeness crabs in Washington (Cleaver 1949) and Oregon (Waldron 1958) and for juvenile crabs in the Columbia River estuary (Durkin et al. 1984).

In this study we examined adult Dungeness crabs in southeastern Alaska to determine the incidence of missing, regenerating, and damaged appendages. Temporal incidence of appendage injury was compared to the molting and mating periods of the crabs and to the commercial fishing season for Dungeness crabs.

Materials and Methods

Adult Dungeness crabs were collected from Icy Strait and the Excursion Inlet fjord near Glacier Bay, AK (lat. 135°30′N, long. 58°25′W), from May through November 1984-85. Data were obtained by monthly surveys of commercially caught crabs. Crab pots (Waldron 1958) were set at depths of 7 to 20 m and remained in the water for 3 to 11 days. All crabs were held in live tanks (<24 hours) before they were measured on board ship. In southeastern Alaska, pots are equipped with escape rings to permit release of crabs with carapace widths <165 mm, but sublegal-sized crabs are often found in the catch.

Carapace width (excluding the 10th anterolateral spines), wet weight, and sex were recorded for each crab. Carapace condition was graded as soft-shell (recent molt), new-shell, worn-shell, or skip-molt (Somerton and Macintosh 1983). The number and identities of missing, damaged, or regenerating chelipeds and walking legs were recorded. An appendage with a cracked cuticle or missing dactyl was considered damaged. Appendages smaller in length and diameter than intact appendages were designated regenerating. Combined missing, damaged, and regenerating appendages are referred to as injured appendages.

Interrelationships between variables were determined with Pearson correlations (SAS 1985). Means were compared with Student's t-tests, and chi-square analyses were used to determine if multiple autotomies occurred by chance (Steel and Torrie 1960). Data are presented as means ±1 standard error of the mean.

Results

Males comprised 65% and females 35% of the 878 Dungeness crabs examined. Average carapace widths were 169 ± 0.6 and 159 ± 0.7 mm for males and females, respectively. Wet weights were 1,102 ± 9 g for males and 884 ± 14 g for females. The greatest number of female crabs was caught in July, and the greatest number of males in August.

Seventy-five percent of the crabs were intact, with no appendage injuries. Twenty-five percent of all crabs had injured limbs; 18% had missing, 5% had regenerating, and 2% had damaged appendages. No relationship existed between carapace width and appendage injury.

Most of the Dungeness crabs sampled were in the worn-shell condition (67%). Twenty-eight percent of all crabs were new-shelled. Only 1% were soft-shelled and 4% were skip-molts. Correlations between carapace condition and appendage injury were not significant.

No significant differences existed in appendage injury between male and female Dungeness crabs. Injuries were bilaterally symmetrical except for the 3d walking leg which was missing more frequently on the left side ($P < 0.05$). Considering only those crabs with missing legs, a total of 246 legs were missing with a mean of 1.5 ± 0.1 missing legs/crab. Ninety-seven crabs had legs missing on the right side and 98 had legs missing on the left side. The maximum number of missing legs per crab was 5. Sixty percent of the crabs had 1 leg missing, 20% had 2 missing legs, and 12% were missing 3 or more legs. Of the crabs with missing legs, 63% were males and 37% were females.

Forty Dungeness crabs had regenerating legs, with a mean of 1.2 ± 0.1 regenerating legs per crab. Sixty percent of those crabs had 1 regenerating leg, 10% had 2 regenerating legs, and 3% had 3 or more regenerating legs. The maximum number of regenerating legs per crab was 4. Of the crabs with regenerating legs, 73% were males and 27% were females.

Seventeen crabs had damaged appendages with a mean of 1.1 ± 0.1 damaged appendages/crab. Of the crabs with damaged appendages, 82% were males and 18% were females.

The observed number of Dungeness crabs with 2 or more missing appendages was significantly higher ($P < 0.01$) than expected for both sexes, indicating that appendage loss was not due only to chance.

Appendage injury was significantly correlated with date, with more injuries occurring later in the year. The number of Dungeness crabs with missing appendages was significantly correlated with date for both males and females ($P < 0.01$). The lowest percentage of crabs with injured appendages occurred in July (4.8%, both sexes combined) and increased to a maximum of 34.3% in November. The percentage of male crabs with regenerating appendages did not vary significantly over time and was about 6% for all months. However, the percentage of female crabs with regenerating legs increased from 0% in May to 10.5% in November ($P < 0.01$). Male crabs with damaged appendages increased from 0% to 8.5% from May to October ($P < 0.05$) and then decreased to 1.7% in November.

Chelipeds and 1st and 4th walking legs were injured most frequently. The hierarchy for frequency of injury for female crabs (chelipeds > 4th walking legs > 1st, 2d, and 3d walking legs) differed slightly from the hierarchy for males (chelipeds > 1st walking legs > 4th walking legs > 2d and 3d walking legs). Months in which high percentages of crabs had injured chelipeds also had high percentages with injured 1st (males) and 4th (females) walking legs (Fig. 1).

The temporal incidence of appendage injury in Dungeness crabs was compared to life history events and to the commercial crab fishing season in southeastern Alaska (Fig. 2). The season opened 15 June and closed 15 August, reopened 1 October and closed 28 February 1986. Appendage injuries were low in July and increased 157% from July to August, a period of simultaneous molting, mating, and fishing. An additional increase in appendage injury of 43% occurred in October, even though the fishery was closed from 16 August to 30 September.

Discussion

Pot samples are biased towards larger sized Dungeness crabs because of the size of the mesh on the pot and the presence of two escape rings with diameters of 11 cm. However, 62% of the crabs collected for this study were either male crabs with carapace widths <165 mm or were females. Very few soft-shell crabs were caught, even though molting was occurring during part of the sampling period. Our dependence on commercial crabbers for data collection restricted us to sampling mostly during the open fishing season when most of the crabs were not in the soft-shelled condition.

Twenty-five percent of the Dungeness crabs sampled in southeastern Alaska had appendage injuries. In other studies of Dungeness crabs in Washington, Oregon, and the Columbia River estuary, 18%, 32%, and 62%, respectively, of the crabs were injured (Cleaver 1949; Waldron 1958; Durkin et al. 1984). The crabs examined in our study were held for up to 24 hours in crowded tanks on board ship before being measured and

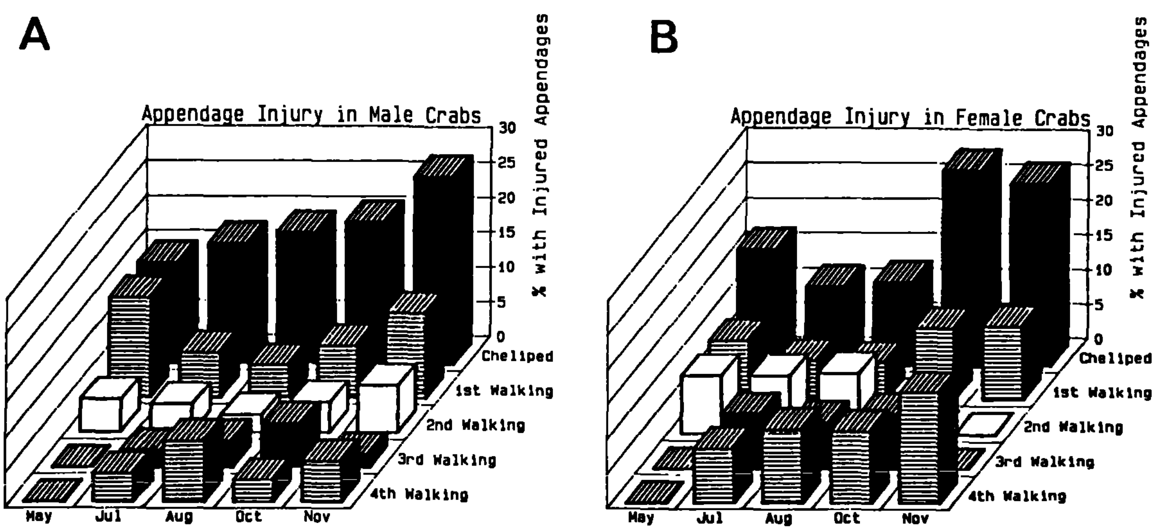

FIGURE 1.—Monthly percentages of male (A) and female (B) Dungeness crabs with injured (missing + regenerating + damaged) chelipeds and walking legs.

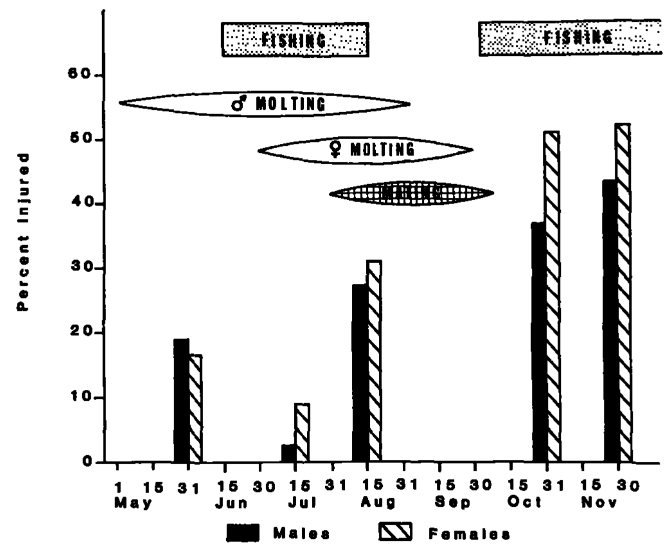

FIGURE 2.—Temporal relationships of percentages of male and female Dungeness crabs with injured (missing + regenerating + damaged) appendages to the crabs' molting and mating periods and the commercial crab fishing season in southeastern Alaska.

were sometimes observed grasping other crabs, but very few autotomized limbs were found in the tanks.

The estimate of appendage injury may be low if Dungeness crabs with injured appendages were less likely to enter pots than intact crabs. In another study, the observed number of *Carcinus maenas* missing 2 or more legs was higher than expected if multiple autotomies occurred by chance, which was interpreted to mean that injured *C. maenas* enter pots as readily as intact crabs (McVean 1976). Because there were more Dungeness crabs with 2 or more missing legs in our collections than would be expected if multiple autotomies occurred by chance alone, our data could be similarly interpreted to suggest that Dungeness crabs with injured appendages showed little decrease in pot-entering ability and that our estimate of injury was accurate. For this interpretation of the chi-square results to be valid, one must assume that all injuries occurred before the crabs entered pots and that injury did not occur within the pots.

Appendage injury in Dungeness crabs was bilaterally symmetrical except for the 3d walking leg. Interestingly, Easton (1972) demonstrated that 3d walking legs of *Hemigrapsus oregonensis* were the most easily autotomized. In other studies, both bilateral symmetry and asymmetry have been reported for different species of crabs (Durkin et al. 1984; Needham 1953). Asymmetrical appendage loss has been associated with crabs that move predominantly in one direction, while symmetrical leg loss occurs in crabs that move randomly (Needham 1953).

The chelipeds, followed by the 1st and 4th walking legs, were most vulnerable to injury. Limb loss has been correlated in other studies with degree of exposure of the limb; the outermost limbs, the longest limbs and limbs with postures that afford little protection are most frequently lost (Needham 1953). Anterior limbs are lost more frequently than posterior limbs (Needham 1953). The chelipeds are the most anterior and one of the most exposed appendages on Dungeness crabs and are frequently used in aggressive threat postures. After loss of chelipeds, the 1st walking legs remain as the most anterior, exposed limbs and therefore, the most vulnerable. The 4th walking legs are the most posterior and also very exposed limbs on an intact crab.

A significantly greater number of Dungeness crabs with 2 or more missing legs was observed than expected if multiple autotomies occurred by chance, indicating an increased susceptibility to subsequent appendage loss after initial injury (Needham 1953; Easton 1972).

The correlations between appendage injury and date were significant but may not be biologically important. Although these correlations were significant, the r^2 values (square of the coefficient of variation) were low. Increased appendage injury later in the year may be related to other factors. Soak times, the length of time pots were left in the water, were longer later in the year. Dungeness crabs may cannibalize other crabs while confined in pots (Waldron 1958). There may also be delays between time of injury and subsequent autotomy and regeneration. Regeneration of legs in Dungeness crabs is usually completed after 2 or 3 molts (Cleaver 1949).

Over the sampling period, only 5% of all crabs had regenerating appendages while 18% had missing appendages. The discrepancy may be due to increased mortality of the crabs following injury (McVean and Findlay 1979), or by the efficient, yearly removal of legal-sized, injured crabs by the commercial fishery.

When temporal incidence of appendage injury was compared with the opening and closing of the commerical Dungeness crab fishing season, considerable appendage injury occurred when the fishery was closed. Closure of the fishery traditionally occurs during the crabs' mating period, when a high percentage of soft-shelled female crabs are present in the population. There was, however, some overlap in late July and early August in fishing, molting, and mating. Excluding damage by humans, potential causes of appendage injury are aggression between males competing for females, the cheliped-to-cheliped mating embrace of Dungeness crabs that can last up to a week, cannibalism, and the increased vulnerability of females which molt prior to mating (Butler 1960; Durkin et al. 1984). Damage to Dungeness crabs can also result from other fishing gear such as trawls (Reilly 1983), but no other commercial fisheries occurred in the study area while the Dungeness crab fishery was closed.

The results of our studies indicate that Dungeness crabs in southeastern Alaska are in comparable condition to adult populations of Dungeness crabs examined in Washington and Oregon, in terms of appendage injury. Further studies are needed to investigate the effect of appendage injury on survival of Dungeness crabs and the contribution of handling injury and mortality of crabs in the commercial fishery.

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REEXAMINATION OF THE USE OF OTOLITH NUCLEAR DIMENSIONS TO IDENTIFY JUVENILE ANADROMOUS AND NONANADROMOUS RAINBOW TROUT, *SALMO GAIRDNERI*[1]

Otoliths are a potential source of taxonomic characteristics for identifying stocks of fish (Ihssen et al. 1981). Differences in dimensions of the otolith nucleus have provided a basis for separating winter from summer races of steelhead, anadromous rainbow trout, *Salmo gairdneri*. In addition, otoliths provided data from which to distinguish steelhead from resident nonanadromous forms as well (McKern et al. 1974; Rybock et al. 1975). Neilson et al. (1985) studied the development of sagittal otoliths in resident rainbow trout and steelhead from south-central British Columbia, and identified sources of variability in the size of otolith nuclei. However, they were unable to find morphometric differences between the two forms of trout. They concluded that the usefulness of dimensions of the otolith nucleus for separating steelhead from resident rainbow trout was much more limited than that suggested by Rybock et al. (1975) for rainbow trout in the Deschutes River, Oregon.

The difference in mean length of the otolith nuclei between the rainbow trout studied by Rybock et al. (1975) and those studied by Neilson et al. (1985) suggested either population differences or differences in defining the nuclear boundary. These disparate results, which led to opposite conclusions, limit the usefulness of measurements of otolith nuclei for the racial identification of juvenile rainbow trout until the source of these differences is better understood. Consequently, to determine whether juveniles of the two forms could be distinguished by differences in dimensions of otolith nuclei, we measured the nuclei in sagittae from steelhead and resident rainbow trout collected from the same Deschutes River, OR, locations used by Rybock et al. (1975). We used the definitions proposed by Rybock et al. and by Neilson et al. (1985), and compared our measurements for the two forms with each other and with published values.

Methods

Resident rainbow trout and steelhead were col-

[1]Oregon State University Agricultural Experiment Station Technical Paper No. 8279.