**PATTERNS OF MISSING PEREIOPODS LOSS RATES IN SNOW CRAB (*CHIONOECETES OPILIO*)**

**IN THE SOUTHERN GULF OF SAINT LAWRENCE**

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**ABSTRACT**

Crustaceans may lose their pereiopods (i.e. walking legs or chelipeds) due to predation, intra- and inter-specific competition, through moulting or during commercial fishing activity.

Missing pereiopod patterns in a snow crab (*Chionoecetes opilio*) population were analyzed based on a long-running annual bottom survey data in the southern Gulf of Saint Lawrence.

Pereiopod loss rates are seen to vary by sex, maturity stage and size, and also shows suggestive spatial and temporal patterns.

**ABSTRACT (DETAILED):**

Preliminary results showed that a significant difference between the sexes and the rates for immature crab were generally low and constant over all sizes, they were found to be two to three times higher in sexually mature versus immature crab. In addition, these rates were twice as high in smaller mature males as for larger ones. This pattern is even apparent in newly moulted crab, with crab which had moulted in previous years showing only a moderate increase in pleopod loss. In addition, the loss rates were twice as high in smaller mature males than for larger ones. Such results strongly hint at mating competition as the main mechanism for pereiopod loss. The rates for females were about half those of males and were more or less constant with crab size. In males the 2nd pereiopods had the highest loss rates whereas the chelipeds and 5th pereiopods had the lowest. In females, the 2nd and 5th pereiopods had the highest rates whereas the chelipeds had a rate less than half that of any other pereiopods. Pereiopod loss rates in females were about 60% those observed in males. Mature females similarly showed higher rates than immature ones with newly moulted females having a moderate increase in pereiopod loss rates than older mature females. This may be a function of the longer life expectancy of mature female versus male snow crab.

Annual changes in the pereiopod rates showed some correlation with underlying population dynamics, most notably high abundance levels in large males. Results suggest that intra-specific competition between crabs may be the main drivers in the appendage loss based on the comparison between non-commercially exploited (females and males smaller than 95 mm CW) and commercially exploited crabs (males larger than 95 mm CW only) rather than commercial fishing activity induced.

**METHODS**

**SURVEY BACKGROUND**

* The southern Gulf of Saint Lawrence snow crab survey has been performed annually since 1988, yielding indices of fishery recruitment, population abundance and biomass used in the management of its fishery.
* Over the years, the areal extent of the survey was expanded to encompass more marginal snow crab habitat areas in shallower areas and deeper waters along the Laurentian Channel.
* Sampling stations from the survey were generally fixed from year to year, through
* lection of subsets new sets of stations though changes in survey design have sometimes resulted in a selection of new sets of stations
* Sampling design was modified from a 10x10 minute grid design with variations in spatial sampling intensity to a uniform sampling density in 2004. In 2011, square survey grids whose surface area was approximately uniform within the survey area was incorporated into the spatial sampling design.
* Currently the survey grids are 12 by 12 km with a target 355 sampling stations per year.
* Since 2004, the snow crab survey is spatially homogenous in that the expected density within the survey area within a given year is uniform.
* As every crab is measured and counted, missing pereiopod frequencies, standardized by trawl swept area can be interpreted as representative of those in the trawlable population.
* For earlier years, samples can be spatially disaggregated either by using a spatially-referenced model (grid or continuous spatial random field).
* Population-level inferences were obtained by integrating out grid terms .
* Maturity was assessed morphometrically using the large increase in relative growth in the height of the cheliped during the terminal moult among males. The discriminant function described in () was used.
* In females, maturity was assessed visually based on obvious changes in size and geometry in mautre females, as the moult to maturity is accompanied by egg laying.
* Interaction effects

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| Figure X: All mature males |

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| **Figure X**: Annual rate of missing legs for mature male crab 95+ mm. |

* Evidence for differential left-right parity in appendage loss is weak.

**Males:**

* The cheliped, despite being the main instrument of offense and defence of snow crab, is more robust than the walking legs and thus has the lowest level of loss among appendages.
* The first pair of walking legs (2nd pereiopds) are the longest of the appendages, protruding slightly in front of the cheliped when the snow crab is in resting position.
* Smaller immature crab have rates which are much lower, less than half, than those of comparably sized mature crab.
* Among mature males, the overall loss rates show considerable variation with size.
* Very small (40-50mm) and very large males (120+ mm) have the lowest loss rates of each appendage, at ~ 0.05 per crab per appendage.
* In contrast, intermediate sizes showed much higher rates of loss, nearing 0.25 / crab for leg 2 and nearing 0.15 / crab for the cheliped.
* The peak loss rates occur at 75-80mm and substantially decrease with increasing size.
* Intermediate sized crab are much more vulnerable to leg loss than larger or smaller crab, on the order of 3-5 times greater.
* Legs 3,4 and 5 show similar rates (leg 3 is slightly higher) but follow the same trends with crab size.
* Immature crab show a markedly different pattern, with rates being about 3 times lower that those of mature males.
* Also, intermediate-sized crab show rates which are only slightly higher than those of larger immature crab.



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| Marginal rates of cheliped loss on left and right sides |

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| Mean number of missing legs per crab for mature males 2007-2017. |

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| Figure X : New-shelled mature (solid) and immature (dashed) male snow crab from 2008-2017. |

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| Figure : New-shelled mature male missing leg rates. 1996 had an incomplete survey. On the left is the mean density of commercial sized mature males. (Missing a legend) |

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| Figure : New-shelled immature male missing leg rates. 1996 had an incomplete survey. On the left is the mean density of commercial sized mature males. |

**COMMENT ON BIAS INDUCED BY MISSING CHELIPEDS**

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| **Figure X**: Annual proportion of legal-sized males having no recorded chela height in snow crab surveys (grey bars). Also shows are the proportions of males with naturally-occurring missing chelae on both right and sides (red lines). |

* Identification of commercial crab from sampled catches, for the purpose of estimating biomass, requires both a measurement of the carapace as well as the chela height measurement, which is used to identify maturity.
* However, a small portion of commercially-sized crab (i.e. >= 95mm) have both chelae either missing of partially regenerated, where these are required to identify the maturity and consequently whether such a crab is, or not, a commercial male.
* Such missing measurements are most often due to naturally-occurring missing chelae on both left and right sides (red line), but may also be the result of cheliped loss during regular trawling operations.
* The issue is that the proportion of such males varies through time. Figure X shows the percentage of legal-sized males having no adequate chela height measurement.
* Annual proportions of missing chelipeds have fluctuated through 1.5 cycles, with lows of 0.4% in 1997 and 0.8% in 2010 and high levels of 2.1% in 2004 and a global high of 2.4% in 2017.
* Thus there is more than a threefold difference between periods of low and high occurrence (2004 and 2017).
* Since these fluctuations are unaccounted for, they contribute to a varying negative bias in the corresponding commercial biomass estimates, on the order of the proportions shown in Figure X.
* While their maturity status is unknown, good predictive estimates of the probability of being mature as a function of crab size are available from empirical observations, with about 50% being mature at 95mm-100mm and most being mature by 110mm.
* Such maturity curves show little variation for commercial sizes, but can easily be estimated for year-specific inferences.
* While it is a trivial matter to correct for this source of bias in our analyses, such crab presently are not included in commercial biomass estimates.
* We recommend that this be done for future analyses and this would provide an easy correction for a known bias in the observations.