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Molt Indicators for Male Snow Crabs (*Chionoecetes opilio*)

by

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Abstract

Examination of mouth parts is a standard method for determining the position in the molt cycle of individual male snow crabs. We showed that the color of the carapace can also be used to determine if a crab is about to molt. A third, destructive method is to tear off the dorsal carapace and look for the presence of a second carapace. During a bottom trawl survey in April 1991 in Conception Bay, Newfoundland, we found that green carapace color and a well-developed second carapace were correlated and each was strongly associated with mouthpart classification D_1 or above. During a subsequent trap survey in May 1991, we found crabs with the normal reddish coloration that had partially formed second carapaces and mouthparts in the C or D_0 stage. We conclude that the presence of a partially formed second carapace may provide the earliest indicator of impending molting, and the collection of green crabs for a growth study is a viable way to obtain crabs which will molt in the near future, thus minimizing any effects of lengthy periods of time in captivity.

Résumé

L'examen des parties buccaux est une méthode utilisée couramment pour déterminer à quelle stade du cycle de mues se trouve le crabe des neiges mâle. On a aussi vu que la couleur de la carapace peut servir à déterminer si le crabe est proche de la mue. Une troisième méthode, celle-ci destructive, consiste à arracher la carapace dorsale pour voir si elle recouvre une deuxième carapace. Lors d'un relevé de recherche au chalut de fond réalisée en avril 1991 dans la baie de Conception, à Terre-Neuve, nous avons constaté une corrélation entre une carapace de couleur verte et la présence d'une deuxième carapace bien développée, chacun de ces phénomènes étant fortement associé à une classification D_1 ou plus des parties buccaux. Au cours d'un relevé subséquent effectué au casier en mai 1991, nous avons trouvé des crabes de couleur rougeâtre normale qui avaient partiellement formé une seconde carapace et dont les parties buccaux étaient au stade C ou D_0. Nous en concluons donc que la présence d'une seconde carapace partiellement développée peut être le premier signe d'une mue imminente et que le prélèvement de crabes verts pour une étude de la croissance est un moyen viable de sélectionner les crabes qui sont prêts à muer dans un proche avenir, réduisant ainsi les effets des périodes prolongées de captivitié.

Introduction

It is important for fishery scientists to be able to determine the position of individual crabs in the molt cycle. The timing of the molting season and the habitats where molting occurs can then be quantified. This information, in turn, is useful for short-term forecasting of recruitment. Crabs identified as being close to molting can also be held in aquaria for short periods of time so that the change in size at molting can be determined. In Atlantic Canada, male snow crabs (*Chionoecetes opilio*) are of special interest because they constitute an important fishery. In this paper we consider indicators of imminent molting for male snow crabs.

Drach and Tcherngovtzeff (1967) showed for a variety of crustacea that certain mouthparts undergo visible changes associated with the molt cycle. Moriyasu and Mallet (1986) and O'Halloran and O'Dor (1988) used that approach to describe a series of mouthpart stages associated with the molt cycle of male snow crabs (*Chionoecetes opilio*). Moriyasu and Mallet (1986) reported that the mouthparts must be stored in chilled sea water and examined under a microscope within 48 hours. Recently, Moriyasu (pers. comm.) has had some success in storing mouthparts in formalin for up to one month. Still, the necessity of removing mouthparts and examining them under a microscope makes the technique unwieldy for field surveys, and subsequent observations on behavior of animals brought into captivity may be affected by mouthpart removal. Additionally, we have found that recognition of mouthpart stages tends to be somewhat subjective.

In 1990, we noticed that some male snow crabs had a dark greenish coloration of the dorsal carapace instead of the usual reddish-brown color. These crabs appeared to be preparing to molt, judging by the mouthpart stages and the presence of well-developed second (internal) carapaces. Interestingly, color was one of the characters evaluated by O'Halloran and O'Dor (1988) in their laboratory study of the molting cycle in male snow crabs. However, they failed to detect any color changes during premolt and active molting.

O'Halloran and O'Dor (1988) indicated that changes in mouthparts associated with active premolt could be detected as much as 10 weeks before molting. However, their study was based on animals kept in captivity for extended periods of time and they acknowledged that their observed stage durations may not correspond to those of wild animals. Ito (1970) showed that, for male *C. opilio* sampled by bottom trawl in the Japan Sea, peak occurrence of second carapaces preceded peak occurrence of newly molted (soft-shelled) crabs by one to two months.

We decided to evaluate the association between coloration, presence or absence of a second carapace and mouthpart stage. We sought methods that would enable the detection of active premolting as early as possible in the molt cycle. To be useful, a method must also be rapid and reliable over a wide range of carapace ages and body sizes.

Materials and Methods

Specimens were collected during the period April 4-10, 1991, on cruise 150 of the R.V. ALFRED NEEDLER in Conception Bay, Newfoundland (centered about 47°40'N, 53°00'W). A standard 30-minute set was executed at each station using a Western IIA bottom trawl equipped with a codend liner of 29 mm stretched mesh. Fifty-one fishing stations were randomly selected within three depth strata; in addition, we made nine exploratory sets to look for concentrations of molting crabs.

Additional specimens were collected from May 21 to May 31, 1991, on cruise 132 of the R.V. MARINUS in Conception Bay. Crabs were captured in Japanese-style conical traps baited with squid and set in fleets of either 6 or 12 traps. Each fleet included two small-meshed traps (25 mm stretched mesh) and either 4 or 10 commercial-type traps (133 mm stretched mesh).

All male crabs captured were examined. Carapace width and height of the right chela (when present) were measured with vernier calipers. Shell condition was characterized as being either "squishy", "soft", "new hard", or "old hard" (Table 1). Criteria for all but the "squishy" condition were adapted from Miller and O'Keefe (1981). Coloration for hard-shelled crabs was characterized as "red" (normal coloration) or "green" according to the following criteria.

red - normal coloration; dorsal carapace is reddish brown; posterior edge of dorsal carapace (adjacent to epimeral line) pinkish in color; undersides of legs reddish

green - dorsal carapace dark greenish, lacking the reddish tinge; posterior edge of dorsal carapace (adjacent to epimeral line) whitish; undersides of legs paler than in red crabs and with a greyish cast; leg joints viewed ventrally were wine colored.

These color criteria are most easily distinguished in new-hard-shelled crabs. Both red and green crabs with old-hard shells tend to be darker than the corresponding crabs with new-hard-shells. Consequently, it is important to note the condition of the shell before deciding on shell color. Otherwise, an old-hard-shelled red crab might be classified as a green crab.

A flat metal rod was inserted from the posterior of the crab into the epimeral line and twisted to lift up the dorsal carapace. The degree of development of the second (internal) carapace was classified as either present (i.e. fully developed) or absent or transitional (i.e. developing).

Mouthparts were taken from the first 24 hard-shelled males examined from each bottom trawl set. In addition, the mouthparts were examined from all green crabs and all crabs with a second carapace. "Squishy" and soft-shelled crabs were not examined since they obviously would not show signs of imminent molting. For trap catches, mostly transitional males were selected (24 per set) for mouthpart staging. The basal endite of the maxilla was clipped off, placed on a slide in a drop of chilled sea water, and examined under 25X or 40X magnification. Representative specimens were photographed to document our characterization of mouthpart stages. Mouthparts were characterized as either in stage C (intermolt), D_0 (early premolt), D_1 or D_{3-4}. The D_1 stage was subdivided into D_1', D_1'', and D_1''' (Moriyasu and Mallet 1986). We pooled stages C and D_0 because we can't reliably distinguish them.

Significance of associations was tested using Spearman's rank order correlation coefficient (r_s). Significance was determined at the 0.05 probability level.

Results

Catch Composition by Gear Type

New-hard-shelled crabs represented the most prominent component of both trawl catches and trap catches (Table 1). The greatest difference in shell condition between gear types was that the bottom trawl catches included very recently molted (i.e. squishy) crabs, which were not represented at all in trap catches. This suggests that newly molted crabs either don't eat or are not capable of entering traps.

The catch composition of the bottom trawl differed markedly from that of the traps with respect to color and second carapace condition (Tables 2 and 3). The bottom trawl regularly collected green crabs (11% of catches, Table 2) which were rarely captured by traps (0.04% of catches, Table 3). In contrast, traps regularly collected crabs with transitional second carapaces in May (29.4%, Table 3), which were rarely collected by bottom trawl in April (0.2%, Table 2).

Association Between Color and Second Carapace Condition

In April the green color was strongly associated with the presence of a well-developed second carapace while, conversely, red color was strongly associated with either the lack of a well-developed second carapace $r_s = 0.94$, $p < 0.0001$) or (rarely) the presence of a developing or transitional second carapace (Table 2). These results were evident in the observations from both readers. However, the association was stronger in the observations by reader #1 than in those by reader #2.

When the second carapace was absent or transitional, the reader almost always assigned the crab the red color. Reader #1 assigned the color red 100% of the time while reader #2 assigned the color red 99.58% of the time when the internal carapace was absent or transitional. In contrast, when the second carapace was present, the readers sometimes failed to assign the green color. Reader #1 assigned the green color 95.89% of the time and reader #2 assigned it 90.57% of the time, when the second carapace was present.

The very few (5) trap-caught crabs with second carapaces were not consistently identified by color as imminent molters; only 2 were assigned the green color. This suggests that they were not as well advanced in the molt cycle as were those captured earlier by bottom trawl and that the green color is only reliably evident soon before molting. All trap-caught males with transitional second carapaces were red (Table 3).

Association of Color and Second Carapace Condition with Mouthpart Stages

Both correlations, of color and of second carapace condition, with mouthpart stage were highly significant (r_s = -0.75 for each, $P < 0.0001$). Virtually all (98.5%) of the 134 bottom-trawled crabs with second carapaces were in active premolt stages D_1' or greater (Table 4), indicating that they were clearly committed to molting. Almost all (99.6%) of the red crabs with no second carapace were in intermolt stage C or early premolt D_0. Ten of 12 bottom-trawled crabs and a single trap-caught crab, with a well-developed second carapace but red color, were in molt stages D_1' and greater. This supports our belief that imminently molting males do not acquire the green color until soon before the molt.

The trap-caught males with red color and transitional second carapaces were, with a single exception, in molt stages C or D_0 (Table 4). This suggests to us that development of the internal carapace is detectable before changes in shell color or mouthparts are observed.

Discussion

The visual identification of imminent molters, by green color, offers a very quick and non-destructive method of identifying crabs about to molt. The reliability of this method is seen in the very close association of the green color to both a well-developed second carapace and advanced mouthpart stages. The objectivity of the method is highlighted by the high performance of two readers in identifying imminent molters by color in their first trial.

The usefulness of the green color as an indicator of molting is potentially limited in that the duration of the period during which crabs have the green color (and well-developed second carapaces) is unknown. The earliest mouthpart stage of crabs with both green color and a second carapace was premolt D_1'. Crabs in this molt stage molt in a little more than 6-9 weeks according to O'Halloran and O'Dor (1988). Conceivably then, some males showing neither the green color, nor a second carapace, nor active premolt mouthpart stages (i.e. D_1' and later) could subsequently acquire these characteristics and then molt in as little as 6 weeks.

Most green crabs with a second carapace (55%) were in premolt stage D_1'', and some of those may molt within 6-9 weeks (O'Halloran and O'Dor 1988). This means that it is now possible to visually identify and select crabs which can be maintained for very brief growth studies in the laboratory.

Green, imminently molting, crabs have so far only been observed in bottom trawl catches. Their absence from our trap catches is consistent with the observation that crabs stop eating (and so would not be attracted to traps) when they reach molt stage D_1' (O'Halloran and O'Dor 1988). Unfortunately bottom trawls, specifically the one we use, do not appear to be as efficient as baited pots for capturing commercial-sized crabs (Hoenig and Dawe 1991).

Baited traps were, however, obviously suitable for sampling crabs which were not yet green but had a developing (transitional) second carapace. Recognition of transitional males offers the capability to identify more of those males within samples which will subsequently molt. It is not yet known when transitional males will molt, but according to O'Halloran and O'Dor (1988) some of those in molt stage D_0 may molt in as little as 2-3 months.

We consider the identification of the earliest premolt stage (D_0), based on mouthparts, to be subjective and unreliable. Alternatively, recognition of the transitional second carapace, although destructive, offers a method of identifying future molters across a broad size range and at a very early stage in the molt cycle. We hypothesize that development of the internal carapace is a gradual process and that this development reaches an advanced stage before mouthparts reflect imminent molting. However seasonal studies of second carapace formation are necessary to confirm the validity of the transitional carapace condition as a molting indicator.

Acknowledgments

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Table 1. Descriptions of shell conditions referred to in the text and the number of specimens caught by shell condition and sampling gear.

Shell condition	Description	Number caught	
		Bottom trawl (Apr.)	Traps (May)
Squishy	Carapace and chelae so soft as to not yet be brittle.	56	0
Soft	Chelae easily bent or shattered with thumb pressure and irridescent on outer edge. Shell without epibionts and brightly colored.	118	1822
New-hard	Chelae not easily bent by thumb pressure but irridescent on outer edge. Shell usually with epibionts but brightly colored.	1402	3005
Old-hard	Shell not brightly colored and chelae not irridescent on outer edge. Leg joints may be dark or soft from decay.	284	1600
TOTAL		**1860**	**6427**

Table 2. Characterization of hard-shelled male snow crabs by color and second carapace condition for all males captured by bottom trawl in April.

Color	Second carapace condition: Present	Absent	Transitional	Total
Reader #1				
Red	3	717	0	720
Green	70	0	0	70
Total	73	717	0	790
Reader #2				
Red	10	711	3	724
Green	96	3	0	99
Total	106	714	3	823
Overall total	**179**	**1431**	**3**	**1613**

Table 3. Characterization of hard-shelled male snow crabs by color and second carapace condition, for all males captured by traps in May.

Color	Second carapace condition: Present	Absent	Transitional	Total
Red	3	3243	1352	4598
Green	2	0	0	2
Total	**5**	**3253**	**1352**	**4600**

Table 4. Characterization of hard-shelled male snow crabs by color, second carapace condition, and mouthpart stage, for samples collected by bottom trawl in April (top) and by traps in May (bottom).

Month / sampling gear		Number with mouthpart stage						Carapace width (mm)	
Color	Second carapace	C/D_0	D_1'	D_1''	D_1'''	D_{3-4}	Total	Mean	Range
April / bottom trawl									
Red	Present	2	7	1	2	0	12	53.8	44-74
Red	Absent	714	3	0	0	0	717	68.5	21-102
Red	Transitional	1	2	0	0	0	3	53.3	46-60
Green	Present	0	47	67	4	4	122	60.7	28-95
Green	Absent	1	0	0	0	0	1	84.0	-
TOTAL		718	59	68	6	4	855		
May / traps									
Red	Present	0	1	0	0	0	1	86.7	-
Red	Absent	5	0	0	0	0	5	81.0	50-122
Red	Transitional	148	1	0	0	0	149	86.5	55-125
TOTAL		153	2	0	0	0	155		