Effect of starvation on the survival, injury and weight of adult snow crab, *Chionoecetes opilio*

Sten Ivar Siikavuopio, Gunhild Seljehaug Johansson, Philip James, and Grete Lorentzen

Nofima, Tromsø, Norway

*Corresponding author: Sten Ivar Siikavuopio, Muninbakken 9-13, Breivika, Tromsø, Norway Tel.: +47 77629000; fax: +47 77629100. E-mail address: sten.siikavuopio@nofima.no

Keywords: Snow crab, *Chionoecetes opilio,* feeding, starvation, social interaction, animal welfare

Abstract

In this study, the effects of feeding (F) and starvation (S) on survival, injury and weight of captive male snow crab were examined. The experiment was carried out with three replicates of each treatment. Each replicate had 11 individually tagged crabs (average weight of 650 g ± 37 S.E) per tank (replicate) in a total of 6 circular tanks (500 L), with stocking densities of 14 kg m^{-3}. The experiment ran for 100 days and the animals were exposed to ambient seawater temperatures ranging from 4.4 to 5.4ºC during the trial period. There were no significant differences in wet weight between the groups at the start or at the end of the experiment. However, the hepatopancreas index (HI) significantly decreased in both groups from 6.1% at the start to respectively 4.6 % (F) and 3.2 % (S) at day 100. The S group had a significantly lower HI than the F group. Only one animal died during the experiment (day 100, F). The frequencies of injuries were similar in all groups. The results show that adult male snow crab can be stored for minimum 100 days (with or without feeding) with relatively low risk of physical injury, or mortality due to social interactions.

Introduction

The snow crab (*Chionoecetes opilio*) is an abundant and commercially important species in the Bering Sea, along the East coast of Canada and the West coast of Greenland (Lorentzen, Voldnes, Whitaker, Kvalvik, Vang, Gjerp Solstad, Thomassen & Siikavuopio 2018). The snow crab was first observed in the Barents Sea in 1996 (Kuzmin, Akhtarin & Menins 1999). However, the time and mode of colonization in the Barents Sea is unknown (Kuzmin et al., 1999; Pavlov & Sundet 2011). Commercial fishing for snow crab in the Barents Sea only started in the last few years but the fishery is rapidly growing (Dvoretsky & Dvoretsky 2015; Lorentzen et al. 2018), and is now permanently established in Norway. In 2016, the export of frozen clusters of snow crabs reached 3.952 tons, at a value of NOK 331 million (Lorentzen et al. 2018). After capture, the snow crab is either processed immediately or kept alive for periods ranging from 1 to 8 weeks (Siikavuopio, James, Olsen, Evensen, Mortensen & Olsen 2017) for subsequent live export. The live storage process includes both storage in water tanks and subsequent dry transport in polystyrene boxes to the destination market. This method enables the industry to control the time of processing and/or transport of live crabs. The further development of this live storage industry will rely on a reliable and consistent supply of crabs. Once this has been secured, storage and transport of crabs in good conditions to overseas markets is the next step (Lorentzen et al., 2018). In Norway, this is referred to as capture based aquaculture (CBA). CBA of snow crab is developing in Norway and effort has been put into establishing small- and medium sized enterprises using intensive holding systems for live holding of snow crabs (Siikavuopio et al. 2017; Lorentzen et al. 2018). Mortality rates during live storage depends on several biotic – and abiotic variables. The snow crab is more sensitive to high temperature and high stocking density under live storage compared to red king crab (Hardy, et al. 1994; Hardy, et al. 2000, James, et al. 2013; Siikavuopio, et al. 2014; Siikavuopio et al. 2017). Reducing the mortality of snow crab during capture and whilst it is being held in live storage is important for both economic and the welfare of the animal (Stoner 2012). Currently 99% of snow crab in Norway are processed as cooked and frozen clusters on board or on land based processing plants, while only 1% are exported live

(Lorentzen et al. 2018). The reason for the low live export is because the fishing boats are set up for capture and processing offshore. However, export of live snow crab is a more lucrative option as the price per kilo is about four times higher than that of clusters (Lorentzen et al. 2018). In addition, it is more favorable to be paid per kilo for the entire animal, rather than just the clusters, as by-products represent about 30% of the total snow crab weight (Lorentzen et al. 2018). The authors believe that due to a higher price for live crabs, the proportion of live snow crab exports will increase significantly. This was observed in the red king crab fisheries in Norway (Siikavuopio et al. 2014; Loretnzen et al. 2018), this will rely on improved live holding methods and protocols being available for snow crabs. This is currently lacking for the snow crab industry (Dutil, Munro & Peloquin 1997; Siikavuopio & James, 2015; Siikavuopio *et al*. 2017). Thus, there is a need to develop and improve techniques for both short-term (vessel) and long-term (land) storage. In the case of red king crab, it has been demonstrated that increasing temperature and stocking densities increase the risk of cannibalism, mortality and injuries (Siikavuopio & James, 2015; Siikavuopio et al., 2014). In Norway, the red king crab and snow crab are currently starved during periods of live storage. For many species of crustacean starvation can lead to cannibalism and increased aggressiveness which in turn can cause poor animal welfare and reduced quality (Wickins & Lee 2002).

This study was therefore undertaken in order to describe the effects of feeding (F) and starvation (S) on survival, injuries and weight changes of wild caught male snow crab held in captivity for 100 days post capture.

Materials and methods

Experimental set up

Mature male snow crabs (*C. opilio)* were caught by the vessel Northeastern (Opilio AS) on 10 January 2017, using traditional snow crab pots in the NEAFC area (74.58 latitude and 38.49 longitude). The crabs were transported to the Aquaculture Research Station in Tromsø, Norway (~70°N), and placed in one 6 m^{-3} tank supplied with running seawater (~ 3.0°C, salinity ~ 32‰). The animal were not fed until the start of the experiment. At the start of the experiment, 60 crabs were individually measured and inspected for injuries before being randomly distributed into 6 circular tanks (500 L, 3 replicates) at a density of 17 kg m^{-3}. The crabs were individually tagged with FT-69 tag (Floy-tag) glued to the carapace. The experiment was conducted from 20 January 2017 to 13 May 2017 (100 days). Each tank was supplied with filtered seawater (filtered to a nominal 150µm through a sand filter, UV-treated and with a salinity of 34 ‰) at a rate of 4 l min^{-1} kg^{-1}. All tanks were supplied with constant seawater with ambient temperature ranging from 4.4 to 5.4ºC during the trial period. Water temperatures were recorded every day. Oxygen levels were measured with a Handy Delta logger (OxyGuard; OxyGard, International A/S, Blokken, Denmark) and were above 95% saturation in all tanks throughout the experiment. The crabs in the F group were fed *ad libitum* with squid twice a week for a period of 3 hours. Uneaten feed was siphoned and sieved from the tanks. Feed intake was calculated as the difference between the wet weight of the feed delivered and uneaten feed collected (g feed $animal^{-1}$ $week^{-1}$). Specific growth rate (SGR) was calculated according to the equation: $SGR = ((\ln W_2 - \ln W_1)\ (t_2 - t_1)^{-1}) *100$, where W_2 and W_1 is the living weight (kg) of the crab at day t_2 (day 100) and t_1 (day 0) day respectively. Hepatopancreas index (HI) was calculated according to the equation: $HI = (H / W) * 100$, where H is the weight of hepatopancreas and W are the live weight of the crab. Presence and type of injury or missing legs were observed at day 0, 30, 60 and 100 during inspection and from images of individual crabs taken at these respective dates for subsequent analysis. A scoring system was established to assess crab injury from the images.

Injury assessment

To measure the injury status of F and S snow crab, a quantitative scoring system was established (Table 1). This scoring system was developed with 4 criteria of crab injuries (See Table 1 for details).

To assess if there were a relationship between injuries and crab anatomy each registered observation was sorted anatomically (Figure 1). The crab anatomy were divided in left and right and each limb and limb segment given a number for easier registration of injuries. An overview of the different damages/injuries present on the crab images from day 0 were used as a reference for the scoring system. All limbs were included in the scoring scheme. "Old" injuries were easily distinguishable with black spots of melanosis. New injuries were harder to observe in the images due to lack of black color, but easier when examining the live crab. Thus, pinching- and undefined injuries were not graded but counted. Figure 2 shows examples of injuries registered in the various criteria.

Statistical treatment

Statistical analyses were performed using SYSTAT v. 12 (Systat Software, Inc., USA). Possible differences between S and F groups in weight, SGR and HI, were analysed using ANOVA with distribution of data compared to normal distribution using Shapiro–Wilk test, and homogeneity checked using Levene's test (Zar 1996). The chi square test were used to compare injury between the S and F group. Significance was assumed when $P < 0.05$. Data are presented as mean ± standard error (SE).

Results

Weight, feed intake and specific growth rate (SGR)

In the current experiment, the average initial wet weight of the snow crab was 649 g (F) (± 38) and 651g (S) (± 39) respectively. The average wet weight at the end of the experiment had increased to 670 g (± 39) (F) and to 653 g (S) (± 40) (P=0.859) (Fig 3). The average feed intake (g feed animal^{-1} week^{-1}) was 7.03 g (± 0.49). There were no significant differences in weight between the groups at the start or at the end of the experiment (Fig 3.). The mean SGR of the F group was 0.03 (0.03) and S group was 0.01(0.006), but there were no significant differences between the groups (P = 0.492).

Hepatopancreas index (HI)

At the start of the experiment, the HI was 6.1 (0.03). At the end the average had significantly decreased in the two groups to 4.6 (0.15) and 3.2 (0.05) respectively. The S group had a significantly lower HI than the F group (P=0.001). Dark spots, i.e. melanosis, were observed on the crabs during the storage period in both groups.

Mortality and frequency of injury

Only one animal died during the experiment (day 100, F). The frequencies of injuries were similar in all groups (Table 2), with a total of 9 (F) and 8 (S).

The most common observation were loss of pereiopods (walking legs) either the whole limb or the merus, carpus, manus or dactyl (limb segments). Loss of limbs were seen in the shoulder joint, between the basis and the ischium.

The position of injuries to the crab limbs at day 0 showed a significantly (Chi square, P<0.05) higher number of injuries at *merus* than any of the other leg segments (Figure 4).

Results from scoring of injuries during trial revealed no visible difference between the starved or the fed crabs. The crabs in the F group started out with 16.7 % having lost cheliped or pereiopods, 23.3 % had lost dactyl tips and 10 % had lost limb segments before arriving to the research station (Table 3). The S crabs had 30 % having loss of limbs, 20 % lost dactyl tips and 23.3 % had lost limb segments. No crab lost their cheliped either before or during trial.

Discussion

The live export of snow crab is a new industry in Norway and it will rely on a consistent supply of wild caught crabs, held in land-based facilities for periods varying from a few days to months (Lorentzen, Rotabakk, Olsen, Skueland & Siikavuopio 2015, Lorentzen *et al.*, 2018). During this period, they will need to survive and maintain their quality at an acceptable level for both discerning export markets as well as to meet the stringent animal welfare standards in Norway.

Godbout et al. (2002) reported that snow crabs were able to survive long periods of food deprivation with low rates of mortality and no marked effects on body condition at low temperatures. Our study supports these results, with the loss of only one crab during the experimental period. Godbout et al. (2002) also reported that an overall improvement of nutritional condition occurred and the meat yield increased markedly in snow crabs held and fed in land-based facilities. However, in our study, there were no significant differences in wet weight of the crab between the F and S group at the end of the experiment.

In crustaceans, the hepatopancreas is generally regarded as a major lipid storage organ and during starvation, body fat especially from the hepatopancreas is metabolized (Wen Ku, Zhou 2006). This was the case in our study, where the hepatopancreas index was significant lower in the S group compared to the F group. It is worth noting that in the F group the hepatopancreas index was also significantly lower compared with the start value. A feed regime of squid fed twice per week for a period of 3 hours appears to be too low to maintain the hepatopancreas index of snow crab held in land-based facilities. The fact that there is difference in HI between F and S would indicate that F group were at least partially fed. However, the F treatment did have a lower HI at the conclusion of the experiment than the initial HI which would indicate that further work is required to describe optimal feed regimes for captive snow crab.

The hepatopancreas is major lipid storage organ and squid muscle has relatively low lipid level, which may also explain the reduction in HI in our study (Wen *et al.*2006).

There is a limited amount of information available on the impact of starvation in snow crab related to physiological and biochemical changes. Mayrand et al., 2000 showed that 60-day period of food deprivation resulted in a reduction of muscle mass, DNA content, and enzyme activity in the merus muscle, and a reduction in size of the digestive gland, while gonad weight increased in male adult snow crab following terminal moult. Hardy et al., (2000), illustrated that water content of merus muscle increased markedly over time, while protein and lipid content decreased over time. This should also be taken in mind evaluating the possible quality changes related to starvation and different feeding regimes of the snow crab. This was not included in the current study.

Both hunger and restriction in food availability can trigger aggression in animals held in land-based holding systems over time. The current study indicates snow crabs have the ability to endure long periods without feeding and during this time will show low territorial and/or aggressive behavior. This explains why we don't observe cannibalism and damage as a consequence of 100 days of starvation. There are relatively few studies focusing on possible negative social interaction of adult snow crab related to live holding conditions (e.g. stocking density and temperature) (Siikavuopio et al., 2017).

In this study, the crabs started with 17 % having lost cheliped or pereiopods, 23 % had lost dactyl tips and 10 % had lost limb segments. These losses may be due to autotomy of the leg after a claw bite to the affected leg. Autotomy is well documented in other crustacean as a means of avoiding predation or limiting the effects of wounds (Jaunes & Smith 1995; Siikavuopio et al., 2017). The crab injury status was reasonably good at the beginning of the experiment and did not change considerably during the 100 days experimental period. Statistical analysis of pinching injury location was significantly higher in the leg segment merus. Most of these injuries was on the left side of the crab. The origin of these injuries can be related to events occurred before the catch or as a result of the capture and transport of the crab. The authors are unsure what the cause of the injuries incurred prior to the experiment were, nor why there is differences between left and right side of the crab. More research is needed to evaluate how these injuries occur. Occasionally, dark spots, i.e. melanosis were observed on the crabs during the storage period. This observation is most probably due to a chemical defense mechanism, activated as part of a damage repair response (Vazquez, et al., 2009). The effector mechanisms include a coagulation cascade to avoid the loss of hemolymph and stimulation of the production of melanin by activating prophenoloxidase (Vargas-Albores & Yepis-Plascencia, 2000). It has been shown that for crustacean held in captivity cannibalism and increased aggressive behavior is also expected to occur more frequently as size heterogeneity increases (Dutil, et al., 1997). In the current study all crabs were in the same size group, and had the space available to sit in a single layer at the bottom of the tank. This may explain the low levels of aggressive behavior mortality in this experiments. Although, the crabs had the space available to be in a single layer at the bottom of the holding tanks in the current experiment, observations during the experimental period showed they chose to crowd together in stacks in small areas of the tank. This is a similar 'crowding' behavior to the red king crab (Siikavuopio et al., 2017). This supports the theory that the snow crab have low levels of territorial aggressiveness.

The current study has shown that adult (commercial size) snow crab can be held at 3ºC for a minimum 100 days, either being feed or starved, without significant risk of injury or death. The current experiment showed that the total wet weight of the crabs prior to and after the experiment were equal. However, the size of the hepatopancreas decreased, indicating that the crab are utilizing this organ during periods of starvation. More study is required, on possible changes in the meat quality as a result of these changes in metabolism. This may have a significant impact on the quality of the crab flesh and subsequently the value of the product.

Acknowledgements

This project has been financed by the Norwegian Seafood Research Fund (FHF, Project no. 901254), NFR and Norwegian Research Council (SnowMap, project no. 267763) and Nofima. The authors would like to thank the Research station in Kårvika for their assistance throughout this experiment.

References

Dutil J. D. Munro J. & Peloquin M. (1997). Laboratory study of the influence of prey size on vulnerability to cannibalism in snow crab (*Chionoecetes opilio* O. Fabricius, 1780). *Journal of Experimental Marine Biology and Ecology*, 212(1), 81-94.

Dvoretsky A.G. & Dvoretsky V.G. (2015). Commercial fish and shellfish in the Barents Sea: Have introduced crab species affected the population trajectories of commercial fish. *Reviews Fish Biology and Fisheries,* 25*,* 297–322.

Godbout G. Dutil J.D. Hardy D. & Munro J. (2002). Growth and condition of post-moult male snow crab (*Chionoecetes opilio*) in the laboratory. *Aquaculture*, 206(3), 323-340.

Hardy D. Munro J. & Dutil J.D. (1994). Temperature and salinity tolerance of the soft-shell and hard-shell male snow crab, *Chionoecetes opilio*. *Aquaculture*, 122(2), 249-265.

Hardy D. Dutil J.D. Godbout G. Munro J. (2000). Survival and condition of hard shell male adult snow crabs (*Chionoecetes opilio*) during fasting at different temperatures. *Aquaculture*, **189**, 259-275.

James P. Vasilyev R. Siikavuopio S. I. Kovatcheva N. & Samuelsen T.A. (2013). The effects of varying the percentage of herring versus salmon protein in manufactured diets on the survival, meat content, hepatosomatic index and meat sensory quality of adult red king crab *Paralithodes camtschaticus* held in captivity. *Aquaculture*, 416–417, 390-395.

Jaunes F. & Smith D. (1995). The ecological consequences of limb damage and loss in decapod crustaceans: a review and prospectus. *Journal of Experimental Marine Biology and Ecology*, 193, 197-223.

Kuzmin S.A. Akhtarin S.M. & Menins D.T. (1999). The first finding of snow crab *Chionoecetes opilio* (Fabricius), in the Barents Sea. *Canadian translation of Fisheries and Aquatic Science*, No. 5667. 5 pp

Lorentzen G. Rotabakk B.T. Olsen S.H., Skueland A.V. & Siikavuopio S.I. (2015). Shelf life of snow crab clusters (*Chioneocetes opilio*) stored at 0 and 4 °C. *Food Control*, 59, 454-460.

Lorentzen G. Voldnes, G. Whitaker R.D. Kvalvik I. Vang B. Gjerp Solstad R. & Siikavuopio S.I (2018). Current status of the Red King Crab (*Paralithodes camtchaticus*) and Snow Crab (*Chioneoecetes opilio*) industries in Norway. *Reviews in Fisheries Science and Aquaculture,* 26(1), 42–54.

Mayrand E. Dutil J.D. & Guderley H. (2000). Changes in muscle of postmoult snow crabs *Chionoecetes opilio* (O. Fabricius) fed different rations. *Journal of Experimental Marine Biology and Ecology*, 243, 95–113.

Pavlov V.A. & Sundet J.H. (2011). Snow crab. The Barents Sea, ecosystem, resources, management. *Tapir academic press*, 168-17.

Siikavuopio S.I. James P. Olsen B.R. Evensen T. & Mortensen A. (2014). Holding wild caught red king crab *Paralithodes camtschatica:* effects of stocking density and feeding on survival and meat content. *Aquaculture Research*, 47, 870–874.

Siikavuopio S.I. & James P. (2015). Effects of feed intake, growth and oxygen consumption in adult male king crab *Paralithodes camtschatica* held in captivity and fed manufactured diets. *Aquaculture Research*, 46(3), 602–608.

Siikavuopio S.I. James P. Olsen B.R. Evensen, T. Mortensen A. & Olsen S.H. (2017). Holding wild Snow crab, *Chionoecetes opilio*: effects of stocking density and feeding on survival and injury. *Aquaculture Research*, **4**8, 1590-1595.

Stoner A.W. (2012). Assessing stress and predicating mortality in economically significant crustaceans. *Reviews in Fisheries Science*, 20(3), 111-135.

Vargas-Albores F. & Yepiz-Plascencia G. (2000). Beta glucan binding protein (BGBP) and its role in immune response. *Aquaculture*, 191, 13–21.

Vazquez L. Alpuche J. Maldonado G. Agundis C. Pereyra-Morales A. & Zenteno A. (2009). Immunity mechanisms in crustaceans. *Innate Immunity*, 15(3), 179-188.

Wen X. Chen L. Ku Y. & Zhou K. (2006). Effect of feeding and lack of food on the growth, gross biochemical and fatty acid composition of juvenile crab, *Eriocheir sinensis. Aquaculture*, 252, 598– 607.

Wickins J.F. & Lee O'C. (2002). Crustacean farming. *Blackwell Science Ltd*., Oxford, UK. 446 pp.

Zar J.H. (1996). Biostatistical Analysis. 3rd ed. Prentice-Hall, Englewood Cliffs, NJ, 662 pp

Table 1. Scoring system for crab injuries: Criteria 1 is based on loss of limbs, criteria 2 on the loss of limb tips, criteria 3 on the loss of carpuses, manuses or dactyls of the limbs, and criteria 4 on the number of damage originating from pinching and or other undefined injuries on the extremities.

Criteria 1 - Loss of limbs		
Score	Change	Appearance
1	No	All limb are intact
2	Mild	Possible beginning loss of limbs
3	Distinct	Leg/claw half way lost
4	Severe	Complete loss of leg/claw
Criteria 2 - Loss of limb tips		
Score	Change	Appearance
1	No	Tips are intact
2	Mild	Possible beginning loss of tip
3	Distinct	Tip half way lost
4	Severe	Complete loss of tip
Criteria 3 - Loss of limbs carpuses, manuses or dactyls		
Score	Change	Appearance
1	No	All limbs is intact
2	Mild	Possible beginning loss of limb segments. Seen as rift in joints between carpus, manus or dactyl
3	Distinct	Joint between limb sections half way lost
4	Severe	Complete loss of carpus, manus or dactyl
Criteria 4 - Pinching or undefined injuries		
Count	Pinching of cheliped or pereipods. Seen as cracks in the exoskeleton transvers of the limb	
Count	Undefined injury. Seen as cracks in the exoskeleton of limbs	

Table 2. Total number of injuries during trial for feed or starved adult male snow crab.

Day	**0**	**30**	**60**	**100**
Fed	83	0	5	4
Starved	79	1	2	5

Table 3. Results from scoring of snow crab limbs (%) and the number caused by aggressive behavior between crabs (pinching) and undefined injuries. Injuries are related to category; No, Mild, Distinct, and Severe, see table 1 for more information.

	Group	Fed				Starved			
	Day	**0**	**30**	**60**	**100**	**0**	**30**	**60**	**100**
Loss of legs	**No**	97,3	97,3	96,9	96,1	94,3	94,0	93,7	93,3
	Mild	1,0	0,0	0,0	0,0	2,0	0,0	0,0	0,0
	Distinct	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Severe	1,7	0,0	0,3	0,7	3,7	0,3	0,3	0,3
	Injured crabs	16,7	0,0	3,4	7,1	30,0	3,3	3,3	3,3
	Whole crabs	83,3	83,3	79,3	71,4	70,0	66,7	63,3	60,0
Loss of dactyl tips	**No**	94,3	94,3	93,4	93,2	96,0	96,0	96,0	95,3
	Mild	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Distinct	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Severe	5,7	0,0	0,7	0,0	4,0	0,0	0,0	0,7
	Injured crabs	23,3	0,0	6,9	0,0	20,0	0,0	0,0	3,3
	Whole crabs	76,7	76,7	69,0	67,9	80,0	80,0	80,0	76,7
Loss of limb segments	**No**	99,7	99,7	99,7	99,6	99,5	99,5	99,5	99,5
	Mild	0,2	0,0	0,0	0,0	0,4	0,0	0,0	0,0
	Distinct	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1
	Severe	0,1	0,0	0,1	0,0	0,1	0,0	0,0	0,0
	Injured crabs	10,0	0,0	3,4	0,0	23,3	0,0	0,0	3,3
	Whole crabs	90,0	90,0	86,2	85,7	76,7	76,7	76,7	73,3
Pinching injuries	Amount	19	0	0	0	11	0	1	3
	Injured crabs	11	0	0	3	7	0	1	2
	Unharmed crabs	19	19	18	14	23	23	22	20
Undefined injuries	Amount	35	0	1	0	32	0	0	0
	Injured crabs	6	0	1	0	12	0	0	0
	Unharmed crabs	24	24	22	21	18	18	18	18

Figure 1. Snow crab anatomy. Figure shows top (A) and bottom (B) of the crab left side.

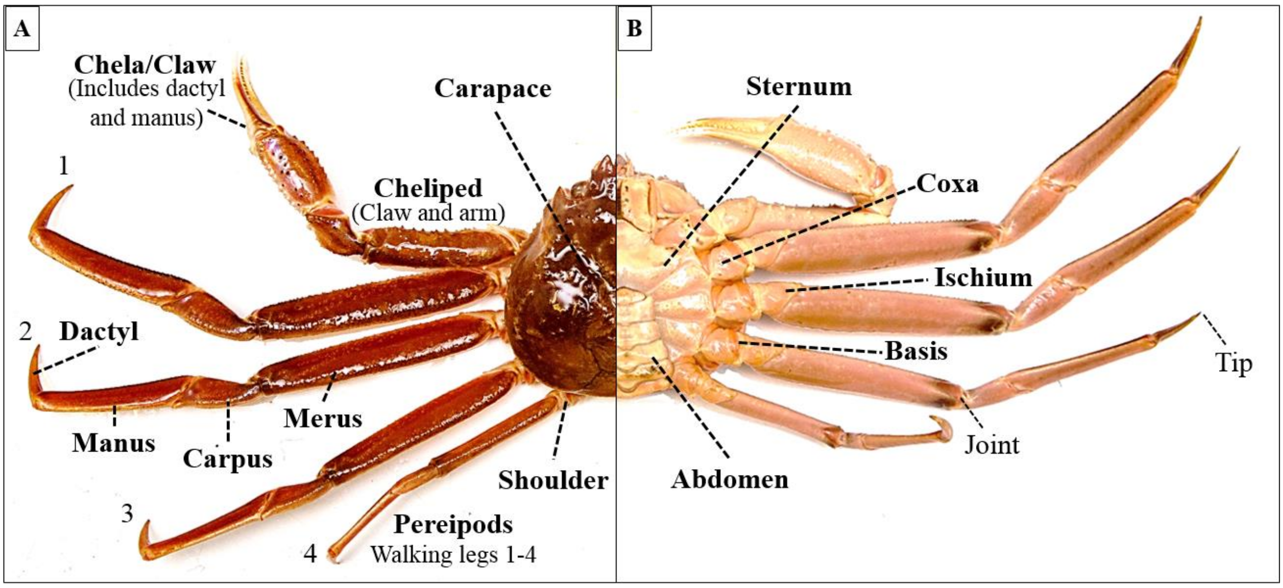

Figure 2. Injury criteria one to four – Loss of limbs, carpuses, manuses, dactyls or tips, pinching injuries and undefined injuries seen in starved or fed Snow crab. (A) Possibly beginning loss of limb at the shoulder joint in pereipod number one and three, score 2 and 1. (B) Complete loss of pereipod number three, score 4. (C) Beginning loss of manus in left pereipod number one, score 3. (D) Complete loss of manus in leg number four, score 4. (E) Intact limb tips, score 1. (F) Tips broken off, score 4. Welfare criteria four – (G + H) Miner pinching injury seen from top (G) and bottom (H) of merus of pereipod number four. (I + J) Two major, assumed to be, pinching injuries on merus and carpus of left pereipod number four, seen from top (I) and bottom (J) of the crab. (K) Injury or damage to the dactyl of right pereipod number three, counted as one in the scoring scheme. (L) Injury to the merus of cheliped.

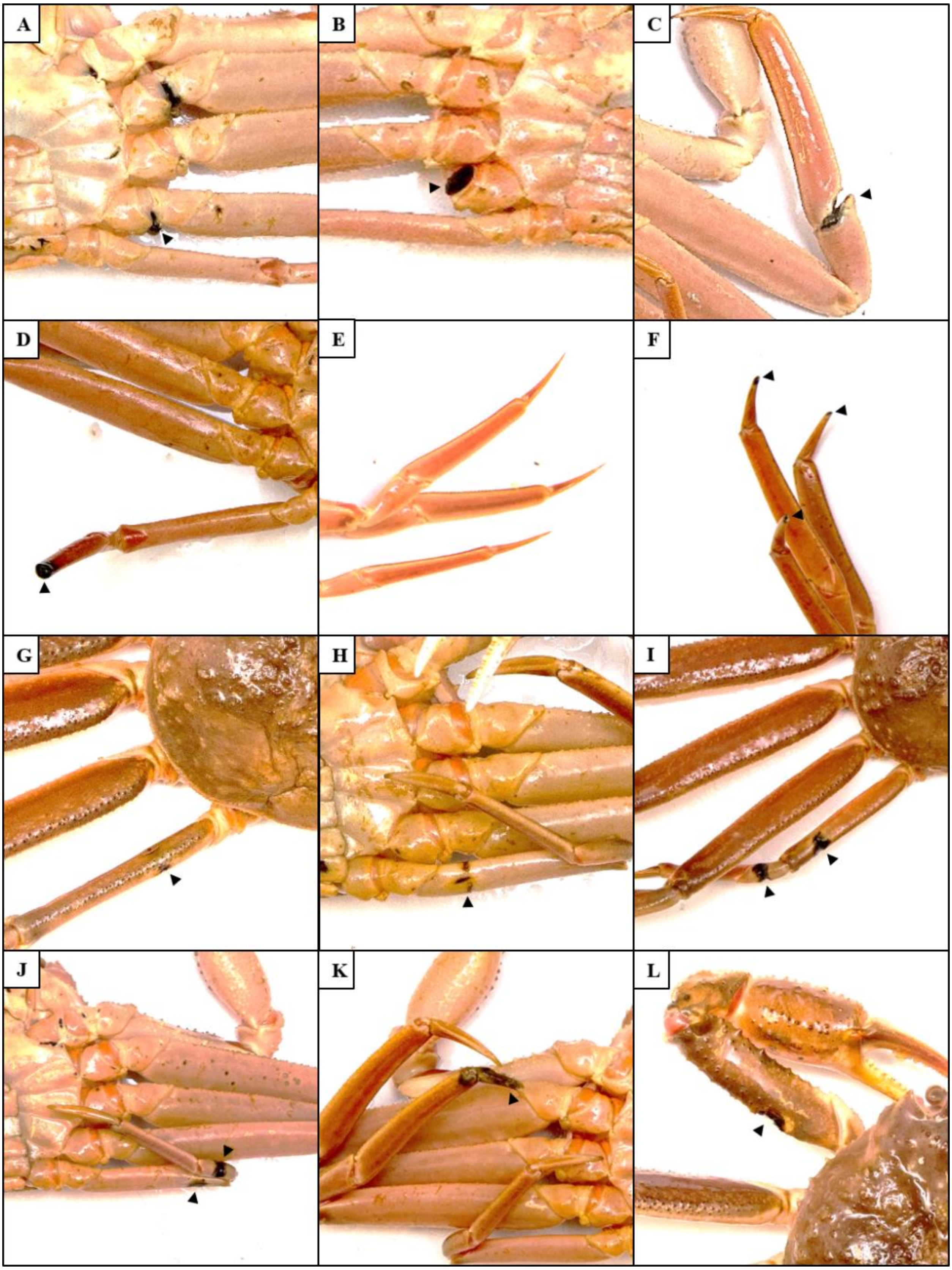
A
B
C
D
E
F
G
H
I
J
K
L

Figure 3. Average wet weight (g) of adult male snow crab in the Fed and Starved treatments at day 0, 30, 60 and 100. Data is presented as mean ± standard error

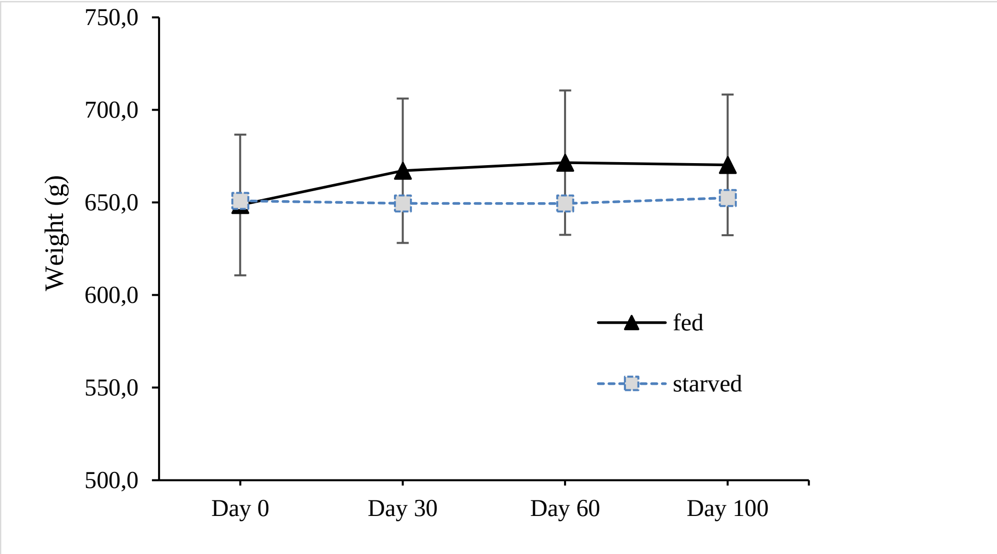

Figure 4. Pinching- and undefined injuries registered at day 0. Registration of injuries shows a higher frequency of on the meruses of the limbs than on the other four limb parts. Limb segments shown as numbers, 1: Shoulder, 2: *Merus*, 3: *Carpus*, 4: *Manus* and 5: *Dactyl*.