

# Scottish Industry Science Partnership Report

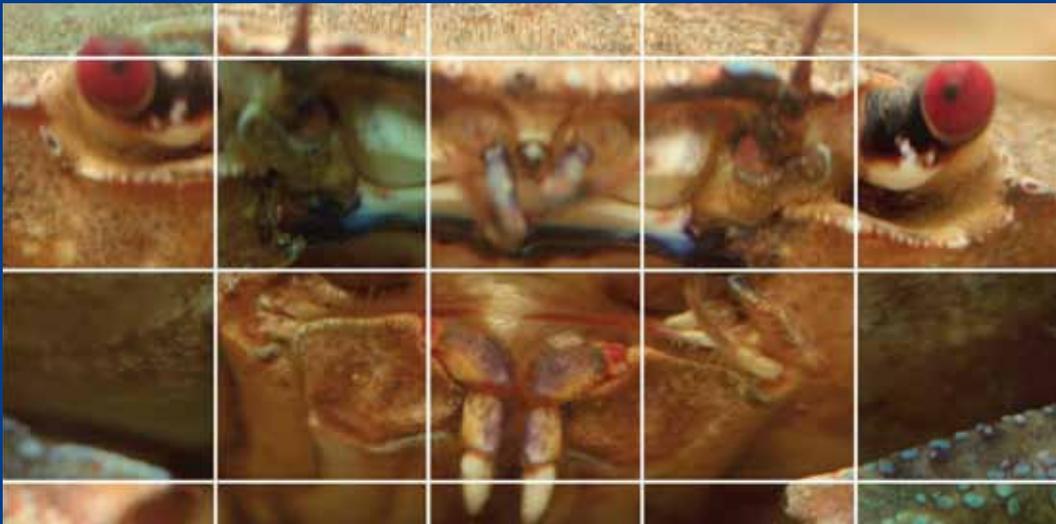


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## Escape gaps for velvet crabs (*Necora puber*); stock and economic benefits for the catching sector

Richard L Shelmerdine and Emma White



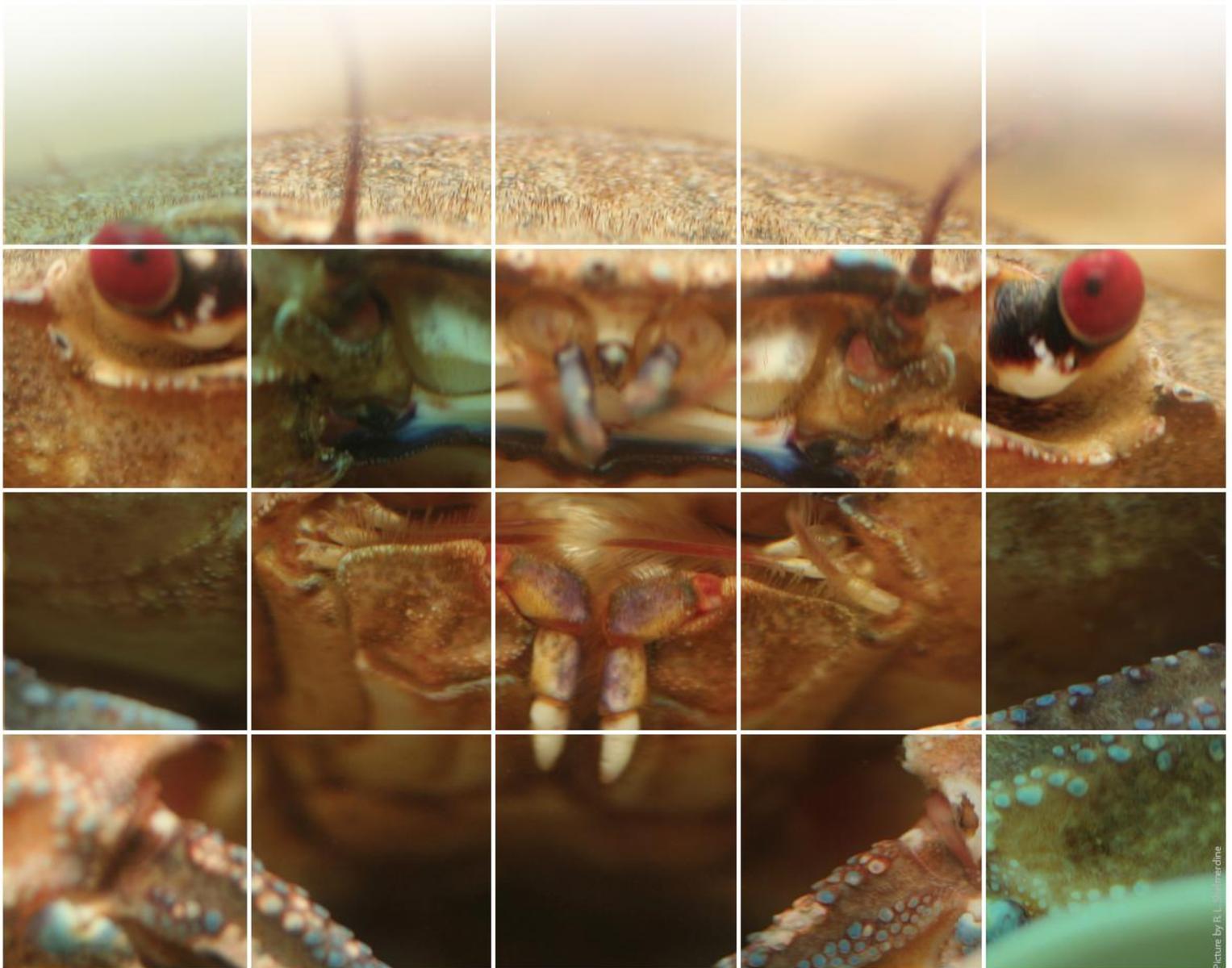
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## 1 Introduction

Velvet swimming crabs (*Necora puber*) are widespread around the British coast, with their range extending around the North Sea, west Africa, and Mediterranean. Locally they are considered both common and abundant inhabiting rocky, stony substrate in relatively shallow water close to shore. They are considered to be an aggressive species for their size with a wide ranging diet.

In Scotland, according to the Scottish Sea Fisheries Statistics, *N. puber*, contribute only 4% of the total shellfish landings (including langoustine, *Nephrops norvegicus*) during 2009 but have the third largest price per weight behind lobsters (*Homarus gammarus*) and *N. norvegicus*. The *N. puber* fishery in Shetland has seen a marked increase in landings from 55 tonnes in 2000 to a peak of 340 tonnes in 2009<sup>1</sup> making this the third largest shellfish fishery, excluding *N. norvegicus*, by weight in the Shetland sector. Since 2000 the Shetland Islands Regulated Fishery (Scotland) Order 1999 has been in place and managed by Shetland Shellfish Management Organisation (SSMO). *Necora puber* is one of the main species covered in the Order which extends out to six nautical miles and stipulates a minimum landing size (MLS) for this species of 70 mm carapace width (the national MLS is currently set at 65 mm). The majority of *N. puber* landed in Shetland are exported live to Europe in vivier trucks.

Although the concept of incorporating a form of escape gap (also known as escape vents, escape rings, or cull rings) into a trap fishery is not a new one, there has been no research conducted to date regarding the velvet swimming crab (*N. puber*) and very little research carried out on crab fisheries in Great Britain. Some species where research has been carried out include; brown crabs (*Cancer pagurus*) (Brown, 1982), other *Cancer* species (Krouse, 1978), blue crabs (*Callinectes sapidus*) (Guillory and Hein, 1998; Guillory, *et al.*, 2004; Havens, *et al.*, 2009; Rudershausen and Turano, 2009), blue swimming crabs (*Portunus plagicus*) (Boutson, *et al.*, 2009), deep water crab species (Salthaug and Furevik, 2004; Tallack, 2007; Winger and Walsh, 2007), mud crabs (*Scylla olivacea*) (Jirapunpipat, *et al.*, 2008), lobsters (*Homarus* species, mainly *H. americanus*) (Stasko, 1975; Krouse, 1978; Nulk, 1978; Pecci, *et al.*, 1978; Fogarty and Borden, 1980; Brown, 1982), rock lobsters (*Jasus* species) (Treble, *et al.*, 1998), and black sea bass (*Centropristis striata*) (Shepherd, *et al.*, 2002). Of these studies only one, Brown (1982), was carried out on a United Kingdom commercial fishery of *C. pagurus* and *H. gammarus*.

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<sup>1</sup> Based on data obtained from the Scottish Sea Fisheries Statistics; an annual publication produced by The Scottish Government.

Many fishers in Scotland, including some in Shetland, have started to voluntarily incorporate escape gaps into their creels primarily with the aim of reducing sorting time of the catch by enabling the undersized animals to escape, as discussed by Brown (1982). A reduction in sorting time would be highly beneficial to the fisher by saving on fuel costs or enabling more gear to be hauled. In addition, escape gaps are thought to be beneficial to the animals themselves by reducing mortalities and appendage loss (especially those of smaller animals) (Pecci, *et al.*, 1978; Brown, 1982; Treble, *et al.*, 1998; Havens, *et al.*, 2009), minimising displacement from their original habitat (Brown, 1982), and reducing growth rates post-handling (Brown and Caputi, 1985). Escape gaps have been used in several trap fisheries as a management tool to reduce undersized animals and bycatch species (Guillory, *et al.*, 2004; Boutson, *et al.*, 2009; Havens, *et al.*, 2009; Rudershausen and Turano, 2009) and have been suggested as a means of minimizing ghost fishing of lost gear (Pecci, *et al.*, 1978).

## 1.1 Aims

The primary aim of the study was to assess the feasibility and workability of installing escape gaps in creels fishing for velvet swimming crabs (*Necora puber*). The study consisted of two stages; 1) determining the height of the escape gap, and 2) sea trials comparing the catch with and without escape gaps. Each stage was designed to answer two key questions:

- What is the optimum height of an escape gap for the Shetland minimum landing size of 70 mm?
- Does the catch from creels fitted with escape gaps differ from those without?

## 2 Materials and Methods

### 2.1 Determining escape gap height

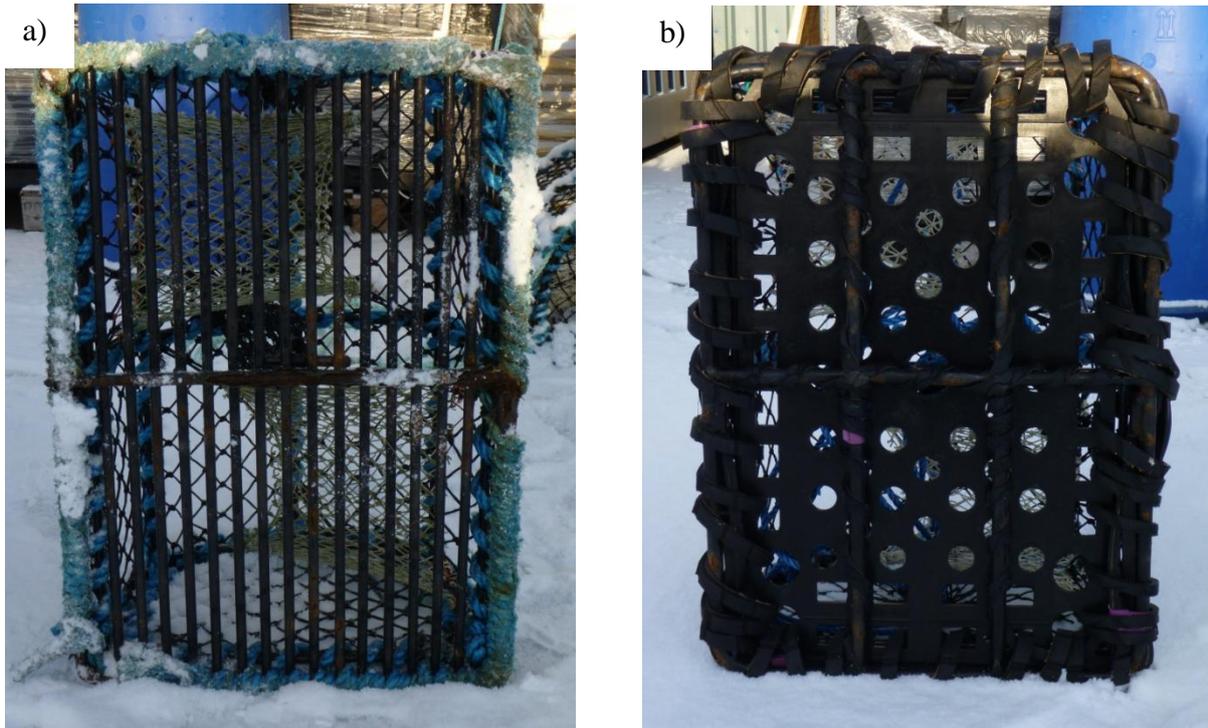
In order to obtain a sample of *Necora puber* for tank experiments, thirty creels were set using the NAFC Marine Centre's boat, *Atlantia II*. From this catch, a sub-sample of 200 crabs (100 male and 100 female), representing the size range of crabs caught, were placed in two separate outdoor tanks, separated by sex, with a continuous flow of filtered sea water. The crabs were left to acclimatize for a month before experimentation started. Daily checks were made on water temperature, dissolved oxygen, mortalities, and cleanliness of the tanks. Fish was offered as food on a regular basis and any remains removed after 24 hours.

In order to give an indication of gap height, carapace width (CW; the distance between the outermost carapace thorns) and carapace height (CH; the largest distance between ventral and dorsal surfaces) were measured from a random selection of crabs in the initial catch. A keep creel was modified, incorporating a rigid but moveable bar in order to alter the height of the gap. Crabs were placed inside the keep creel which was placed on bricks inside the tank to ensure no escaped crabs re-entered the creel. To encourage crabs out of the keep creel, bait was placed around the tank. All escaped and retained crabs were measured and sexed after being left for 24 hours.

In addition, gap heights were selected and a manual test was carried out (as discussed by Stasko, 1975) to see if each crab was able to pass through the gap. Those that were able to pass through were deemed as capable of escaping the creels and were measured and sexed, as above.

### 2.2 Sea trials

Three leaders of 22 creels to a leader were used to test the effectiveness of escape gaps. Each leader consisted of three different types of creels, namely; six creels with escape gaps and bars on the base (referred to here as "escape gap creels", Figure 2.1a), six creels with no escape gaps but bars on the base (referred to here as "normal creels", Figure 2.1a), and six creels with a plastic base (referred to here as "control creels", Figure 2.1b). All creels were 66 cm (26") long and creel type was alternated along the leader. An additional two creels were positioned at each end of the leader but were not sampled. Sea trials were carried out aboard a local commercial fishing boat with the leaders fished alongside the regular gear from the boat. Two Marine Centre staff members sampled the catch aboard the boat. During a sampling trip the contents of each creel type were emptied into one of three baskets and all *N. puber* were measured and sexed. This was repeated for each leader. In addition, anecdotal information was gathered from the fisherman regarding creel processing time and the fisherman's perception on the effectiveness of the escape gaps.



**Figure 2.1** The two creel types used in the experiment viewed from their base; a) normal and escape gap creels with base bars positioned 16 mm apart and b) control creels with a plastic base.

### 2.3 Size-selectivity curves

The SELECT (Share Each Length's Catch Total) model is used to analyse data where two or more types of fishing gear are used at the same time (Millar, 1992; Millar and Walsh, 1992; Millar, 1993; Xu and Millar, 1993; Treble, *et al.*, 1998; Millar and Fryer, 1999); gear of an unknown size-selectivity which is fished alongside gear which acts as a size-selection control (i.e. gear which encompasses the full size range of catch encountering the gear). Such a model is suitable for trawl gear but is also highly useful in analysing data from trap fisheries (see: Xu and Millar, 1993; Treble, *et al.*, 1998; Shepherd, *et al.*, 2002; Groeneveld, *et al.*, 2005).

As with previous studies (Xu and Millar, 1993; Treble, *et al.*, 1998; Groeneveld, *et al.*, 2005), a symmetrical logistic function and an asymmetrical Richards function were incorporated. The logistic size-selectivity function is given by the equation;

$$r(l) = \frac{\exp(a + bl)}{1 + \exp(a + bl)} \quad (2.1)$$

where  $r(l)$  is the probability that an individual of length  $l$  (for the purpose of this study length refers to the carapace width of the crab), attempting to pass through a gap of a given size, is retained within the gear while  $a$  ( $<0$ ) and  $b$  ( $>0$ ) are constants (see Xu and Millar, 1993; Groeneveld, *et al.*, 2005). The equation of the Richards function is given by;

$$r(l) = \left( \frac{\exp(a + bl)}{1 + \exp(a + bl)} \right)^{\frac{1}{\delta}} \quad (2.2)$$

and is a generalization of the logistic function (equation 2.1) where  $\delta$ , a constant, is equal to one. Treble *et al.* (1998) explain that  $\delta$  defines the amount and direction of asymmetry which the size-selection curve will have;  $\delta > 1$  producing a longer tail to the left of  $l_{50}$  (length of 50% retention),  $0 < \delta < 1$  giving a longer tail to the right of  $l_{50}$ . Groeneveld *et al.* (2005) defined  $l_{50}$  and the selection range (SR) as;

$$l_{50} = \frac{\ln \left( \frac{0.5^\delta}{1 - 0.5^\delta} \right) - a}{b}, \text{ simplifying to } l_{50} = - \frac{a}{b} \text{ when } \delta=1 \quad (2.3)$$

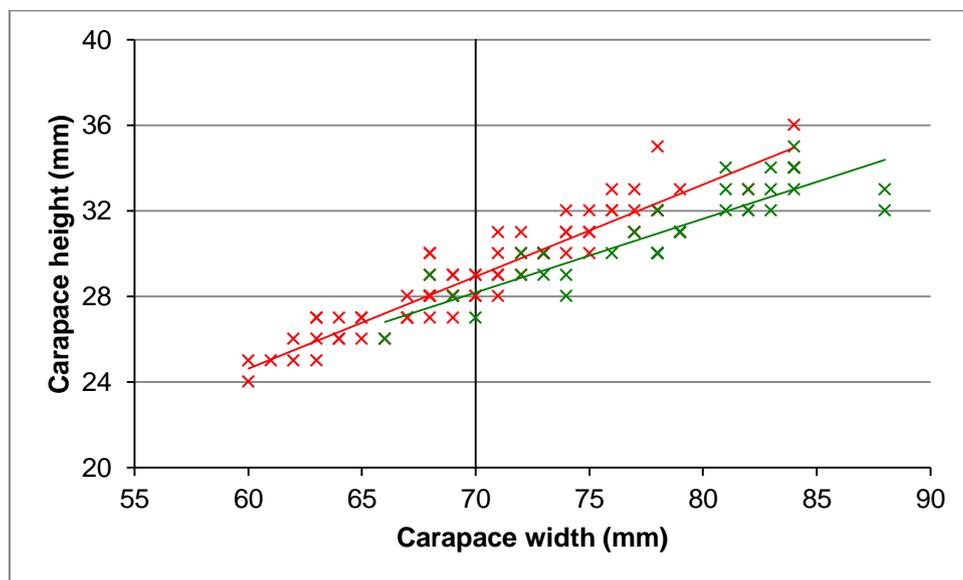
$$l_{50} = \frac{\ln \left( \frac{0.75^\delta}{1 - 0.75^\delta} \right) - \ln \left( \frac{0.25^\delta}{1 - 0.75^\delta} \right)}{b}, \text{ simplifying to } SR = \frac{2 \ln 3}{b} \text{ when } \delta=1 \quad (2.4)$$

Logistic and Richards size-selectivity models were calculated in Microsoft Excel following the methodology of Tokai (1997) and Tokai and Mitsuhashi (1998). The resultant curves were plotted onto size-retention plots using a maximum likelihood estimation procedure.

### 3 Results

#### 3.1 Determining escape gap height

A total of 108 crabs were randomly measured to obtain a relationship between carapace width (CW) and height (CH). Of the 108 crabs, the majority were female ( $n = 74$ ) with a mean CW of 70.6 mm ( $\pm 5.6$  mm) and mean CH of 29.2 mm ( $\pm 2.6$  mm). Males were found to have a mean CW of 78.3 mm ( $\pm 5.6$  mm) and a mean CH of 31.1 mm ( $\pm 2.2$  mm). Male and female crabs were found to have a significantly different relationship between CH and CW (ANCOVA  $F_{1,105} = 27.58$ ,  $P < 0.001$ ). The smallest crabs both had CWs of 60 mm (CH = 24 and 25 mm) with all crabs greater than 65 mm found to have a CH greater than or equal to 27 mm. All crabs greater than the minimum landing size (MLS) of 70 mm were also found to have a CH greater than or equal to 27 mm (Figure 3.1).

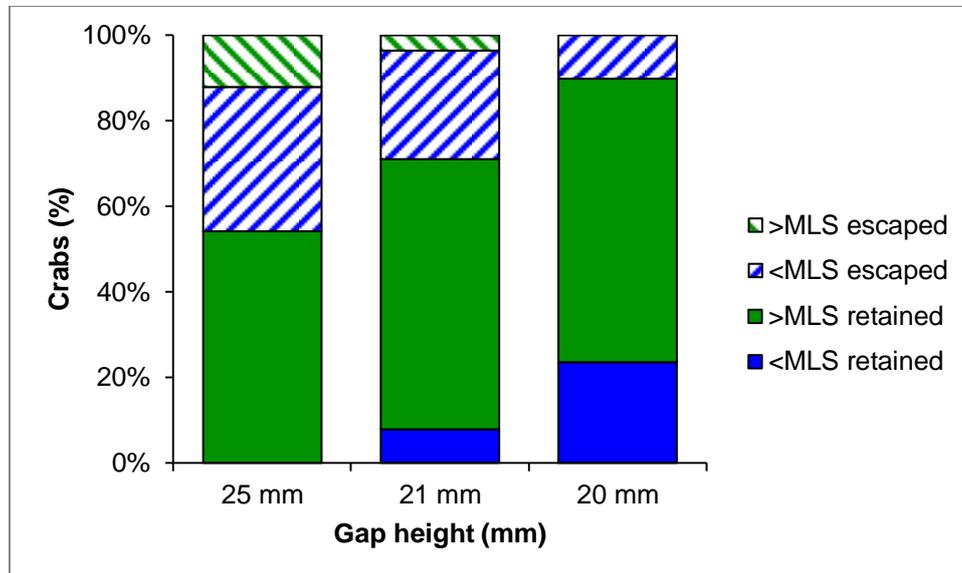


**Figure 3.1** Relationship between carapace width (CW) and height (CH) for males (green crosses;  $CH = 0.43CW - 1.20$ ,  $r^2 = 0.89$ ) and females (red crosses;  $CH = 0.35CW + 4.03$ ,  $r^2 = 0.78$ ). The minimum landing size (MLS) of 70 mm is shown as a vertical line.

The initial gap was set at 35 mm in order to eliminate sampling error due to lack of crab movement or altered natural behaviour. The crabs placed inside the keep creel were all able to pass through the 35 mm gap. After 24 hours, no crabs were found to have moved out of the keep creel. It was also noted that the crabs were displaying a limited amount of movement around the tanks and were not found to be feeding as voraciously as would be expected in the wild. For these reasons it was decided to focus purely on manually passing crabs through differing gap sizes.

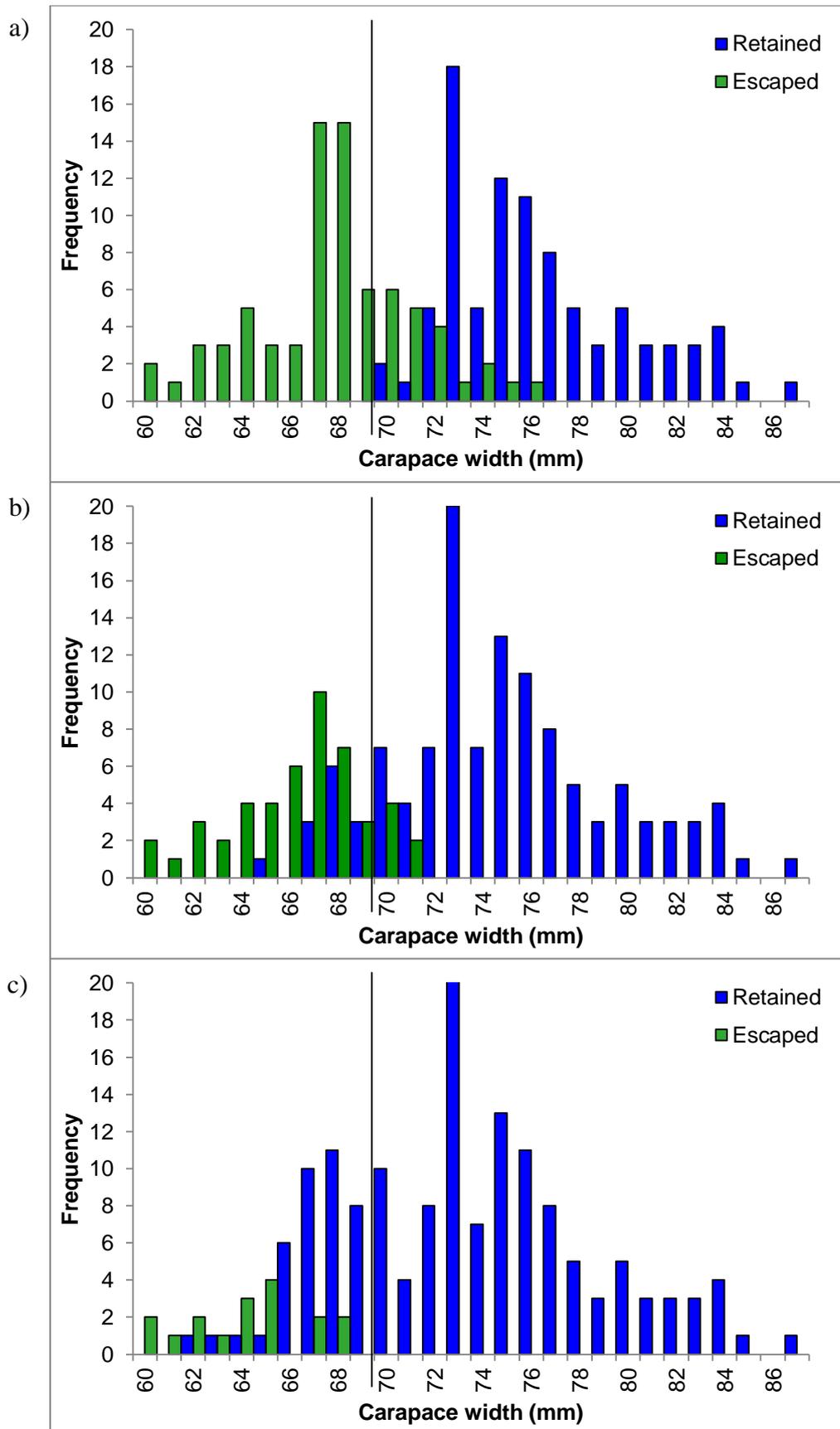
Based on Figure 3.1, a starting gap height of 25 mm was trialled. The results clearly showed that although all crabs less than the MLS could pass through the gap, 12% of legal sized crabs were also able to pass through (Figure 3.2). The gap height was reduced by 5 mm to 20 mm with no crabs above the MLS found to be able to escape, which was also true for 23% of

undersized crabs. These results gave a height range for the gap of 20 to 25 mm. By increasing the gap height to 21 mm, it was found that although more undersized crabs were able to escape, so were crabs which were above the MLS (4% of the catch, Figure 3.2). There was a significant difference between escaped and retained crabs of the three gap sizes (nested ANOVA  $F_{3,300} = 17.58$ ,  $P = 0.021$ , Figure 3.2 and Figure 3.3).



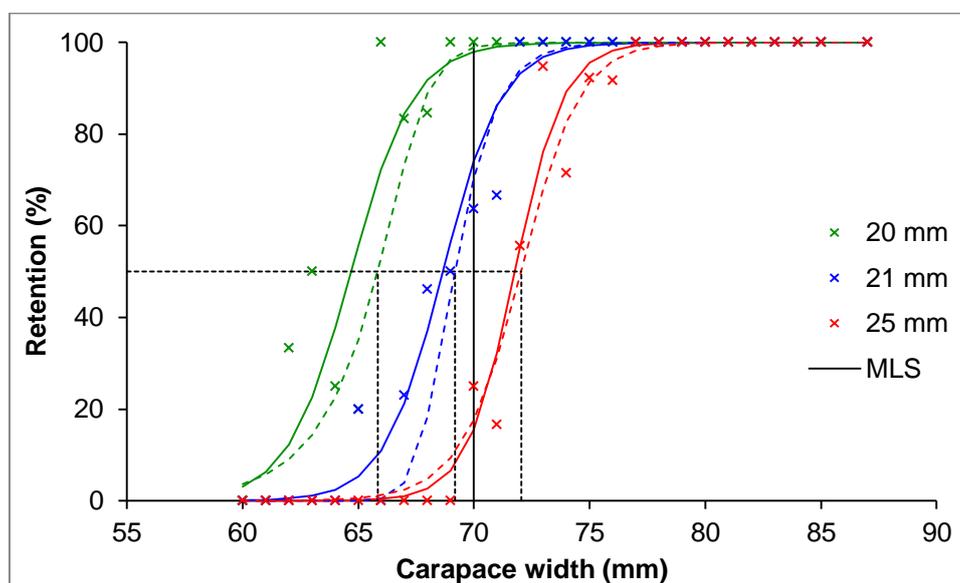
**Figure 3.2** Escaped and retained crabs, expressed as a percentage, and subdivided according to the minimum landing size (MLS) of 70 mm. Three gap heights for 25, 21, and 20 mm are shown.

The results were broken down by size class for the three gap heights of 25, 21, and 20 mm (Figure 3.3a to c, respectively). Although all undersized crabs were able to pass through the 25 mm gap, the largest crab able to pass through measured 76 mm (Figure 3.3a). At the 21 mm gap, the largest crab able to escape measured 71 mm and the smallest which was retained measured 65 mm (Figure 3.3b). No crabs above the MLS were able to escape through the 20 mm gap however, a larger proportion of undersized crabs were also retained with the smallest crab measured at 62 mm (Figure 3.2 and Figure 3.3c). Of the crabs able to escape, the largest measured 68 mm (Figure 3.3c).



**Figure 3.3** Carapace width-frequency of escaped (green bars) and retained (blue bars) crabs at gap heights of; a) 25 mm, b) 21 mm, and c) 20 mm. Vertical lines denote the MLS of 70 mm.

Size-retention curves were calculated and plotted for the three experimental gap heights of 20, 21, and 25 mm (Figure 3.4). According to Akaike's Information Criterion (AIC) the Richards function was the best fit to the data in all three cases (Table 3.1). Only the 25 mm gap had a  $l_{50}$  value greater than the MLS which was calculated from the Richards function to be 72 mm. As expected the 20 mm gap had the smallest  $l_{50}$ , calculated as 65.9 mm while the  $l_{50}$  from the 21 mm gap was calculated as 69.2 mm (Figure 3.4 and Table 3.1).



**Figure 3.4** Logistic (solid lines) and Richards (broken lines) curves fitted to the percentage of retained crabs in the 20 mm (green), 21 mm (blue), and 25 mm (red) gap experiments. The minimum landing size (MLS) is also shown (solid vertical line) along with the three corresponding  $l_{50}$ 's derived from the Richards function (dotted black lines).

**Table 3.1** Values for the constants  $a$ ,  $b$  and  $\delta$  used in the logistic and Richards functions and their corresponding outputs for length at 50% retention ( $l_{50}$ ), Selection Range (SR) and Akaike's Information Criterion (AIC) for the three gap heights of 20, 21, and 25 mm. AIC is a measure of the goodness of fit of the model with lower values denoting a better fit to the data.

	20 mm gap		21 mm gap		25 mm gap	
	Logistic	Richards	Logistic	Richards	Logistic	Richards
$a$	-47.34	-84.78	-54.12	-60.01	-68.64	-59.53
$b$	7.32	12.61	7.88	8.90	9.56	8.23
$\delta$		2.77		0.28		1.19
$l_{50}$ (cm)	6.47	6.59	6.87	6.92	7.18	7.20
$l_{50}$ (mm)	64.68	65.85	68.67	69.18	71.78	72.04
SR (cm)	0.30	0.29	0.28	0.19	0.23	0.28
AIC	26.25	11.73	27.32	12.47	30.64	15.85

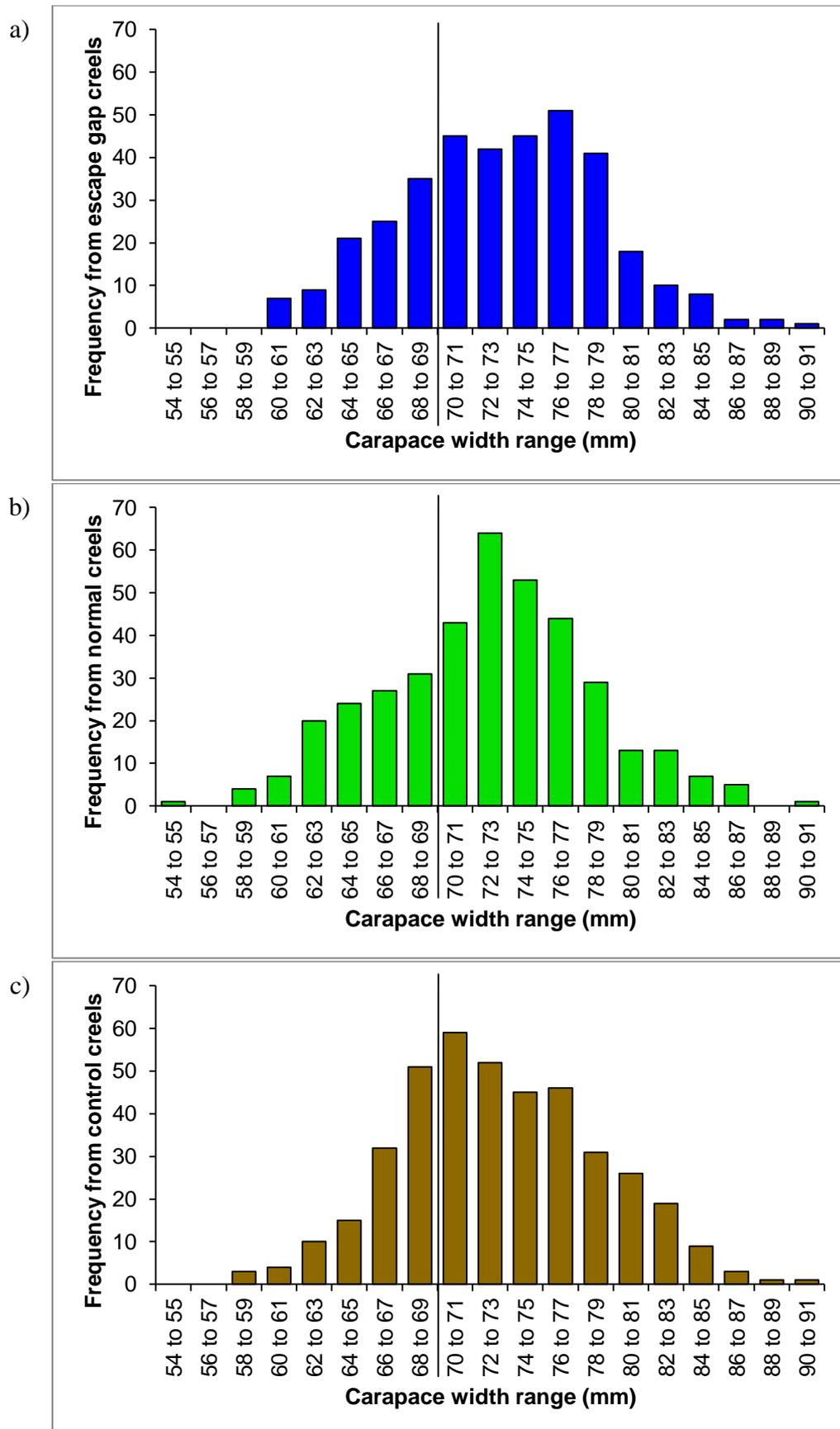
### 3.2 Sea trials

It was decided to take a conservative approach to the size of the gap and opt for a 20 mm height (Figure 3.5). Based on the tank experiments, this would ensure no loss of crabs above the MLS. Escape gaps were constructed using 11 mm round steel with a central support for increased rigidity. Each escape gap unit effectively consisted of two openings, each 20 mm high and 140 mm wide fitted into a side panel of the creel (Figure 3.5).



**Figure 3.5** A creel with the 20 mm escape gap height secured into a side panel. Gaps were constructed using 11 mm round steel with a central support to increase rigidity which left two escape areas of approximately 140 mm wide, each. A 5p coin is shown for scale (diameter of 17.9 mm).

There was no significant difference in total number ( $\chi^2 = 2.63$ ,  $P = 0.268$ ), number of undersized crabs ( $\chi^2 = 1.88$ ,  $P = 0.390$ ), or number of legal sized crabs ( $\chi^2 = 1.42$ ,  $P = 0.491$ ) between the three creel types. *Necora puber* caught in creels fitted with escape gaps were found to be significantly larger than those caught in control and normal creels (three-way ANOVA  $F_{2,1143} = 3.07$ ,  $P = 0.047$ , Figure 3.6), the latter had the smallest mean CW of 72 mm. All three creel types had a unimodal carapace width-frequency distribution with the furthest right peak found from escape gap creels (CW range of 76 to 77 mm, Figure 3.6a), followed by normal (range 72 to 73 mm, Figure 3.6b), and control (range 70 to 71 mm, Figure 3.6c) creels. Escape gap creels were found to have proportionally less undersized crabs and more legal crabs than the catch from normal and control creels, although this was not found to be significant (three-way ANOVA  $F_{2,1143} = 1.25$ ,  $P = 0.285$ , Table 3.2). There was also no significant difference between the minimum CW from each creel type ( $\chi^2 = 0.22$ ,  $P = 0.896$ ), although the largest minimum CW crab was recorded in an escape gap creel (Table 3.2). All three creel types had the same maximum CW of 90 mm.



**Figure 3.6** Carapace width-frequency of all velvet crabs caught in the a) escape creels, b) normal creels, and c) control creels. The MLS of 70 mm is represented by the solid vertical line.

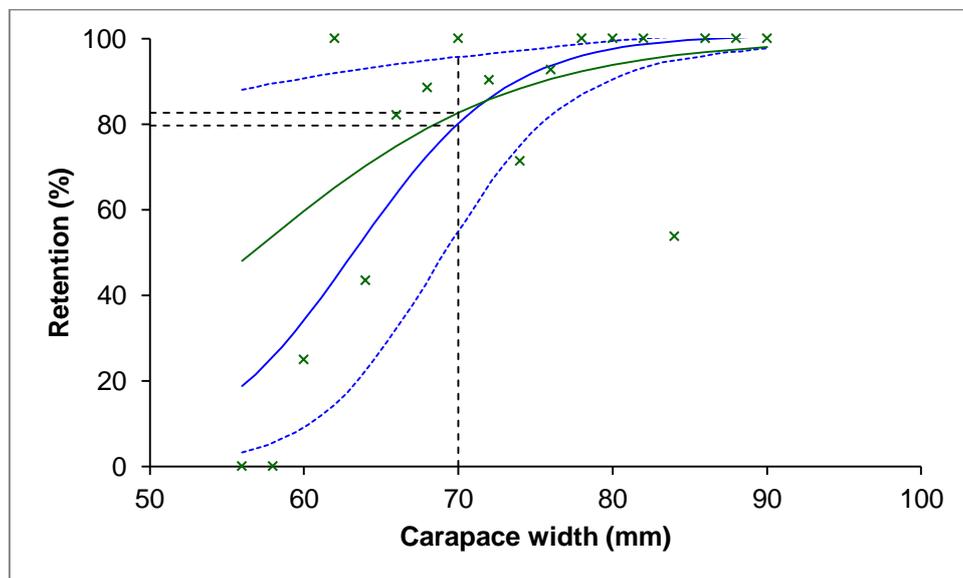
**Table 3.2** Catch summary from the three creel types of escape, normal, and control.

	<b>Escape</b>	<b>Normal</b>	<b>Control</b>
<MLS (%)	26.8	29.5	28.3
>MLS (%)	73.2	70.5	71.7
Mean CW (mm, ±95% CI)	73.12 (±0.58)	72.33 (±0.59)	73.03 (±0.56)
Minimum CW (mm)	60	55	58
Maximum CW (mm)	90	90	90

Logistic curves were fitted to a size retention plot, following the same format as that of Figure 3.4, for the escape gap creels (curve A of Figure 3.7) and of a simpler function (curve B of Figure 3.7). The AIC for curve A was high at 123.4, suggesting the curve was a poor fit to the data. It was not possible to fit a Richards curve to the data. Curve B was constructed using the following formula;

$$y = \frac{a}{1 + be^{-cx}} \quad (3.1)$$

where values for a, b, and c were 1.01, 4.36, and 0.20, respectively. Although curve B has a more representative fit to the data, the confidence intervals were found to be wide, especially at smaller CW sizes. Both curves returned a similar retention of around 80% at the MLS of 70 mm (Figure 3.7).



**Figure 3.7** Crabs retained in the escape gap creels clustered in 2 mm size classes. Two fitted logistic curves A (green solid line) and B (blue solid line) are plotted. Dashed black lines represent the MLS of 70 mm and the corresponding estimated retention of 82.8% (curve A) and 79.8% (curve B). Dotted blue curves represent the 95% confidence intervals of curve B.

## 4 Discussion

Many studies have demonstrated the benefits of fitting escape gaps to static gear with gaps ranging in size, shape, position, and number depending on the desired outcome. This is the first study looking specifically at the velvet swimming crab, *Necora puber*, with the aim of determining whether escape gaps work in the *N. puber* fishery and to gain an understanding of an appropriate sized gap for the fishery. Although a conservative approach to the size of the escape gap was chosen, this study shows that there is a real potential for escape gaps to be incorporated into creels catching *N. puber* and for the gap to have a measured effect on catch composition.

A creel fitted with an appropriate escape gap not only has the potential to reduce the number of undersized crabs caught but also to increase the catch efficiency of larger crabs (Pecci, *et al.*, 1978; Guillory and Hein, 1998; Guillory, *et al.*, 2004; Tallack, 2007; Boutson, *et al.*, 2009). Crabs which are successful in escaping free up space in the creel for other, potentially larger, crabs to enter and be retained thus demonstrating a positive selective function of the escape gap. This was noted in the CW-frequency plots with a greater proportion of the catch distributed to the right in escape gap creels. Such a positive selective function should be more evident as the gap size increases. Escape gaps will also ensure that the catch which were able to escape do so on the habitat from which they came, thus increasing their chance of survival (Brown, 1982), reducing disruption of feeding and limiting the effects on growth increments (Brown and Caputi, 1985). Although previous work was carried out on the survival of discarded *N. puber* in Shetland (see Henderson and Leslie, 2006), it was under ideal conditions, over a short time period, with crabs larger than the MLS which would be expected to be retained within the creel. The study did not focus on undersized crabs discarded by the fisherman which would be of importance to future stocks.

A balance has to be reached, when determining escape gap height, between retaining legal crabs and enabling undersized ones to escape. An ideal situation would be to not permit any legal crabs to escape but ensure all undersized animals did. In reality this would not be possible (Guillory and Hein, 1998; Treble, *et al.*, 1998; Guillory, *et al.*, 2004). Guillory and Hein (1998) suggested that in order to maximize the benefits of an escape gap the catch of undersized animals should be maximized with an additional loss of small legal-sized animals. A loss of small legal crabs could be offset by an increase in the proportion of larger crabs in creels with escape gaps (as discussed previously in this section).

The presence of undersized crabs in creels with escape gaps has been reported elsewhere (Guillory and Hein, 1998; Salthaug and Furevik, 2004), as well as this study, and have been explained by the presence of bait which is still attracting the crab to the creel but also the possibility that the crab has not yet encountered the gap to enable it to escape. On one occasion during the study it was noted that bait was still present in the creels, probably due to a short soak time but may also have been influenced by low water temperatures reducing feeding rates. The latter is the more probable cause in this study as low water temperature may also have an effect on *N. puber* activity rates. This may in fact be one of the causative

effects for the lack of activity noted during the tank trials. Combined with the additional stress of being in an unnatural environment, emphasises the need in this instance for manual manipulation of crabs through gaps. Stasko (1975) found that the smallest opening an animal could be pushed through was also the smallest opening that animal could then pass through unaided.

Fitting escape gaps to existing creels is a relatively easy and cheap way of helping reduce the number of undersized crabs caught and their subsequent handling. This study constructed gaps out of 11 mm round steel (chosen for its good strength to price ratio with the knowledge that gaps would not be in the water for years at a time) but other options are available. Fishers constructing their own gaps have used old plastic boxes, cut to shape, with great effect (personal communication). Several companies already supply plastic gaps to the trap fisheries at fixed heights and shape although the effectiveness of these in the *N. puber* fishery is untested. For fishers purchasing new creels, it would be possible to stipulate a certain gap size by incorporating in an additional bar prior to the creels being made. This can be done for a small additional cost and would have the advantage of being plastic coated, reducing the potential for rust accumulation.

#### 4.1 Potential further work

This study focused on the size of the escape gap but shape, position, and number of gaps should also be considered in future work. Studies have stressed the importance of more than one gap per creel (Brown, 1982; Boutson, *et al.*, 2009) in order to optimise escapability with the position of the gaps paramount (Nulk, 1978; Winger and Walsh, 2007; Jirapunpipat, *et al.*, 2008; Boutson, *et al.*, 2009; Havens, *et al.*, 2009). Positioning of the gaps would be directly related with catch behaviour while in the creel. As there are no known studies looking into *N. puber* behaviour while in a creel with conspecifics but more importantly with predators; this would have to be examined further. The shape of the gap would play an increasingly important role (see Krouse, 1978; Nulk, 1978; Boutson, *et al.*, 2009) with a need to enable more than one species to escape. This would be of importance in a mixed fishery where, for example, the fisher or manager wished to reduce the number of small *N. puber* along with small European lobster (*Homarus gammerus*). Berried crabs pose an additional problem due to the egg mass increasing the carapace height of the animal. It may be necessary to look at the effectiveness of a circular escape gap taking into account carapace depth (the maximum distance between the posterior and anterior sections of the crab) rather than carapace height as in this study. Incorporating in escape gaps would further pose additional questions related with optimal soak times for creels and survivability of escaped and retained animals.

## 4.2 Conclusions

An escape gap height of 20 mm was chosen to ensure no legal sized crabs (crabs with a CW more than 70 mm) escaped the creel. Although a significant difference was found between the size of caught crabs in the three creel types, an obvious difference was not apparent. As discussed above, in order to maximize the functionality of escape gaps, the gap height should be increased to at least 21 mm, if not slightly larger (based on the manual manipulation studies of this work), which would also enable some small legal crabs to escape. The benefits of correctly incorporating escape gaps into creels would be seen by the fisher (with regard to time spent sorting the catch which should have an increased proportion of larger crabs) and the crab stocks by ensuring reduced handling of animals, habitat displacement, and increased survivability.

## **5 Acknowledgements**

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