Puyallup Tribe of Indians Shellfish Department

Dungeness crab trap catch efficiency related to escape ring location and size

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Introduction:

The Dungeness crab (*Cancer magister*) fishery on the west coast of the United States is regulated by sex and size restrictions. Only male crab above a certain size limit may be retained (legal-size males). Females and sub-legal sized males must be released. A portion of the sub-legal males are sexually mature. Females and sub-legal males contribute to the future population provided that they are released unharmed. Sub-legal males retained in a trap can be injured due to competition with other crab (Barber and Cobb 2007). The catch sorting process may expose crab to dehydration, temperature, and impact stress. Yochum et al. (2016) found Dungeness discard mortality rates of 1% - 9% depending on fishery, sex, and shell condition. From a commercial crabbers' perspective fewer females and sub-legal males retained means less time required to sort the catch. Fewer sub-legal males injured and killed from retention and handling means more and higher quality crab for next year's catch. The ideal trap would retain zero females or sub-legal males while not reducing the catch of legal size males.

Escape rings are used in traps to create circular holes which facilitate the release of females and sub-legal males. Local regulations during the experiment required two 4.25" diameter escape rings located in the upper half of the trap. Havens et al. (2009), found that sub-legal Blue Crab (*Callinectes sapidus*) escaped at a faster rate and in higher overall proportions when escape rings were moved from the upper to the lower portion of the trap adjacent with the floor. Jow (1961) found that commercial Dungeness traps retained significantly fewer females and sub-legal males in traps with (2) 4.5" escape rings compared to traps with two 4.25" escape rings.

This experiment combines the previous work with escape ring location from Havens and escape ring size from Jow. Catch efficiency for Dungeness crab are compared when escape ring location and size are varied.

Methods:

Experimental design

The trap used for this experiment is called a "Danielson" or box style trap. Dimensions are given in figure 1. This trap is common in the recreational fishery and represents a majority of commercial traps used at the study site during the experiment.

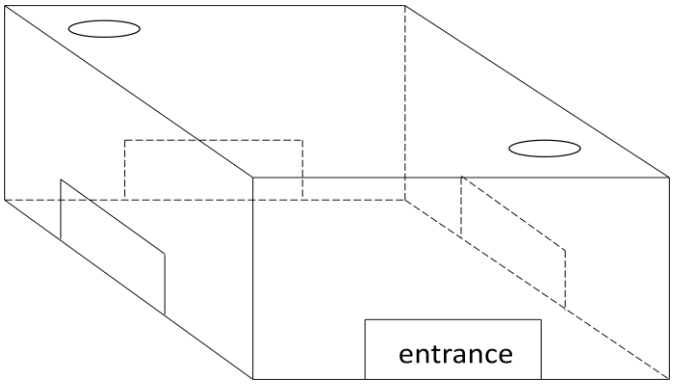


Figure 1. Trap used for the experiment. Sides are 24” long, height is 12”. One, one way entrance is located on each side adjacent with the bottom. Escape rings are typically placed on the top.

The four different crab trap configurations compared were (figure 2):

1) Control - a standard trap with escape rings tied shut
2) Standard – an unmodified trap with two 4.25" diameter escape rings on top
3) Modified 4.25" - a standard trap with one 4.25” diameter escape ring placed in each corner adjacent with the bottom. This trap modifies the location of the escape rings.
4) Modified 4.5" - a trap with two 4.5" diameter escape rings on top and one 4.5” diameter escape ring placed in each corner adjacent with the bottom. This trap modifies both the location and size of the escape rings.

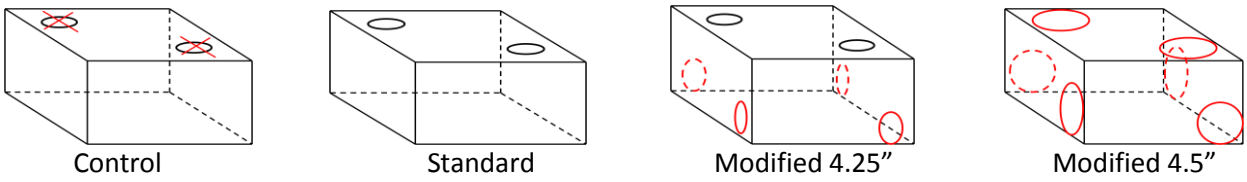


Figure 2. Trap escape ring configurations used. Red indicates configuration changes from a standard trap. Entrances not shown for clarity.

Traps were set for approximately 24 hours. Each trap configuration was assigned a unique number between 1 and 4. A random sequence between 1 and 4 was generated to determine the setting order of each trap configuration. A new sequence was generated for every set. Baits were standardized for each trap. Garmin mapping software and handheld GPS device was used to set the traps 246’ apart along a 60’ contour line.

Experiments were conducted at two locations in 2016: Quartermaster Harbor from February 19 to February 26, and Normandy Park from April 13 to April 15. Both locations are near Vashon Island in southern Puget Sound.

Data analysis

Four different mean catch statistics were compared for each trap configuration:

1) catch of legal-size males
2) catch of females
3) catch of sub-legal males
4) total catch of females and sub-legal males

Catch composition or the percentage of crab potentially to be kept versus discarded was compared as well.

Summary statistics for each trap configuration by location are presented in Appendix Table 1. Within a trap configuration (control, standard, modified), mean catches of each catch component were very similar between the two locations. Two-factor analysis of variance (ANOVA) was used to examine whether there was a significant difference in the mean catches of each catch component between locations for each trap configuration (i.e., a separate two-factor analysis was conducted for each trap configuration). Appendix Table 2 summarizes the results of the two-factor ANOVA analyses[1]. The location-catch component interaction term was not significant for any of the full model analyses. For the main-effects only models, catch component was significant (all $P \leq 0.001$) for each trap configuration while location was not a significant effect (all $P > 0.05$). Because there were not significant differences between the locations in mean catches of each component for each trap configuration, catch data from the two locations were pooled for subsequent analyses to increase the sample sizes and increase the statistical power of the analyses. Single-factor ANOVA was used to examine whether there was a significant difference in the mean catches of each catch component among the four trap configurations. When differences among trap configuration means were significant ($P \leq 0.05$), Fisher's Least-Significant-Difference (LSD[2]) test was used to conduct pair-wise comparisons of the different trap configurations and determine which were significantly different.

Results:

Catch of legal-size males

Figure 3 compares the mean catch by each trap configuration for the combined data (these data correspond to the Combined section in Appendix Table 1). Appendix Table 3 summarizes the results of the single-factor ANOVA analyses for catch of legal-size males. There was not a significant difference in the mean catch of legal-size male Dungeness crab among the four trap configurations (ANOVA $P = 0.760$). All four trap configurations averaged about two legal-size male crab per trap; mean and maximum legal-size male catch for the control trap (escape rings closed) was similar to the three other trap configuration.

[1] A full-factorial ANOVA model with location and catch component as the main effects and the interaction term was conducted initially. If the interaction was not significant ($P \leq 0.05$), then a second two-factor ANOVA was conducted with only the main effects.

[2] Fisher's LSD was used as the multiple-comparison test as it accommodates unequal group sample sizes better than some *post hoc* multiple-comparison tests.

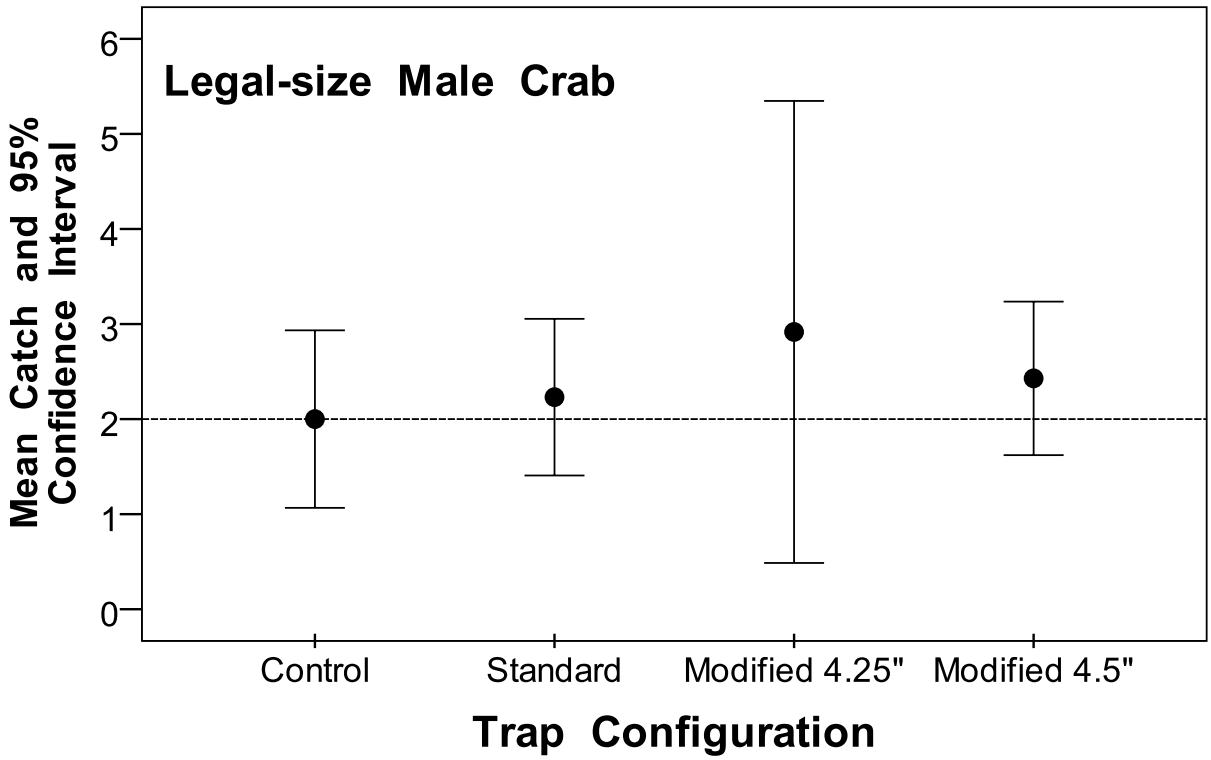


Figure 3. Comparison of mean catches of legal-size male Dungeness crab by trap configuration, locations combined.

Catch of females

Figure 4 compares the mean catch of females by each trap configuration for the combined data (these data correspond to the Combined section in Appendix Table 1). Appendix Table 3 summarizes the results of the single-factor ANOVA analyses for catch of females. There was a significant difference in the mean catch of female Dungeness crab among the four trap configurations (ANOVA $P < 0.001$). Compared to a standard trap, both modified traps with escape rings placed lower retained significantly fewer females (ANOVA $P < 0.05$). The results of Fisher's LSD multiple-comparison test indicated that:

- the mean catch of female crab by the Control configuration was significantly higher than the other three trap configurations (all $P < 0.001$).
- the mean catch of female crab by the Standard configuration was significantly higher than the two modified trap configurations (all $P < 0.050$).
- there was not a difference in the mean catch of female crab by the two modified trap configurations ($P = 0.257$).

Catch of sub-legal males

Because of the very small catch of sub-legal males by all trap configurations (mean catches ≤ 0.50 crab/trap and maximum of two sub-legal male crab caught in a trap across 53 total sets), conclusions about differences between trap configurations in catching sub-legal males were not made based on these experiments due to the low statistical power of the analyses.

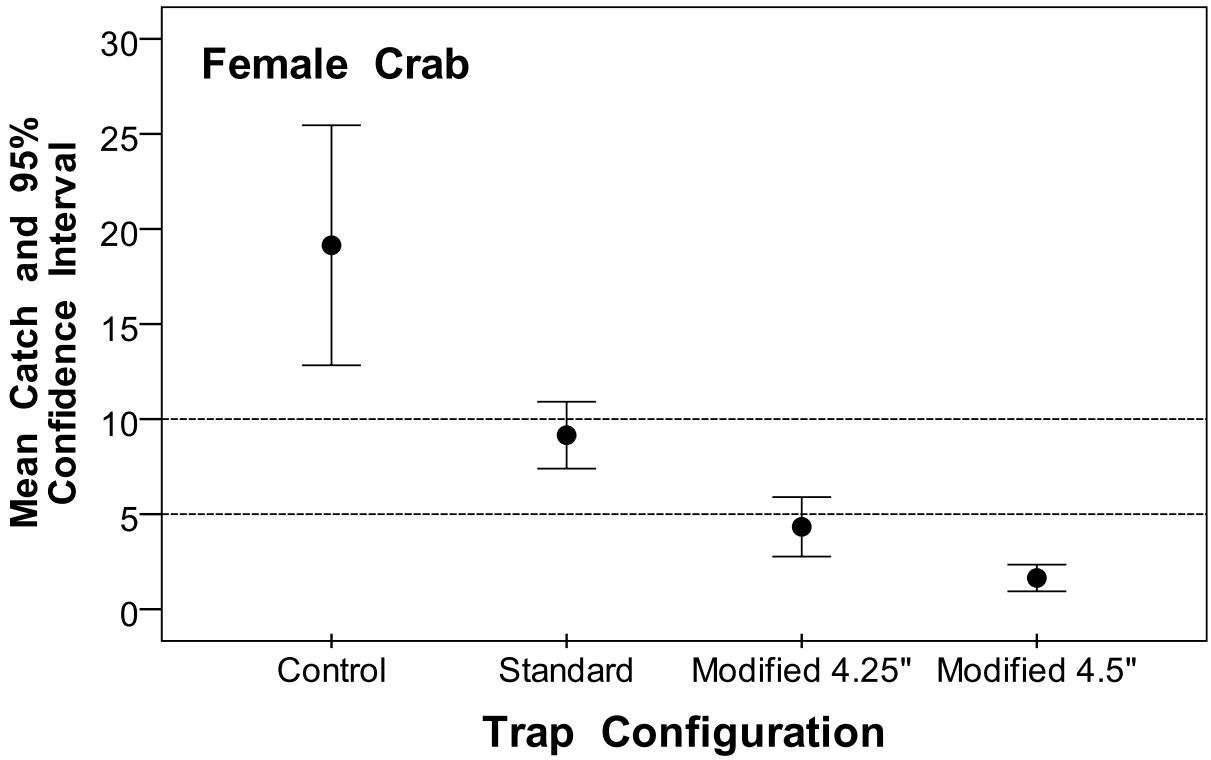


Figure 4. Comparison of mean catches of female Dungeness crab by trap configuration, locations combined.

Total catch of females and sub-legal males

The results for the analyses of the combined catch of females and sub-legal male crab (i.e., all crab which must be discarded) was very similar to the results of the females-only analysis because of the very small catches of sub-legal male crab. Figure 5 compares the mean catch of females and sub-legal males by each trap configuration for the combined data (these data correspond to the Combined section in Appendix Table 1). Appendix Table 3 summarizes the results of the single-factor ANOVA analyses for the combined catch of females and sub-legal males. There was a significant difference in the mean combined catch of female and sub-legal male Dungeness crab among the four trap configurations (ANOVA $P < 0.001$). Compared to a standard trap, both modified traps with escape rings placed lower retained significantly fewer females and sub-legal males (ANOVA $P \leq 0.05$). The results of Fisher's LSD multiple-comparison test indicated that:

- the mean combined catch of female and sub-legal male crab by the Control configuration was significantly higher than the other three trap configurations (all $P < 0.001$).
- the mean combined catch of female and sub-legal male crab by the Standard configuration was significantly higher than the two modified trap configurations (all $P \leq 0.050$).
- there was not a difference in the mean combined catch of female and sub-legal male crab by the two modified trap configurations ($P = 0.232$).

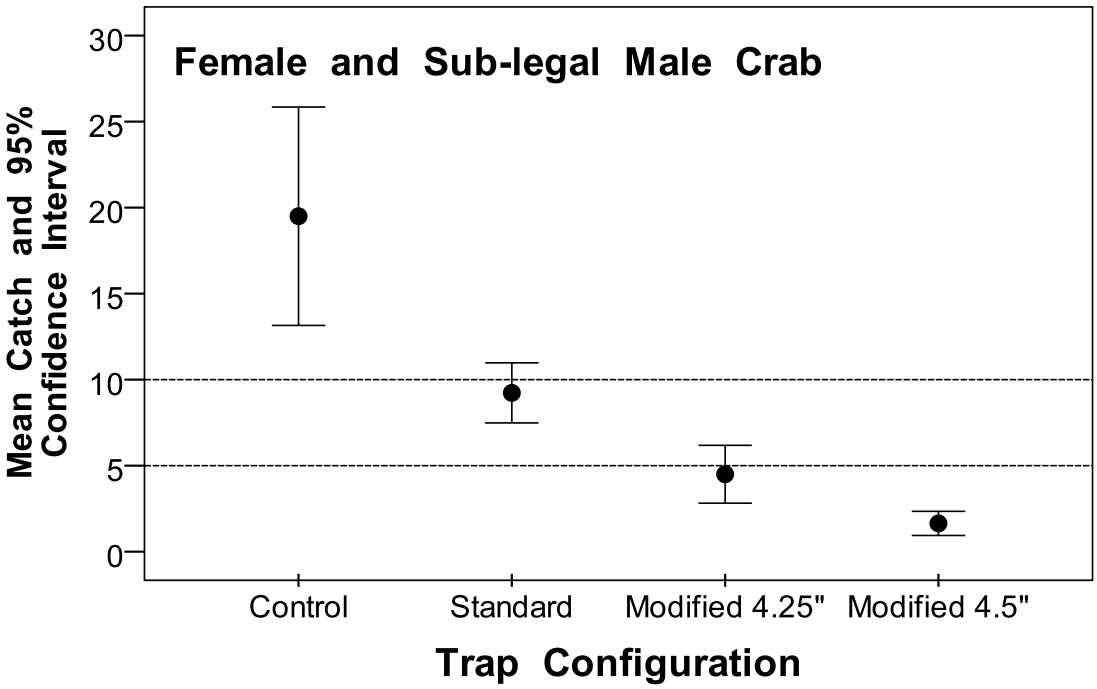


Figure 5. Comparison of mean combined catches of female and sub-legal male Dungeness crab by trap configuration, locations combined.

Catch Composition

The following analyses compare the percentage composition of the catch across all sets conducted for the experiment. Dungeness crab catch is reduced to two components, (1) legal-size males and (2) females plus sub-legal males (i.e., all Dungeness crab which must be sorted and discarded). Catch data from both locations were again combined as preliminary analyses indicated that, for each trap configuration, there was not a significant difference between locations in the composition as defined above.

Figure 6 compares the percentage composition of Dungeness crab, totaled across all sets, for each trap configuration. Approximately 90% of the Control and 80% of the Standard configurations must be released (i.e., are either females or sub-legal males). For the two modified trap configurations, the Modified 4.5" trap had about a 20% higher percentage of legal-size male Dungeness crabs and a corresponding lower percentage of Dungeness crabs that must be released.

Appendix Figure 1 shows photos of a subset of the experiment taken on the last two days of sampling. Ordered from control to modified 4.5” configurations, the decrease in the proportion of crab that must be sorted and discarded is obvious to the eye.

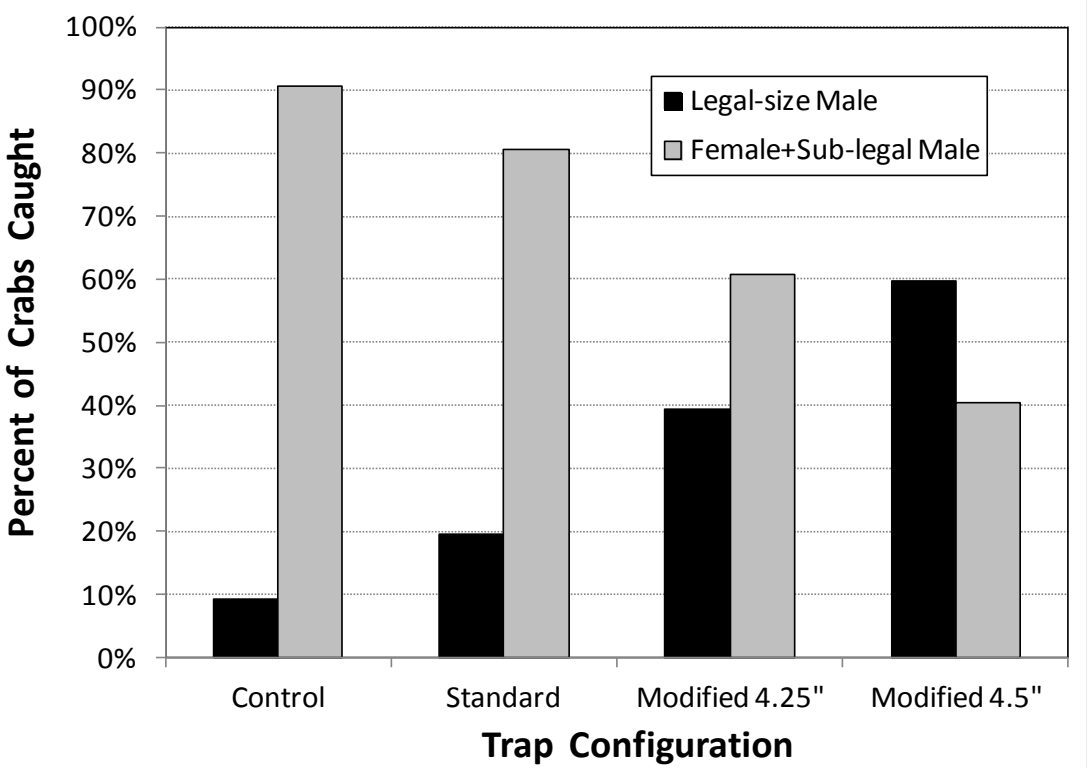


Figure 6. Comparison of the percentage catch composition of Dungeness crab by trap configuration, locations combined.

Discussion

The reduction in catches of females and sub-legal males combined in the modified traps was dramatic. Compared to a standard trap the modified 4.25" and modified 4.5" traps caught on average 51.2% and 82.2% fewer females and sub-legal males combined, respectively. This study did not find a statistical difference in female and sub-legal male combined retention rates between the modified 4.25" and 4.5" traps overall. An initial analysis of the Quartermaster Harbor catch alone did show a statistical difference in female and sub-legal male combined retention rates between the two modified traps, so statistical significance between the two modified traps in retention rates of female and sub-legal male combined may depend on the particular stock of crab being fished. Requiring additional escape rings to be placed lower and possibly increasing the diameter from 4.25" to 4.5" on the box style trap would benefit both the resource and the fisher. The resource would benefit from fewer females being retained in a trap. This would result in lower injury and mortality rates for females allowing for potentially higher overall reproduction success rates. The fisher would benefit from having fewer crab to sort through, reducing the time spent sorting. Both of these benefits could be realized while not affecting the catch of legal-size males. Escape rings in the upper portion of the trap should be retained as it is possible for traps to sink into bottom substrates over time, possibly rendering lower escape rings useless. Catches during the experiment were characterized by unusually low levels of sub-legal males. Catches of sub-legal males were too low to make any comparisons.

Important information that could be gathered with future escape ring location and size experiments include:

What are the retention rates of sub-legal males?
If it could be shown that escape ring location and size modifications could lower sub-legal male retention rates, the benefits would be twofold: (1) the sexually mature portion of sub-legal males that contribute to the future population would be increased, and (2) more and higher quality crab would be available in future fisheries.

What effect does shorter set times have on catch composition?
This experiment used 24 hour sets. 24 hour sets are typical in the commercial fishery however shorter sets are common in the recreational fishery where approximately half of the Dungeness harvest occurs. Havens et al. showed a strong time related effect to moving the escape rings lower on modified blue crab traps: The odds of a sub-legal blue crab escaping from the modified trap after 24 hours were 18 times greater compared to a standard trap, however in the first 4 hours the odds of a sub-legal blue crab escaping from the modified trap was 39 times greater compared to unmodified traps (Havens et al. 2009). Results may differ if this experiment was repeated with shorter set times.

What are the results when other trap styles are used?
This experiment used one trap style. In actuality other trap styles are also used which may or may not have similar results if used to replicate this experiment.

What is the minimum number of lower escape rings required?
A total of four escape rings placed lower were used in each modified trap. It's possible that fewer escape rings placed lower could still have similar results.

Appendix

Appendix Table 1. Mean catch per trap of Dungeness crab for four trap configurations fished at two locations. Summarized by catch component: legal-size males, females, sub-legal males, and females+sub-legal males. Sample size = number of traps sampled. QMH = Quartermaster Harbor, NP = Normandy Park.

Legal-size Males

Location	Trap Type	Mean	Sample Size	Standard Error	Rel. Pre.[a] SE	Median	Min.	Max.
QMH	Control	2.25	8	0.675	30.0%	2	0	6
	Standard	2.38	8	0.565	23.7%	2.5	0	4
	Modified 4.25"	2.71	7	1.392	51.4%	1	0	9
	Modified 4.5"	2.88	8	0.611	21.2%	3	0	6
NP	Control	1.67	6	0.494	29.6%	1.5	0	3
	Standard	2.00	5	0.447	22.4%	2	1	3
	Modified 4.25"	3.20	5	1.985	62.0%	0	0	9
	Modified 4.5"	1.83	6	0.167	9.1%	2	1	2
Combined	Control	2.00	14	0.432	21.6%	1.5	0	6
	Standard	2.23	13	0.378	17.0%	2	0	4
	Modified 4.25"	2.92	12	1.104	37.8%	1	0	9
	Modified 4.5"	2.43	14	0.374	15.4%	2	0	6

Females

Location	Trap Type	Mean	Sample Size	Standard Error	Rel. Pre.[a] SE	Median	Min.	Max.
QMH	Control	18.13	8	4.506	24.9%	22	0	33
	Standard	8.38	8	1.149	13.7%	8.5	2	12
	Modified 4.25"	4.57	7	0.782	17.1%	5	1	7
	Modified 4.5"	1.88	8	0.515	27.4%	1	1	5
NP	Control	20.50	6	3.640	17.8%	19.5	10	35
	Standard	10.40	5	0.872	8.4%	11	8	13
	Modified 4.25"	4.00	5	1.414	35.4%	4	0	8
	Modified 4.5"	1.33	6	0.333	25.0%	1.5	0	2
Combined	Control	19.14	14	2.922	15.3%	21.5	0	35
	Standard	9.15	13	0.807	8.8%	9	2	13
	Modified 4.25"	4.33	12	0.711	16.4%	4.5	0	8
	Modified 4.5"	1.64	14	0.325	19.8%	1	0	5

Sub-legal Males

Location	Trap Type	Mean	Sample Size	Standard Error	Rel. Pre.[a] SE	Median	Min.	Max.
QMH	Control	0.25	8	0.164	65.6%	0	0	1
	Standard	0.13	8	0.125	96.2%	0	0	1
	Modified 4.25"	0.00	7	0.000		0	0	0
	Modified 4.5"	0.00	8	0.000		0	0	0
NP	Control	0.50	6	0.342	68.4%	0	0	2
	Standard	0.00	5	0.000		0	0	0
	Modified 4.25"	0.40	5	0.400	100.0%	0	0	2
	Modified 4.5"	0.00	6	0.000		0	0	0
Combined	Control	0.36	14	0.169	46.9%	0	0	2
	Standard	0.08	13	0.077	96.3%	0	0	1
	Modified 4.25"	0.17	12	0.167	98.2%	0	0	2
	Modified 4.5"	0.00	14	0.000		0	0	0

Females + Sub-legal Males

Location	Trap Type	Mean	Sample Size	Standard Error	Rel. Pre.[a] SE	Median	Min.	Max.
QMH	Control	18.38	8	4.547	24.7%	22	0	34
	Standard	8.50	8	1.150	13.5%	9	2	12
	Modified 4.25"	4.57	7	0.782	17.1%	5	1	7
	Modified 4.5"	1.88	8	0.515	27.4%	1	1	5
NP	Control	21.00	6	3.606	17.2%	21	10	35
	Standard	10.40	5	0.872	8.4%	11	8	13
	Modified 4.25"	4.40	5	1.600	36.4%	4	0	8
	Modified 4.5"	1.33	6	0.333	25.0%	1.5	0	2
Combined	Control	19.50	14	2.938	15.1%	22	0	35
	Standard	9.23	13	0.802	8.7%	9	2	13
	Modified 4.25"	4.50	12	0.764	17.0%	4.5	0	8
	Modified 4.5"	1.64	14	0.325	19.8%	1	0	5

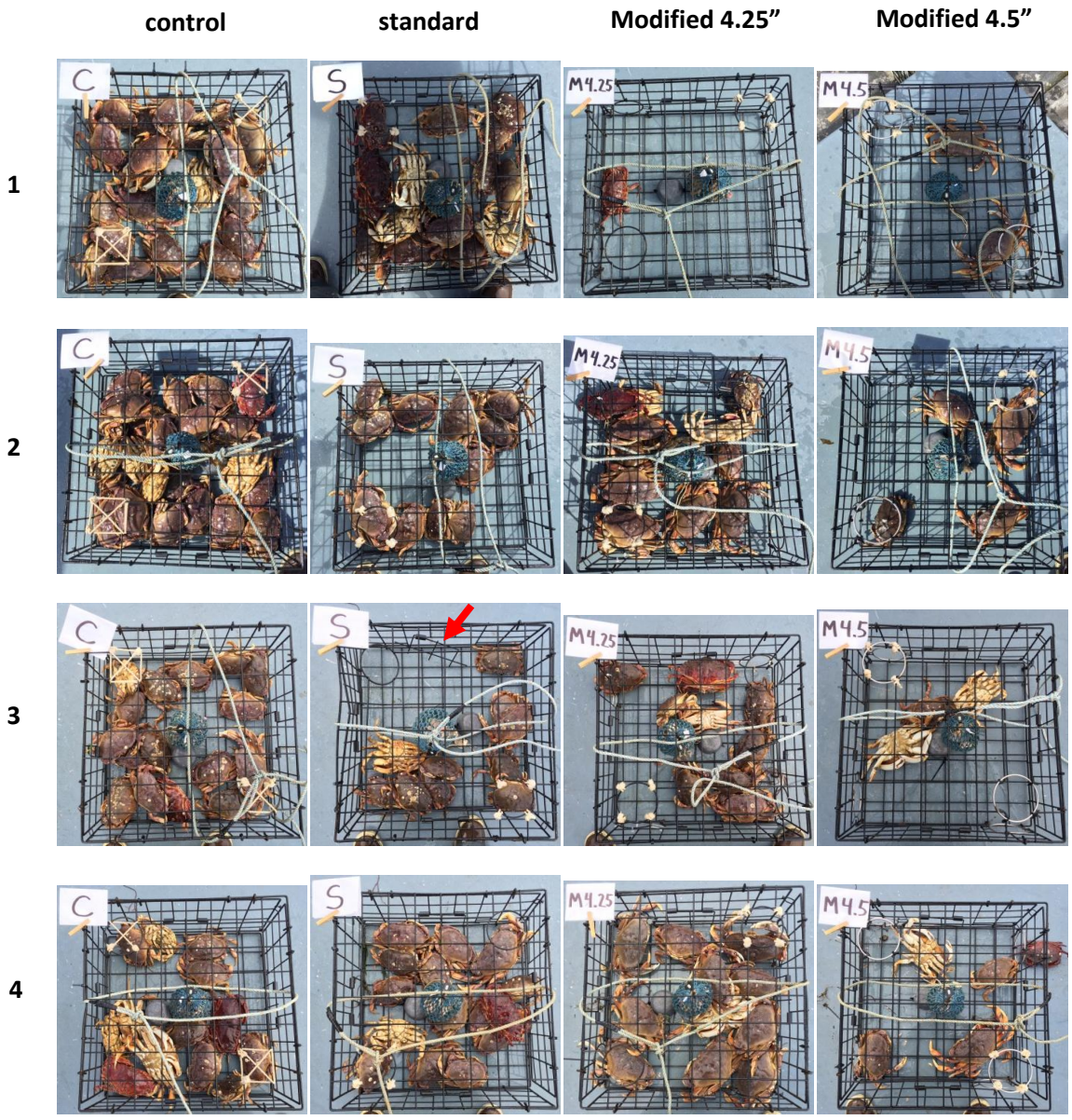
[a] Relative Precision of standard error = standard error/mean.

Appendix Table 2. Results of two-factor ANOVA test comparing mean catch of each Dungeness crab catch component by location for each trap configuration.

Trap Configuration	Significance of *Interaction term* for Full Model	Significance of Main Effects for Main-Effects Only Model	
		Catch Component	*Location*
Control	0.941	< 0.001	0.585
Standard	0.356	< 0.001	0.168
Modified 4.25"	0.962	0.001	0.964
Modified 4.5"	0.676	< 0.001	0.076

Appendix Table 3. Results of single-factor ANOVA test comparing mean catch of each Dungeness crab catch component for each trap configuration.

Catch Component	F Statistic	Significance (*P*)
Legal-size Males	0.390	0.760
Females	23.032	< 0.001
Sub-legal Males	1.647	0.191
Females + Sub-legal Males	23.502	< 0.001



Average catch

Legal size males:	1.3	2.3	4.0	1.8
Females + Sub-legal males:	17.0	11.0	3.5	0.9

Appendix Figure 1. A subset of the experiments in photos (last two days of sampling). Average catches of Dungeness crab are given. Trap configurations are along columns. Going from left to right the decrease in the proportion of females plus sub-legal males (crab that should not be retained or handled) is obvious to the eye. One trap failure occurred during the photo period (standard #3, red arrow points to a broken entrance) this trap was excluded from analyzed data. Compared to the standard trap the modified 4.5” trap retained nearly 92% fewer females + sub-legal males on average in this subset.

Acknowledgements

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