COMPARISON OF THE COLLECTION RATES OF AGE-0 RED KING CRABS USING UNFOULED AND FOULED SAUSAGE-SHAPED ARTIFICIAL COLLECTORS

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Alaska Department of Fish and Game
Division of Commercial Fisheries
211 Mission Road
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INTRODUCTION

An attempt to develop an artificial collector which could assess year class strength of age-0 red king *Paralithodes camtchaticus* and Tanner crab *Chionoecetes bairdi* in Chiniak Bay, Kodiak Island, began in 1989 by ADF&G (Blau et al. 1990). Of the seven different artificial collectors tried, none were believed to collect Tanner crabs in numbers representative to their true abundance, as observed by divers. Conversely, red king crabs occurred on all seven types of artificial collectors tested. The "sausage" collector was judged the best overall artificial collector tested both in terms of crabs caught per volume, and ease of use during deployment, retrieval and cleaning. This collector was later renamed the sausage-shaped artificial collector or SAC (Blau and Byersdorfer 1994). SACs were selected for use in a 5-year research project (1990-1994) to investigate their feasibility to assess year-class strength of age-0 red king crabs in Chiniak Bay, with a long term goal of correlating age-0 year class strength with the number of 5-year old or older red king crabs caught in annual trawl surveys in ensuing years (Blau et al. 1992). During that 5-year study, collectors were initially placed in the water around the start of April and retrieved in September and October. Experiments were also performed in 1992 and 1993 with age-0 red king crabs seeded in SAC's to test for density dependence. Significant decreases in numbers of crabs over time were found due to density dependence, for which cannibalism, frequency of molting, food availability and spatial limitations were all implicated (Murphy and Blau 1996).

A period of project review occurred at the end of the 5-year age-0 red king crab SAC study in 1994. In a meeting held at ADF&G in Juneau on March 15, 1995 the following Commercial Fisheries Division staff met to discuss the future of research involving SAC's and red king crabs around Kodiak: Margaret Murphy, statewide shellfish biometrician, Dr. Gordon Kruse, fishery scientist, and Douglas Pengilly, Westward Regional research supervisor. A summary of the comments follow. Kruse stated that in light of the discovery of density dependence effects, we would need to know what sampling frequency would be appropriate in order to develop a meaningful measure of age-0 red king crab settling. Murphy recommended fall retrieval of age-0 red king crabs be abandoned and a new program be considered, which included comparing average number of crabs accumulated by daily or longer retrieval intervals. She also suggested using bongo tows as a first value to correlated late larval planktonic zoea IV numbers, with the number of settled crabs from the zoea V (glaucothoe), and first instars (C1) stages. In addition, she questioned what was the correct time period to pull SACs. Furthermore, Murphy recommended to follow-up larval and postlarval work with dive and annual trawl surveys. She suggested using Gibson Cove and near a dock in Womens Bay for the study sites. Pengilly questioned whether SACs could be a useful index tool in light of red king crab density dependence occurring in them. He also asked how 'peak abundance' would be determined every year.

In an attempt to answer some of the previous mentioned concerns the following experiment was designed using both unfouled and fouled SACs.

OBJECTIVES

1. Determine if larval and postlarval red king crabs settle on and are retained in unfouled SACs.

2. Evaluate weekly differences in performance between unfouled and fouled SACs in collecting larval and postlarval red king crabs, from the onset of glaucothoe settlement through the period of peak abundance of age-0 crabs.

METHODS

For this experiment an unfouled SAC was one that was placed in the ocean for seven days and a fouled SAC was one that had been in the ocean 45 days or more. SACs were made to the specifications found in Blau and Byersdorfer 1994. Each string of gear was comprised of five SACs placed 2-meters apart in the center of a 30.3 m groundline, anchored at each end by a 18 to 20 kg Kedge anchor. The south end of each string had one numbered and one unnumbered buoy marking the string's location; they were connected by a buoyline to an anchor.

The study site for this experiment was located in the marine waters east of the Gibson Cove headland, in the City of Kodiak, Alaska. Three rows were deployed, each containing 10 strings of gear (Figure 1). One end of each string was set approximately 30.3 m from the buoyed end of the adjacent string. One string of gear per row had unfouled SACs and the remaining nine strings in that row contained fouled SACs. All strings were set for row target depths using a fathometer. Depths were adjusted from mean lower low water. The first and shallowest row of gear was set at approximately 9.2 m (5 fm). The second (middle) row of gear was set roughly parallel to the first row along the 11.0 m (6 fm) depth contour. The third and deepest row was set at approximately 11.9 m (6.5 fm), generally parallel to the first two rows. Target depths where gear was set probably varied by plus or minus a meter, due to irregularity of bottom and timing of dropping anchor. Rows were closer together at the southern end, spreading further apart on the northern end, but generally averaged 10 meters between rows.

Gear for the fouled SACs was set April 16-19, 1996. There were nine weekly pull periods, every Wednesday, from June 5 to July 31, 1996 (Table 1). In each row both an unfouled and fouled string of gear were pulled during each of the nine sample periods. The date of pulling fouled gear was randomized by row (Figure 1). Each string of unfouled gear was pulled then reset in the same location with five unfouled SACs each week.

The *RV/Instar*, a 7.9 m long ADF&G crab research skiff was used to set and pull gear. Latitude and longitude of the midpoint of each string was located by a global position system (GPS) using a Magellan[1] receiver. Gear was retrieved with the assistance of a small hydraulic crab block. When retrieving the gear, each SAC was designated from #1 (southernmost) through #5 (northernmost) within each string and recorded on the sampling form (Appendix A.1.). The contents of the SACs were washed in a wash-down table, using seawater pumped from a 3.7 kJ/sec (5 hp) pump and sprayed through a fire hose nozzle. Marine life in each SAC was

[1] Use of a company's name does not constitute endorsement by ADF&G.

collected on a tray having a 1 mm^2 screen and the contents of each SAC were fixed in 10% formalin in seawater and later saved in 70% ETOH. The biota and detritus from SACs were examined through a dissecting scope and the number of red king crabs were recorded on the sampling form (Appendix A.1.). Glaucothoe and age-0 postlarval instars were distinguished using Marukawa (1933). The size of age-1 red king crabs were estimated using the size-age classes of age-0 in Donaldson et. al. (1992) and those for age-1 crabs in McCaughran and Powell (1977). An additional category of "age-0 pieces" was used, which included age-0 crab parts that had meat in them (not molts) that could have been either from glaucothoe or C instars. These pieces were unique and did not belong to previously identified whole crabs in the sample. Crab age-0 pieces were remnants from crabs as a result of washing and processing the samples.

Unfouled samples were examined first, following the weekly retrieval. Fouled samples were examined at a reduced rate due to the colonization of tube-dwelling polychaetes which added significantly more time to the processing of each SAC. A subsample from the fouled SACs was selected each week, with three SACs randomly chosen in the first row, one randomly selected from the second row, and two randomly selected in the third row. Samples which contained greater than or equal to 250 ml of tubed polychaetes, were considered "wormed" and noted on the sampling form.

An analysis was developed to test whether unfouled and fouled strings of SACs would collect glaucothoe and postlarval age-0 red king crabs in equal numbers each week. A row (depth) factor was evaluated to see if rows (depth) were a significant factor in glaucothoe and postlarval age-0 red king crab abundance on collectors. For this analysis, the following log-linear model was used:

$$\log(y_{ijk}) = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

where y_{ijk} is the number of red king crab (glaucothoe and/or postlarval age-0) found on a single SAC, μ is the grand mean, α_i is the fouling factor (fouled versus unfouled), β_j is the row (depth) factor, $(\alpha\beta)_{ij}$ is the interaction term between fouling and row, and ε_{ijk} is the Poisson error associated with the model (Healy 1988, McCullagh and Nelder 1989, MathSoft 1997). Though not a specific objective, age-1 red king crab abundance on SACs was also analyzed using the log-linear model described above.

The interpretation of a log-linear model is similar to the interpretation of an ANOVA (Healy 1988, McCullagh and Nelder 1989). Specifically for the analysis, if there was a significant fouling effect then there was on average more or less crab collected on unfouled SACs than on fouled SACs. Similarly, if the row effect was significant then at least one row had on average collected more or less crab than the other rows. Lastly, if the interaction effect of fouling and row was significant, then the proportion of crab collected in fouled versus unfouled SACs changed between rows.

Scuba divers observed the condition of a string of SACs, the surrounding habitat, and the affect of settled tube worms on SACs in that string. The dive was performed about mid-way during the study on June 25, 1996.

RESULTS

There were 135 unfouled and 135 fouled SACs set for the experiment (Table 1). Ninety-seven percent (131) of the unfouled and 39% (53) of the fouled SACs were examined for the presence of red king crabs (Table 2).

Glaucothoe were recovered on SACs only in the first four weeks (Table 3). Unfouled SAC's collected significantly ($p < 0.002$) fewer glaucothoe than the fouled SACs (Table 4). No model was fit for weeks 3 and 4 because few glaucothoe were present. Row was a significant ($p < 0.010$) effect in the first two weeks, due to a higher catch per unit of effort (CPUE) in the first row than the second or third rows (Table 3 and 4). The interaction between fouling and row was significant ($p=0.0045$) for week 1 but insignificant ($p > 0.995$) in week 2 (Table 4). The significant interaction term in week 1 was likely due to the fact that all glaucothoe found on fouled SACs were from row one, whereas all glaucothoe found on unfouled SACs were from row two.

Postlarval age-0 crabs were recovered in all nine weeks of the study; overall CPUEs > 2 occurred in weeks 4-9 (Table 5). The unfouled SACs collected significantly ($p < 0.01$) fewer postlarval age-0 crabs than the fouled SACs for each week (Table 6). The row effect was significant ($p < 0.02$) in weeks 2, 4, 5, 6 and 9, and insignificant ($p > 0.2$) for weeks 1, 7 and 8 (Table 6). No model was fit for week 3, because there were too few postlarval red king crabs recovered. There was no significant ($p > 0.1$) interaction between fouling and row for any week, though week 8 was marginal ($p = 0.197$).

Some red king crabs either glaucothoe, postlarval and age-0 pieces, were recovered every week of the study. Overall CPUEs by week for fouled SACs ranged from 1.0 to 6.3 with an overall average of 3.3 (Table 7). Unfouled SACs contained significantly ($p < 0.001$) fewer age-0 crabs than did the fouled SACs for each week, except week 3 which had a marginal insignificant ($p=0.139$) fouling factor (Table 8). The row effect was significant ($p < 0.02$) in weeks 1, 2, 4, 5, 6, and 9, and insignificant ($p > 0.1$) for weeks 3, 7 and 8 (Table 8). There was no significant ($p > 0.1$) interaction between fouling and row for any week, except week 1 ($p = 0.006$).

Age-1 red king crabs were only collected in weeks 4-6, at relatively low numbers (Table 9). Due to the low recovery, the three weeks were combined for the analysis. As with age-0, the unfouled SACs caught significantly ($p=0.004$) fewer age-1 crab than did the fouled SACs (Table 10). There was a marginally significant ($p = 0.093$) row effect. The fouling and row interaction factor was insignificant ($p = 0.474$), similar to the majority of age groups (Table 10).

Tube dwelling polychaete worms (Boccardia sp.) settled and grew only on fouled SACs. Fifty-one percent of the fouled SACs were "wormed". CPUEs of red king crabs were usually lower on wormed SACs (Table 11).

One string of fouled SACs was examined by divers (row 2, week 4). The bottom surrounding it was muddy and inhabited by the infaunal tube-dwelling worms. The SACs in that string were weighted down by the abundance of worms on them so the SACs were in direct contact with the bottom, resulting in them not being in their normal vertical state (Donaldson et. al. 1992, Blau and Byersdorfer 1994).

DISCUSSION

Both objectives of this experiment were met. Glaucothoe and postlarval red king crabs were found on unfouled SACs. Timing of the experiment encompassed initial settlement of glaucothoe through peak abundance of age-0 red king crabs dates based on previous ADF&G studies using SACs which were also set east of the Gibson Cove headland. The earliest glaucothoe was detected on June 1, with peak glaucothoe numbers occurring on June 14 (1990 and 1991) with the latest glaucothoe detected on July 18. Peak numbers of age-0 red king crabs at the same location occurred during mid-July (12^{th} to 26^{th}) in the 1990-1993 research.

Unfouled SACs were poor collectors of larval and postlarval age-0 red king crabs compared to fouled SACs in this experiment. Unfouled SACs contributed only 6% of the age-0 crabs collected and had an overall CPUE of $1/10^{th}$ that of fouled SACs. Perhaps the major reason for this difference, regardless of depth sampled, was that the unfouled SACs are a sterile habitat for glaucothoe larvae, since the SACs lack food. Glaucothoe and postlarval red king crabs eat diatoms and a variety of animals and algae (Marukawa 1933; Feder et al. 1980). Glaucothoe can leave unsuitable habitats by swimming away from unsuitable habitats they settle on, like unfouled SACs (Stevens and Kittacca 1998). Fouled SACs have been inhabited by age-0 red king crabs for at least a year as they provide both a "house" and food for the crabs (Blau and Byersdorfer 1994). Another reason unfouled SACs did not collect as many age-0 crabs as did fouled SACs was that the last two sampling periods (week 8 and 9) were set in the water after the known settling period (June 1 to July 18) was over (Blau and Byersdorfer 1994).

The depths that SACs were deployed for this experiment appears to be in the zone of highest CPUE for age-0 red king crabs. For fouled SACs, the average CPUE increased for all age-0 red king crabs from the deepest 11.9 m (6.5 fm) to the shallowest row 9.2 m (5 fm) fished. In previous studies by ADF&G, CPUEs for age-0 red king crabs were found in SACs for similar depths as those fished in 1996. In 1990, SACs were deployed in Chiniak Bay, Kodiak Island from 7 to 27 m (4 to 14 fm) with the shallowest depths having the highest CPUEs (Blau et al. 1992). Also 1993 SACs were fished in a horizontal position attached to parallel groundline from 1 to 7 m (0.5 to 3.8 fm), 5.6 km (3 nautical miles) southeast of the Gibson Cove headland by ADF&G (Blau unpublished data). SACs retrieved from the 7 m (4 fm) groundline had the highest CPUE.

The settlement of the tube-dwelling polychaetes on the fouled SACs had a profound effect on the results of this experiment and interpretation of the data. The presence of these worms increased greatly the time needed to process samples containing them, thereby reducing the desired number of samples that were examined to only one-third the study's initial sampling goal. Previous research in the Gibson Cove headland area, 1989 to 1994, never revealed SACs heavily colonized by the tube-dwelling polychaetes.

Fouled SACs that were heavily wormed were probably a less desirable habitat for age-0 red king crabs due the dense settlement of the worms on them. There were lower CPUEs, in general, on fouled SACs with worms, and since the wormed SACs occurred mostly in the two deeper rows, worming confounded any reasonable attempt to interpret a depth factor by itself.

SACs densely populated with tube-dwelling worms were observed by divers. The wormed SACs were in partial contact with the bottom and may have provided a means of "escape" for age-0 red king crabs from the SACs. SACs deployed in a horizontal manner collected significantly fewer age-0 red king crabs than the vertical style SACs used in this experiment (Johnson 1991, Blau et al. 1992). Abundant tubed worms in the SACs may also have decreased living space and food sources for the age-0 red king crabs.

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Table 1. Set and retrieval dates with the number of unfouled and fouled SACs deployed, east of Gibson Cove headland in the City of Kodiak, Alaska,1996.

Date-1996	Unfouled SACs	Fouled SACs	No. of SACs
4/16-4/19		Set 27 strings	135
5/29	Set 3 strings		15
6/5	Pull 3 strings; Set 3 strings	Pull 3 strings	29[a]
6/12	Pull 3 strings; Set 3 strings	Pull 3 strings	30
6/19	Pull 3 strings; Set 3 strings	Pull 3 strings	30
6/26	Pull 3 strings; Set 3 strings	Pull 3 strings	30
7/3	Pull 3 strings; Set 3 strings	Pull 3 strings	30
7/10	Pull 3 strings; Set 3 strings	Pull 3 strings	30
7/17	Pull 3 strings; Set 3 strings	Pull 3 strings	29[a]
7/24	Pull 3 strings; Set 3 strings	Pull 3 strings	29[a]
7/31	Pull 3 strings; Set 3 strings	Pull 3 strings	29[a]

[a] SAC was missing or unuseable for the experiment when retrieved.

Table 2. Number of juvenile red king crabs recovered from SACs during the collector project, east of Gibson Cove headland in the City of Kodiak, Alaska, 1996.

		Glaucothoe		Age-0		Pieces		All Age-0		Age-1		No. SACs Sampled	
Week	Date	Unfouled	Fouled	Unfouled	Fouled	Unfouled	Fouled	Unfouled	Fouled	Unfouled	Fouled	Unfouled	Fouled
1	6/5	4	18	0	4	1	2	5	24	0	0	14	8
2	6/12	0	5	0	8	0	1	0	14	0	0	15	6
3	6/19	3	0	0	3	0	0	3	3	0	0	15	3
4	6/26	0	1	0	36	0	1	0	38	0	3	15	6
5	7/3	0	0	0	20	0	0	0	20	1	1	15	6
6	7/10	0	0	0	23	0	0	0	23	0	2	15	6
7	7/17	0	0	0	18	0	0	0	18	0	0	14	6
8	7/24	0	0	2	15	0	0	2	15	0	0	14	6
9	7/31	0	0	0	20	2	0	2	20	0	0	14	6
Totals		7	24	2	147	3	4	12	175	1	6	131	53

Table 3. Catch per unit effort (CPUE) of glaucothoe red king crabs per SAC, along with the number of unfouled and fouled SACs sampled per row, east of Gibson Cove headland in the City of Kodiak, Alaska, 1996.

		Unfouled							Fouled						
		Row 1		Row 2		Row 3		Overall	Row 1		Row 2		Row 3		Overall
Week	Date	CPUE	No. of SACs	CPUE	No. of SACs	CPUE	No. of SACs	Average CPUE	CPUE	No. of SACs	CPUE	No. of SACs	CPUE	No. of SACs	Average CPUE
1	6/5	0	4[a]	0.80	5	0	5	0.286	3.60	5	0	1	0	2	2.250
2	6/12	0	5	0	5	0	5	0	1.67	3	0	1	0	2	0.833
3	6/19	0	5	0.20	5	0.40	5	0.200	[b]	[b]	0	1	0	2	0
4	6/26	0	5	0	5	0	5	0	0.33	3	0	1	0	2	0.167
5	7/3	0	5	0	5	0	5	0	0	3	0	1	0	2	0
6	7/10	0	5	0	5	0	5	0	0	3	0	1	0	2	0
7	7/17	0	5	0	4[a]	0	5	0	0	3	0	1	0	2	0
8	7/24	0	5	0	4[a]	0	5	0	0	3	0	1	0	2	0
9	7/31	0	5	0	5	0	4[a]	0	0	3	0	1	0	2	0
Average		0		0.116		0.046		0.053	0.923		0		0		0.453

[a] SAC was missing from string when retrieved or was not useable because too torn or "bunched up".

[b] In week 3, the SACs from row one had moved out of the 9.2 m (5 fm) depth they were originally placed in and were discarded from the experiment.

Table 4. Analysis of factors (row, fouling and their interaction), by week, for the glm model with Poisson error, using counts of glaucothoe red king crabs collected on SACs, east of Gibson Cove headland, in the City of Kodiak, Alaska, 1996.

Week 1

Factors	Model Degrees of Freedom	Model Deviance	Change in Degrees of Freedom	Change in Deviance	Chi-Squared p-value
NULL (no factors)	21	53.1845			
Row	19	31.4757	2	21.7088	0.00002
Fouling	18	19.6686	1	11.8071	0.00059
Row:Fouling	16	8.8566	2	10.8121	0.00449

Week 2

Factors	Model Degrees of Freedom	Model Deviance	Change in Degrees of Freedom	Change in Deviance	Chi-Squared p-value
NULL (no factors)	20	25.4412			
Row	18	15.7909	2	9.6503	0.00803
Fouling	17	5.9824	1	9.8085	0.00174
Row:Fouling	15	5.9824	2	0.0000	0.99999

Table 5. Catch per unit effort (CPUE) of postlarval age-0[a] red king crabs per SAC, along with the number of unfouled and fouled SACs sampled per row, east of Gibson Cove headland, in the City of Kodiak, Alaska, 1996.

		Unfouled							Fouled						
		Row 1		Row 2		Row 3		Overall	Row 1		Row 2		Row 3		Overall
Week	Date	CPUE	No. of SACs	CPUE	No. of SACs	CPUE	No. of SACs	Average CPUE	CPUE	No. of SACs	CPUE	No. of SACs	CPUE	No. of SACs	Average CPUE
1	6/5	0	4[b]	0	5	0	5	0	0.40	5	0	1	1.00	2	0.500
2	6/12	0	5	0	5	0	5	0	2.67	3	0	1	0	2	1.333
3	6/19	0	5	0	5	0	5	0	[c]	[c]	2.00	1	0.50	2	1.000
4	6/26	0	5	0	5	0	5	0	7.33	3	5.00	1	4.50	2	6.000
5	7/3	0	5	0	5	0	5	0	5.33	3	0	1	2.00	2	3.333
6	7/10	0	5	0	5	0	5	0	6.33	3	2.00	1	1.00	2	3.833
7	7/17	0	5	0	4[b]	0	5	0	3.33	3	4.00	1	2.00	2	3.000
8	7/24	0	5	0	4[b]	0.40	5	0.143	2.00	3	3.00	1	3.00	2	2.500
9	7/31	0	5	0	5	0	4[b]	0	5.00	3	0	1	2.50	2	3.333
Average		0		0		0.046		0.015	3.769		1.778		1.833		2.774

[a] Only whole crab of the postlarval age-0 crab were used in CPUE calculations.

[b] SAC was missing from string when retrieved or was not useable because too torn or "bunched up".

[c] In week 3, the SACs from row one had moved out of the 9.2 m (5 fm) depth they were originally placed in and were discarded from the experiment.

Table 6. Analysis of factors (row, fouling and their interaction), by week, for the glm model with Poisson error, using counts of postlarval age-0[a] red king crabs collected on SACs, east of Gibson Cove headland, in the City of Kodiak, Alaska, 1996.

Factors	Model Degrees of Freedom	Model Deviance	Change in Degrees of Freedom	Change in Deviance	Chi-Squared p-value
Week 1					
NULL (no factors)	21	16.4106			
Row	19	13.8006	2	2.6100	0.27118
Fouling	18	6.4379	1	7.3627	0.00666
Row:Fouling	16	6.4379	2	0.0000	0.99997
Week 2					
NULL (no factors)	20	32.0768			
Row	18	16.6361	2	15.4408	0.00044
Fouling	17	0.9423	1	15.6938	0.00007
Row:Fouling	15	0.9423	2	0.0000	> 0.99999
Week 4					
NULL (no factors)	20	92.7653			
Row	18	84.3621	2	8.4031	0.01497
Fouling	17	0.7383	1	83.6238	< 0.00001
Row:Fouling	15	0.7383	2	0.0000	> 0.99999
Week 5					
NULL (no factors)	20	62.9708			
Row	18	43.3172	2	19.6536	0.00005
Fouling	17	1.9068	1	41.4104	< 0.00001
Row:Fouling	15	1.9068	2	0.0000	> 0.99999
Week 6					
NULL (no factors)	20	72.2270			
Row	18	52.9473	2	19.2797	0.00007
Fouling	17	3.4978	1	49.4495	< 0.00001
Row:Fouling	15	3.4978	2	0.0000	0.99999
Week 7					
NULL (no factors)	19	44.7022			
Row	17	42.7084	2	1.9938	0.36903
Fouling	16	0.1943	1	42.5142	< 0.00001
Row:Fouling	14	0.1943	2	0.0000	> 0.99999
Week 8					
NULL (no factors)	19	34.2980			
Row	17	33.1530	2	1.1450	0.56411
Fouling	16	7.5907	1	25.5623	< 0.00001
Row:Fouling	14	4.3449	2	3.2458	0.19732

-Continued-

Table 6. (page 2 of 2)

Factors	Model Degrees of Freedom	Model Deviance	Change in Degrees of Freedom	Change in Deviance	Chi-Squared p-value
Week 9					
NULL (no factors)	19	58.9582			
Row	17	41.9250	2	17.0332	0.00020
Fouling	16	1.5122	1	40.4128	< 0.00001
Row:Fouling	14	1.5122	2	0.0000	0.99998

[a] Postlarval age-0 red king crab category included only whole crabs and excluded crabs in the age-0 pieces category.

Table 7. Catch per unit effort (CPUE) of all age-0[a] red king crabs per SAC, along with the number of unfouled and fouled SACs sampled per row, east of Gibson Cove headland, in the City of Kodiak, Alaska, 1996.

		Unfouled							Fouled						
		Row 1		Row 2		Row 3		Overall	Row 1		Row 2		Row 3		Overall
Week	Date	CPUE	No. of SACs	CPUE	No. of SACs	CPUE	No. of SACs	Average CPUE	CPUE	No. of SACs	CPUE	No. of SACs	CPUE	No. of SACs	Average CPUE
1	6/5	0	4[b]	1.00	5	0	5	0.357	4.20	5	1.00	1	1.00	2	3.000
2	6/12	0	5	0	5	0	5	0	4.33	3	1.00	1	0	2	2.333
3	6/19	0	5	0.20	5	0.40	5	0.200	[c]	[c]	2.00	1	0.50	2	1.000
4	6/26	0	5	0	5	0	5	0	7.67	3	5.00	1	5.00	2	6.333
5	7/3	0	5	0	5	0	5	0	5.33	3	0	1	2.00	2	3.333
6	7/10	0	5	0	5	0	5	0	6.33	3	2.00	1	1.00	2	3.833
7	7/17	0	5	0	4[b]	0	5	0	3.33	3	4.00	1	2.00	2	3.000
8	7/24	0	5	0	4[b]	0.40	5	0.143	2.00	3	3.00	1	3.00	2	2.500
9	7/31	0.40	5	0	5	0	4[b]	0.143	5.00	3	0	1	2.50	2	3.333
Average		0.046		0.140		0.091		0.092	4.731		2.000		1.889		3.302

[a] The all ag-0 group includes glaucothoe, whole postlarval age-0 and pieces from unique age-0 crabs.

[b] SAC was missing from string when retrieved or was not useable because too torn or "bunched up".

[c] In week 3, the SACs from row one had moved out of the 9.2 m (5 fm) depth they were originally placed in and were discarded from the experiment.

Table 8. Analysis of factors (row, fouling and their interaction), by week, for the glm model with Poisson error, using counts of all age-0[a] red king crabs collected on SACs, east of Gibson Cove headland, in the City of Kodiak, Alaska, 1996.

	Factors	Model Degrees of Freedom	Model Deviance	Change in Degrees of Freedom	Change in Deviance	Chi-Squared p-value
Week 1						
	NULL (no factors)	21	54.1643			
	Row	19	39.6115	2	14.5528	0.00069
	Fouling	18	20.0972	1	19.5143	0.00001
	Row:Fouling	16	9.9138	2	10.1834	0.00615
Week 2						
	NULL (no factors)	20	53.9884			
	Row	18	33.5964	2	20.3919	0.00004
	Fouling	17	4.5108	1	29.0856	< 0.00001
	Row:Fouling	15	4.5108	2	0.0000	> 0.99999
Week 3						
	NULL (no factors)	17	15.9559			
	Row	15	12.0158	2	3.9401	0.13945
	Fouling	14	9.8229	1	2.1929	0.13865
	Row:Fouling	13	8.2705	1[b]	1.5524	0.21279
Week 4						
	NULL (no factors)	20	97.9352			
	Row	18	89.1194	2	8.8159	0.01218
	Fouling	17	1.0284	1	88.0910	< 0.00001
	Row:Fouling	15	1.0284	2	0.0000	> 0.99999
Week 5						
	NULL (no factors)	20	62.9708			
	Row	18	43.3172	2	19.6536	0.00005
	Fouling	17	1.9068	1	41.4104	< 0.00001
	Row:Fouling	15	1.9068	2	0.0000	> 0.99999
Week 6						
	NULL (no factors)	20	72.2270			
	Row	18	52.9473	2	19.2797	0.00007
	Fouling	17	3.4978	1	49.4495	< 0.00001
	Row:Fouling	15	3.4978	2	0.0000	0.99999
Week 7						
	NULL (no factors)	19	44.7022			
	Row	17	42.7084	2	1.9938	0.36903
	Fouling	16	0.1943	1	42.5142	< 0.00001
	Row:Fouling	14	0.1943	2	0.0000	> 0.99999

-Continued-

Table 8. (page 2 of 2)

Factors	Model Degrees of Freedom	Model Deviance	Change in Degrees of Freedom	Change in Deviance	Chi-Squared p-value
Week 8					
NULL (no factors)	19	34.2980			
Row	17	33.1530	2	1.1450	0.56411
Fouling	16	7.5907	1	25.5623	< 0.00001
Row:Fouling	14	4.3449	2	3.2458	0.19732
Week 9					
NULL (no factors)	19	54.7645			
Row	17	35.1550	2	19.6096	0.00006
Fouling	16	6.4429	1	28.7120	< 0.00001
Row:Fouling	14	5.1774	2	1.2655	0.53113

[a] All age-0 included whole glaucothoe, whole postlarval age-0 and unique pieces from age-0 crabs.

[b] In the 3rd week, row 1 the string of SACs to be pulled for that week had moved deeper, so was not used in this experiment.

Table 9. Catch per unit effort (CPUE) of age-1 red king crabs per SAC, along with the number of unfouled and fouled SACs sampled per row, east of Gibson Cove headland in the City of Kodiak, Alaska, 1996.

		Unfouled							Fouled						
		Row 1		Row 2		Row 3		Overall	Row 1		Row 2		Row 3		Overall
Week	Date	CPUE	No. of SACs	CPUE	No. of SACs	CPUE	No. of SACs	Average CPUE	CPUE	No. of SACs	CPUE	No. of SACs	CPUE	No. of SACs	Average CPUE
1	6/5	0	4[a]	0	5	0	5	0	0	5	0	1	0	2	0
2	6/12	0	5	0	5	0	5	0	0	3	0	1	0	2	0
3	6/19	0	5	0	5	0	5	0	[b]	[b]	0	1	0	2	0
4	6/26	0	5	0	5	0	5	0	1.00	3	0	1	0	2	0.500
5	7/3	0	5	0	5	0.20	5	0.067	0.33	3	0	1	0	2	0.167
6	7/10	0	5	0	5	0	5	0	0	3	0	1	1.00	2	0.333
7	7/17	0	5	0	4[a]	0	5	0	0	3	0	1	0	2	0
8	7/24	0	5	0	4[a]	0	5	0	0	3	0	1	0	2	0
9	7/31	0	5	0	5	0	4[a]	0	0	3	0	1	0	2	0
Average		0		0		0.023		0.008	0.154		0		0.111		0.113

[a] SAC was missing from string when retrieved or was not useable because too torn or "bunched up".

[b] In week 3, the SACs from row one had moved out of the 9.2 m (5 fm) depth they were originally placed in and were discarded from the experiment.

Table 10. Analysis of factors (row, fouling and their interaction) for the glm model with Poisson error, using counts of age-1 red king crabs collected on SACs, east of Gibson Cove headland in the City of Kodiak, Alaska, 1996.

Combined Weeks 4-6

Factors	Model Degrees of Freedom	Model Deviance	Change in Degrees of Freedom	Change in Deviance	Chi-Squared p-value
NULL (no factors)	62	33.5337			
Row	60	28.7829	2	4.7509	0.09297
Fouling	59	20.5656	1	8.2173	0.00415
Row:Fouling	57	19.0711	2	1.4945	0.47367

Table 11. Catch per unit effort (CPUE) of glaucothoe, postlarval age-0[a], all age-0[b] and age-1 red king crabs per SAC, of SACs that had worms on them versus those which did not, east of Gibson Cove headland in the City of Kodiak, Alaska, 1996.

		Glaucothoe			Age-0			All Age-0			Age-1		
		Row 1 No worms	Row 2 Worms	Row 3 Worms	Row 1 No worms	Row 2 Worms	Row 3 Worms	Row 1 No worms	Row 2 Worms	Row 3 Worms	Row 1 No worms	Row 2 Worms	Row 3 Worms
Week	Date	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE	CPUE
1	6/5	3.60	0	0	0.40	0	1.00	4.20	1.00	1.00	0	0	0
2	6/12	1.67	0	0	2.67	0	0	4.33	1.00	0	0	0	0
3	6/19	[c]	0	0	[c]	2.00	0.50	[c]	2.00	0.50	[c]	0	0
4	6/26	0.33	0	0	7.33	5.00	4.50	7.67	5.00	5.00	1.00	0	0
5	7/3	0	0	0	5.33	0	2.00	5.33	0	2.00	0.33	0	0
6	7/10	0[d]	0	0	6.33[d]	2.00	1.00	6.33[d]	2.00	1.00	0[d]	0	1.00
7	7/17	0	0	0	3.33	4.00	2.00	3.33	4.00	2.00	0	0	0
8	7/24	0	0	0	2.00	3.00	3.00	2.00	3.00	3.00	0	0	0
9	7/31	0	0[e]	0[e]	5.00	0[e]	2.50[e]	5.00	0[e]	2.50[e]	0	0[e]	0[e]
Average		0.923	0	0	3.769	1.778	1.833	4.731	2.000	1.889	0.154	0	0.111

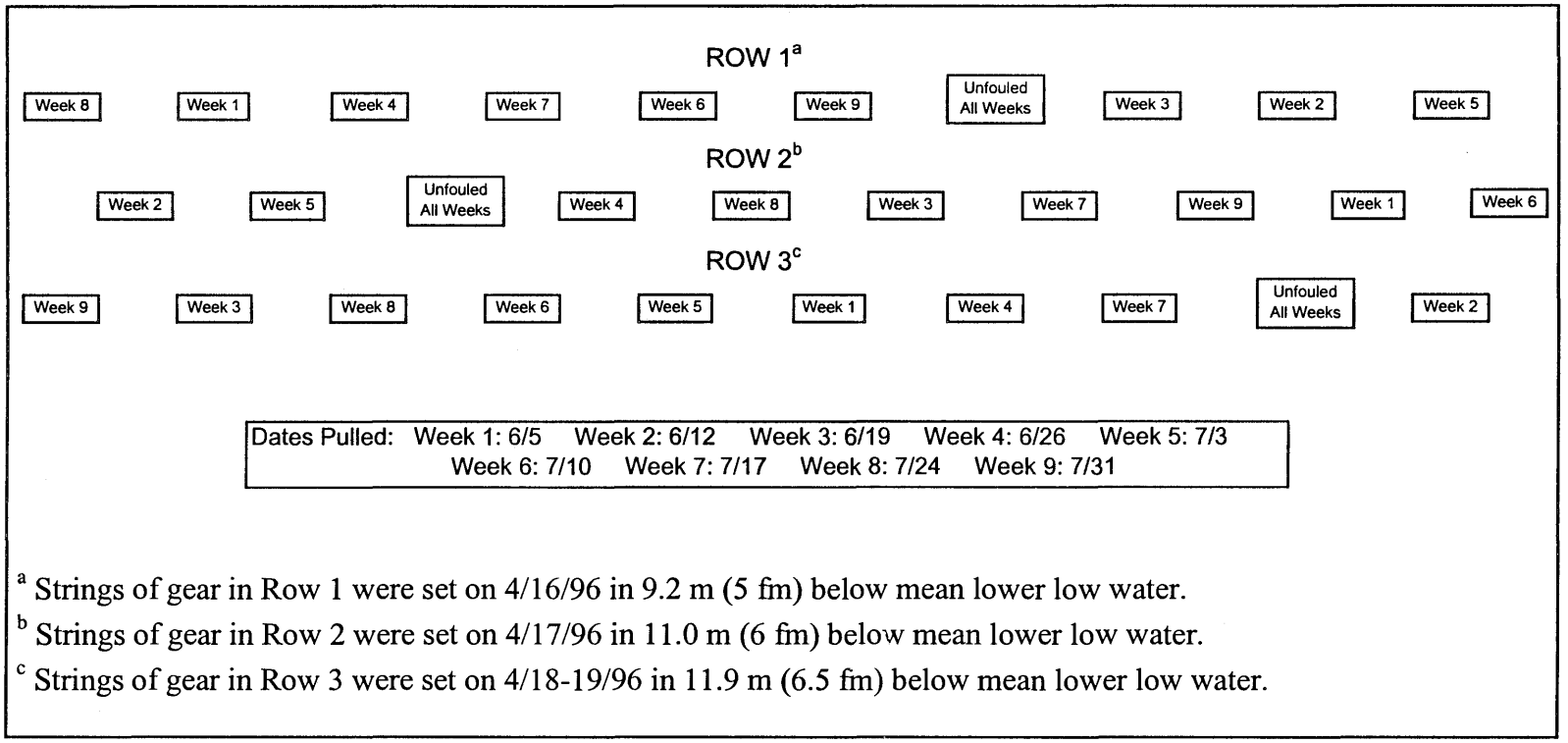
[a] Only whole crab of the postlarval age-0 crab were used in CPUE calculations.

[b] The all age-0 group includes glaucothoe, whole postlarval age-0 and pieces from unique age-0 crabs.

[c] In week 3, the SACs from row one had moved out of the 9.2 m (5 fm) depth they were originally placed in, so were discarded from the experiment.

[d] In week 6, the SACs from row one had worms on them.

[e] In week 9, the SACs from rows two and three did not have worms on them.



[a] Strings of gear in Row 1 were set on 4/16/96 in 9.2 m (5 fm) below mean lower low water.

[b] Strings of gear in Row 2 were set on 4/17/96 in 11.0 m (6 fm) below mean lower low water.

[c] Strings of gear in Row 3 were set on 4/18-19/96 in 11.9 m (6.5 fm) below mean lower low water.

Figure 1. Randomization by row for week of fouled SAC retrieval for 30 strings of gear. There was one unfouled string of gear in each row, that was replaced every week. The study location was east of Gibson Cove headland in the City of Kodiak, Alaska, 1996.

APPENDIX

Appendix A.1. Sampling form used during the collection of age-0 red king crabs near Gibson Cove, Kodiak Island.

1996 Age-0 Red King Crab Collector Project, Gibson Cove Row No. ____ Buoy No. ____ Mo./Day ___/

Recorder _____ Measurer _____ Counter _____

Station (String) Quality Code: ___ **0** = station string laid out on the ocean bottom as set; SACs spaced properly, and SAC bases ≤1 m off bottom; confirmed by divers and was not tangled when retrieved; **1** = entire string of SAC's when retrieved was as set but its condition on the bottom was not verified by divers; **Note:** SAC condition codes 0-3 may be included in station quality code 1; **2** = string had one or more SAC's whose bases were ≥1 m off the bottom as observed by divers; **3** = all SAC's tangled when retrieved, their number sequence when washed was arbitrary, one or more SAC's may have their bases ≥1 m off the bottom; (Note station code 4 drop in 1994) **5** = string of gear completely missing (not retrieved after repeated attempts to retrieve it) or due to technical difficulties, no useable data could be obtained from the string; and **6** = station is considered ancillary since it was retrieved at a location different from its proper index station location where it was originally set (i.e. moved by fishermen or storm).

SAC. Retrieval Order	Lead Wt Present 1=yes 2=no	Hydroids on SAC 1=none, 2=light 3=med., 4=heavy	Number RKC Age Classes Glauc. 0 1 2	Red King Crab Carapace Lengths Measure to Nearest 0.1 mm
1. Southern-most				
2.				
3.				
4.				
5. Northern-most				

[a]SAC Condition Codes: **0** = SAC in good condition (no rips, tears; not bunched-up); **1** = SAC had a small rip or tear in outer skin and/or ≤ 25% herring gillnet missing; **2** = SAC was processed but data not useable because net loss too great (> 25%), or the SAC was bunched up, tangled, and not fishing correctly, or divers observed it covered by sand; **3** = was not processed because it was missing or ripped and the netting was mostly gone; **4** = horizontal SAC off bottom ≥ 1 m as observed by divers and in good condition; therefore fishing similar to a vertical SAC.

[b]Age/size estimates for of red king crabs collected in Sept. & Oct. are: age-0 ≤ 7.5 mm CL, age-1 crabs >7.5-20.0 mm CL, age-2 >20.0 mm CL.

Species identification and counts from SAC order # ____.

6/3/96