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Use of Lower Minimum Size Limits to Reduce Discards in the Bristol Bay Red King Crab (Paralifhodes camtschaticus) Fishery

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INTRODUCTION

It has recently been reported by Beers (1991) that bycatch rates of red king crabs (Paralithodes camtschaticus) are substantial in the eastern Bering Sea red king crab and Tanner crab (Chionoecetes bairdi) fisheries. For example, in the 1990 Bristol Bay red king crab fishery, the catch per potlift-of females and sublegal males was 1.4 times the catch rate of legal male crabs. During the 1990 winter Tanner crab fishery, red king crab catch rates were 80% of the catch per potlift of legal-sized Tanner crabs. These catch rates were estimated using data collected from the catcher/processor portion of the fleet. If the samples are representative of the fleet as a whole, then it can be estimated that the 262,181 potlifts exerted by the red king crab fishery would result in the discard of 4.4 million red king crabs, while the 711,137, potlifts of the winter Tanner crab fishery would result in the discard of 11.5 million red king crabs. The total estimate of discarded red king crabs, assuming each--was handled only once, is about 16 million crabs. during these two fisheries. This bycatch estimate represents over 40% of the mature stock, as estimated by the 1990 National Marine Fisheries Service Bering Sea trawl survey, and signals a potential problem for the red king crab resource.

If these bycatch estimates are even approximately correct, they immediately raise the question of the impact of discard mortality. The question of the impact of discard mortality is in need of study. While little information on the subject is available, a study by Carls and O'Clair (1990) indicates that red king crabs are adversely affected by exposure to cold air temperatures, which may occur when crab pots are brought onboard during winter fishing seasons. Additionally, some insight into the question may be gained from the recent work of Shirley (pers. comm., University of- Alaska Fairbanks, 11120 Glacier Highway, Juneau AK) with Dungeness crabs (*Cancer magister*) in Southeast Alaska. In aquarium experiments intended to simulate the handling process or this species in local fisheries; delayed mortality of up to several: weeks was observed. This mortality was related to the number of times crabs were handled. Crabs were subjected to handling one, two, three, and four times per month, and then mortality rates were compared to crabs that had not been handled. Proportionally increasing mortality rates were observed, with a 100% death rate resulting from four simulated -handling treatments. The unhandled (control) crabs had no mortalities.

The apparent high discard rates of king crab and the possibility. of significant associated mortality provide a strong argument for conducting experiments to estimate discard mortality, even if only a rough estimate can be obtained. Knowledge of discard mortality rates can provide guidance on what approach should be taken to achieve a solution to the problem, and possibly improve stock productivity. If discard mortality is low, then the most prudent approach might be to maintain the status quo that is, continue the current management strategy and await rebuilding via a strong year &ass., If the mortality rate is high,. alternate solutions having to do with changes in the selective properties and operation of the gear, changes in time and area of the fishery, or other modifications may well be preferable in order. to increase stock productivity. It may be possible through experimentation to design gear and gear operations to minimize crab bycatch. Design, however, is complicated by the interaction of the selective properties of mesh and escape port sizes, with soak time and other factors affecting the attractive properties, of baited pots. Thus, this type of experimentation could be time-consuming and result in considerable costs to research agencies and to the industry.. It may also be possible, to devise time or area closures, but it is likely that the overlap of the. legal and non-legal components of the stocks is substantial, indicating, an ineffective solution.

Another management alternative to deal with high discard mortalities could be to reduce discard mortality through the retention of a larger portion of the catch normally thrown back; Under this management strategy, the quota is reached sooner with the same fleet, thereby shortening the fishing season and reducing discards and unintended mortality on the stock of any given year. This basic idea of keeping more of what comes up in a pot could be realized through a lower size limit, or relaxation, of the males-only restriction, or a combination of both regulation changes. Discard reduction could prove to be an effective approach to the problem, but not without perhaps substantial costs to the industry.

The purpose of this report is to provide a preliminary examination of discard reduction via lower male size limits and its effect on fishery characteristics through a simple computer simulation of the 1990 red king crab males-only fishery in Bristol Bay. Information from the 1990 fishery and NMFS research: trawl survey was used to construct a model which was then exercised under several lower size limits. Results of these variations were then compared to simulated actual results of the 1990 red king crab season in terms of catches, average weights, discards, and exploitation rates.

METHODS

The 1990 Bristol Bay red king crab fishery was simulated using a PC spreadsheet by applying observed rates of exploitation to estimated stock to obtain a total. catch and average weight per crab similar to the actual fishery. Discard mortality was assigned two different values to simulate low and high rates, 25% and 75%, and the number of crabs dying from the discard process was calculated. Three alternate management options, represented by three different minimum size limits on male crabs, were applied to the stock and compared to the simulated actual fishery having a 6.5-inch carapace width (CW) size limit: (1) lower the minimum size limit to 6.0 inches CW, (2) lower it to 5.5 inches CW, or (3) lower it to 5.0 inches CW. The harvest strategy for this stock is to limit the rate of exploitation to 20% on mature male crabs greater than 119 mm carapace length (CL)(ADF&G 1990,). Thus, the simulated fisheries were terminated when this target was attained.

Estimates of exploitation rates by size groups were obtained by combining information on the size composition of landings and on-deck catches from the 1990 ADF&G Observer Program (Appendix Table 1). These catches were then compared to 1990 NMFS survey estimates of abundance made prior to the fishing season (Appendix Table 2). Using 5 mm grouping, the size composition of the 1990 landings was estimated by applying the dockside CL sample of the landings (Griffin, pers. comm., ADF&G, Box 308, Dutch Harbor AK) to the-total landed catch in numbers. 'Size composition of the discard was estimated by applying the sample composition of on-deck catches to total discarded catch.. Total discarded catch was estimated by multiplying catch rates for females and sublegal males (10.1 and 6.5 crabs per potlift, respectively, from Beers 1991) by the total potlifts during the 1990 fishery (Griffin 1991). In applying the size 'composition of sublegal males to total discards, 40% of the 135-,139 mm CL group was assumed to be sublegal, assuming legal crabs are greater than 136 mm, and a uniform distribution of crabs existed within this length group. This value, plus values for all smaller male groups, was used to obtain the percent size composition of the male portion of the on-deck catch. Exploitation rates were then calculated by 5 mm groups for males and females by dividing estimated' catches by estimates of the stock from the survey.

Landings in weight were underestimated by the initial simulation of the fishery. To correct for this, the-weight-length exponent used for estimating average weight per male crab for the survey data was adjusted upward slightly from 3.174 to 3.181 to attain agreement with actual landings.

Using exploitation rates as calculated above, the fishery was simulated under four different minimum size limits: 6.5, 6.0, 5.5, and 5.0 inches CW. The various size limits were simulated by a sliding scale of size-specific selection factors (1.0, 0.4, 0.1, and 0.0; see Appendix Tables 3-6) determined- in the following way. The predominant 5 mm size groups in the 1990. landings ranged from 140 to 169 mm. Each of these groups contained 2 million lb or more, and taken collectively comprised 87% of the catch in weight (Appendix Table 2). Thus, the smallest of these groups, the 140-144 mm group, was considered the first size group fully recruited to the landings, and was assigned selection- factor of -1.0, as were all larger size groups. Size groups smaller than this were assigned selection factors calculated as the ratio of the size group-specific exploitation rate to the average exploitation rate of groups with catches of 2 million pounds or more (0.37). The 6.5 inch CW size limit, when converted to length in millimeters using a carapace width-length coefficient of 1.25 (Alverson 1980), falls into the size group 10 mm smaller than the -first fully recruited group. Thus, for each 0.5 inch decrease in the simulated CW size limit, the first fully recruited CL group was lowered by 10 mm:

Harvest strategy-for this stock dictates that 20% of the mature males- (>119 mm) may be taken (ADF&G 1990). Thus, for each size limit simulation, this strategy was used to terminate the fishery. The actual. value calculated for the 1990 fishery was 0.22, and the days fished and size-specific exploitation rates for the season were adjusted until the value 0.22 on males >119 mm was achieved for each simulation. For each sex-size group, the adjusted exploitation rate (u') = DF/12*u, where DF is. days fished, set to achieve the target exploitation rate for each size limit simulation, and u is the exploitation rate. under a 6.5 inch size limit: -Catch (c) =u'*N and landings,.(l) = s*c, where N is stock,, and, s is the selection, or sorting, factor. The unknown. discard mortality (dm) was assigned low (0.25) and high (0.75) values-for each simulation. Discard mortality was applied to each sex equally, and discard deaths were calculated -for each group as (1-s)*dm*c. Calculations were summed over groups and, along with average weight of landings and exploitation rates, were compared among simulations. The 6.5 inch simulation was considered the control to which other size limit strategies were compared.

RESULTS

As lower size limit strategies were employed, the number of days fished and average weight of crabs in the landings decreased (Fig. 1). Lowering the size limit increased the retention of smaller crabs, which lowered the average weight of crabs in landings. Additionally, as more crabs were included in landings, the fishing rate required at higher size limits needed lowering to stay within the 0.22 target value. As would realistically be expected, the required reduction in fishing mortality was attained. by reducing days fished. Landings in pounds overall decreased, but they increased. slightly at the lowest size limit. This increase was due to significant numbers of crabs less than 120 mm entering the catch; these crabs were not counted toward attainment of the target exploitation rate. This ocurred to a lesser degree with the 5.5 inch CW size limit simulation. Thus, the lowest simulated size limit strategies, especially the 5.0 inch CW simulation, must be considered unrealistic in light of an exploitation strategy based on males less than 119 mm.

As the size limit was lowered and more of the catch was retained as landings, deaths due to discard mortality declined compared to deaths due to landings (Fig. 2). Discard deaths which, at the

0.75 discard mortality level were higher than landings dropped off substantially with the 6.0 inch CW size limit and more, gradually thereafter. The magnitude of this and other trends reflects the 1990 population size. composition: Although untested, these trends are probably dependent on size composition to a significant degree.

Simulated discard deaths by sex are, shown in Figure 3. The decline in deaths with decreasing size limit was due to a greater rate of decline for males, as opposed to females. Two factors are involved in the male process, that of conversion of discards to catch, and fewer days fished. Only the latter factor is involved in the decline in female discard deaths, and-this explains the flattening out of discard deaths at lower size limits.

The presence of discard mortality caused the target exploitation rate to be, exceeded (Fig. 4), with the degree depending on the level of discard' mortality; As the size limit waslowered, this overshooting effect. diminished as a result of decreasing male discard deaths. The proportion of discard deaths and landings (as noted above) that are less than 120 mm increased as the size limit was lowered (Appendix Tables 3-6), and these did not enter into the exploitation rate calculation; Their exclusion leads to the formation of a plateau in the exploitation rate at lower size limits. This pattern is an artifact associated with lowest simulated size limits.

DISCUSSION

From the foregoing results,, the following conclusions may be drawn. Under current harvest policy and stock conditions, and assuming the discard mortality rate is greater than zero, a minimum size limit lower than 6.5 inches CW will decrease the number of deaths due to discards in the fishery. Such a. decrease in discard deaths means that the actual exploitation rate on male crabs greater than 119 mm will be closer to that dictated by harvest strategy. The average size of crabs in the landings will decrease and, given the same fishing effort as with the 6.5 inch CW size limit, the seasonwill be shorter.

This study is limited in scope and the universality of these conclusions is open to question. The magnitude, and perhaps the direction,of trends upon which these conclusions are based is dependent' on the stock size composition during the fishery. Year-to-year variations in recruitment strength will cause changes in size composition, which in turn will alter the patterns found in this study. Thus, it would be useful to test the generality of the above results through multi-year simulations of the stock and fishery. Such simulations could provide insight into the effect of year class fluctuations as well aschanges in other population parameters.

Another extension of this study' would 'be to examine, the. effects of retention of females. The limited pot bycatch data available indicates that female red king crabs are predominant in the discard. If discard mortality rates are high, it seems that gains in production would be enhanced by the retention of females, especially at higher stock levels.

This study emphasizes the need to
discard mortality for Bristol Bay
that the severity of the problem and the need for remedial action 'is directly related to the magnitude of discard mortality. It is not clear, however, that the higher exploitation rates caused by 'higher discard mortality rates are actually retarding this stock's' recovery.. But circumstantial evidence does exist that the stock's decline and subsequent failure to significantly rebound may be related to fishing effort. This is shown in Figure 5A, where the total potlift trend in red king crab habitat (east of 166" E long'.) is compared to the abundance of nonlegal crabs.' It is possible that the buildup in effort. in the late

1970s contributed to the decline in the early 1980s through discard mortality. Further,' it is possible that the current buildup in potlifts is contributing to the continuing depressed state of the stock. The possibility that discards may be affecting the stock provides additional impetus for evaluating discard mortality.

The multispecies nature of the pot discard problem is becoming apparent. As mentioned in the Introduction, if the estimate of discards in 1990 is assumed to be representative of the total fleet, then more red king crabs are thrown back in the eastern Bering Sea Tanner crab fishery than in the target fishery. This argues strongly for a multispecies, as well as a multiyear approach in evaluating the red king crab discard problem. Figure 5B shows that potlift effort in red king crab habitat is currently increasing after a period of decline and bottoming. As in the previous buildup,. the composition of effort is made up predominately of potlifts from-the Tanner and red king crab fisheries. Thus, further studies on discard mortality impact should be tailored to include probable interactions of the Tanner crab fishery with the red king crab fishery. Studies similar to this one should be conducted for Tanner crab, including the concept of a multispecies or one-season fishery for these stocks.

Finally, the economic implications of the these results have not been considered. Further studies ondiscard reduction through lower size limits should examine various tradeoffs between 'industry perturbations. caused by smaller crabs, shorter or multispecies seasons, and possible benefits of stock rehabilitation. Also, costs of a solution such as the one proposed in this paper should be compared to costs of gear modifications or other potential solutions.

CITATIONS

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APPENDIX

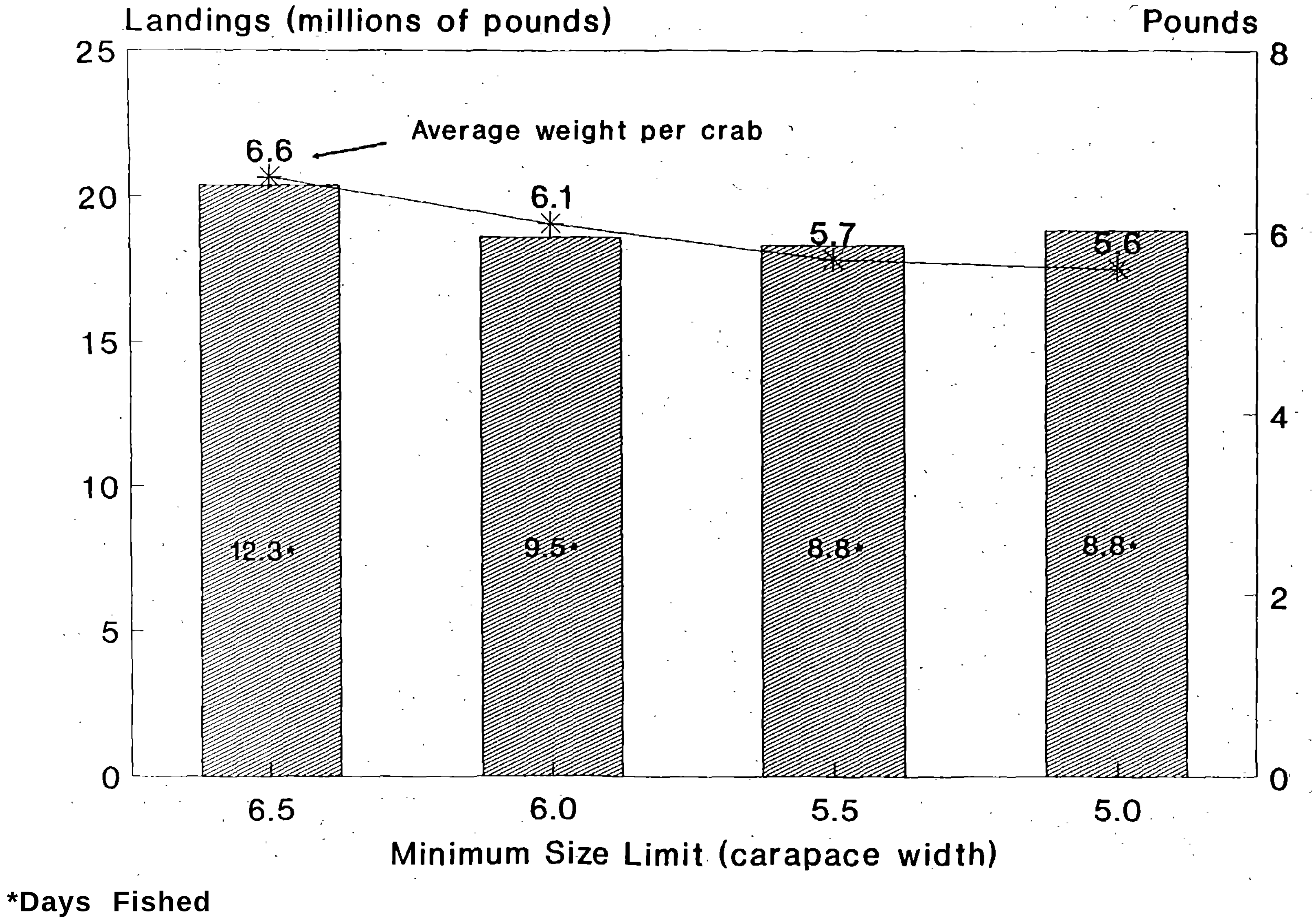


Figure 1. Landings, average weights, and days fished for simulations of the 1990 Bristol Bay red king crab fishery, under different minimum size limits (inches').

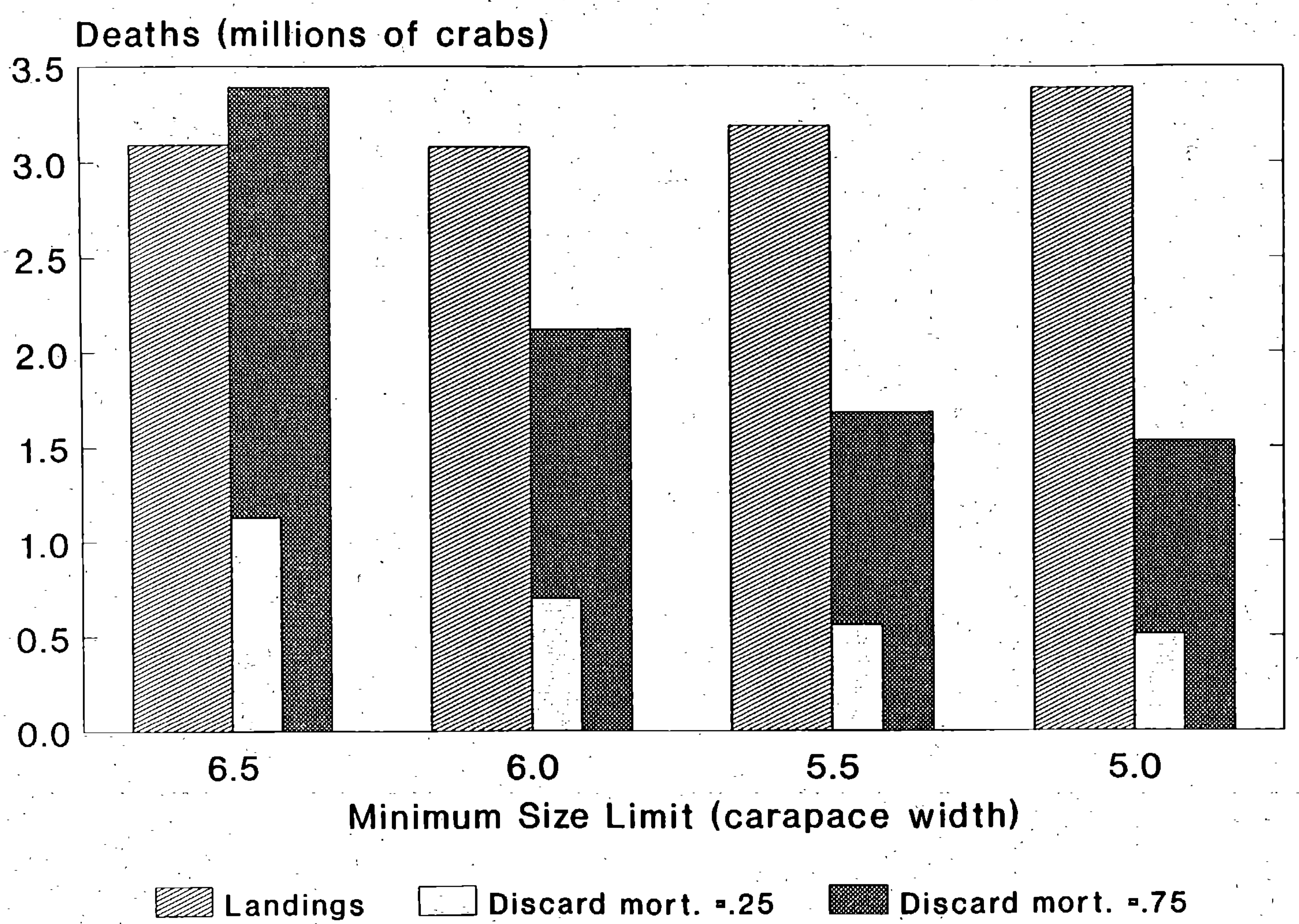
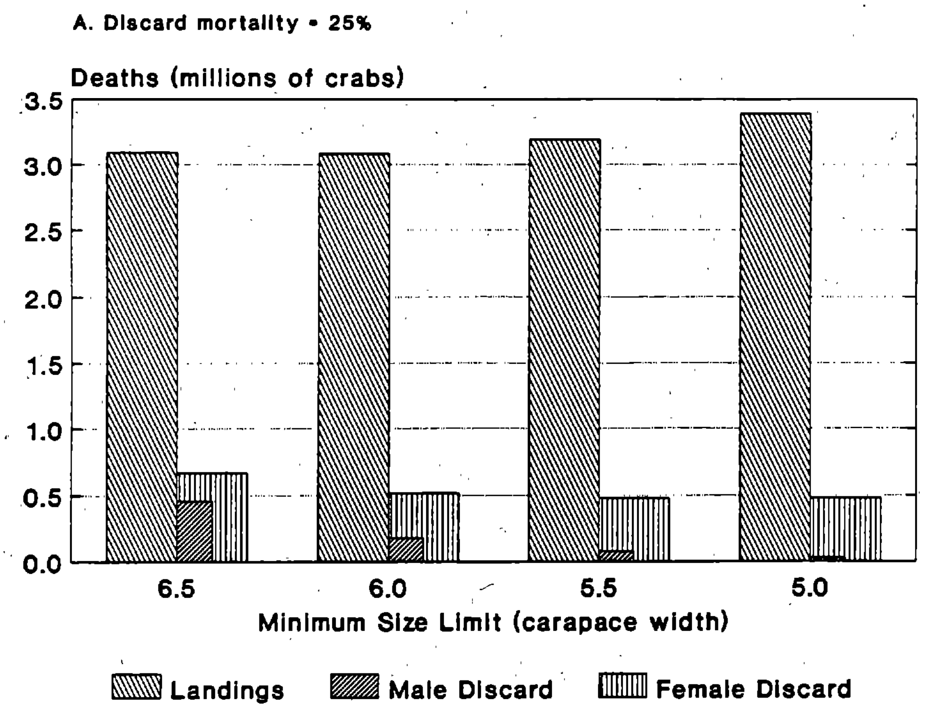


Figure 2. Discard deaths compared to landings for two levels of discard mortality from simulations of the 1990 Bristol Bay red king crab fishery under different minimum size limits (inches).



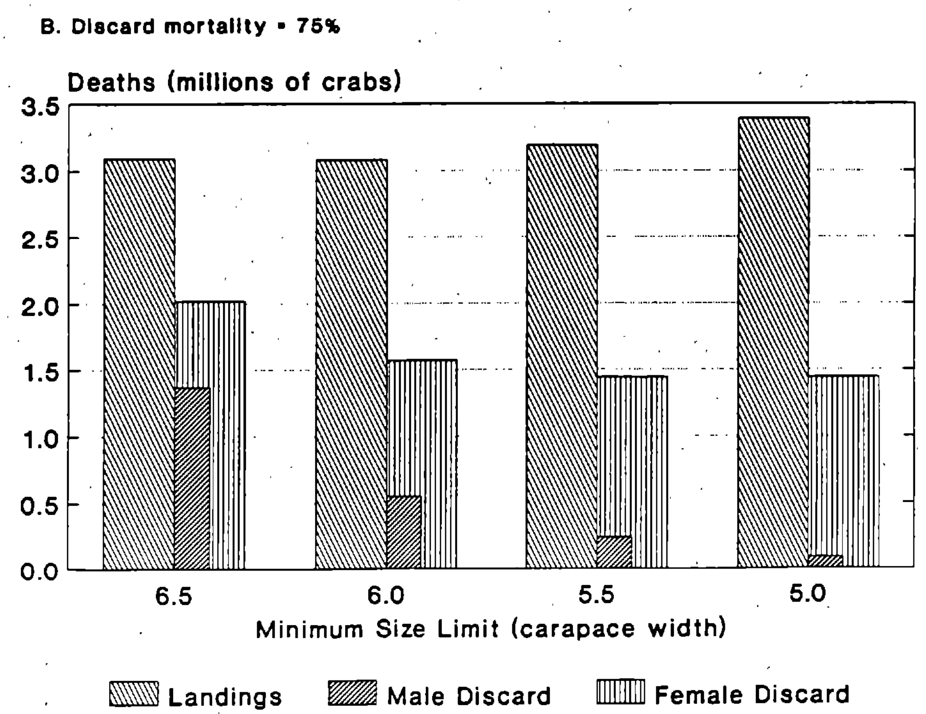


Figure 3. Discard deaths by sex compared to landings for two levels of discard mortality, A. 0.25 and B. 0.75, from simulations. of the 1990 Bristol Bay red king crab fishery under different minimum size limits (inches).

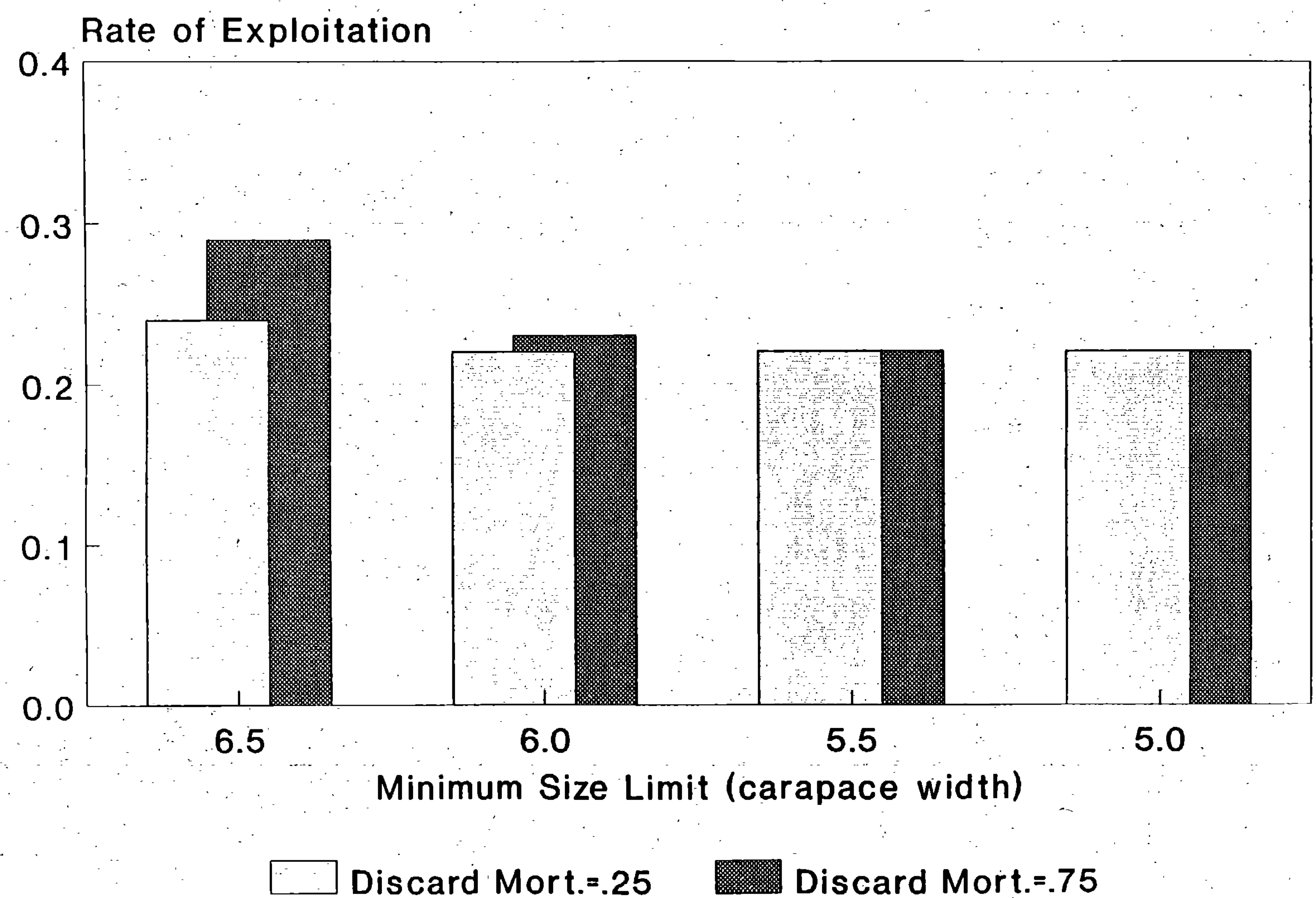
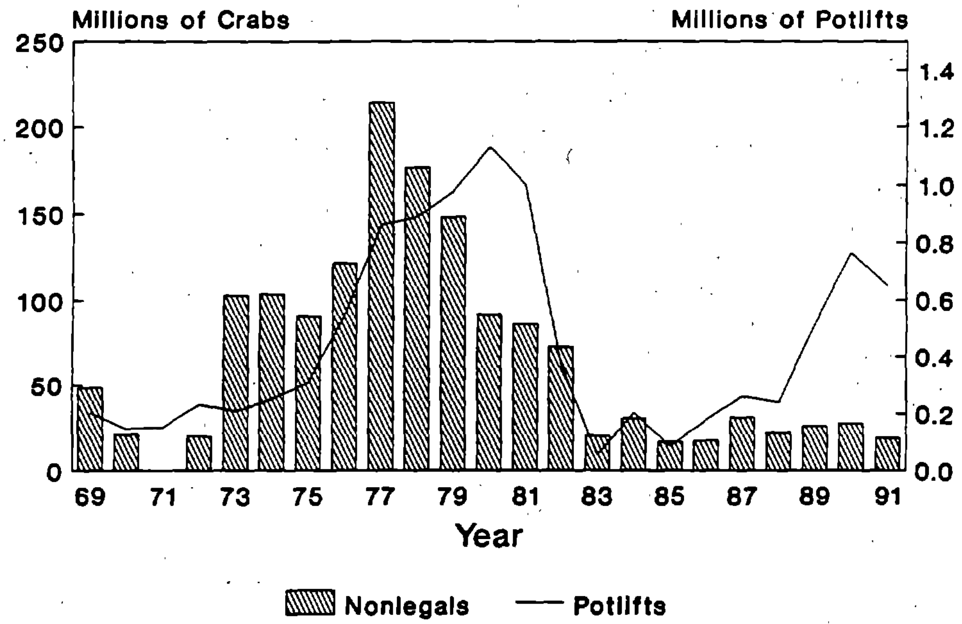


Figure 4. Rates of exploitation for males-greater than 119 mm, for two levels of discard mortality from simulations of the 1990 Bristol Bay red king crab fishery under different minimum size limits (inches).

A. Nonlegal Abundance vs. Fishing Effort



B. Composition of Fishing Effort

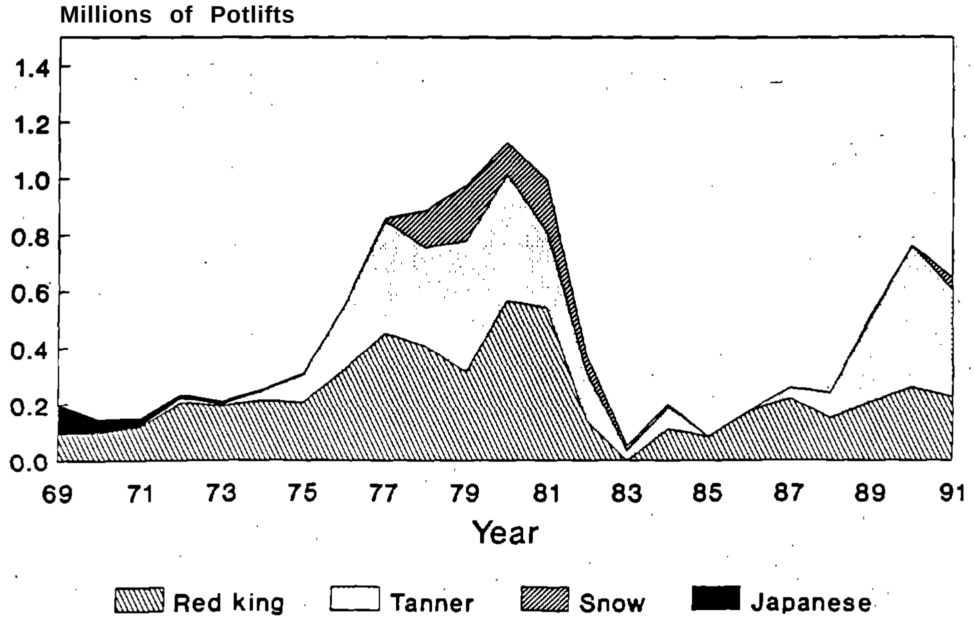


Figure 5. Bristol Bay red king crab (A) estimated-abundance of nonlegal crabs compared to total potlifts east of 166" E long. and (B) potlift composition by fishery.

Appendix Table 1: 1990 Bristol Bay red king crab fishery site composition-date from dockside and on-board observer sampling programs.

CARAPACE LENGTH GROUP (mm)	SAMPLING DOCKSIDE MALES (Nos.)	SAMPLING OBSERVER MALES (Nos.)	SAMPLING OBSERVER FEMALES (Nos.)	SAMPLING DOCKSIDE MALES (%)	SAMPLING OBSERVER MALES (%)	SAMPLING OBSERVER FEMALES (%)	ESTIMATED NUMBER LANDINGS MALES (MLns.)	ESTIMATED NUMBER DISCARD MALES (MLns.)	ESTIMATED NUMBER DISCARD FEMALES (MLns.)
60 - 64		2		0.00%	0.22%	0.00%	0.00	0.00	0.00
65 - 69				0.00%	0.00%	0.00%	0.00	0.00	0.00
70 - 74			2	0.00%	0.00%	0.14%	0.00	0.00	0.00
75 - 79		2	4	0.00%	0.22%	0.29%	0.00	0.00	0.01
80 - 84		9	2	0.00%	0.97%	0.14%	0.00	0.02	0.00
85 - 89		6	8	0.00%	0.65%	0.57%	0.00	0.01	0.02
90 - 94		12	9	0.00%	1.29%	0.64%	0.00	0.02	0.02
95 - 99		8	22	0.00%	0.86%	1.57%	0.00	0.01	0.04
100 -104		33	94	0.00%	3.56%	6.72%	0.00	0.06	0.18
105 -109		42	141	0.00%	4.53%	10.08%	0.00	0.08	0.27
110 -114		70	239	0.00%	7.55%	17.08%	0.00	0.13	0.45
115 -119		108	237	0.00%	11.64%	16.94%	0.00	0.20	0.45
120 -124	2	132	300	0.03%	14.23%	21.44%	0.00	0.24	0.57
125 -129	0	160	192	0.00%	17.25%	13.72%	0.00	0.29	0.36
130 -134	105	240	100	1.46%	25.87%	7.15%	0.05	0.44	0.19
135 -139	637	259	34	8.87%	11.17%	2.43%	0.28	0.19	0.06
140 -144	1294	270	10	18.01%		0.71%	0.56	0.00	0.02
145 -149	1226	291	2	17.07%		0.14%	0.53	0.00	0.00
150 -154	1241	236		17.28%		0.00%	0.54	0.00	0.00
155 -159	1028	242		14.31%		0.00%	0.45	0.00	0.00
160 -164	831	205	3	11.57%		0.21%	0.36	0.00	0.01
165 -169	523	122		7.28%		0.00%	0.23	0.00	0.00
170 -174	228	68		3.17%		0.00%	0.10	0.00	0.00
175 -179	51	18		0.71%		0.00%	0.02	0.00	0.00
180 -184	14	6		0.19%		0.00%	0.01	0.00	0.00
185 -189	3	4		0.04%		0.00%	0.00	0.00	0.00
TOTALS	7183	2545	1399	100.00%	100.00%	100.00%	3.12	1.70	2.65

Appendix Table 2. Survey and fishery data used for size-specific exploitation rate calculations for use in simulations of the 1990 Bristol Bay red king crab fishery.

Size limit =	6.50	Average wt.(lbs.) =	6.52
Days fished =	12	Potlifts(mlns.) =	0.26
Landings(mlns.) =	3.12	Expl. rate, >119 mm =	0.22
Landings(mln. lbs.) =	20.36	Expl. rate, >134 mm =	0.34

CARAPACE LENGTH GROUP (mm)	STOCK MALES (mlns.)	STOCK MALES (mln. lbs.)	STOCK MALES (avg. wt.)	STOCK FEMALES (mlns.)	STOCK FEMALES (mln. lbs.)	STOCK FEMALES (avg. wt.)	FISHERY LANDINGS (mlns.)	FISHERY LANDINGS (mln. lbs.)	FISHERY DISCARD Male (mlns.)	FISHERY DISCARD Female (mlns.)	FISHERY EXPLOIT. RATE Legals	FISHERY EXPLOIT. RATE Sub-legals	FISHERY EXPLOIT. RATE Fe-males
60 - 64	0.19	0.07	0.38	0.29	0.15	0.52	0.00	0.00	0.00	0.00	0.00	0.02	0.00
65 - 69	0.06	0.03	0.49	0.19	0.12	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70 - 74	0.51	0.30	0.61	0.23	0.16	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.02
75 - 79	0.66	0.48	0.75	1.02	0.84	0.84	0.00	0.00	0.00	0.01	0.00	0.01	0.01
80 - 84	1.48	1.31	0.92	2.16	2.05	0.97	0.00	0.00	0.02	0.00	0.00	0.01	0.00
85 - 89	1.40	1.50	1.11	2.23	2.41	1.11	0.00	0.00	0.01	0.02	0.00	0.01	0.01
90 - 94	0.44	0.56	1.32	0.30	0.37	1.26	0.00	0.00	0.02	0.02	0.00	0.05	0.06
95 - 99	0.41	0.62	1.56	1.20	1.65	1.42	0.00	0.00	0.01	0.04	0.00	0.04	0.03
100 -104	0.38	0.67	1.83	2.58	3.99	1.59	0.00	0.00	0.06	0.18	0.00	0.16	0.07
105 -109	0.86	1.77	2.13	3.22	5.54	1.77	0.00	0.00	0.08	0.27	0.00	0.09	0.08
110 -114	1.44	3.43	2.46	2.98	5.68	1.96	0.00	0.00	0.13	0.45	0.00	0.09	0.15
115 -119	1.24	3.38	2.83	2.74	5.76	2.16	0.00	0.00	0.20	0.45	0.00	0.16	0.16
120 -124	1.48	4.62	3.23	1.72	3.97	2.37	0.00	0.00	0.24	0.57	0.00	0.16	0.33
125 -129	1.64	5.79	3.67	0.85	2.15	2.59	0.00	0.00	0.29	0.36	0.00	0.18	0.43
130 -134	1.89	7.54	4.15	0.26	0.71	2.83	0.05	0.19	0.44	0.19	0.02	0.23	0.74
135 -139	1.78	8.01	4.67	0.15	0.45	3.07	0.28	1.29	0.19	0.06	0.16	0.11	0.43
140 -144	2.01	10.11	5.23	0.12	0.38	3.33	0.56	2.94		0.02	0.28		0.16
145 -149	1.38	7.76	5.83	0.02	0.08	3.60	0.53	3.11			0.39		0.16
150 -154	1.50	9.34	6.49			3.88	0.54	3.50			0.36		
155 -159	0.94	6.48	7.19			4.17	0.45	3.21			0.48		
160 -164	0.75	5.75	7.94			4.48	0.36	2.87		0.01	0.48		
165 -169	0.57	4.82	8.74				0.23	1.99			0.40		
170 -174	0.10	0.95	9.60				0.10	0.95			0.96		
175 -179	0.13	1.34	10.51				0.02	0.23			0.17		
180 -184			11.49				0.01	0.09					
TOTALS	14.2 (>119 mm) 9.2 (>134 mm)						3.12	20.36	1.70	2.65			

Appendix table 3. Simulation results for the 1990 fishery 6.5' size limit,

Size limit =	6.50	Average wt.(lbs.) =	6.57
Days fished =	12.25	Target expl. rate,>119 mm =	0.22
Landings(mlns.) =	3.09		
Landings(mln. lbs.) =	20.28		

CARAPACE LENGTH GROUP (mm)	SELECTION FACTOR M	SELECTION FACTOR F	EXPL. RATE M	CATCH MALES (mlns.)	LANDINGS MALES (mlns.)	LANDINGS MALES (mln. lbs.)	EXPL. RATE F	CATCH FEMS (mlns.)	DISCARD DEATHS* dm= 0.25 M (mlns.)	DISCARD DEATHS* dm= 0.25 F (mlns.)	DISCARD DEATHS* dm= 0.75 M (mlns.)	DISCARD DEATHS* dm= 0.75 F (mlns.)
60 - 64	0.0	0.0	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 - 69	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70 - 74	0.0	0.0	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
75 - 79	0.0	0.0	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01
80 - 84	0.0	0.0	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
85 - 89	0.0	0.0	0.01	0.01	0.00	0.00	0.01	0.02	0.00	0.00	0.01	0.01
90 - 94	0.0	0.0	0.05	0.02	0.00	0.00	0.06	0.02	0.01	0.00	0.02	0.01
95 - 99	0.0	0.0	0.04	0.02	0.00	0.00	0.04	0.04	0.00	0.01	0.01	0.03
100 -104	0.0	0.0	0.16	0.06	0.00	0.00	0.07	0.18	0.02	0.05	0.05	0.14
105 -109	0.0	0.0	0.09	0.08	0.00	0.00	0.08	0.27	0.02	0.07	0.06	0.20
110 -114	0.0	0.0	0.09	0.13	0.00	0.00	0.15	0.46	0.03	0.12	0.10	0.35
115 -119	0.0	0.0	0.16	0.20	0.00	0.00	0.17	0.46	0.05	0.11	0.15	0.34
120 -124	0.0	0.0	0.17	0.25	0.00	0.00	0.34	0.58	0.06	0.14	0.19	0.43
125 -129	0.0	0.0	0.18	0.30	0.00	0.00	0.43	0.37	0.08	0.09	0.23	0.28
130 -134	0.1	0.0	0.26	0.50	0.05	0.21	0.75	0.19	0.11	0.05	0.34	0.14
135 -139	0.4	0.0	0.27	0.48	0.19	0.89	0.44	0.07	0.07	0.02	0.21	0.05
140 -144	1.0	0.0	0.29	0.57	0.57	3.00	0.17	0.02	0.00	0.00	0.00	0.01
145 -149	1.0	0.0	0.39	0.54	0.54	3.17	0.16					0.00
150 -154	1.0	0.0	0.37	0.55	0.55	3.57						
155 -159	1.0	0.0	0.49	0.46	0.46	3.28						
160 -164	1.0	0.0	0.49	0.37	0.37	2.93						
165 -169	1.0	0.0	0.40	0.23	0.23	2.03						
170 -174	1.0	0.0	0.98	0.10	0.10	0.97						
175 -179	1.0	0.0	0.17	0.02	0.02	0.24						
180 -184	1.0	0.0										
TOTAL				4.92	3.09	20.28		2.69	0.46	0.67	1.37	2.02
TOTAL<120 mm					0.00	0.00			0.14		0.41	
TOTAL EXPL. RATE, by sex									0.24	0.04	0.29	0.12
TOTAL EXPL. RATE, sexes combined									0.13		0.20	

* dm = discard mortality rate

Appendix Table 4. Simulation results for the 1990 fishery 6.0' size limit.

Size limit =	6.00	Average wt.(lbs.) =	6.05
Days fished =	9.50	Target expl. rate, >119 mm =	0.22
Landings(mlns.) =	3.08		
Landings(mln. lbs) =	18.60		

CARAPACE LENGTH GROUP (mm)	SELECTION FACTOR M	SELECTION FACTOR F	EXPL. RATE M	CATCH MALES (mlns.)	LANDINGS MALES (mlns.)	LANDINGS MALES (mln. lbs.)	EXPL. RATE F	CATCH FEMS (mlns.)	DISCARD DEATHS * dm= 0.25 M (mlns.)	dm= 0.25 F (mlns.)	dm= 0.75 M (mlns.)	dm= 0.75 F (mlns.)
60 - 64	0.0	0.0	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 - 69	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70 - 74	0.0	0.0	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
75 - 79	0.0	0.0	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
80 - 84	0.0	0.0	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
85 - 89	0.0	0.0	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01
90 - 94	0.0	0.0	0.04	0.02	0.00	0.00	0.04	0.01	0.00	0.00	0.01	0.01
95 - 99	0.0	0.0	0.03	0.01	0.00	0.00	0.03	0.03	0.00	0.01	0.01	0.02
100 - 104	0.0	0.0	0.13	0.05	0.00	0.00	0.05	0.14	0.01	0.04	0.04	0.11
105 - 109	0.0	0.0	0.07	0.06	0.00	0.00	0.07	0.21	0.02	0.05	0.05	0.16
110 - 114	0.0	0.0	0.07	0.10	0.00	0.00	0.12	0.36	0.03	0.09	0.08	0.27
115 - 119	0.0	0.0	0.13	0.16	0.00	0.00	0.13	0.36	0.04	0.09	0.12	0.27
120 - 124	0.1	0.0	0.13	0.19	0.02	0.06	0.26	0.45	0.04	0.11	0.13	0.34
125 - 129	0.4	0.0	0.14	0.23	0.09	0.34	0.34	0.29	0.03	0.07	0.10	0.22
130 - 134	1.0	0.0	0.20	0.39	0.39	1.60	0.58	0.15	0.00	0.04	0.00	0.11
135 - 139	1.0	0.0	0.21	0.37	0.37	1.73	0.34	0.05		0.01		0.04
140 - 144	1.0	0.0	0.22	0.45	0.45	2.33	0.13	0.01		0.00		0.01
145 - 149	1.0	0.0	0.31	0.42	0.42	2.46	0.12	0.00				0.00
150 - 154	1.0	0.0	0.29	0.43	0.43	2.77						
155 - 159	1.0	0.0	0.38	0.35	0.35	2.54						
160 - 164	1.0	0.0	0.38	0.29	0.29	2.27						
165 - 169	1.0	0.0	0.31	0.18	0.18	1.57						
170 - 174	1.0	0.0	0.76	0.08	0.08	0.75						
175 - 179	1.0	0.0	0.13	0.02	0.02	0.18						
180 - 184	1.0	0.0										
TOTAL				3.81	3.08	18.60		2.09	0.18	0.52	0.55	1.57
TOTAL<120 mm					0.00	0.00			0.11		0.32	
TOTAL EXPL. RATE, by sex									0.22	0.03	0.23	0.10
TOTAL EXPL. RATE, sexes combined									0.12		0.16	

* dm = discard mortality rate

Appendix Table 5. Simulation results for the 1990 fishery 5.5' size limit.

Size limit =	5.50	Average wt.(lbs.) =	5.74
Days fished =	8.75	Target expl. rate, >119 mm =	0.22
Landings(mlns.) =	3.19		
Landings(mln. lbs) =	18.31		

CARAPACE LENGTH GROUP (mm)	SELECTION FACTOR M	F	EXPL. RATE M	CATCH MALES (mlns.)	LANDINGS MALES (mlns.)	(mln. lbs.)	EXPL. RATE F	CATCH FEMS (mlns.)	DISCARD dm= 0.25 M (mlns.)	F (mlns.)	DEATHS * dm= 0.75 M (mlns.)	F (mlns.)
60 - 64	0.0	0.0	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 - 69	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70 - 74	0.0	0.0	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
75 - 79	0.0	0.0	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
80 - 84	0.0	0.0	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
85 - 89	0.0	0.0	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
90 - 94	0.0	0.0	0.04	0.02	0.00	0.00	0.04	0.01	0.00	0.00	0.01	0.01
95 - 99	0.0	0.0	0.03	0.01	0.00	0.00	0.03	0.03	0.00	0.01	0.01	0.02
100 -104	0.0	0.0	0.12	0.04	0.00	0.00	0.05	0.13	0.01	0.03	0.03	0.10
105 -109	0.0	0.0	0.07	0.06	0.00	0.00	0.06	0.19	0.01	0.05	0.04	0.15
110 -114	0.1	0.0	0.07	0.09	0.01	0.02	0.11	0.33	0.02	0.08	0.06	0.25
115 -119	0.4	0.0	0.12	0.14	0.06	0.16	0.12	0.33	0.02	0.08	0.07	0.25
120 -124	1.0	0.0	0.12	0.18	0.18	0.57	0.24	0.41	0.00	0.10	0.00	0.31
125 -129	1.0	0.0	0.13	0.21	0.21	0.79	0.31	0.26		0.07		0.20
130 -134	1.0	0.0	0.19	0.35	0.35	1.47	0.54	0.14		0.03		0.10
135 -139	1.0	0.0	0.19	0.34	0.34	1.59	0.31	0.05		0.01		0.04
140 -144	1.0	0.0	0.20	0.41	0.41	2.14	0.12	0.01		0.00		0.01
145 -149	1.0	0.0	0.28	0.39	0.39	2.27	0.11					0.00
150 -154	1.0	0.0	0.26	0.39	0.39	2.55						
155 -159	1.0	0.0	0.35	0.33	0.33	2.34						
160 -164	1.0	0.0	0.35	0.26	0.26	2.09						
165 -169	1.0	0.0	0.29	0.17	0.17	1.45						
170 -174	1.0	0.0	0.70	0.07	0.07	0.69						
175 -179	1.0	0.0	0.12	0.02	0.02	0.17						
180 -184	1.0	0.0										
TOTAL				3.51	3.19	18.31		1.92	0.08	0.48	0.24	1.44
TOTAL<120 mm					0.07	0.19			0.08		0.24	
TOTAL EXPL. RATE, by sex									0.22	0.03	0.22	0.09
TOTAL EXPL. RATE, sexes combined									0.12		0.15	

* dm = discard mortality rate

Appendix Table 6. Simulation results for the 1990 fishery, 5.0' size limit.

Size limit =	5.00	Average wt.(lbs.) =	5.56
Days fished =	8.75	Target expl. rate, >119 mm =	0.22
Landings(mlns.) =	3.39		
Landings(mln. lbs.) =	18.82		

CARAPACE LENGTH GROUP (mm)	SELECTION FACTOR M	SELECTION FACTOR F	EXPL. RATE M	CATCH MALES (mlns.)	LANDINGS MALES (mlns.)	LANDINGS MALES (mln. lbs.)	EXPL. RATE F	CATCH FEMS (mlns.)	DISCARD DEATHS* dm= 0.25 M (mlns.)	DISCARD DEATHS* dm= 0.25 F (mlns.)	DISCARD DEATHS* dm= 0.75 M (mlns.)	DISCARD DEATHS* dm= 0.75 F (mlns.)
60 - 64	0.0	0.0	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65 - 69	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70 - 74	0.0	0.0	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
75 - 79	0.0	0.0	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00
80 - 84	0.0	0.0	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
85 - 89	0.0	0.0	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01
90 - 94	0.0	0.0	0.04	0.02	0.00	0.00	0.04	0.01	0.00	0.00	0.01	0.01
95 - 99	0.0	0.0	0.03	0.01	0.00	0.00	0.03	0.03	0.00	0.01	0.01	0.02
100 -104	0.1	0.0	0.12	0.04	0.00	0.01	0.05	0.13	0.01	0.03	0.03	0.10
105 -109	0.4	0.0	0.07	0.06	0.02	0.05	0.06	0.19	0.01	0.05	0.03	0.15
110 -114	1.0	0.0	0.07	0.09	0.09	0.23	0.11	0.33	0.00	0.08	0.00	0.25
115 -119	1.0	0.0	0.12	0.14	0.14	0.41	0.12	0.33		0.08		0.25
120 -124	1.0	0.0	0.12	0.18	0.18	0.57	0.24	0.41		0.10		0.31
125 -129	1.0	0.0	0.13	0.21	0.21	0.79	0.31	0.26		0.07		0.20
130 -134	1.0	0.0	0.19	0.35	0.35	1.47	0.54	0.14		0.03		0.10
135 -139	1.0	0.0	0.19	0.34	0.34	1.59	0.31	0.05		0.01		0.04
140 -144	1.0	0.0	0.20	0.41	0.41	2.14	0.12	0.01		0.00		0.01
145 -149	1.0	0.0	0.28	0.39	0.39	2.27	0.11					0.00
150 -154	1.0	0.0	0.26	0.39	0.39	2.55						
155 -159	1.0	0.0	0.35	0.33	0.33	2.34						
160 -164	1.0	0.0	0.35	0.26	0.26	2.09						
165 -169	1.0	0.0	0.29	0.17	0.17	1.45						
170 -174	1.0	0.0	0.70	0.07	0.07	0.69						
175 -179	1.0	0.0	0.12	0.02	0.02	0.17						
180 -184	1.0	0.0										
TOTAL				3.51	3.39	18.82		1.92	0.03	0.48	0.09	1.44
TOTAL<120 mm					0.27	0.70			0.03		0.09	
TOTAL EXPL. RATE, by sex									0.22	0.03	0.22	0.09
TOTAL EXPL. RATE, sexes combined									0.12		0.15	

* dm = discard mortality rate