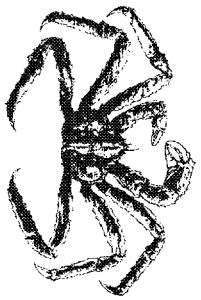

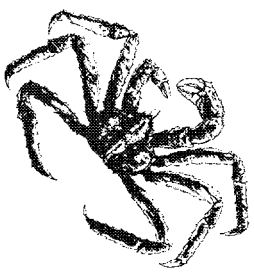

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Doug Pengilly
and
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Special Publication Number 7

Alaska Department of Fish and Game
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INTRODUCTION

This document explains and documents the harvest strategy used by the Alaska Department of Fish and Game (ADF&G) in the management of blue king crab *Paralithodes platypus* and red king crab *P. camtschaticus* in selected fisheries of the Gulf of Alaska and the Bering Sea. The harvest strategy presented in this plan was developed in accordance with 5 AAC 34.080 (ADF&G 1992) to be consistent with the Policy on King and Tanner Crab Resource Management (Finding No. 90-04-FB; ADF&G 1992) adopted by the Alaska Board of Fisheries (ABOF) on March 23, 1990.

Harvest rates and guideline harvest levels (GHLs) are identified in the ABOF's policy statement on king crab as 2 of the management measures available to carry out those policies. In 5 AAC 34.080, the ABOF also directed ADF&G to establish "threshold levels of abundance" for king crab stocks where "adequate data are available" and to "close the fishery during the entire fishing season on any stock that is below its threshold level of abundance" (ADF&G 1992). This document presents the current harvest strategy, threshold criteria, and procedures used by ADF&G when determining the harvest rates and GHLs for the Kodiak (Statistical Area K) and Bristol Bay (Statistical Area T) red king crab fisheries and for the St. Matthew Island (Statistical Area Q, Northern District, St. Matthew Island Section) and Pribilof (Statistical Area Q, Pribilof District) blue king crab fisheries.

The harvest strategy presented in this plan is operable under the assumption that annual surveys will be completed that will provide sufficient information to estimate the required population parameters. Note that this document does not have regulatory force. Details on other management measures and regulations for these fisheries, such as size limits and fishing seasons, can be found in the most current ADF&G commercial shellfish regulations.

DEFINITIONS OF TERMS

Guideline harvest level (GHL): A preseason estimate of the level of allowable harvest for a fishery, expressed in pounds.

Legal males: Male king crabs with carapace widths (including spines) greater than or equal to the minimum size for legal commercial harvest as established by regulation (also see "mature males").

Legal male harvest rate: The percentage of legal male crabs in a managed geographical unit that is harvested during the commercial fishery season (also see "mature male harvest rate") — i.e., the number of legal males harvested divided by the number of legal males available for harvest.

Mature males: Male king crabs that are functionally mature — i.e., those that participate in mating in a natural environment. To allow for identification during surveys, mature males are defined in the harvest strategy by using estimates of the minimum carapace length at functional maturity (also see "legal males").

Mature male harvest rate: The percentage of mature male crabs in a managed geographical unit that is harvested during the commercial fishery season (also see "legal male harvest rate") — i.e., the number of legal males harvested divided by the number of mature males present before the harvest.

Stock: According to Ricker (1975), a stock is "the part of a fish population which is under consideration from the point of view of actual or potential utilization." Note that this definition is based on resource exploitation considerations, including fishery districts and areas as defined by regulation; it is not necessarily based on genetic identity or relatedness.

Threshold, threshold criteria, or threshold level: A stock abundance level at or below which a fishery is closed entirely — i.e., the harvest rate is set to 0%. Determination of threshold level is based on identification of a level of abundance below which the ability for stocks to rebuild is uncertain.

HARVEST STRATEGY SUMMARY AND EXAMPLES

This harvest strategy controls the removal of mature male king crabs from the stock during a commercial harvest. The harvest strategy uses thresholds, a 20% mature male harvest rate, and a maximum allowable legal male harvest rate of 60% to determine a targeted legal male harvest rate in a statistical area, district, or section. If preseason abundance estimates indicate that threshold criteria are not met, the legal male harvest rate is set to 0% — that is, the fishery is closed entirely. When threshold criteria are met, the 20% mature male harvest rate determines the target number of legal males to harvest, up to the maximum of 60% of the estimated number of legal males. The targeted number of legal males to harvest is multiplied by an estimate of the average weight of legal males to determine a preseason GHL expressed in pounds.

In the king crab fisheries considered here, legal males are currently defined by a minimum legal size that is greater than current estimates of minimum size at maturity (Table 1). Hence, legal males are a subset of the mature males. If stocks are above threshold, the targeted legal male harvest rate will vary inversely with the proportion of mature males that are legal males. For example, if all of the mature males are legal sized, the targeted legal male harvest rate will be 20%. As the proportion of mature

Table 1. Estimates of minimum sizes at maturity for male king crabs in western Alaska fisheries, compared with minimum legal sizes as defined by regulation.

Fishery	Estimated minimum carapace length (mm) of mature males	Minimum legal male size (by regulation)	
		Carapace width including spines (in)	Equivalent carapace length (mm)
Kodiak red king crab	130	7	148
Bristol Bay red king crab	120	6.5	137
St. Matthew Island blue king crab	105	5.5	120
Pribilof blue king crab	120	6.5	138

males that are legal sized decreases, the targeted legal male harvest rate increases. When one-third of the mature males are legal sized, the targeted legal male harvest rate attains its maximum of 60%. When less than one-third of the mature males are legal sized, the mature male harvest rate is allowed to drop below 20% so that the legal male harvest rate does not exceed the maximum of 60%.

When more than one-third of the mature males are legal sized, the GHL is easily computed by multiplying the point estimate of mature male abundance by 0.2 and then multiplying that product by the estimated average weight of legal males. Otherwise, the GHL is computed by multiplying the number of legal males by 0.6 and then multiplying that product by the estimated average weight of legal males. The process of determining a GHL is depicted graphically as a flow chart in Figure 1. The hypothetical scenarios for the Northeast District of the Kodiak Area in Examples 1 through 3 below cover the 3 principal ways GHLs are calculated under the harvest strategy.

Example 1: Stocks are above threshold and more than one-third of mature males are legal.

Survey Data for Kodiak Northeast District:

- Number of fertilized females is estimated at 9 million.
- Number of legal males is estimated at 5 million.
- Number of mature males is estimated at 10 million.
- Average weight legal males is estimated at 7.5 lb.

Conditions and Preliminary Calculations:

- The number of fertilized females (9 million) is above the threshold value of 1.93 million (Table 2).
- A 20% mature male harvest rate would allow a harvest of 0.20 x 10 million = 2 million animals.
- Two million is less than 60% of the estimated number of legal males (0.60 x 5 million = 3 million), so a harvest of 2 million legal males is used to set the GHL.

Final GHL Computation:

- GHL for the Northeast District = 2 million legal males x 7.5 lb per legal male = 15 million lb.

Example 2: Stocks above threshold and less than one-third of mature males are legal.

Survey Data for Kodiak Northeast District:

- Number of fertilized females is estimated at 9 million.
- Number of legal males is estimated at 2 million.
- Number of mature males is estimated at 10 million.
- Average weight legal males is estimated at 7.5 lb.

Conditions and Preliminary Calculations:

- The number of fertilized females (9 million) is above the threshold value of 1.93 million (Table 2).
- A 20% mature male harvest rate would allow a harvest of 0.20 x 10 million = 2 million animals.
- Two million is greater than 60% of the estimated number of legal males (0.60 x 2 million = 1.2 million), so a harvest of 0.60 x 2 million = 1.2 million legal males is used to set the GHL.

Final GHL Computation:

- GHL for the Northeast District = 1.2 million legal males x 7.5 lb per legal male = 9 million lb.

Example 3: Stocks below threshold.

Survey Data for Kodiak Northeast District:

- Number of fertilized females is estimated at 0.2 million.
- Number of legal males is estimated at 0.1 million.
- Number of mature males is estimated at 0.1 million.
- Average weight legal males is estimated at 7.5 lb.

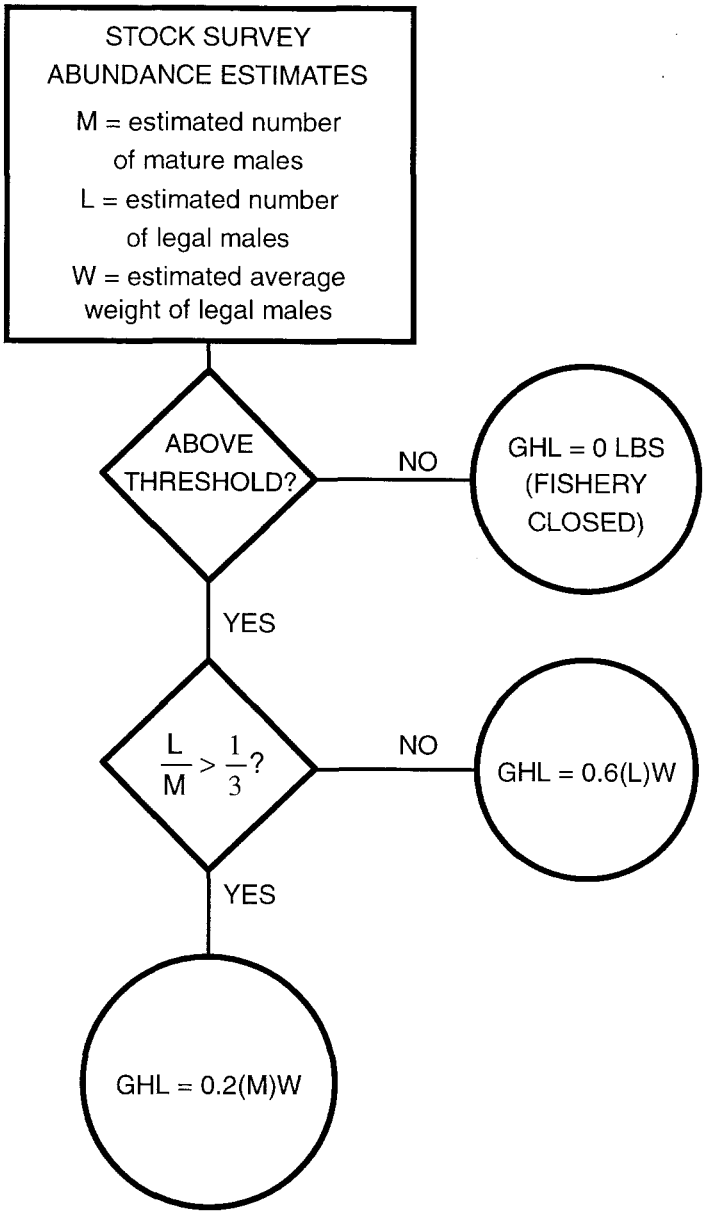
Conditions and Preliminary Calculations:

- The number of fertilized females (0.2 million) is below the threshold value of 1.93 million (Table 2).

Final GHL Computation:

- GHL for the Northeast District = 0 lb. The district is closed to commercial fishing because stocks are below threshold.

Figure 1. The process of computing a preseason guideline harvest level (GHL), in pounds, from survey-based population abundance estimates according to the harvest strategy for Westward Region king crab fisheries. Refer to Table 2 for threshold criteria.



RATIONALE FOR USE AND DERIVATION OF THRESHOLDS

Thresholds provide fixed criteria to determine if a biological surplus of adult king crabs sufficient to warrant a commercial fishery exists. If the threshold criteria are not met, the fishery is closed entirely because further commercial removals at this level would jeopardize recovery of the stock. This protects depressed stocks from fishing mortality, as well as additional mortality due to lost pots and handling.

Threshold criteria were established for each district in the Kodiak area by ADF&G staff in 1986 following a review of historical Kodiak area pot survey data. Threshold values were established in terms of the minimum number of "fertilized females per pot" needed for stock recovery in each Kodiak area district. Those values have since been adapted for trawl survey data and are now expressed in terms of "total fertilized female crabs" for each district (Table 2). The conversion of threshold values was based on abundance data collected from the Southwest District in 1985, when both pot and trawl surveys were performed.

Threshold values for Bristol Bay red king crab and St. Matthew Island and Pribilof blue king crab were determined by the King and Tanner Crab Plan Team of the North Pacific Fishery Management Council (1990). A Ricker stock-recruitment curve was fit using trawl survey data on the abundance of fertilized females in a given year and the abundance of the 8-year-old males subsequently produced by those females. Following Thompson (1990), the threshold for the Bristol Bay stock was estimated as 20% of the equilibrium level of fertilized females as estimated from the fitted Ricker curve. The median size at maturity for Bristol Bay female red king crab is 90 mm carapace length (Stevens et al. 1991). Furthermore, the National Marine Fisheries Service (NMFS) Eastern Bering Sea crab survey summaries provide population estimates for females >89 mm in carapace length rather than for fertilized females. Accordingly, the Bristol Bay threshold values are expressed as the "number of females >89 mm in carapace length" rather than as the "number of fertilized females" (Table 2).

Lacking estimates of stock-recruitment parameters for the St. Matthew Island and Pribilof blue king crab, the King and Tanner Crab Plan Team estimated thresholds (Table 2) for

Table 2. Threshold criteria developed for king crab fisheries in western Alaska.

Statistical Area	District or Section Species	Threshold (millions of crabs)
K	Northeast red king crab	1.93 million fertilized females
K	Southeast red king crab	0.72 million fertilized females
K	Southwest red king crab	2.28 million fertilized females
K	Shelikof red king crab	0.19 million fertilized females
T	Bristol Bay red king crab	8.4 million females >89 mm
Q	Pribilof blue king crab	0.77 million males >119 mm
Q	St. Matthew blue king crab	0.60 million males >104 mm

these fisheries by extrapolation of the Bristol Bay red king crab threshold. The extrapolation computation assumed that threshold levels relative to average spawning stock abundance are the same for all Bering Sea king crab stocks. Because trawl survey abundance estimates in these areas are believed to be more reliable for males than for females, the King and Tanner Crab Plan Team expressed the thresholds for St. Matthew Island and Pribilof blue king crab as "number of mature males," rather than as "number of fertilized females."

Rationale for 20% Mature Male Harvest Rate

When stocks are above threshold, this plan protects the reproductive potential of king crab stocks by limiting the harvest to only 20% of the mature males. The 20% mature male harvest rate used here is similar to the 20% exploitation rate applied to those finfish species in the Bering Sea that have longevity similar to king crabs. It also corresponds with the low end of a wide range of instantaneous mortality estimates that exist for mature male red king crabs (Schmidt and Pengilly 1993). An analysis of simulated recruitment histories (see Appendix D in Schmidt and Pengilly 1990a) indicates levels of mature males providing an acceptable sex ratio would be maintained by this harvest strategy even during the population declines observed in the Kodiak area. The 20% mature male harvest rate also assures protection from overfishing as defined by Amendment 1 to the Fishery Management Plan for the commercial fisheries in the Bering Sea/Aleutian Islands (McKean 1991). By restricting the harvest to a maximum of 60% of the legal males, losses in future crab production due to excessive sorting and handling are reduced with minimal impacts on the long-term yield.

Current king crab legal size limits were originally based on market economics, but were retained because they were also believed to allow several years of potential breeding from males prior to commercial harvesting (Donaldson and Donaldson 1992). However, in 3,432 grasping pairs of red king crabs collected from the Kodiak area from 1964 to 1971, 75% of the mature males grasping females were of legal size or larger (see Figures 3 and 4 in Schmidt and Pengilly 1990b). Those data indicate that the current legal size limits alone actually provide only minimal protection for breeding males and that controlling the fishery's removal rate of mature males is preferable to using size limits as a primary tool for maintaining a reproductive stock of male crabs.

DETERMINATION OF MINIMUM CARAPACE LENGTH FOR MATURE MALES

To allow for identification of mature males during stock surveys, as required by harvest strategy, estimates of minimum size at maturity were developed (Table 1). These are the best estimates of the minimum size of functionally mature males.

The only data available for direct estimation of minimum size at maturity for Alaskan king crabs comes from the 3,432 red king crab grasping pairs collected from the Kodiak Area from 1964 to 1971 by G. C. Powell (see Figures 3 and 4 in Schmidt and Pengilly 1990b). Those data demonstrate that the minimum carapace length of mating males in

nature is greater than would be indicated by laboratory studies (e.g., Paul and Paul 1990). Grasping-pair data comparable to that collected from Kodiak red king crabs does not exist for the other king crab stocks considered here. However, Powell's Kodiak data, in which males are larger than females in all but 95% of the grasping pairs, indicate that previously existing minimum size-at-maturity estimates for Bristol Bay male red king crabs (Balsiger 1974) and for male blue king crabs (Somerton and MacIntosh 1983) greatly underestimate the minimum size of mating males.

In the Kodiak area, the minimum carapace length for mature male red king crabs was estimated at 130 mm using Powell's grasping-pair data, in which less than 3% of the male crabs had lengths less than 130 mm. The estimated minimum size at maturity for male Kodiak red king crabs is about 80% of the difference between the estimated average carapace lengths of 6- and 7-year-old male Kodiak red king crabs: 116 mm and 134 mm (Schmidt and Pengilly 1990a). Based on that, an 80% equivalent was used to estimate the minimum carapace length of mature male Bristol Bay red king crabs. Using the nearest 5 mm by linear interpolation between the estimated lengths for 6- and 7-year-old males (111 mm and 125 mm; Balsiger 1974), the minimum size at maturity for male Bristol Bay red king crabs was estimated to be 120 mm in carapace length.

In the case of blue king crabs, a growth model is poorly established. However, minimum size at maturity for female St. Matthew Island and Pribilof blue king crabs has been estimated (Otto et al. 1990), as has the growth per molt of male blue king crabs (Otto and Cummiskey 1990). We assumed that the average carapace length of a 5-year-old male blue king crab is the same as the minimum size at maturity for females (81 mm for St. Matthew Island and 96 mm for Pribilof). Growth per molt estimates for males were used to estimate the average carapace lengths of 6- and 7-year-old male blue king crabs. As for the Bristol Bay red king crabs, the minimum size of mature male St. Matthew and Pribilof blue king crabs was estimated to the nearest 5 mm by linear interpolation between the carapace lengths estimated for them at 6 and 7 years of age. This produced an estimated size-at-maturity of 105 mm for St. Matthew Island male blue king crabs and 120 mm for Pribilof male blue king crabs.

OTHER CONSIDERATIONS

The precision of population estimates and the ability to maintain an orderly and controlled harvest are always considerations when setting GHLs or determining whether a fishery should be opened or remain closed. Sometimes fishery managers may have to depart from the harvest strategy presented here due to unusual situations or other compelling reasons. For example, if the preseason survey indicates that a large surplus of mature males exists beyond that needed for reproduction, a season may be warranted even if the abundance of females is below threshold. Conversely, if the mature male population is below the minimum number necessary to fertilize the threshold level of females, serious consideration should be given to closing the season, even if the female population is above threshold.

The harvest strategy should evolve with the accumulation of new data, reassessment of old data, changes in the fisheries, and new insights into the population biology of king

crabs and the management of crab fisheries. The harvest strategy presented here lays a groundwork for adding refinements on threshold criteria, improved operational definitions of mature males, and optimal mature male harvest rate. The threshold criteria, for example, can be revised whenever research and survey data or approaches to determining thresholds other than those presented here (e.g., Quinn et al. 1990) warrant changing the threshold. Any such changes in the harvest strategy presented here and the rationale should be well documented.

Finally, the current harvest strategy was developed under present regulations that restrict the commercial harvest of king crabs to males. Although sex restrictions have been a standard practice in Alaskan crab management for decades, current biological evidence (Kruse 1992) indicates that males-only harvest strategies may exacerbate resource waste and suppress crab populations. Continued males-only harvest practices may be difficult to justify solely for economic and market reasons. The conservation and economic tradeoffs from harvesting both sexes need to be fully explored and discussed (Bibb and Matulich 1994). Any resulting changes in management strategy will ultimately be included in this plan.

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