MEMORANDUM

TO: Council, SSC and AP Members

FROM: Clarence G. Pautzke
Executive Director

DATE: April 10, 1995

ESTIMATED TIME
4 Hours

SUBJECT: Crab Bycatch Management and Rebuilding

ACTION REQUIRED

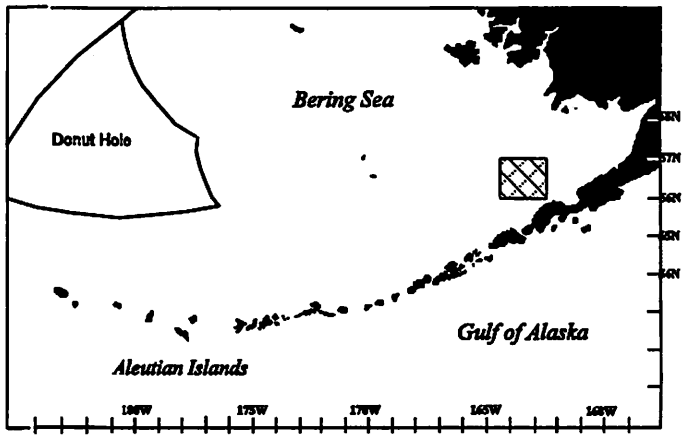
(a) Initial review of analysis of Bristol Bay red king crab protection area.

(b) Report of Joint Groundfish and Crab Plan teams on crab rebuilding.

BACKGROUND

Bristol Bay Red King Crab Closure Area

On January 16, 1995, NMFS implemented by emergency rule (ER) a closure to trawling in a portion of Bristol Bay to protect red king crabs. The closed area encompasses from 162° to 164°W longitude, 56° to 57°N latitude. The ER also required observers on trawl vessels targeting flatfish in Zone 1 outside the closed area, and allowed pelagic trawling for pollock within the closed area but with 100% observer coverage. At the January meeting, the Council reviewed the ER and recommended that six alternatives to the status quo be analyzed for possible plan amendment.



A draft EA/RIR was distributed on April 7 for Council review. An executive summary with selected figures is attached as Item D-2(b)(1). Note that the economic analysis is not yet complete; Bering Sea bycatch model results are forthcoming. Alternatives to the status quo all have an eastern border along Area 512, which is permanently closed to all trawling. All six alternatives to the status quo have longitudinal boundaries of 162°W longitude and 164°W longitude. Southern and northern boundaries of each alternative are:

Alternative 1: Status quo.
Alternative 2: 56° 10' to 57°N latitude.
Alternative 3: 56° 00' to 57°N latitude (same as emergency rule).
Alternative 4: 55° 45' to 57°N latitude.
Alternative 5: 56° 10' to 58°N latitude.
Alternative 6: 56° 00' to 58° N latitude.

Alternative 7: 56° 45' to 58°N latitude.

At this meeting, the Council can recommend additional alternatives or analysis, release the document for public review, or table the proposal. If the document were released for public review at this meeting, final action could be taken in June, such that the amendment could be implemented by January 1996.

Crab Rebuilding Committee Report

In January, the Council requested member Dr. David Fluharty to chair a committee composed of members of the BSAI groundfish and crab plan teams to develop a rebuilding plan for Bering Sea crab stocks. The teams met jointly on March 21-22 in Seattle. The goal of the meeting was to synthesize available information on sources and magnitude of crab mortality and ecosystem relationships and to identify alternative strategies the Council might use to enhance the survival of crab stocks and thus promote rebuilding. Minutes of the meeting are attached as Item D-2(b)(2). Chairman Fluharty will report on the Committee's progress.

DRAFT FOR COUNCIL REVIEW

Environmental Assessment/Regulatory Impact Review/Initial Regulatory Flexibility Analysis

of

RED KING CRAB BYCATCH

IN THE BERING SEA TRAWL FISHERIES:

ALTERNATIVES FOR

CLOSURE AREAS

Prepared by

Alaska Department of Fish and Game
North Pacific Fishery Management Council

April 7, 1995

EXECUTIVE SUMMARY

Results from the 1994 NMFS summer trawl survey indicated that red king crab stocks in the Bristol Bay area were at continuing low levels, and that the estimated abundance of mature female king crab of 7.5 million individuals was below the threshold level set in the State of Alaska management plan for king crabs in the Bering Sea and Aleutian Islands of 8.4 million crab. Because of this low abundance of mature female crab, the 1994 directed fishery for red king crab was closed in Bristol Bay, and the directed fishery for Tanner crab was closed in Zone 1 east of 163° W. longitude due to bycatch concerns. Because trawl fisheries had experienced high king crab bycatch, especially in the first months of the rock sole fishery in the same area, the Council took emergency action to close a designated four block area to trawling for the duration of the emergency order (120 days). During the January 1995 meeting, the Council directed staff to analyze 6 alternatives for closure to bottom trawling and to present the results for initial Council review at the April Council meeting. Due to the possible economic impact any closure might have on the rock sole fishery in particular, the Council, AP and SSC all recommended that the analysis include output from the Bering Sea bycatch model as a means of weighing alternatives in light of the myriad of existing and potential closures that impact fisheries.

The six alternatives in addition to status quo are in an area which has experienced high king crab bycatch but has also sustained a roe fishery for rock sole. The alternatives represent closures of varying size, all with an eastern border along Area 512, permanently closed to all trawling. The alternatives are indicated in Figure 1. All six alternatives have longitudinal boundaries of 162° West longitude and 164° West longitude and have northern and southern boundaries as follows:

1) Status Quo - no new closure;
2) Northern boundary of 57° North latitude and southern boundary of 56° 10' North latitude;
3) Northern boundary of 57° North latitude and southern boundary of 56° North latitude;
4) Northern boundary of 57° North latitude and southern boundary of 55° 45 ' North latitude;
5) Northern boundary of 58° North latitude and southern boundary of 56° 10' North latitude;
6) Northern boundary of 58° North latitude and southern boundary of 56° North latitude;
7) Northern boundary of 58° North latitude and southern boundary of 55° 45 ' North latitude.

The alternative recommended by the Council during a teleconference in November 1994 was Alternative 4, and the alternative subsequently enacted by NMFS was Alternative 3. The closure had a dramatic effect on reductions in king crab bycatch. In 1992, this fishery bycaught approximately 59,000 red king crab, in 1993 the rock sole fishery took 166,154 red king crab and in 1994 the fishery took 216,821 crab. The rock sole fishery exceeded its red king crab PSC cap in both 1993 and 1994. In 1995 through the month of March, the rock sole fishery took only 19,000 red king crab. It is unlikely that crab bycatch numbers in the rock sole fishery will increase substantially in the coming months because red king crab have primarily been taken during the first few months of the year.

The success of this closure in protecting red king crab is however diminished by the impacts it had on the rock sole fishery. Data from the 1995 fishery were unavailable for this document, but since the fishery has had a high reliance on the closed area for obtaining spawning rock sole for roe, the closure is expected to have had economic consequences. Whereas the majority (in 1990, 89%; in 1991, 65%; in 1992 95%; in 1993, 90%; and in 1994 84% of the fishery total Zone 1 bycatch of red king crab) of the red king crab historically taken in the rock sole fishery were within the area (Alternative 3) designated for emergency closure, this area has also provided a significant percentage of groundfish catch (in 1990, 40%; in 1991, 28%; in 1992, 54%; in 1993, 50%; and in 1994, 58% of the fishery Zone 1 groundfish catch). The impacts of the closure are made more significant because of the recent Pribilof Islands closure which had historically been important to the rock sole fishery as well. However, much of the rock sole effort in the Pribilof Islands area and along the Alaska Peninsula did not occur simultaneously in the first few months of the year.

In summary, the rock sole fishery has bycaught the majority of red king crab during the January - March fishery for rock sole roe. The major savings to red king crab are found in Alternative 3 with a southern boundary of 56° North latitude. A subsection of this area between 56° North latitude and 56° 10' North latitude is productive to the rocksole fishery. In 1990, 15%; in 1991, 13%; in 1992, 35%; in 1993, 26%; and in 1994, 18% of the fishery's Zone 1 groundfish catch came from this area. However, this area has also had high king crab bycatch rates, and in 1990, 12%; in 1991, 32%; in 1992, 47%; in 1993, 31% and in 1994, 20% of the Zone 1 bycatch of king crab came from this area.

The bycatch and economic tradeoffs and implications that such a closure will have on various fisheries require that a model-based economic analysis be performed. The results of the Bering Sea bycatch model are not yet available because of the magnitude of the changes in the data structure, regulations, and in the model itself since it was last used in 1992. Data management and analysis wil be completed in the coming weeks.

Figure 1. Six area closure alternatives with longitudinal boundaries of 162° West and 164° West. Northern and southern boundaries as follows: 2) North 57° South 56° 10'; 3) North 57° South 56°; 4) North 57° South 55° 45 '; 5) North 58° South 56° 10'; 6) North 58° South 56° ; 7) North 58° South 55° 45 '.

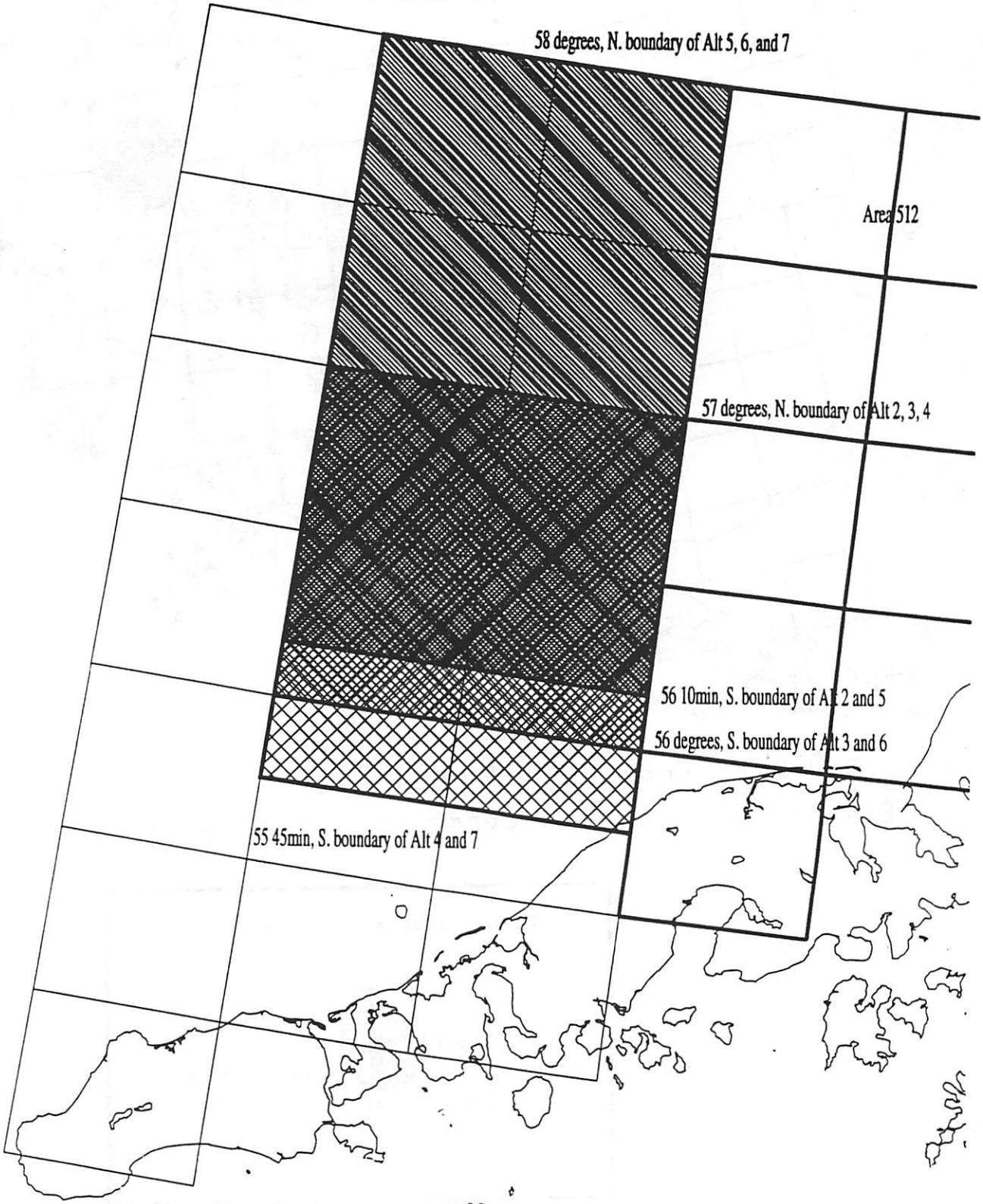


Figure 10. Distribution of hauls containing red king crab from the 1994 NMFS trawl survey. Categories indicate proportion of size/sex, and circle size is proportional to total catch.

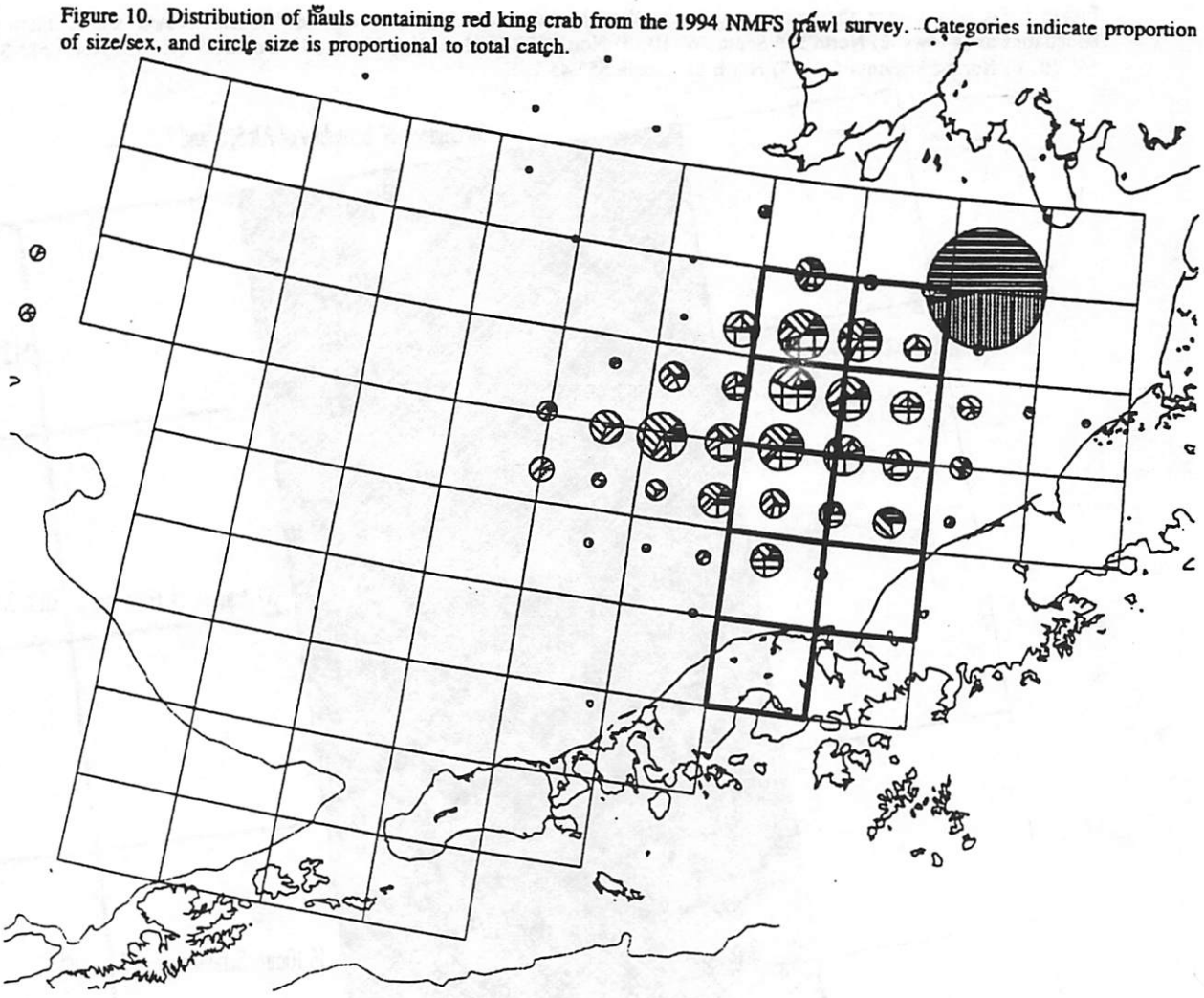


Figure 27. Distribution of observed hauls with catch greater than 25 mt in the rock sole fishery, 1990 - 1994.

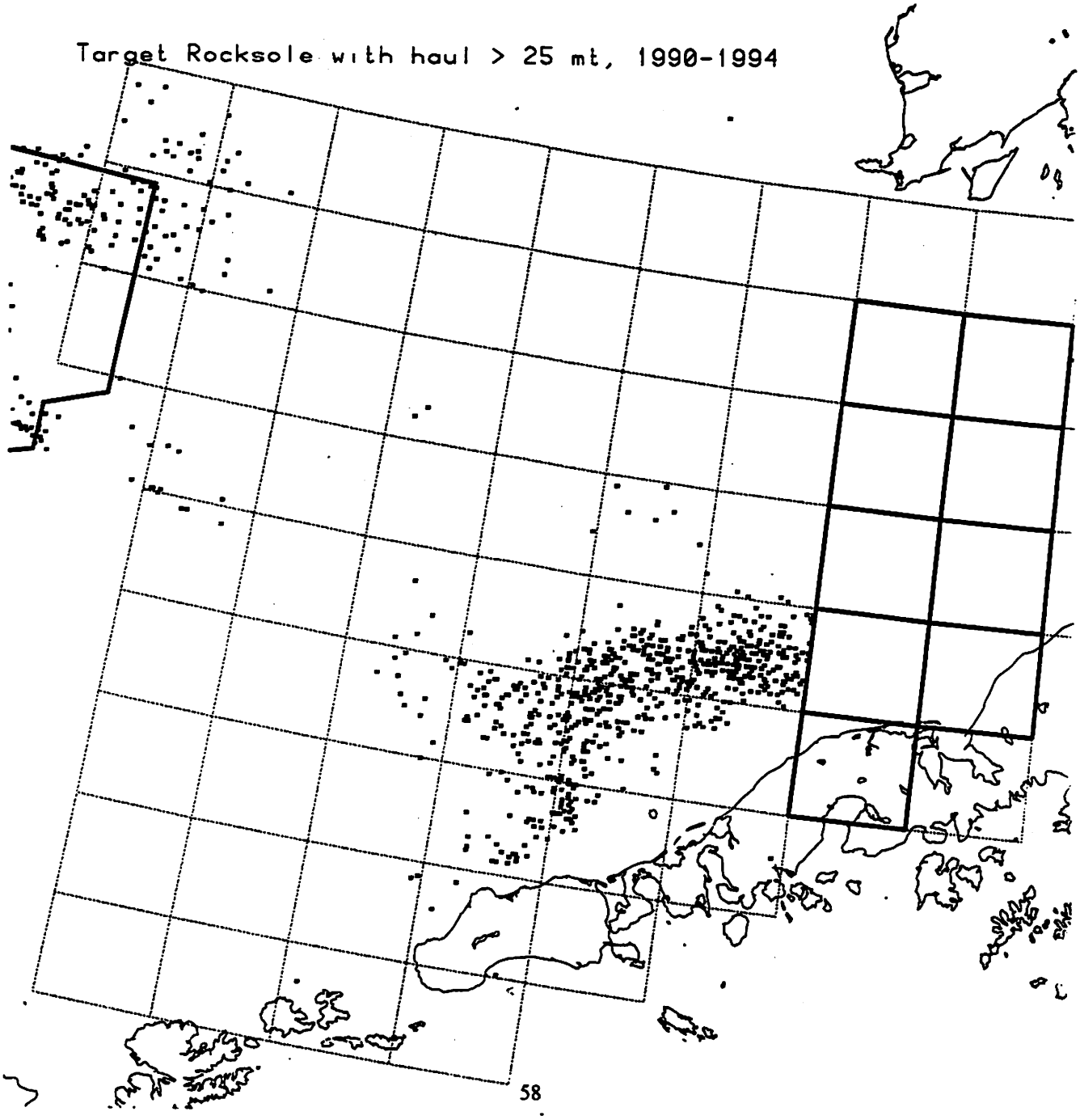
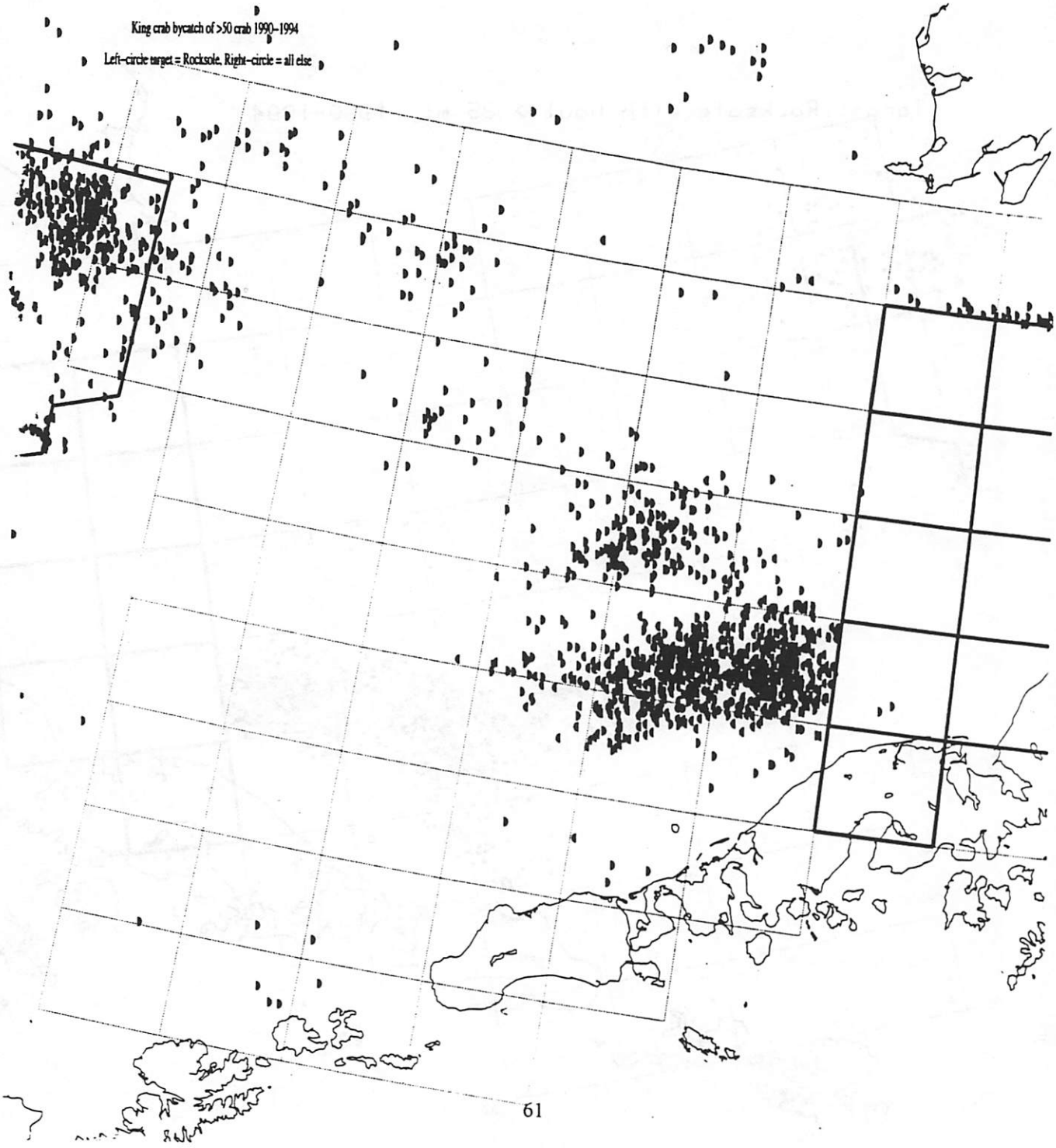


Figure 30. Distribution of observed hauls with more than 50 king crab. Circles to the left = rock sole target, circles to right = any other target.



Crab Rebuilding Committee Report:

Minutes of the BSAI Groundfish and Crab Plan Team Meeting March 21-22, 1995

Prepared by:
David Witherell

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605 West 4th Avenue
P.O Box 103136
Anchorage, Alaska 99510

Note: *The Committee invites suggestions from the public regarding strategies the Council might use to enhance crab stock rebuilding. An informal feedback session is scheduled for Wednesday, April 19, at 7 p.m. Formal presentations are scheduled for April 20 to the SSC and AP, and April 22 to the Council.*

Draft Agenda

Joint Meeting of the BSAI Crab and Groundfish Plan Teams

8:30 a.m. - 5:00 p.m., March 21 - 22, 1995
Building 9, Rooms A&B, Alaska Fisheries Science Center
7600 Sand Point Way NE, Seattle, WA

I. Introduction

Dave Fluharty - proposed direction and focus of meeting

II. Status and Management of Bering Sea Crab Stocks

III. Bycatch Management in Groundfish Fisheries

current strategies, accounting, and observer methodology

IV. Sources and Magnitude of Crab Mortality

A. Direct sources
   crab fishery
B. Indirect sources
   bycatch in crab, groundfish, and scallop fisheries
      number of crabs bycaught by species
      size (age) of crab bycatch
      mortality rate of bycatch
C. Other sources
   unobserved mortality due to fisheries
      ghost fishing
      unobserved mortality by trawls, dredges, and pots
   predation
      e.g. sockeye salmon, yellowfin sole, rock sole, Pacific cod

V. Habitat Considerations

A. Critical habitat for crab stocks
B. Potential impacts of trawls, dredges, pots on habitat
C. Competition with fish for food
D. Physical environment effects on recruitment and mortality

VI. Alternative Management Strategies

strategies not otherwise presented through informal discussion

VII. Public Testimony

VIII. Plan Team Discussion

Information synthesis and recommendations
   determine how to structure the report
   determine the process and timing to complete work

Joint Meeting of the Bering Sea/Aleutian Islands
Groundfish and Crab Plan Team
March 21-22, 1995

Members Present:

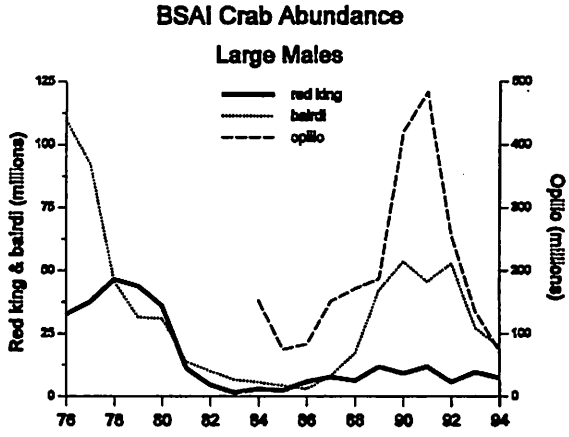
Groundfish Plan Team
Dave Ackley (ADF&G-Juneau)
David Colpo (NMFS-AFSC)
Loh-lee Low (NMFS-AFSC)
Richard Merrick (NMFS-AFSC)
Grant Thompson (NMFS-AFSC)
Farron Wallace (WDF)
Dave Witherell (NPFMC)

Crab Plan Team
Rance Morrison (ADF&G-Dutch)
Peggy Murphy (ADF&G-Juneau)
Bob Otto (NMFS-Kodiak)
Doug Pengilly (ADF&G-Kodiak)
Jerry Reeves (NMFS-AFSC)
Dave Witherell (NPFMC)
Gordon Kruse (ADF&G-Juneau, substitute)

The Bering Sea/Aleutian Islands (BSAI) Groundfish and Crab Plan Teams met jointly in Seattle beginning at 8:30 a.m. Tuesday, March 21, 1995. Council member Dave Fluharty chaired the meeting. The goal was to synthesize available information on sources and magnitude of crab mortality and ecosystem relationships and to identify alternative strategies the Council might use to enhance the survival of crab stocks and thus promote rebuilding. Discussion focused on Bristol Bay red king crab (*Paralithodes camtschaticus*), and Bering Sea Tanner crab (*Chionoecetes bairdi*) and snow crab (*C. opilio*) stocks. An information packet containing pertinent data and research reports was distributed to team members and industry representatives prior to the meeting. Active public participation and feedback were encouraged. The meeting format was to hear staff reports on each item, followed by questions and discussion. These minutes provide a synopsis of each staff report and a summary of the discussion that followed.

Status and Management of Bering Sea Crab Stocks

Bob Otto characterized the Bristol Bay red king crab, and Bering Sea Tanner and snow crab stocks as being in poor shape and declining based on the 1994 survey. Survey abundance estimates of large males in each of the three crab stocks are shown in the accompanying figure (note that Bristol Bay and Pribilof red king crab stocks are combined). The Bristol Bay red king crab fishery was canceled in 1994 due to low female abundance, which was below a threshold of 8.4 million females > 90 mm (3.5", the size at 50% maturity). Very few pre-recruit red king crab were detected in the survey. The survey also indicated low abundance of pre-recruit Tanner crab, as a high proportion of sublegal males (<140 mm) had reached terminal molt, and consequently most would never be harvested. [Jerry Reeves cited a laboratory study by A.J. Paul that showed 74% of pre-recruit sized Tanner crabs molted within 27 months. Bob and Gordon Kruse felt that AJ's results were non-representative, and Gordon indicated that his modeling studies showed a 20% molting rate for functionally mature males]. Although snow crab stocks were declining, a fair amount of pre-recruits was observed in the northern area.



Bob speculated that the crash in Tanner and red king crab abundances observed in the late 1970's and early

80's and subsequent poor recruitment may have resulted from large scale changes in the Bering Sea ecosystem. He noted population changes for crab in the eastern Bering sea that were much different than stable crab stocks observed in areas to the north. He also noted the dramatic increase in flatfish biomass and other changes that have occurred in groundfish populations. The teams discussed this at length the following day.

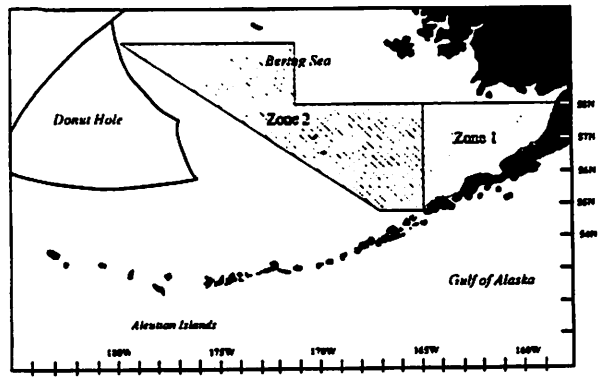
Rance Morrison provided a summary of crab fisheries management. The fishery management plan (FMP) for BSAI king and Tanner crab fisheries essentially defers crab management to the State of Alaska. The FMP establishes three categories of management measures: 1) fixed measures that require amendment to change, 2) frameworked measures that the State may implement and amend subject to FMP criteria, and 3) measures the State can implement and amend not subject to FMP criteria. To manage the BSAI crab fisheries, the State requires vessels to register with the state by obtaining licenses and permits, and register for each fishery and each area. Observers are required on all vessels processing crab in the BSAI. Pre-season guideline harvest levels (GHL) are established based on surveys or historical landings. GHLs correspond to exploitation rates of 20% for red king crabs > 120 mm, 40% for Tanner crabs, and 58% for snow crabs. Season opening dates are set through the Board of Fisheries to maximize yield per recruit and minimize handling of softshell crabs. Pot limits, based on vessel size, are currently 250 for vessels > 125 feet, and 200 for vessels < 125 feet. Minimum size limits (as measured by carapace width) in the Bering Sea are 6.5" for red king crab, 5.5" for Tanner crab, and 3.1" for snow crab. Only males are harvested.

Rance also reported on recent crab landings. The 1994 Bristol Bay red king crab fishery, which was scheduled to open on November 1, did not due to the low abundance observed by the NMFS bottom trawl survey. The survey indicated little prospect for increased recruitment of mature males or females, and female threshold (8.4 million mature females) was not reached. The fishery was also closed in 1983 due to low stock abundance. After re-opening in 1984, catches gradually increased to 20 million pounds in 1990, well below the record catch of 129.9 million pounds in 1980. The 1993 catch of red king crabs was 14.6 million pounds and worth $55 million. The 1994 Bering Sea Tanner crab fishery opened on November 1. The area east of 163 W was closed to minimize handling of red king crabs. Consequently, the GHL for Tanner crabs was set at 7.5 million pounds. A total of 7.6 million pounds were harvested during the 20 day fishery. Landings were down substantially from 1990, when 39.7 million pounds worth $45 million were landed. At an exvessel price of $3.75 per pound, the 1994 Tanner fishery was worth over $28 million. The 1995 snow crab fishery opened on January 15 with a preseason GHL of 55.7 million pounds of crab over 4". Although the legal size for opilio snow crab is 3.1" cw, current markets and processor prefer 4" crab. Over 255 vessels registered and caught 73.6 million pounds in the 32 day fishery. This fishery produced over 325 million pounds in 1991, but due to poor recruitment both GHL and landings have been reduced. Ex-vessel price, on the other hand, has sharply increased such that the 1995 fishery was worth over $191 million.

Bycatch Management in the Groundfish Fisheries

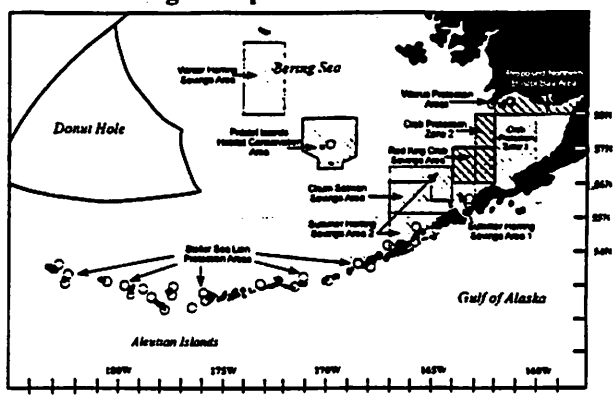
Dave Witherell described how crab bycatch is managed in groundfish fisheries. Among the objectives of the Bering Sea/Aleutian Islands (BSAI) groundfish fishery management plan is minimizing the impact of groundfish fisheries on crab and other prohibited species, while providing for rational and optimal use of the region's fishery resources. Prohibited species (all king crab and Tanner crab, halibut, herring, salmon, and steelhead) must be returned to sea as soon as possible. Prohibited species bycatch limitation zones and limits were set to control the number of red king crabs and *C. bairdi* crabs taken as bycatch each year. Bycatch limits for

Prohibited Species Bycatch Limitation Zones



trawl fisheries are set for each bycatch limitation zone, which are then apportioned among the various directed fisheries. Prohibited species catch (PSC) limits are 1,000,000 *C. bairdi* crab and 200,000 red king crab in Zone 1 and 3,000,000 *C. bairdi* crab in Zone 2. To optimize total groundfish harvest under established PSC limits, PSC is apportioned to directed trawl fisheries during the annual specification process. When a target fishery attains a PSC apportionment or seasonal allocation specified in regulations, the bycatch zone to which the allocation applies closes to that target fishery for the remainder of the season.

Bering Sea Species Protection Areas



Closed areas have been established to protect prohibited species and their habitat in the BSAI. The adjacent figure shows these areas, some of which are seasonal so that not all are closed simultaneously. Some of these areas were specifically closed to protect crab resources. Crab protection zones were implemented in 1987 to prevent the incidental catch of crabs in trawl fisheries. The Pribilof Islands Habitat Conservation Area was implemented in 1995 to protect blue king crabs and their habitat. The Bristol Bay Red King Crab Savings Area was closed by emergency order in 1995 to protect red king crab populations and habitat, and the Council is considering making this closure permanent. Another closure area in Northern Bristol Bay has been proposed to protect juvenile red king crabs.

Several other measures have been taken to reduce the incidental capture of crabs in groundfish fisheries including a vessel incentive program (VIP) and gear restrictions. The intended effect of the VIP program is to increase the opportunity to harvest groundfish TACs (quotas) before established PSC limits are reached. The VIP program is based on specification of bycatch rate standards that, when exceeded, constitute a violation of the regulations implementing the VIP. In the BSAI, bycatch rate standards were 2.5 red king crabs per ton of groundfish in the yellowfin sole and non-pollock trawl fisheries in Zone 1. It was noted that very few cases have been prosecuted for VIP violations, however. Gear restrictions have been implemented in the groundfish pot fishery to reduce the potential for ghost fishing by lost pots by requiring a biodegradable panel constructed of # 30 or less cotton thread that is a minimum of 18" long, parallel to and within 6" of the bottom of each pot. In the trawl fisheries, minimum mesh sizes regulations, that were recently adopted by the Council, may reduce the bycatch of juvenile crabs.

Bycatch Estimation Procedures

Martin Loefflad (NMFS-AFSC) reported on how data are collected by the observer program, and detailed the steps taken to produce estimates of crabs bycaught in groundfish fisheries. Observer coverage depends on vessel length; 100% observers on vessels > 125 feet, 30% coverage on vessels 60-125 feet, and 0% coverage on vessels <60 feet. Shoreside processors have 100% coverage. 100% coverage means that an observer is always onboard; it does not mean that every haul or landing is observed.

On trawl vessels, observers sample about 3 to 4 tows per 24 hour period, which equate to about 50-60% of the hauls observed on at sea processing vessels, which have 100% observer coverage. The tows to be sampled are pre-selected based on a random sequence. The two primary goals of biological sampling for the observer is to estimate total catch size and to determine species composition of the catch. Catch size is generally estimated volumetrically based on codend size and fullness. Species composition is estimated from basket samples or by whole haul samples. For basket samples, a 300 kg sample (about 8 baskets) is randomly taken from the catch (usually from holding bin below deck). The observer weighs each component of the sample. Crabs are counted and a portion of these sexed and weighed. Sampling for crab length frequency has not been a priority item for observers, and consequently data are sparse. Catch data are reported on a haul by haul basis to the NMFS-AFSC

Observer Program in Seattle, where the sampled haul data are extrapolated to the entire catch. From there, the information is forwarded to NMFS in-season management division, where it is run through the BLEND program to estimate total catch. The PSC bycatch rate observed is then applied to total catch to get the number of PSC bycaught that is reported on the Bulletin Board and used for bycatch management.

Estimates of crabs taken as bycatch assume that basket samples are representative of entire hauls. Dr. Pennington (NMFS) is comparing the accuracy of basket sampling versus whole haul sampling at the Alaska Fisheries Science Center.

Rance Morrison briefed the teams on the State observer program for directed crab fisheries. The State observer program was promulgated in 1988 to enforce minimum size limits, and has since expanded to include biological sampling. The observer program operates on a third party contract like the groundfish program, and observers are briefed and debriefed in Dutch Harbor. Catcher/processors and floating processors require 100% observer coverage. Observers randomly sample 4-10 pots per day. The entire catch is counted and sexed, and a subsample is measured. Bycatch is estimated from the CPUE of observed pots and the number of pots lifted.

Bycatch Estimates

Rance Morrison summarized information on crab bycatch in directed crab fisheries. Length frequency data are available by species, sex, and shell condition. Crab bycatch includes females of target species, sublegal males of target species, and non target crab species. Beginning in 1993, the Tanner crab season opened on November 1 to coincide with the red king crab fishery, This allowed retention of legal males of both species, thereby reducing bycatch. Prior to 1993, the Tanner crab fishery opened 7 days after the Bristol Bay red king crab fishery closed. Additionally, some legal size male Tanner and snow crabs were retained when fishing seasons overlapped (prior to 1994/95). A regulation instituted in 1993 to restrict tunnel openings to a 3" maximum has reduced the bycatch of red king crab in both Tanner and snow crab fisheries. For example, king crab bycatch in the Tanner crab fishery showed a 84% reduction from 1992 to 1993.

Crab bycatch in the 1992 and 1993 directed crab fisheries is summarized in the tables below. Note that the snow crab fishery catches few non-target crabs, in part because snow crab females do not grow very large. The snow crab fishery also concentrates further to the north than other crab fisheries. Bob Otto noted that research is being conducted on escape vents (rings) that would further filter out sublegal male and female Tanner crab, as well as reduce bycatch of non-target species. Gordon noted that ADF&G is supporting a study by UA on red king crab behavior in relation to pot design. Significant progress has been made to reduce bycatch and results are expected within the year. A regulation scheduled to be implemented in September 1995 will require all king crab pots in Bristol Bay to have at least one-third of one vertical surface of the pot composed of not less than 7.75" stretched mesh webbing.

Crab Catch and Bycatch in Directed Fisheries, 1992

	Red king crab fishery	Tanner crab fishery	Snow crab fishery
legal males*	1,070,472	14,629,181	267,767,184
non-legals	4,714,194	25,958,176	6,024,441
red king crab	--	1,477,695	33,731
Tanner crab	1,543,952	--	14,740,655
snow crab	20,586	2,758,365	--
hybrid**	NR	886,617	8,459,854

Crab Catch and Bycatch in Directed Fisheries, 1993

	Red king crab fishery	Tanner crab fishery	Snow crab fishery
legal males*	2,022,165	7,209,948	228,487,123
non-legals	5,502,508	18,150,624	4,563,916
red king crab	--	233,272	24,465
Tanner crab	3,968,374	--	6,700,215
snow crab	20,012	1,485,835	--
hybrid**	NR	293,428	9,613,355

*refers to commercial size (>4") males for snow crab.
**hybrid = opilio X bairdi crab

Dave Witherell provided a summary of red king crab, Tanner crab, snow crab bycatch in the Bering Sea and Aleutian Islands area (BSAI) groundfish trawl, pot, and hook and line fisheries. Although length frequency data have been collected by observers when time permits, data are limited. Therefore, bycatch of crabs from various fisheries could not be compared on the same scale (such as adult equivalents). Bycatch of crabs in the 1992-1994 BSAI groundfish fisheries is shown in the table below.

Crab Bycatch in Groundfish Fisheries

Year	Red king crab	Tanner crab	Snow crab
1992	179,348	4,292,033	17,662,549
1993	248,550	3,421,826	14,760,722
1994	281,023	2,544,982	12,482,127

Dave compared the number of crabs taken as bycatch to the total population size as determined from the trawl survey. Bycatch accounted for a low percentage of crab abundance: red king crab 0.5 - 0.8%; Tanner crab 1.0-1.3%, and snow crab 0.1-0.2%. Bob noted that the survey was not designed to estimate abundance indices for immature crabs, and indices for small crab are probably the least reliable. The total survey estimate is simply the sum of indices for each size group and is not representative of the total population. Bob further noted that bycatch limits were not derived based on survey estimates.

In January, the Council's Scientific and Statistical Committee (SSC) recommended that estimating mortality in terms of adult equivalents would provide better estimates of bycatch impacts across fisheries. The difficulty, of course, is the limited amount of length frequency data that are available. It was noted that although length frequency data were sparse, some information has been gleaned from the observer program. For example, based on crab distribution and trawling effort, one would predict that red king crab bycatch consisted primarily of legal sized males. Average size of red king crab males bycaught in 1989 JV groundfish fisheries was 132 mm carapace length, as reported by Armstrong. Dave Ackley's preliminary analysis of red king crabs taken in recent trawl fisheries agrees with these results. The team agreed that all red king crab bycaught in trawl fisheries could thus be considered adult equivalents, as every indication is that bycatch consists of large mature crab. For snow crabs,

preliminary analysis of observer data indicated that bycatch consisted of small (40-80 mm) individuals, although a good proportion of these would be mature (50% maturity = 65mm (♂) and 50 mm (♀)). Length frequency information for Tanner crabs taken as bycatch in the groundfish fisheries has not been examined.

Doug Pengilly summarized crab bycatch management in the BSAI weathervane scallop fishery. Crab bycatch caps were instituted for the scallop fishery beginning in 1993, along with a mandatory observer program (100% coverage). In areas other than the Bering Sea, crab bycatch caps were set at 1% of the population if the crab fishery was open, and 1/2% the population if the crab fishery was not open. In the Bering Sea, caps were not set based on crab biomass because the numbers would be astronomical relative to other caps. Instead, the caps were set at a rate that ADF&G determined could be accommodated, and extrapolated out based on the projected number of vessels and length of season. For 1994, Bering Sea crab caps were 260,000 Tanner crab (all species) and 17,000 red king crab.

Bycatch in the 1993 Bering Sea scallop fishery totaled 276,500 Tanner crabs, 15,000 snow crabs, and one king crab. The original report contained an estimate of 212 red king crab, but when Doug re-edited the data last week, he discovered that there was only one king crab actually observed. The fishery occurred south and west of the red king crab population. Scallop dredges apparently catch all sizes of Tanner crabs > 20 mm; in the Bering sea, most crab taken were > 60 mm in carapace width. About 11.3 % of the Tanner crabs were observed to be dead and about 26% had new injuries. The largest and smallest crab had the highest mortality rates. For large Tanners, mortality was related to number of injuries which were dependent on size. Bycatch of snow crabs consisted of very large crabs (most 100 mm - 140 mm). About 19% were moribund when observed. Of the 20 red king crabs bycaught in scallop fisheries throughout Alaska, 2 were moribund.

Bycatch Mortality

Gordon Kruse briefed the teams on crab bycatch mortality studies. Gordon and Peggy Murphy are publishing a bibliography on handling mortality studies of crabs and lobsters done around the world. There are a variety of effects from sublethal (reduced growth rates, molting probabilities, visual acuity from bright lights, and vigor) to lethal effects. Studies have shown a range of mortality due to handling based on gear type, species, molting stage, number of times handled, temperature, and exposure time.

Several studies have been done on Dungeness crabs. One study showed that handling mortality was 20-30% for softshell crabs held over a 4-6 day period; mortality of hard shell crabs was only 1-9% over the same period. Softshell crabs handled 3 times had a 41% mortality, whereas those handled only once had a 23% mortality rate. A study on discard mortality of Dungeness crab done in Alaska by Tom Shirley showed that crabs handled 4 times had 100% mortality over a 4 month period. The control crabs had a 10% mortality. Tag studies also have shown higher mortality for softshell and injured crabs.

Studies on red king crabs indicate that bycatch mortality in pot fisheries may be low. A study by Shijie Zhou and Tom Shirley simulated the catching and discard of red king crabs held over a 3 month period. Controls were also held over the same period. No significant difference in mortality was found across treatments and no difference in feeding rates, righting times (time for crabs to turn over), or bacterial counts was observed. Injury rates were directly related to the number of times handled. Doug Pengilly and Leslie Watson tagged 4,000 crabs during a test fish project to compare mortality of crabs returned to the sea in the most careful manner (control) versus those thrown off the deck while the vessel was moving (treatment). Return rates (27%) were nearly equal indicating that the discarding did not affect recovery rates, and hence no bycatch mortality due to discard procedure.

Other work has been done with Tanner crabs. Bob Otto described NMFS experiments in which Tanner crab were dropped either once or four times from about 2.5 m, as well as crabs that weren't dropped (controls), and held them for two months. No significant difference in mortality among treatments was observed. Another test was

conducted to measure the impact of injuries (leg loss, cracked carapace) on subsequent mortality, and again found no significant difference in mortality among treatments, including controls. Preliminary results from another experiment underway indicates that crabs do not suffer additional mortality from being brought to the surface multiple times. Bob noted that in all these studies, mortalities are similar to the rates estimated by natural mortality (M = 0.3).

A study of red king crabs and Tanner crabs found that mortality was related to air temperature and exposure duration. Exposed crabs exhibited reduced vigor and righting times, feeding rates (Tanner crabs), and growth (red king crabs). For surviving females, there was no impact on eggs or larvae. Cold air resulted in leg loss or immediate mortality for Tanner crabs, whereas red king crabs exhibited delayed mortality, which occurred during molting. A relationship was developed to predict mortality as the product of temperature and duration of exposure. It was noted that the temperatures used in the tests were not considered extreme cold for BSAI crab fisheries.

A study on the mortality of trawl caught red king crabs and Tanner crabs done by Brad Stevens found that on average, 21-22% of the bycaught crabs held in tanks over a 2 day period survived. One of the factors that determined survival was captivity time, which was the sum of towing time and processing time. At 3 hours captivity time, the mortality rate was zero; after 17 hours, mortality was 100%. Shell age was also a factor, with new shell crabs having lower survival. It was noted that other factors affecting bycatch mortality have not been tested. Other factors include predation on discarded crabs, discarding in unsuitable habitat, etc..

Unobserved Mortality

The team discussed the unobserved impact of trawling on crab stocks. One concern was that trawling could scatter crabs by breaking up pods and exposing crab to predation or leaving them in an unsuitable area. Another concern was the effects of trawls and dredges running over or filtering crabs and perhaps injuring or killing them. Studies done in other areas indicate that impacts on crabs may be none to major. In general, the heavier the gear, the larger the impact. There is hope that laser line technology may be the ticket to examining trawl impacts, and ADF&G is pursuing this research. These lasers have the precision to actually get measurements of crab even in turbid conditions.

Gordon Kruse reported on unobserved mortality and ghost fishing in the pot fisheries. Ghost fishing is the term used to describe mortality caused by lost or derelict gear. "Catching mortality" is ascribed to those crabs that enter a pot and are eaten by other pot inhabitants before the pot is retrieved. Gordon discussed how catching mortality may happen in some Dungeness crab fisheries that occur during the molting period, when crabs are more susceptible to cannibalism. Other crab fisheries are set to occur outside of the molting season, and catching mortality in these fisheries may be limited to octopus or large fish entering a pot. Because no evidence of crab is left in the pot, these mortalities remain un-assessed.

The impact of ghost fishing on crab stocks remains unknown. It is estimated that 10-20% of crab pots are lost each year. [About 10,000 pots were estimated lost in the 1992 Bristol Bay red king, and Bering Sea Tanner and snow crab fisheries combined.] Fewer pots are expected to be lost under pot limit regulations and shorter seasons. It was suggested that data on lost pots and their contents could be extracted from NMFS trawl survey logs and observer database. Some high resolution side-scan sonar work done by NMFS Kodiak mapped the distribution of lost pots in Chiniak Bay. A total of 284 crab pots were found in inner Chiniak Bay alone. NMFS plans to observe these pots directly with a submersible and ROVs this spring, and this study may yield information on ghost fishing by crab pots.

Since 1993, the State has required crab pots be fitted with degradable escape mechanisms consisting of #30 cotton thread or 30-day galvanic timed release (GTR) mechanisms. A #30 cotton thread section is also required in groundfish pots. The average time for #30 cotton twine to degrade is 89 days, and the GTR about 30 days to

degrade. This is somewhat of a tradeoff between degradability and the amount of time required of fishermen to replace the biodegradable section. Biodegradable escape mechanisms have been required for some years, but prior to 1993, maximum allowable twine size was considerably larger.

Crabs captured in lost pots may die of starvation or predation. Gordon reported on two studies of Tanner crabs; one indicated that about 10% of the crabs died of starvation in 90 days and the other study observed 39% mortality after 119 days. In the first study, the 90% that had survived were subsequently fed, but all died anyway.

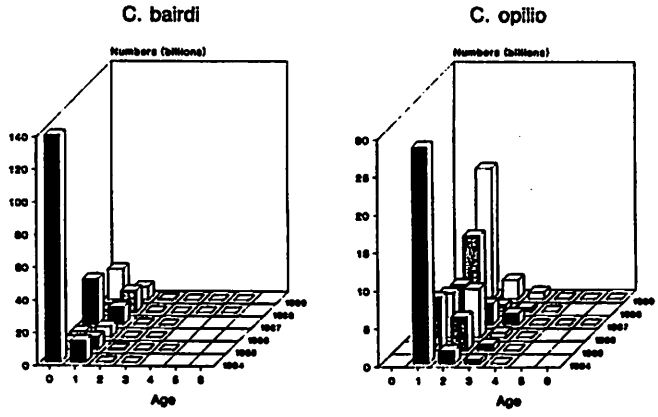
Bob Otto estimated that mortality of crabs caused by "pot bombing" was extremely minor, based on some earlier calculations of number of pots and area they occupy relative to the Bering Sea. Pot bombing is a term used to mean a pot landing on the ocean floor when it is being set, presumably impacting any crab on which it lands.

Predation and Competition

Pat Livingston (NMFS-AFSC) reported on predation and competition of crabs and groundfish. She noted how the total biomass of inshore benthic infauna consumers (starfish, crabs, flatfish) has increased about 40% from 1979-1993. Most of this increase is attributable to a growing rock sole biomass, and to a lesser extent starfish and flathead sole biomass. Of the crab species, only snow crab comprises a substantial portion of the infauna consumer guild (species that eat clams, polycheates, etc.). Yellowfin sole had dramatically increased in abundance in the early 1980's to become the largest component of this guild until the early 1990's when rock sole became co-dominant. Mean size at age has declined for yellowfin sole and rock sole, indicating stress caused by competition with rock sole, and to a lesser extent a decrease in average bottom temperature. Reduced mean size at age has also been observed for halibut. Unfortunately, a survey of infaunal biomass has not been conducted since the 1970's, so we don't know what or how much food is available. Crab eat small clams, marine worms, brittle stars, sand dollars, and other echinoderms.

Several studies have examined the relationship of crab abundance with predators and competitors. Pat found a significant inverse relationship in red king crab recruitment and the exploitable biomass of yellowfin sole. Vidar Wespestad and others found a significant inverse relationship between the abundance of sockeye salmon smolts and subsequent red king crab recruitment. One team member recalled that Don Rogers (U.WA) has sockeye smolt samples collected off Port Moller and is planning to examine stomach contents, which may provide additional information on predation of crabs by sockeye salmon.

Pat has also estimated the number of crabs eaten based on groundfish stomach samples from the 1984-1989 summer bottom trawl surveys. Annual consumption of snow crabs from May through September ranged from 11 billion to 31 billion crabs. Snow crabs consumed were primarily age 1, and to a lesser extent age 2 and 3 crabs. Impacts of predation on crab stocks were measured by examination of the instantaneous annual natural mortality coefficient by age, obtained from reconstructing population sizes of ages 0-2 using survey estimates of population size at age 3. Estimates range from 0.41 to 1.77 for Age 1 snow crabs, and 0.14 to 1.53 for age 2 snow crabs for the years 1984-1989. Pacific cod was the primary predator, particularly on older crabs. Flathead sole, yellowfin sole, and rock sole were also found to be predators on younger snow crabs.



Annual consumption of Tanner crabs by groundfish ranged from 10 billion to 153 billion crabs, consisting primarily of Age 0 and Age 1 crabs. Instantaneous

annual natural mortality coefficients ranged from 0.26-2.92 for age 0, 2.92-3.22 for age 1, and 0.93 to 2.69 for age 2. Yellowfin sole and flathead sole were found to be the primary consumers of Tanner crabs < 20 mm. Pacific cod also preyed on young crabs, and were responsible for all of the larger (20-35 mm) Tanner crabs consumed. The figure above shows the number of Tanner and snow crabs consumed by age, May through September. Consumption during other times of the year has not been estimated.

The little information concerning predation on red king crab suggests that mortality caused by groundfish predators may be low. Pat found red king crab in some Pacific cod stomach samples, but the numbers were low. It was noted, however, that sampling occurs in the summer, when king crabs have hard shells and less vulnerable to predation.

Habitat Considerations

Dave Ackley and Bob Otto summarized available information on crab habitat requirements. Juvenile red king crabs < 18 months old are solitary and cannibalistic, and require habitat that provides protection. Habitat is characterized as relatively shallow (20-60 m) with rocks, shell hash, and biological cover. In the Bering Sea, age 1 juveniles occur along the Alaska Peninsula, and around Kvichak and Togiak Bays as shown in the accompanying figure from Armstrong (1993), and likely in other areas not sampled. One study found small red king crabs exhibit a patchy distribution from the east end of Unimak Island to Port Moller, and are associated exclusively with stalked ascidians, bryozoans, and other living substrates. Age 2-4 red king crabs form pods and progressively move to deeper waters and away from protective nearshore habitat. Adult red king crabs occupy deeper waters with sand/silt bottom. Both adult and juvenile Tanner and snow crabs apparently utilize mud bottom habitat throughout the BSAI.

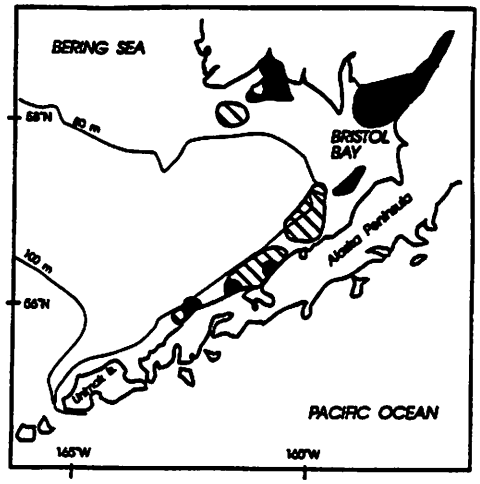


Fig. 5. Areas of the southeastern Bering Sea with substrate of more than 10% gravel (shading) during surveys in 1983 and distribution (cross-hatching) of early juvenile (age 0+ to 1+ yr) RKC collected at the same time. Redrawn from McMurray et al. (1984, fig. 3.1–14 and 3.5–4, 5, 6).

Red king crabs in Bristol Bay begin spawning as early as January and typically finish in June. It is thought that first time spawners spawn the earliest, and the older crabs later in the season. Males molt at least two weeks prior to female molting and egg extrusion. [Males do not have to molt to mate, however.] Peak hatching occurs in mid-May and the zoea and megalopae (glaucothoe) drift and swim in the currents. Zoea are nocturnally active and exhibit diel vertical migrations. Tidal currents move northward along the Alaska Peninsula and into Bristol Bay. Gordon suggested that dominant tidal currents may assist in retaining crab larvae in the Bristol Bay area; however, wind driven currents do move larvae and these currents may have shifted in the late 1970's due to a climatic phenomenon. Settling of larvae occurs in July and August. To survive, the juveniles need structure to avoid predation by fish and each other. Early juveniles have even been observed to hide between starfish arms during the day.

Dave Witherell and Gordon Kruse reviewed studies on the potential impacts of fishing gear on crab habitat. Studies indicated that all gear used to harvest aquatic resources may have some potential to adversely affect crabs and other organisms comprising benthic communities, and the magnitude of these effects are presumably linked to fishing effort, gear type, and substrate. The primary ways in which trawling and dredging can disrupt the habitat: 1) scraping and plowing the sea-floor, (2) sediment re-suspension and redistribution of sediment layers, (3) damaging or removing non-target benthic organisms, and (4) dumping of processing waste. Generally, the heavier the gear in contact with the seabed, the greater the damage. The effects vary greatly, depending on the amount of gear contact with the bottom, together with the depth, nature of the seabed, and the strengths of the

currents or tides. Overall, studies show that bottom trawling and dredging have an impact on the environment, but that the extent and duration of that impact varies from severe to minimal. Although no studies have been done on longline or pot gear, these gears may also impact habitat by sediment re-suspension and upending small rocks, shells, ascidians, bryozoans, and other bottom structure during the process of setting and retrieval. Submersible observations in the Gulf of Alaska showed that longlines snag on whatever objects are in its path, including rocks and corals, which may be dragged across the seafloor, upended or broken.

Alternative Management Strategies

Team members and participating public suggested some strategies the Council might consider pursuing to assist crab stock rebuilding.

It was generally agreed that minimum spawning stock sizes need to be maintained to provide a possibility of rebuilding, particularly for the Bristol Bay red king crab stock. A plan needs to be developed that would protect a strong year-class when one comes along. ADF&G is placing high emphasis on maintaining spawning stocks. A new analysis using stock reduction and a length-based model has indicated that perhaps threshold biomass for Bristol Bay red king crabs has been set too low. ADF&G is considering increasing the spawner threshold to 12 million females > 90 mm.

The team also discussed protecting areas of critical habitat. Areas to be closed may include those areas where crabs are congregated or nearshore habitat for juveniles. Other and perhaps less discrete areas could be closed during times when crabs are molting. One team member suggested that for adults, the time of year was a critical aspect for closures. For juveniles, it may be more important to close areas with appropriate habitat. Someone also suggested that perhaps instead of closing areas, we should designate open areas. Areas with historically low bycatch rates could be opened to bottom trawling to increase the harvest of flatfish stocks without impacting crab stocks. Outer Kuskokwim Bay was cited as one possible area that this might be able to occur (halibut bycatch may be a problem at times here, however). The possibility was raised that trawling was in part responsible for increasing the biomass of crab predators by mixing nutrients, exposing food, and providing food in the form of discards.

There was considerable discussion about reducing stocks of Pacific cod and flatfish that may prey on crabs. One person suggested that the 2 million mt optimum yield (OY) cap set for the Bering Sea be re-examined to allow increased harvesting of flatfish; the mechanism suggested would be to decouple pollock from the OY cap. Another team member pointed out that an increase in flatfish TAC could be made under the existing management system and OY cap; however, the Council may need to reduce pollock TAC and increase flatfish TAC. It was agreed that bycatch of halibut may be limiting, however.

All of these alternatives imply a fair amount of research and analysis. Plan team members and participating public identified areas of research to answer questions regarding factors affecting crab stock recovery. In other cases, we were left with questions. These research needs are listed in the order they were discussed, and have not been prioritized.

- What is the natural variation in crab population size; how would the population fluctuate in the absence of fishing? Also, how has fishing changed these dynamics? It was suggested that in the long term, environment plays the biggest role in population fluctuation. One team member suggested that core samples be analyzed to determine historical population sizes of fish and crab (Bob noted that this is probably not possible for crab). This work may be done by F.R.I.

- Define areas of critical habitat for crabs, so that they can be protected. The group recommended literature and survey data be compiled to identify known areas of critical habitat in the Bering Sea. Additional and specialized surveys would be needed.

- Examine potential habitat alterations and impacts caused by trawl and dredge gear. Laser line technology may provide some answers here.

- Examine larval transport to see where they are being carried. Some type of seasonal collector system was suggested.

- Would a comprehensive rationalization program or other program resolve bycatch problem?

- Develop or modify gear and fishing behavior to reduce bycatch or impacts. It was suggested by industry that bigger discs on the footrope with wider spacing would catch less crabs. Shorter tows and pre-sorting were suggested to reduce mortality of those discarded.

- Examine changing seasons to reduce bycatch rates. For example, industry suggested that rock sole roe can be processed in December when they may be in areas with low crab bycatch.

- Examine the effects of existing area closures, which result in crowding the fleet and chumming, on crab bycatch rates. The new closed areas in 1995 may provide a comparison. Also, see what effect the pot sanctuary and 12 mile closure area had on foreign fisheries.

- Examine time area closures relative to crab molting periods.

- Repeat the survey of benthic infauna that was conducted in the 1970's. See if there was a change in standing stock of infaunal invertebrates.

- Collect information on bycatch and incorporate into models in the same units, such as adult equivalents. Information on crab length frequency by sex needs to be collected and examined.

- Urge the observer program to examine existing length frequency data to provide some information we can use now.

- Conduct food habit studies year-round. Current predation studies are limited by data collected only in the summer on research surveys. Current estimates may not be accurate depending on when crabs molt. For example, predation on red king crabs may be underestimated because their shells are hard in the summer. Perhaps collections by observers could be made, or have biologists collects samples from trawlers.

- Determine how heavily predators would need to be fished to increase crab recruitment.

- Compare BSAI ecosystem and management with other systems. Has the closed area in Kamchatka prevented crab population declines? What factors allowed transplants in the Barents Sea to establish a viable population? How about comparing the Bristol Bay stocks to those around Kodiak and Southeast Alaska? Even within SE Alaska, certain bays have high crab populations, whereas others nearby are at all time lows; why?

- The disproportional harvest rates of groundfish may have had some impact on crabs. It would be helpful to construct a history of exploitation rates relative to groundfish ABCs. How many crabs would have been consumed each year if groundfish had been harvested at ABC levels?

- Measure the precision of crab bycatch estimates from the observer program. How precise are estimates obtained from basket samples?

- Determine the proportion of crabs encountered by trawls that are actually captured. What happens to crabs not retained by the net?

- Examine the entire issue of bycatch caps. Where did they originate and what do they mean relative to crab stocks and groundfish catch? If bycatch caps are needed, what should they be? Should caps fluctuate with biomass?

- Examine market solutions to bycatch. Would IFQs or individual bycatch quotas (IBQs) reduce crab bycatch?

- Consider that Bristol Bay is not a closed system. Do stocks in the Gulf of Alaska contribute to recruitment in the Bering Sea.

- Have observers examine pots caught in trawl gear. How many pots encountered? For those brought aboard, how many had biodegradable panels and were they still fishing? How many crabs were in the pots? How did the vessel get rid of the pot; was it full of fish and set back baited? Was the pot discarded in a fishable condition? Also check NMFS survey for lost pot data.

- Determine crab bycatch mortality rate and examine ways to improve survival of discarded crabs.

- Examine the potential of sonar (Roxanne device?) to map substrate in the BSAI to define areas of critical habitat.

- Investigate potential changes to crab management strategies, such as gear modifications or changes to the sex and size restrictions.

- Add observers to crab catcher vessels to compare data with catcher-processors. The vessels likely fish quite differently in terms of areas fished, soak times, and may thus have different bycatch.

- Examine effects of a Sea State type program on reducing crab bycatch in the groundfish fleet, so that areas with high bycatch rates can be voluntarily avoided.

Recommendation and Information Synthesis

The teams were asked to comment on the proposed area closure in Bristol Bay designed to protect red king crabs. A 90 day emergency rule (ER) closing this area to trawling is scheduled to expire April 28. The ER can be extended for an additional 90 days. Although the teams did not make a recommendation regarding extension of the ER, it was noted during the discussions that some molting and spawning would occur during this time period, and that crabs in the closure area were primarily mature crabs. At the April meeting, the Council will review an analysis of making this closure permanent. The teams recommended that if the Council needs to take action, that they don't make the closure permanent until other options for crab rebuilding are examined. A closure with a sunset after 1 year (and the possibility of extension) could be considered until a more comprehensive program is developed.

The team discussed how this information would be synthesized and presented to the Council. It was agreed that Dave Witherell would prepare meeting minutes for presentation at the April Council meeting. Dave Fluharty suggested that we have an informal meeting with the public during a night at the April Council meeting as a means of getting additional feedback and suggestions. If the Council wants the teams to flesh out more details of potential rebuilding options, then an additional meeting of the group would be required, and a full report from the group would be finalized and presented to the Council in September.

The meeting adjourned at about 5 p.m. on Wednesday, March 22.

Others in attendance were:

Bill Karp
Martin Loefflad
Sue Salveson
Chris Blackburn
Gretchen Harrington
Laure Jansen
Brent Paine
Pat Livingston
Ken Tippett
Gordon Blue
Arni Thompson
Tom Casey
Garry Loncon
Joe Terry
Rich White
Mark Kandianis
Teressa Kandianis
Vince Curry
Dave Benson
Wally Pereyra
Seth Macinko

Literature Review

Copies of the following reports were distributed before and during the meeting. Papers distributed before the meeting are identified by Agenda Item and reference number.

Agenda Item II

(1) ADF&G. 1995. Report to the crab and groundfish plan teams, March 21-22, 1995. 7p.

(2) NPFMC. 1994. Description of crab FMP.

(3) B.G. Stevens, J.A. Haaga and R.A. MacIntosh. 1994. Report to industry on the 1994 eastern Bering Sea crab survey. NMFS, Kodiak. 29p.

(4) Otto, R.S. 1990. An overview of eastern Bering Sea king and Tanner crab fisheries. Proceedings of the International Symposium of King and Tanner Crabs. Alaska Sea Grant College Program, UAF. p. 9-26.

Agenda Item III

(1) NPFMC. 1995. Exerpts from: Fishery management plan for the Bering Sea/Aleutian Islands groundfish. Chapter 14.

(2) NPFMC. 1995. Draft regulatory and closure areas for the groundfish fisheries in the Bering Sea and Aleutian Islands. 14p.

(3) Kruse, G.H. 1991. Issues paper: the application of basket sampling methods to estimate bycatch rates of prohibited species aboard domestic fishing vessels. ADF&G, Juneau, AK. 7p.

(4) Smith, T.P. 1993. Allocating the incidental catch of crab, halibut, herring, and salmon in the groundfish fisheries off Alaska. Proc. of Int. Symp on Mgmt. Strategies for Exploited Fish Populations. 93: 745-760.

Witherell, D.B. 1995. Management of crab bycatch in the BSAI groundfish fisheries. March 1995. 4 p.

Thompson, A. 1989. An industry perspective on problems facing the rebuilding of king and Tanner (bairdi) crab stocks of the eastern Bering Sea. Proceedings of the International King and Tanner Crab Symposium. 533-545.

Hughes, S. 1995. Testimony of United Catcher Boats on crab bycatch and crab management to the North Pacific Fishery Management Council, January 1995. 12 p.

Agenda IV (A)

(1) Morrison, R., R. Gish. 1994. Bering Sea/Aleutian Islnads crab fishery reports by management area: Bristol Bay red king crab (Statistical Area T), Bering Sea Tanner crab (Statistical Area J). ADF&G. 34p.

Agenda Item IV (B)

(1) Armstrong, D.A., T.C. Wainwright, G.C. Jensen, P.A. Dinnel, and H.B. Andersen. 1993. Taking refuge from bycatch issues: red king crab (Paralithodes camtschaticus) and trawl fisheries in the eastern Bering Sea. Can. J. Fish. Aquat. 50: 1993-1999.

(2) Murphy, M.C., G.H. Kruse. 1995. Excerpts from: an annotated bibliography of capture and handling effects on crabs and lobsters. ADF&G, Juneau, AK. 13p.

(3a) Pengilly, D., L. Watson. 1994. Summary and review of Bristol Bay red king crab tagging studies, 1990-1994. ADF&G, Kodiak, AK. 1p.

(3b) Zhou, S., T.C. Shirley. 1994. Abstract - Effects of handling on feeding, activity and survival of red king crabs. Juneau Center, School of Fisheries & Oceans, UAF, Juneau, AK. 1p.

(3c) Stevens, B.G., R.A. MacIntosh. 1993. Preliminary results of the 1992 survival experiment for crabs discarded from commercial pot fisheries. NMFS, Kodiak, AK. 2p.

(3d) Carls, M.G., C.E. O'Clair. 1989. Abstract - Influence of cold air exposures on ovigerous red king crabs (Paralithodes camtschatica) and Tanner crabs (Chionoecetes bairdi) and their offspring. Proc. Int. Symp. King and Tanner Crabs. p. 329.

(4) Kruse, G.H. 1994. Excerpts from: Fishery management plan for commercial scallop fisheries in Alaska. ADF&G, Juneau, AK. 12p.

(5) Stevens, B.G. 1990. Survival of king and Tanner crabs captured by commercial sole trawls. Fishery Bulletin 88:731-744.

(6) Carls, M.G., C.E. O'Clair. 1994. Responses of Tanner crabs, Chionoecetes bairdi, exposed to cold air. Fishery Bulletin 93:44-56.

(7) Tracy, D.A. 1994. Excerpts from: Alaska Department of Fish and Game Biological Summary of the 1992 Mandatory Shellfish Observer Program Database. ADF&G, Kodiak, AK. 44 p.

(8) ADF&G, NMFS Staff. 1994. Draft Discussion Paper - An analysis of red king crab bycatch in the Bering Sea with alternatives for trawl closures. ADF&G, NMFS. 48p.

(9) ADF&G Staff. 1994. Addendum to the draft discussion paper: An analysis of red king crab bycatch in the Bering Sea with alternatives for trawl closures. ADF&G. 22p.

Witherell, D.B. 1995. Bycatch of Red King Crab, Tanner crab, and snow crab in the BSAI groundfish fisheries. March 1995. 9 p.

Agenda Item IV (C)

(1) Kruse, G.H., A. Kimker. 1993. Excerpts from: Degradable escape mechanisms for pot gear: A summary report to the Alaska Board of Fisheries. ADF&G, Juneau, AK.

(2) Urban, D., D. Pengilly, and I. Vinning. 1994. Excerpts from: The scallop observer program and statewide data analysis summary to the Board of Fisheries. ADF&G: 4K94-28.

(3) Livingston, P.A. 1989. Interannual trends in Pacific cod, Gadus macrocephalus, predation on three commercially important crab species in the eastern Bering Sea. Fishery Bulletin 87:807-827.

(4) Westpestad, V.G., P.A. Livingston, and J.E. Reeves. 1994. Juvenile sockeye salmon, (Oncorhynchus nerka) predation on Bering Sea red king crab (Paralithodes camtschaticus) larvae as a cause of recruitment variation. ICES C.M. 1994/R: 10.

(5) McLellan, G.L., J.K. Leong. 1981. Summer food of Pacific cod, Gadus macrocephalus, in coastal waters of Southeastern Alaska. Fishery Bulletin 78(4): 968-973.

(6) Haflinger, K.E., C.P. McRoy. 1983. Summary - Yellowfin sole (Limanda Aspera) predation on three commercial crab species (Chionoecetes Opilio, C. Bairdi, and Paralithodes Camtschatica) in the Southeastern Bering Sea. Institute of Marine Science, UAF, Fairbanks, AK. 1p.

(7) Livingston, P.A., A. Ward, G.M. Lang, and M-S. Yang. 1993. Groundfish food habits and predation on commercially important prey species in the Eastern Bering Sea from 1987 to 1989. NOAA-NMFS-AFSC-11.

(8) Livingston, P.A., G.M. Lang, R. Pacunski, J. Parkhurst., M-S. Yang. 1991. Executive Summary - Groundfish food habits and predation on commercially important prey species in the Eastern Bering Sea from 1984-1986. NOAA/NMFS-F/NWC-207.

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