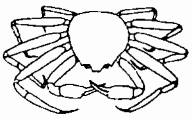
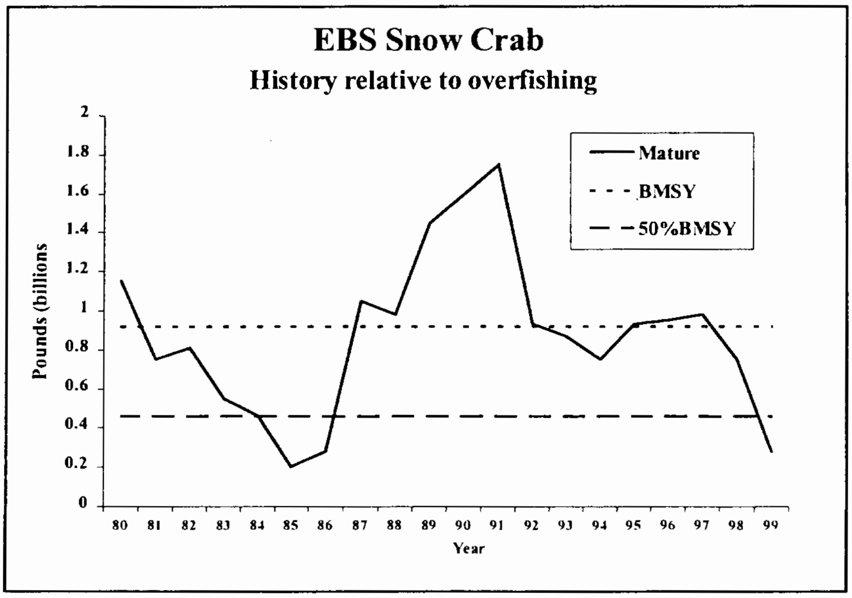
ENVIRONMENTAL ASSESSMENT
for proposed
AMENDMENT 14
to the Fishery Management Plan for the
King and Tanner Crab Fisheries in the Bering Sea/Aleutian Islands

A Rebuilding Plan for the Bering Sea Snow Crab (C. opilio) Stock





Prepared by staff of the
North Pacific Fishery Management Council
Alaska Department of Fish and Game
National Marine Fisheries Service

December2000

TABLE OF CONTENTS

Executive Summary

The 1999 NMFS Bering Sea survey indicated that the snow crab (*Chionoecetes opilio*) stock was below the minimum stock size threshold (MSST) established for this stock. Abundance of snow crab had declined sharply, resulting in a spawning biomass value (283.3 million pounds) that fell below the MSST (460.8 million pounds) and hence precipitated a severe curtailment of the fishery in the 2000 season. On September 24, 1999, NMFS informed the Council that this stock was declared "overfished" pursuant to the Magnuson-Stevens Fishery Conservation and Management Act guidelines, which requires a rebuilding plan to be developed within one year. This Environmental Assessment (EA) addresses alternatives for rebuilding the overfished stock of snow crab in the Eastern Bering Sea. Alternatives and options were developed by the Council at their October, 1999 meeting and revised at the April 2000 meeting. The alternatives examined were the following:

Alternative 1: No Action. No rebuilding plan would be adopted for Bering Sea snow crab. Note that adoption of this alternative would be violation of the Magnuson -Stevens Act.

Alternative 2: **(preferred)** Establish a rebuilding plan for Bering Sea snow crab. The rebuilding plan provides a framework that may have three components: a harvest strategy, bycatch control measures, and habitat protection. Note that more than one option can be adopted for each component.

A. **Harvest Strategy**: In previous years when there was a directed fishery, harvest rates for Bering Sea snow crab were established at 58% of males ≥ 4-inches carapace width (CW). This harvest strategy could be modified to reduce mortality on legal males, females, and juvenile crabs.

Option 1: Status quo - no action. Continue to establish harvest rates for Bering Sea snow crab at 58% of males ≥ 4-inches CW.

Option 2: **(preferred)** Adopt the Alaska Board of Fisheries harvest strategy for Bering Sea snow crab. The strategy, as detailed in Section 1.6.1 includes lower harvest rates at low biomass levels, and incorporates a threshold biomass.

B. **Bycatch Controls**: Bycatch control measures have previously been implemented in the crab, scallop, and groundfish fisheries. These measures could be adjusted to reduce mortality on unharvested crabs.

Option 1: **(preferred)** Status quo - no action. Maintain existing snow crab bycatch control measures. The snow crab PSC limit would be set at 0.1133% of total survey abundance (minus 150,000 crabs) with a maximum of 12.85 million crabs, and a minimum of 4,350,000 crabs.

Option 2: Reduce the snow crab PSC limit so there is no minimum level. The snow crab PSC limit would be set at 0.1133% of total survey abundance (minus 150,000 crabs) with a maximum of 12.85 million crabs.

Option 3: **(preferred)** Adopt the Board of Fisheries new gear modification measures to reduce bycatch of snow crab in crab fisheries.

C. **Habitat protection**: Adequate habitat is essential for maintaining the productivity of fishery resources. Measures previously implemented that protect snow crab habitat from fishing impacts include several areas where trawling and dredging is prohibited. Essential fish habitat (EFH) has been defined and potential threats have been identified. Additional measures could be implemented to further protect habitat.

Option 1: Status quo - no action. Maintain existing habitat protection measures, which include trawl area closures where some snow crabs occur.

Option 2.: **(preferred)** For agency consultation purposes, highlight the importance of snow crab EFH in maintaining stock productivity. To the extent feasible and practicable, this area should be protected from adverse impacts due to non-fishing activities.

Alternative 3: No fishing. Prohibit a fishery for Bering Sea snow crab until the stock is rebuilt.

The proposed actions contained in this amendment are intended to rebuild the Bering Sea snow crab stock. Adoption of Alternative 2 (particularly Part A, Option 2) is expected to allow the Bering Sea snow crab stock to rebuild, with a 50% probability, to the Bmsy level in 7 to 10 years, depending upon recruitment scenario used in the model. Adoption of the revised harvest strategy should result in more spawning biomass as more larger male crab would be conserved and fewer juveniles and females would die due to discarding. This higher spawning biomass would be expected to produce an above average year-classes when environmental conditions are favorable. Protection of habitat and/or reduction of bycatch may reduce mortality on juvenile crabs, thus allowing a higher percentage of each year-class to contribute to spawning and future landings. Any or all of these actions proposed under Alternative 2 would be expected to improve the status of this stock. No rebuilding benefits are provided by Alternative 1, Alternative 2A option 1, Alternative 2B option 1, or Alternative 2C option 1.

Alternative 2B, Option 2, could impact the groundfish trawl fisheries (the flatfish trawl fisheries in particular). The crab bycatch limits are apportioned among fisheries pre-season, and reaching one of these limits shuts down a fishery for the remainder of the season. Additional costs to the groundfish trawl fisheries would be incurred if additional areas were closed to trawling to protect crab habitat.

Under the framework rebuilding plan, changes to the components of the plan must; (1) comply with the existing criteria in the FMP and the national standard guidelines at 50 CFR 600.310(e), (2) be sufficient to rebuild the stock to the Bmsy level within a rebuilding time period that satisfies the requirements of section 304(e)(4)(A) of the Magnuson-Stevens Act, and (3) be consistent with applicable Federal law.

None of the alternatives are likely to significantly affect the quality of the human environment, and the preparation of an environmental impact statement for the proposed action is not required by Section 102(2)(C) of the National Environmental Policy Act or its implementing regulations. The rebuilding plan does not contain implementing regulations so a regulatory impact review under E.O. 12866 and initial regulatory flexibility analysis under the Regulatory Flexibility Act are not required.

1.0 INTRODUCTION

The king and Tanner crab fisheries in the Exclusive Economic Zone (EEZ) (3 to 200 miles offshore) of the Bering Sea and Aleutian Islands off Alaska are managed under the Fishery Management Plan for King and Tanner Crab Fisheries in the Bering Sea/Aleutian Islands. This fishery management plan (FMP) was developed by the North Pacific Fishery Management Council (Council) under the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act). The BSAI King and Tanner crab FMP was approved by the Secretary of Commerce and became effective in 1989.

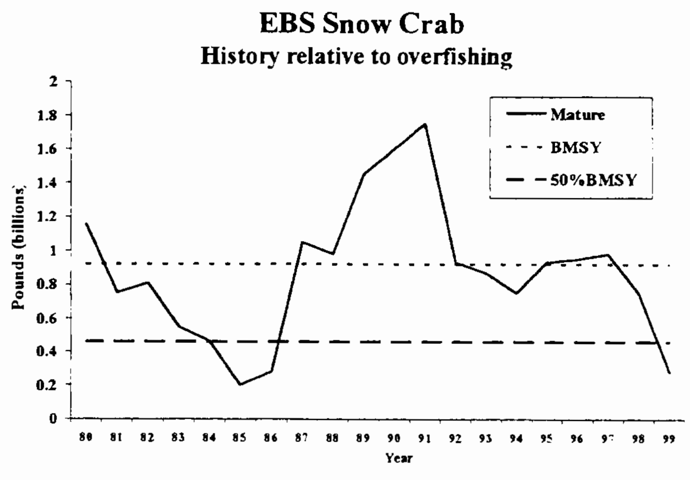
The groundfish fisheries in the EEZ off Alaska are managed under the Fishery Management Plan for Groundfish of the Gulf of Alaska and the Fishery Management Plan for the Groundfish Fisheries of the Bering Sea and Aleutian Islands Area. The Gulf of Alaska Groundfish (GOA) FMP was approved by the Secretary of Commerce and became effective in 1978 and the Bering Sea and Aleutian Islands Area (BSAI) FMP become effective in 1982.

Actions taken to amend the FMPs or implement other regulations governing the BSAI crab and groundfish fisheries must meet the requirements of Federal laws and regulations. In addition to the Magnuson-Stevens Act, the most important of these are the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), Executive Order (E.O.) 12866, and the Regulatory Flexibility Act (RFA). The rebuilding plan does not contain implementing regulations so a regulatory impact review under E.O. 12866 and initial regulatory flexibility analysis under the Regulatory Flexibility Act are not required. NEPA requires a description of the purpose and need for the proposed action as well as a description of alternative actions which may address the problem. This information is included in Section 1 of this document. Section 2 contains information on the biological and environmental impacts of the alternatives as required by NEPA. Impacts on endangered species and marine mammals are also addressed in this section. Section 3 addresses economic and socioeconomic impacts.

This Environmental Assessment (EA) addresses alternatives for rebuilding the snow crab stock in the Eastern Bering Sea as required under the Magnuson-Stevens Act. The sections of the Magnuson-Stevens Act that must be satisfied are: National Standard 1 section 301(a)(1); Required provisions 303(a)(10) and 303(a)(14); Rebuilding overfished fisheries 304(e); and national standard guidelines 50 CFR 600.310. To the fullest extent possible, the rebuilding alternatives adhere to the NMFS Technical Guidance on Rebuilding (Restrepo et al 1998).

1.1 Purpose of and Need for the Action

The Magnuson-Stevens Act, in section 303(a)(10), requires that each FMP specify objective and measurable criteria (status determination criteria) for identifying when stocks or stock complexes covered by the FMP are overfished. To fulfill the intent of the Magnuson-Stevens Act, such status determination criteria are comprised of two components: A maximum fishing mortality threshold and a minimum stock size threshold (see Sec. 600.310(d)(2)).



Amendment 7 to the BSAI King and Tanner Crab FMP redefined overfishing, optimum yield (OY), and maximum sustainable yield (MSY), and updated the FMP with new information. The amendment established MSY point estimates, along with minimum stock size thresholds (MSST) for individual crab stocks based on prevailing environmental conditions (1983-1997 period). Overfishing is now defined as a fishing mortality rate in excess of natural mortality (M=0.2 for king crabs, M=0.3 for Tanner and snow crabs) and overfished is defined as a biomass that falls below MSST. The 1999 NMFS Bering Sea survey indicated that the snow crab stock was below the minimum stock size threshold (MSST) established for this stock. Abundance of snow crab declined sharply this year, resulting in a spawning biomass value (283.3 million pounds) that falls below the MSST (460.8 million pounds) and hence precipitated a severe curtailment of the fishery in the 2000 season. On September 24, 1999, NMFS informed the Council that this stocks was declared "overfished" pursuant to the Magnuson Act guidelines, which require a rebuilding plan to be developed within one year.

The Bering Sea snow crab stock has undergone several large fluctuations. Catches increased from 26 million pounds in 1984 to over 320 million pounds in 1991. The 1991 peak catch was followed by a decline resulting in low landings (<66 million lbs) in 1996. Good recruitment led to higher guideline harvest levels (GHL) and higher landings (240 million pounds) in 1998, which was followed by a decline as the year-class (es) passed through the fishery. The fishery was severely curtailed for the January 2000 opening, with a GHL of only 28 million pounds.

This stock is currently near historical low abundance. The 1999 estimates of total stock abundance is the second lowest in the history of the NMFS bottom trawl survey (**Table 1**). The near-term outlook for this stock is bleak, as the 1999 survey encountered very few crab of any size. Nevertheless, the stock is capable of rebounding in a relatively short time period when conditions are favorable, as was the case in the mid 1980's.

1.2 Alternatives Considered

This EA addresses alternatives for rebuilding the overfished stock of snow crab in the Eastern Bering Sea. Alternatives and options were developed by the Council at their October, 1999 meeting and finalized in April 2000. The alternatives examined were the following:

1.2.1 Alternative 1: Status Quo. No rebuilding plan would be adopted for Bering Sea snow crab.

1.2.2 Alternative 2: (preferred) Establish a rebuilding plan for Bering Sea snow crab. The rebuilding plan provides a framework that may have three components: a harvest strategy, bycatch control measures, and habitat protection.

A. Harvest Strategy: In previous years when there was a directed fishery, harvest rates for Bering Sea snow crab were established at 58% of males $\geq$ 4-inches CW. This harvest strategy could be modified to reduce mortality on legal males, females, and juvenile crabs.

Option 1: Status quo. Continue to establish harvest rates for Bering Sea snow crab at 58% of males $\geq$ 4-inches CW.

Option 2: (Preferred) Adopt the Board of Fisheries new harvest strategy for Bering Sea snow crab. The strategy, as detailed in Section 1.6.1 includes lower harvest rates at low biomass levels, and incorporates a threshold biomass.

B. Bycatch Controls: Bycatch control measures have previously been implemented in the crab, scallop, and groundfish fisheries. These measures could be adjusted to reduce mortality on unharvested crabs.

Option 1: (preferred) Status quo. Maintain existing snow crab bycatch control measures. The snow crab PSC limit would be set at 0.1133% of total survey abundance (minus 150,000 crabs from the limit) with a maximum of 12.85 million crabs and a minimum of 4.35 million crabs.

Option 2: Reduce the snow crab PSC limit so there is no minimum level. The snow crab PSC limit would be set at 0.1133% of total survey abundance (minus 150,000 crabs from the limit) with a maximum of 12.85 million crabs.

Option 3: (preferred) Adopt the Board of Fisheries new gear modification measures to reduce bycatch of snow crab in crab fisheries.

C. **Habitat protection**: Adequate habitat is essential for maintaining the productivity of fishery resources. Measures previously implemented that protect snow crab habitat from fishing impacts include several areas where trawling and dredging is prohibited. Essential fish habitat (EFH) has been defined and potential threats have been identified. Additional measures could be implemented to further protect habitat.

Option 1: Status quo. Maintain existing habitat protection measures, which include trawl area closures where some snow crabs occur.

Option 2.: **(preferred)** For agency consultation purposes, highlight the importance of snow crab EFH in maintaining stock productivity. To the extent feasible and practicable, this area should be protected from adverse impacts due to non-fishing activities.

1.2.3 Alternative 3: No fishing. Prohibit a fishery for Bering Sea snow crab until the stock is rebuilt.

1.3 Requirements for Stock Rebuilding

Stock rebuilding is required by the Magnuson Stevens Act, Section 304. Thus, the adoption of the No Action Alternative is a violation of law. The applicable section of the Act is provided below.

(e) REBUILDING OVERFISHED FISHERIES.--

(1) The Secretary shall report annually to the Congress and the Councils on the status of fisheries within each Council's geographical area of authority and identify those fisheries that are overfished or are approaching a condition of being overfished. For those fisheries managed under a fishery management plan or international agreement, the status shall be determined using the criteria for overfishing specified in such plan or agreement. A fishery shall be classified as approaching a condition of being overfished if, based on trends in fishing effort, fishery resource size, and other appropriate factors, the Secretary estimates that the fishery will become overfished within two years.

(2) If the Secretary determines at any time that a fishery is overfished, the Secretary shall immediately notify the appropriate Council and request that action be taken to end overfishing in the fishery and to implement conservation and management measures to rebuild affected stocks of fish. The Secretary shall publish each notice under this paragraph in the Federal Register.

(3) Within one year of an identification under paragraph (1) or notification under paragraphs (2) or (7), the appropriate Council (or the Secretary, for fisheries under section 302(a)(3)) shall prepare a fishery management plan, plan amendment, or proposed regulations for the fishery to which the identification or notice applies--

(A) to end overfishing in the fishery and to rebuild affected stocks of fish; or

(B) to prevent overfishing from occurring in the fishery whenever such fishery is identified as approaching an overfished condition.

(4) For a fishery that is overfished, any fishery management plan, amendment, or proposed regulations prepared pursuant to paragraph (3) or paragraph (5) for such fishery shall--

(A) specify a time period for ending overfishing and rebuilding the fishery that shall--

(i) be as short as possible, taking into account the status and biology of any overfished stocks of fish, the needs of fishing communities, recommendations by international organizations in which the United States participates, and the interaction of the overfished stock of fish within the marine ecosystem; and

(ii) not exceed 10 years, except in cases where the biology of the stock of fish, other environmental conditions, or management measures under an international agreement in which the United States participates dictate otherwise;

(B) allocate both overfishing restrictions and recovery benefits fairly and equitably among sectors of the fishery; and

(C) for fisheries managed under an international agreement, reflect traditional participation in the fishery, relative to other nations, by fishermen of the United States.

(5) If, within the one-year period beginning on the date of identification or notification that a fishery is overfished, the Council does not submit to the Secretary a fishery management plan, plan amendment, or proposed regulations required by paragraph (3)(A), the Secretary shall prepare a fishery management plan or plan amendment and any accompanying regulations to stop overfishing and rebuild affected stocks of fish within 9 months under subsection (c).

(6) During the development of a fishery management plan, a plan amendment, or proposed regulations required by this subsection, the Council may request the Secretary to implement interim measures to reduce overfishing under section 305(c) until such measures can be replaced by such plan, amendment, or regulations. Such measures, if otherwise in compliance with the provisions of this Act, may be implemented even though they are not sufficient by themselves to stop overfishing of a fishery.

(7) The Secretary shall review any fishery management plan, plan amendment, or regulations required by this subsection at routine intervals that may not exceed two years. If the Secretary finds as a result of the review that such plan, amendment, or regulations have not resulted in adequate progress toward ending overfishing and rebuilding affected fish stocks, the Secretary shall--

(A) in the case of a fishery to which section 302(a)(3) applies, immediately make revisions necessary to achieve adequate progress; or

(B) for all other fisheries, immediately notify the appropriate Council. Such notification shall recommend further conservation and management measures which the Council should consider under paragraph (3) to achieve adequate progress.

1.3.1 National Standard Guidelines

Below in this section (Section 1.3.1) is an excerpt from the Final Rule on National Standard Guidelines, published in the Federal Register on May 1, 1998.

Sec. 600.310 National Standard 1--Optimum Yield.

(e) Ending overfishing and rebuilding overfished stocks-- (1) Definition. A threshold, either maximum fishing mortality or minimum stock size, is being ``approached" whenever it is projected that the threshold will be breached within 2 years, based on trends in fishing effort, fishery resource size, and other appropriate factors.

(2) Notification. The Secretary will immediately notify a Council and request that remedial action be taken whenever the Secretary determines that:

(i) Overfishing is occurring;
(ii) A stock or stock complex is overfished;
(iii) The rate or level of fishing mortality for a stock or stock complex is approaching the maximum fishing mortality threshold;
(iv) A stock or stock complex is approaching its minimum stock size threshold; or
(v) Existing remedial action taken for the purpose of ending previously identified overfishing or rebuilding a previously identified overfished stock or stock complex has not resulted in adequate progress.

(3) Council action. Within 1 year of such time as the Secretary may identify that overfishing is occurring, that a stock or stock complex is overfished, or that a threshold is being approached, or such time as a Council may be notified of the same under paragraph (e)(2) of this section, the Council must take remedial action by preparing an FMP, FMP amendment, or proposed regulations. This remedial action must be designed to accomplish all of the following purposes that apply:

(i) If overfishing is occurring, the purpose of the action is to end overfishing.
(ii) If the stock or stock complex is overfished, the purpose of the action is to rebuild the stock or stock complex to the MSY level within an appropriate time frame.
(iii) If the rate or level of fishing mortality is approaching the maximum fishing mortality threshold (from below), the purpose of the action is to prevent this threshold from being reached.
(iv) If the stock or stock complex is approaching the minimum stock size threshold (from above), the purpose of the action is to prevent this threshold from being reached.

(4) Constraints on Council action.

(i) In cases where overfishing is occurring, Council action must be sufficient to end overfishing.
(ii) In cases where a stock or stock complex is overfished, Council action must specify a time period for rebuilding the stock or stock complex that satisfies the requirements of section 304(e)(4)(A) of the Magnuson-Stevens Act.

(A) A number of factors enter into the specification of the time period for rebuilding:
(1) The status and biology of the stock or stock complex;
(2) Interactions between the stock or stock complex and other components of the marine ecosystem (also referred to as ``other environmental conditions");
(3) The needs of fishing communities;
(4) Recommendations by international organizations in which the United States participates; and
(5) Management measures under an international agreement in which the United States participates.

(B) These factors enter into the specification of the time period for rebuilding as follows:

(1) The lower limit of the specified time period for rebuilding is determined by the status and biology of the stock or stock complex and its interactions with other components of the marine ecosystem, and is defined as the amount of time that would be required for rebuilding if fishing mortality were eliminated entirely.

(2) If the lower limit is less than 10 years, then the specified time period for rebuilding may be adjusted upward to the extent warranted by the needs of fishing communities and recommendations by international organizations in which the United States participates, except that no such upward adjustment can result in the specified time period exceeding 10 years, unless management measures under an international agreement in which the United States participates dictate otherwise.

(3) If the lower limit is 10 years or greater, then the specified time period for rebuilding may be adjusted upward to the extent warranted by the needs of fishing communities and recommendations by international organizations in which the United States participates, except that no such upward adjustment can exceed the rebuilding period calculated in the absence of fishing mortality, plus one mean generation time or equivalent period based on the species' life-history characteristics. For example, suppose a stock could be rebuilt within 12 years in the absence of any fishing mortality, and has a mean generation time of 8 years. The rebuilding period, in this case, could be as long as 20 years.

(C) A rebuilding program undertaken after May 1, 1998 commences as soon as the first measures to rebuild the stock or stock complex are implemented.

(D) In the case of rebuilding plans that were already in place as of May 1, 1998, such rebuilding plans must be reviewed to determine whether they are in compliance with all requirements of the Magnuson- Stevens Act, as amended by the Sustainable Fisheries Act.

(5) Interim measures. The Secretary, on his/her own initiative or in response to a Council request, may implement interim measures to reduce overfishing under section 305(c) of the Magnuson-Stevens Act, until such measures can be replaced by an FMP, FMP amendment, or regulations taking remedial action.

(i) These measures may remain in effect for no more than 180 days, but may be extended for an additional 180 days if the public has had an opportunity to comment on the measures and, in the case of Council- recommended measures, the Council is actively preparing an FMP, FMP amendment, or proposed regulations to address overfishing on a permanent basis. Such measures, if otherwise in compliance with the provisions of the Magnuson-Stevens Act, may be implemented even though they are not sufficient by themselves to stop overfishing of a fishery.
(ii) If interim measures are made effective without prior notice and opportunity for comment, they should be reserved for exceptional situations, because they affect fishermen without providing the usual procedural safeguards. A Council recommendation for interim measures without notice-and-comment rulemaking will be considered favorably if the short-term benefits of the measures in reducing overfishing outweigh the value of advance notice, public comment, and deliberative consideration of the impacts on participants in the fishery.

1.3.2 Technical Guidance on Rebuilding

The National Standard 1 guidelines indicate that once biomass falls below the minimum stock size threshold (MSST), then remedial action is required "to rebuild the stock or stock complex to the MSY level within an appropriate time frame." Guidance for determining the adequacy and efficacy of rebuilding plans was prepared by Restrepo et al. (1998) "Technical Guidance on the Use of Precautionary Approaches to Implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act". This guidance manual does not have the force of law, but instead provides technical details for stock assessment scientists.

1.4 Definitions from Crab FMP

The definition of optimum yield, MSY, and threshold levels were derived from definitions contained in the Magnuson-Stevens Act or on the guidelines. These definitions were adopted under Amendment 7.

Maximum sustainable yield (MSY) is the largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions. MSY is estimated from the best information available. Proxy stocks are used for BSAI crab stocks where insufficient scientific data exists to estimate biological reference points and stock dynamics are inadequately understood. MSY for crab species is computed on the basis of the estimated biomass of the mature portion of the male and female population or total mature biomass (MB) of a stock. A fraction of the *MB* is considered sustained yield (*SY*) for a given year and the average of the *SY*s over a suitable period of time is considered the MSY.

Overfishing: The term "overfishing" and "overfished" mean a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce MSY on a continuing basis. Overfishing is defined for king and Tanner crab stocks in the BSAI management area as any rate of fishing mortality in excess of the maximum fishing mortality threshold, F_{msy}, for a period of 1 year or more. Should the actual size of the stock in a given year fall below the minimum stock size threshold, the stock is considered overfished. If a stock or stock complex is considered overfished or if overfishing is occurring, the Secretary will notify the Council to take action to rebuild the stock or stock complex.

MSY control rule means a harvest strategy which, if implemented, would be expected to result in a long-term average catch approximating MSY. The MSY control rule for king and Tanner crabs is the mature biomass of a stock under prevailing environmental conditions, or proxy thereof, exploited at a fishing mortality rate equal to a conservative estimate of natural mortality.

MSY stock size is the average size of the stock, measured in terms of mature biomass of a stock under prevailing environmental conditions, or a proxy thereof. It is the stock size that would be achieved under the MSY control rule. It is also the minimum standard for a rebuilding target when remedial management action is required. For king and Tanner crab, the MSY stock size is the average mature biomass observed over the past 15 years, from 1983 to 1997.

Maximum fishing mortality threshold (MFMT) is defined by the MSY control rule, and is expressed as the fishing mortality rate. The MSY fishing mortality rate F_{msy} = M, is a conservative natural mortality value set equal to 0.20 for all species of king crab, and 0.30 for all *Chionoecetes* species.

Minimum stock size threshold (MSST) is whichever is greater: one half the MSY stock size, or the minimum stock size at which rebuilding to the MSY level would be expected to occur within 10 years if the stock or stock complex were exploited at the maximum fishing mortality threshold. The minimum stock size threshold is expressed in terms of mature biomass of a stock under prevailing environmental conditions, or a proxy thereof.

1.5 Current Crab Management Regime

1.5.1 Snow Crab Biology and Fishery Management

1.5.1.1 Biology: Snow crabs (*Chionoecetes opilio*) are distributed on the continental shelf of the Bering Sea, Chukchi Sea, and in the western Atlantic Ocean as far south as Maine. Snow crab are not present in the Gulf of Alaska. In the Bering Sea, snow crabs are common at depths less than 200 meters. The eastern Bering Sea population within U.S. waters is managed as a single stock, however, the distribution of the population extends into Russian waters to an unknown degree. The 1999 NMFS trawl survey length frequency distribution of male snow crabs is shown in **Figure 1**; abundance data from the survey are listed in **Table 1**. While 50% of the females are mature at 50 mm, the mean size of mature females varies from year to year over a range of 63 mm to 72 mm carapace width. Females cease growing with a terminal molt upon reaching maturity, and rarely exceed 80 mm carapace width. It has also been hypothesized that males similarly cease growing upon reaching a terminal molt when they acquire the large claw characteristic of maturity. The median size of maturity for males is 65 mm carapace width (approximately 4 years old). Males larger than 60 mm grow at about 20 mm per molt, but individuals vary widely in this regard. Female snow crabs are able to store spermatophores in seminal vesicles and fertilize subsequent egg clutches without mating. At least two clutches can be fertilized from stored spermatophores, but the frequency of this occurring in nature is not known. Snow crab feed on an extensive variety of benthic organisms including bivalves, brittle stars, crustaceans (including other snow crabs), polychaetes and other worms, gastropods, and fish. In turn, they are consumed by a wide variety of predators including bearded seals, Pacific cod, halibut and other flatfish, eel pouts, sculpins, and skates.

1.5.1.2 Management: The Bering Sea snow crab stock is managed by the State of Alaska through a federal BSAI king and Tanner crab fishery management plan (FMP). Under the FMP, management measures fall into three categories: (1) those that are fixed in the FMP under Council control, (2) those that

Management measures implemented in the BSAI king and Tanner crab fisheries, as defined by the federal crab FMP, by category.

Category 1 (Fixed in FMP)	Category 2 (Frameworked in FMP)	Category 3 (Discretion of State)
* Legal Gear	* Minimum Size Limits	* Reporting Requirements
* Permit Requirements	* Guideline Harvest Levels	* Gear Placement and Removal
* Federal Observer Requirements	* Inseason Adjustments	* Gear Storage
* Limited Access	* Districts, Subdistricts and Sections	* Gear Modifications
* Norton Sound Superexclusive Registration Area	* Fishing Seasons	* Vessel Tank Inspections
	* Sex Restrictions	* State Observer Requirements
	* Closed Waters	* Bycatch Limits (in crab fisheries)
	* Pot Limits	* Other
	* Registration Areas	

are frameworked so that the State can change following criteria outlined in the FMP, and (3) those measures under complete discretion of the State. The State sets pre-season guideline harvest levels for snow crab based on a mature male harvest rate of 58% for snow crab larger than 4 inches. Although the minimum legal size for snow crab is 78 mm (3.1 inches), the fishery has generally harvests crabs over 4 inches (101 mm) in carapace width.

In addition to minimum size and sex restrictions, the State has numerous other regulations for the Eastern Bering Sea 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. Season opening dates are set to maximize yield per recruit and minimize handling of softshell crabs. The season opening date for snow crab fisheries is January 15. Pot limits have been established based on vessel size; the current pot limits are 250 for vessels > 125 feet, and 200 for vessels < 125 feet. A 3" maximum tunnel height opening for snow crab pots is required to inhibit the bycatch of red king crab. Escape rings and mesh size requirements were adopted by the Board in 1996 and modified in 2000 to reduce capture and handling mortality of non-target crab; a minimum of four 4" rings within one mesh of the bottom of the pot are required on each of at least two sides of a snow crab pot or, instead of rings, ½ of one vertical panel must be composed of at least 5 1/4" stretched mesh. To reduce snow crab bycatch in Tanner crab fisheries, a minimum of four 5.0" rings, or 1/3 of the web on one panel of 7 1/4" stretched mesh, is required. Other gear restrictions include a requirement that crab pots be fitted with a degradable escape mechanism consisting of #30 cotton thread (max. diameter) or a 30-day galvanic timed release mechanism. There are no recreational fisheries for Bering Sea Snow crab.

"Overfishing" for Bering Sea snow crabs adopted under Amendment 7 is defined as a fishing mortality rate in excess of F_{MSY} estimated as $F = M = 0.3$ based on longevity. The Amendment 7 definition of overfishing is more conservative than was previously in place under Amendment 1. Under Amendment 7 a minimum stock size threshold (MSST) was specified for Bering Sea snow crabs to equal ½ the estimated MSY stock size. Estimated spawning biomass of snow crabs from the 1999 survey was 283.3 million pounds, which was well below the MSST of 460.8 million pounds. Hence, the Bering Sea snow crab stock was designated overfished by the Secretary of Commerce.

Abundance of large males (millions of crab ≥4.0" from NMFS trawl survey), pre-season guideline harvest levels (millions of pounds), and total catches (millions of pounds, including deadloss) of Bering Sea snow crab, 1980-2000.

Year	Abundance	GHL	Catch
1980	na	n/a	39.6
1981	na	39.5 - 91.0	52.8
1982	na	16.0 - 22.0	29.4
1983	na	15.8	26.1
1984	153	49.0	26.8
1985	75	98.0	66.0
1986	83	57.0	98.0
1987	151	56.4	101.9
1988	171	110.7	134.0
1989	187	132.0	149.5
1990	420	139.8	161.8
1991	484	315.0	328.6
1992	256	333.0	315.3
1993	135	207.2	230.8
1994	72	105.8	149.8
1995	69	73.6	75.3
1996	172	50.7	65.7
1997	306	117.0	119.4
1998	255	234.8	252.0
1999	94	195.9	194.0
2000	*	28.5	33.5

<u>**Eastern Bering Sea Stock**</u>: Abundance of large male snow crab increased dramatically from 1983 to 1991, but has since declined. The 1993 NMFS Bering Sea trawl survey indicated the total abundance of large males (over 4 inches) at 135 million crab, a 48% decrease from 1992. Small (3-4") legal-size males also declined in abundance, consistent with the decline in large males observed since 1991. The 1995 NMFS bottom trawl survey indicated relatively low levels of large male crab. However, the survey indicated an 88% increase in the numbers of pre-recruits, and a 44% increase in the number of large females. These signs of strong recruitment were apparent in the 1996 survey, as survey results indicated the number of large crab doubled.

Catch of Bering Sea snow crab increased from under 1 million pounds in 1974 to over 315 million pounds in 1992.

The 1992 peak catch was followed by reduced landings thereafter. The 1995 snow crab fishery was prosecuted by 253 vessels. The season began on January 15 and lasted 33 days. A total of 74 million pounds were landed. Average weight of crab retained was 1.2 pounds worth $2.43 per pound exvessel. Total value of the 1995 snow crab fishery was $180 million exvessel.

Increased landings occurred in recent years due to good recruitment of sublegal males. In 1997, 119.4 million pounds of snow crab were harvested. Average weight of crab taken was 1.2 pounds. A total of 226 vessels have participated. Exvessel price was $0.79/lb, for a total fishery value of $92.5 million. The 1998 fishery opened with a GHL of 234 million pounds, of which 3.5% was allocated as community development quota, CDQ. A total of 243 million pounds of snow crab were harvested before the fishery was closed. The fishery performance of 207 crabs per pot was the best ever observed. The GHL for the 1999 fishery was 196 million lbs, based on a 58% harvest rate on male crab over 102 mm. The 1999 total harvest of snow crab (including deadloss) was 143,296,568 crabs.

Catch, effort, and economic data from the Bering Sea snow crab fishery, 1989-1999 (catch includes CDQ, other columns do not). Catch (millions of lbs) includes deadloss.

Year	Catch	# of vessels	# of days	# of pots	price per lb	total value
1989	149.5	168	112	663,442	0.75	$ 110,700,000
1990	161.8	189	148	911,613	0.64	$ 102,300,000
1991	328.6	220	159	1,391,583	0.50	$ 162,600,000
1992	315.3	250	97	1,281,796	0.50	$ 156,500,000
1993	230.8	254	59	971,046	0.75	$ 171,900,000
1994	149.8	273	45	716,524	1.30	$ 192,400,000
1995	75.3	253	33	506,802	2.43	$ 180,000,000
1996	65.7	234	45	520,651	1.33	$ 85,600,000
1997	119.5	226	65	754,140	0.79	$ 92,600,000
1998	243.3	229	64	891,268	0.56	$ 134,650,000
1999	194.0	241	66	899,043	0.88	$ 162,390,000
2000	33.6	231	8	173,000	1.85	$ 55,000,000

For the 2000 fishery, a different harvest rate was applied given that the stock was below MSST. The 2000 GHL of 28.5 million pounds was based on a reduced exploitation rate of 22%. This harvest rate was applied to a biomass of 131 million pounds of male crab over 101 mm. In addition to low spawning biomass, the survey found very little sign of young crab, thereby necessitating a conservative approach.

The 2000 fishery season for eastern Bering Sea snow crab

The 1999 survey estimates for eastern Bering Sea snow crab indicated that the stock was below the minimum stock size threshold (MSST) established in the FMP. Hence, special consideration was required for the establishment of any harvest guideline level (GHL) for the 2000 snow crab fishery. The GHL for the 2000 fishery season was established by ADF&G with the consultation and involvement of NMFS and Council staff, most of whom are Crab Plan Team members. Although some harvest from a stock that is below MSST can be permissible, a precautionary approach must be applied in development of the GHL to assure that harvest does not constitute overfishing and does not unduly impact the ability of the stock to rebuild to the B_{MSY} level. The need to apply precautionary measures when developing a GHL for eastern Bering sea snow crab in 2000 is especially important because a rebuilding plan for the stock has not yet been developed. ADF&G relied heavily on Restrepo et al. (1998) for guidance in establishing the snow crab GHL for 2000.

As background, prior to the Board's adoption of the new harvest strategy in March 2000, status quo management of eastern Bering Sea snow crab was to set the GHL by applying a 58% exploitation rate on the biomass of males 4-inches (102-mm) or greater in carapace width (CW) as estimated from the summer trawl survey. The 4-inch minimum reflects the industry-standard minimum size. The 58% exploitation rate is the suggested harvest rates based on yield-per-recruit considerations (Somerton 1981, Somerton and Low 1977) adapted for the 4-inch minimum by NMFS AFSC biologists. As further background, Restrepo et al. (1998)

suggest that a stock that is below 50% of the MSST should be closed to directed fishing. On the other hand, a stock that is between 50% MSST and MSST should be prosecuted with a fishing mortality at 75% of a precautionary fishing mortality rate that is below F_{MSY}. At an estimated 283.5 million pounds of spawning biomass (i.e., total mature male and female biomass), the snow crab stock is roughly 62% of the MSST value of 460.8 million pounds. Finally, the overfishing rate defined in the FMP for snow crab is defined as a fishing mortality in excess of 0.3 as applied to the spawning biomass.

As well as the survey population estimates, other information was presented and discussed during the meetings that lead to the setting of the 2000 snow crab GHL. Included in the discussions were: model predictions for number of males > 101-mm CW in summer of 2000 after varying levels of harvest during the 2000 fishery season; survivorship of mature males and females into summer of 2000 for various natural mortality and harvest scenarios; considerations and data on the impact of bycatch; considerations on the effect of various removals on the remaining ratio of mature females to mature males; and, discussions and data on the tendency of the commercial fleet to remove newshell crabs at a higher rate than oldshell crabs.

Status quo, 58% harvest rate applied to males greater than 4 inches in carapace width, was clearly not acceptable for the 2000 season. At a 76 million pound GHL, even without any considerations of bycatch mortality the status quo approach would have produced a GHL close to the maximum sustainable yield value of 85.1 million pounds. Application of the status quo would have resulted in fishing rates that would have greatly exceeded the long term average and which would have been exceeded only by the rates estimated for the 1986 and 1987 fishery seasons. The status quo could also, under some reasonable scenarios, have resulted in a fishing mortality in excess of 0.3 for the year-long period between the 1999 and 2000 surveys.
Halving the status quo harvest rate from 58% of males > 101-mm CW to 29% of males > 101-mm CW appeared to protect from overfishing under most natural mortality scenarios. Nonetheless, the 50% reduction to the status quo cannot be considered precautionary in the present situation because the resulting harvest rate on mature males is close to the long-term average and because, under some more severe assumptions on natural mortality, the annual fishing mortality to the spawning biomass could come close to 0.3.

The 29% harvest rate dealt with above was reduced to 75% to provide a harvest rate of 22% applied to males > 101-mm CW. That harvest rate provides a GHL of 28.5 million pounds. Under realistic exceptions for bycatch rates and reasonably conservative assumptions on handling mortality, the total removal of mature biomass due to a 28.5 million pound GHL would be 30.2 million pounds. The result provides for a fishing mortality well below the overfishing definition and well below the long term average harvest rates applied to numbers of mature males, biomass of mature males, and total male and female biomass. It also provides for expected mature female to male ratios in surviving crabs that are close to the long term average. Finally, beyond the conservation concerns, the 28.5 million pound GHL is at a level that could be considered manageable for the 2000 fishery season. Of the 28.5 million GHL for the 2000 season, 7.5% or 2.1 million pounds was set aside for CDQ fishery. As a result, the GHL available to the open access fishery was 26.4 million pounds.

The 2000 eastern Bering Sea snow crab open access fishery season opened at noon on April 1 and closed at noon on April 8. A total of 231 vessels participated in the fishery. The fishery was scheduled to open at noon on January 15, but was delayed until April due to severe ice and weather conditions in early January that raised concerns for gear conflicts, gear loss, increased handling mortality, and vessel safety resulting from a derby-style fishery under extreme weather conditions. Preliminary processor reports indicate that the harvest during the 2000 open access fishery was 31.1 million pounds, approximately 18% over the GHL of 26.4 million pounds. Preliminary estimated CPUE for the 2000 fishery was 129 retained crabs per pot lift, as compared to a CPUE of 158 for the 66-day 1999 fishery. Fishers reported encountering high percentages of old-shell crabs in the first two days of the fishery, but thereafter located areas that contained predominantly new shell animals. As a result, less than 10% of crabs landed were old-shell animals. The preliminary estimated average weight of crabs landed during the 2000 fishery is 1.4 pounds as compared to a 1.3 pound average in 1999. The exvessel price for snow crabs harvested in the 2000 fishery was two tiered due to concerns for higher than normal old-shell crabs expected in the catch. Based on an estimated overall exvessel price of $ 1.85 per pound, the estimated 2000 snow crab fishery value is $55 million. This compares to an exvessel value of $0.88 per pound and an overall fishery value in excess of $162 million in 1999.

Analysis of 1999 survey data

At 283.5 million pounds, the spawning biomass estimates for eastern Bering Sea snow crab for 1999 are below the minimum stock size threshold of 460.8 million pounds. Moreover, spawning biomass estimates as low as or lower than the 1999 estimate have not been observed since 1985 and 1986. The historical trends in size and shell-age composition for the snow crab stock provides a basis for what near-term future trends may or may not be expected. Our examination of the historical snow crab size and shell-age frequency distribution focuses on data collected by the NMFS eastern Bering Sea summer trawl survey during 1978-1999 and from those stations south of 61.2° N. latitude. We excluded the data from survey stations north of 61.2o N. latitude because small snow crab from the more northern trawl survey stations may not necessarily grow and recruit to the mature-sized and harvestable-sized portions of the stock.

The 1999 male size frequency distribution shows uniformly low abundance across all age classes **(Figure 2)**. Although only males >101-mm carapace width (CW) are targeted by the commercial fishery, animals of that size typically constitute only a small portion of the male population. In most years, the male population is dominated by large numbers of animals in the pre-recruit size-classes, especially those in the range of 30- to 60-mm CW. Only in 1985 were such low overall numbers of males coupled with poor representation of pre-recruits. Examination of the female size frequency distribution **(Figure 3)** also show that only the 1985 data may be considered comparable to the 1999 data in terms of abundance and size frequency distribution.

Figures 4 and 5 provide expanded views of the size frequencies for males and females, respectively, in the five years preceding and including the population lows of 1985 and 1999. The 1981 to 1985 data shows the same precipitous drop in numbers and lack of recruitment as was seen more recently in the 1995 to 1999 data. There are some differences between the 1981-1985 and 1995-1999 data sets, however. In the male data, there were hints of the presence of some small pre-recruit males in 1983 through 1985, although their numbers were small in a historical context **(Figure 2)** and track poorly from year to year. There was no such evidence of small, prerecruit males in the 1997 to 1999 data. The 1995-1999 data is also distinguished from the 1981-1985 data by the accumulation of old-shell crabs that was present in 1999 relative to that seen in 1985. In the female data **(Figure 5)**, we again see some hint of the presence of small immature crabs in 1983 to 1985 that are largely lacking in the 1997 to 1999 data. The 1999 data also indicates that there were more mature females present in 1999 than in 1985, although, old-shelled animals -- unlike 1985 -- dominate the 1999 mature females **(Figure 3)**. Overall, the comparison of the 1995-1999 data with 1981-1985 data indicates that the animals that remain in 1999 tend to be composed more of old-shells than those in 1985 and that there are less indications of the presence of pre-recruit males and immature females in 1999 than in 1985.

Figure 6 shows the rapidity and unpredictability with which large and significant recruitment events can occur following a population low. The presence of a large cohort of pre-recruit male and immature female snow crab that was first detected during the 1987 survey led to the population levels that supported the record fisheries of the early-1990's. The larger than expected increase in all size classes and in both sexes that occurred from 1985 to 1987 may have reflected distributional changes that increased catchability during the trawl survey as well as the presence of a strongly recruiting cohort.

Further insight into the status and productivity of the snow crab stock in the 1999 survey can be gained by examining the shell-age composition of both sexes and the reproductive condition of mature females. The 1999 survey indicated that 78% of the mature females were in old-shell or older shell conditions and 41% of the large males (≥ 4-inches CW) were in old-shell or older condition. Prerecruit-sized males 75-101 mm CW were also dominated by old-shell or older individuals (**Figure 1**). Hence, the shell-age composition indicated that those portions of the population were in or approaching senescence. A tendency towards senescence of the adult portion of population, coupled with the poor representation of prerecruit and juvenile crabs as was seen in the 1999 survey, raises conservation concerns.

The 1999 survey data also indicated low reproductive output by mature females. Only 77% of mature females are estimated to have been carrying new eggs. That higher than normal percentage of barren mature females is attributable at least in part to the aging of the mature female component of the population. More troubling, however, is that the incidence of barren females was higher than normal in new-shell and old-shell crabs (**Figure 7**; note that soft-shell and very-very-old-shell crabs constitute less than 5% of sampled mature females and their data were not included in the figure). The incidence of barren females amongst the old-shell mature females was the highest observed during, at least, the last 10 years. Although effects due to senescence would be expected in the very-old-shell portion of the mature female population, senescence would usually not be invoked to explain increased incidence of barren females in the new-shell and old-shell components of the mature population. The 1999 survey data also revealed a lower than normal incidence of full clutches in all shell-age classes of egg-bearing females (**Figure 8**; note that soft-shell and very-very-old-shell crabs constitute less than 5% of sampled mature females and their data were not included in the figure). In fact, the incidence of full clutches in egg-bearing females has shown a rather steady decrease over the last 10 years.

Data on reproductive condition of crabs generally should be interpreted with caution, because there is some subjectivity in the assignment of shell-age and clutch fullness by survey biologists. Changes in the reference of clutch fullness instituted on the NMFS survey in 1992 may also affect the observed trends. Indications of poorer than normal reproductive condition of a stock deserve attention, however, particularly when the population is at a low level with no indications of recruitment. The trends observed here might be largely reflective of the aging condition of the population and some misidentification of very-old-shell females as old-shell females. Preliminary analyses (not included here) have not revealed a relationship between male:female ratios and the incidence of barren mature females in the same year. Nonetheless, effects on the reproductive output of mature females due to fishery removals of large mature males should also be considered as a factor in the observed trends (Orensanz et al. 1998, Sainte-Marie 1997).

1.5.2 Overview of Snow Crab Bycatch

1.5.2.1 Crab Fisheries

Bycatch of crab in directed crab fisheries is another source of mortality to be considered in a rebuilding plan. Crab bycatch includes females of target species, sublegal males of target species, and non-target crab. Numbers of snow crab taken as bycatch in recent major Bering Sea crab fisheries are listed in the adjacent table. Due to the difference in legal size versus market size for snow crab, a portion of the legal crabs are not retained as harvest, and are thus considered bycatch.

Bycatch of Bering Sea snow crab (*C. opilio*) (numbers) in recent crab fisheries. ADF&G Observer Program data. Note that the red king crab fishery was closed 1994-95, and the Tanner crab fishery was closed in 1997 and 1998.

Year	Fishery	Legal	Sublegal	Females	Total
1994	opilio	46,979,869	4,657,400	1,146,400	52,783,669
	St. Matthew	3,000	300	0	3,300
	hair crab	140,086	52,299	37,110	229,495
	Bristol Bay	0	0	0	0
	bairdi	49,900	16,200	0	66,100
	Total	**47,172,855**	**4,726,199**	**1,183,510**	**53,082,564**
1995	opilio	33,044,000	13,304,000	634,000	46,982,000
	St. Matthew	*	*	*	*
	hair crab	147,700	143,200	6,100	297,000
	Bristol Bay	0	0	0	0
	bairdi	887,000	354,000	214,000	1,455,000
	Total	**34,078,700**	**13,801,200**	**854,100**	**48,734,000**
1996	opilio	39,231,000	5,758,000	219,000	45,208,000
	St. Matthew	1,007,000	2,714,000	4,600	3,725,600
	hair crab	357,617	72,684	1,948	432,248
	Bristol Bay	0	910	0	910
	bairdi	6,973,000	225,000	6,000	7,204,000
	Total	**47,568,617**	**8,770,593**	**231,548**	**56,570,758**
1997	opilio	69,283,000	3,737,000	1,020,000	74,040,000
	St. Matthew	*	*	*	*
	hair crab	878,000	64,800	1,350	944,150
	Bristol Bay	11,536	8,874	887	21,296
	Total	**70,172,536**	**3,810,674**	**1,022,237**	**75,005,446**
1998	opilio	49,427,332	2,037,542	78,592	51,464,874
	St. Matthew	*	*	*	*
	hair crab	97,294	11,693	899	109,886
	Bristol Bay	13,496	2,841	355	16,692
	Total	**49,538,122**	**2,052,077**	**79,847**	**51,591,453**
1999	opilio	40,735,722	815,467	95,516	41,646,705
	St. Matthew	*	*	*	*
	hair crab	315	1,102	157	1,574
	Bristol Bay	0	17,342	826	18,168
	Total	**40,736,037**	**833,911**	**96,499**	**41,666,447**

*= Observers deployed on less than three vessels during fishery; data confidential or non-existent

1998 was the inaugural year of the Bering Sea king and Tanner crab Community Development Quota (CDQ) Program fisheries. Four CDQ crab fisheries were prosecuted during 1998 (Gish 1999). Each 1998 CDQ crab fishery was prosecuted after closure of the corresponding open-access fishery. Mandatory shellfish observers were stationed on each vessel participating in the 1998 CDQ fisheries and collected data on bycatch of crabs. Observer data indicates that bycatch of snow crabs during the CDQ Bering Sea king crab fisheries was non-existent to negligible, whereas some snow crab were captured and returned to the sea during the CDQ Bering Sea snow crab fishery.

Some crabs taken as bycatch die due to handling mortality. Several laboratory and field studies have been conducted to determine mortality caused by handling juvenile and female crab taken in crab fisheries. There are a variety of effects caused by handling, ranging from sublethal (reduced growth rates, molting probabilities, decreased 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 (Murphy and Kruse 1995). Handling mortality may have contributed to the high natural mortality levels observed for Bristol Bay red king crab in the early 1980's (65% for males and 82% for females), that along with high harvest rates, resulted in stock collapse (Zheng et al. 1995). However, another study concluded that handling mortality from deck and temperature impacts was not responsible for the decline on the red king crab fishery (Zhou and Shirley 1995, 1996).

Byersdorfer and Watson (1992, 1993) examined red king crab and Tanner crab taken as bycatch during the 1991 and 1992 red king crab test fisheries. Instantaneous handling mortality of red king crab was <1% in 1991, and 11.2% in 1992. Stevens and MacIntosh (1993) found average overall mortality of 5.2% for red king crabs and 11% for Tanner crabs on one commercial crab vessel. Authors recommend these results be viewed with caution, noting that experimental conditions were conservative. Mortality for red king crab held 48 hours was 8% (Stevens and MacIntosh 1993, as cited in Queirolo et al. 1995). A laboratory study that examined the effects of multiple handling indicated that mortality of discarded red king crabs was negligible (2%), although body damage increased with handling (Zhou and Shirley 1995).

Delayed mortality due to handling does not appear to be influenced by method of release. In an experiment done during a test fishery, red king crab thrown off the deck while the vessel was moving versus those gently placed back into the ocean showed no differences in tag return rates (Watson and Pengilly 1994). Handling methods on mortality have been shown to be non-significant in laboratory experiments with red king crab (Zhou and Shirley 1995, 1996) and Tanner crab (MacIntosh et al. 1996). Although handling did not cause mortality, injury rates were directly related to the number of times handled.

Mortality of crabs is also related to time out of water and air temperature. A study of red king crabs and Tanner crabs found that crabs exposed to air exhibited reduced vigor and righting times, feeding rates (Tanner crabs), and growth (red king crabs) (Carls and Clair 1989). For surviving females, there was no impact on survival of eggs or larvae. Cold air resulted in leg loss or immediate mortality for Tanner crabs, whereas red king crabs exhibited delayed mortality that occurred during molting. A relationship was developed to predict mortality as the product of temperature and duration of exposure (measured as degree hours). Median lethal exposure was -8°C for red king crab and -4.3°C for Tanner crab. For example, if crabs were held on deck for 10 minutes and it was -23°C (10 degrees below zero Fahrenheit) outside, about 15% of the king crab and 50% of the Tanner crab would die of exposure. Because BSAI crab fisheries occur from November through March, cold exposure could cause significant handling mortality to crabs not immediately returned to the ocean. Zhou and Shirley (1995) observed that average time on deck was generally 2 to 3 minutes, and they concluded that handling mortality was not a significant source of mortality.

Further research has indicated that windchill may be an important mortality factor. In 1997, a laboratory study examined the effects of cold windchill temperature on mortality, limb loss, and activity (righting response) for sublegal sized male Tanner crabs (Zhou and Kruse, 1998, Shirley 1998). The study found significant inverse relationships between windchill and crab mortality, limb loss, and activity. Crabs were exposed to combinations of temperatures and wind speeds for a duration of 5 minutes, then placed in seawater tanks and held for 7 days. Zhou and Kruse (1998) found that virtually all crabs died when exposed to windspeeds greater than 7.7 m/s (15 nautical miles per hour) and air temperatures less than -10.4°C (13.3°F). Stronger winds, even at warmer temperatures (but still below freezing), can have the same effect. Shirley (1998) estimated that 50% of the crabs would die in windchill temperatures of -11°C (this windchill temperature can result from air temperatures of 21°F and wind speeds of 30 nautical miles per hour). He concluded that "The effects of windchill on sublegal Tanner crabs is dramatic, and undoubtedly results in decreased recruitment to adult stocks. Management steps should be taken to restrict exposure of discarded crabs to debilitating windchill by regulating aerial exposure (sorting within water tables) or by regulating fishing effort during periods of extreme windchill".

On the other hand, there is evidence from the fishery itself that windchill during the snow crab fishery may not be as important a mortality factor as would be expected from the laboratory study (Shirley 1998) and prevailing weather conditions. The primary evidence in this regard is the low rate of deadloss that occurs during the snowcrab fishery. The snow crabs that are delivered to processors are subjected to the same windchill exposures before being sorted on deck and deposited into the holding tank as are non-legal snow crabs and Tanner crabs before they are sorted and discarded. Data collected by onboard observers during the 1999 snow crab fishery indicate that bycatch crabs generally are not exposed to the air any longer than the retained catch (D. Tracy, ADF&G, pers. comm). The effects of windchill on snow crabs have not been directly studied. It would, however, be expected for retained legal snow crabs (males, generally > 101 mm CW) to show similar effects due to windchill as bycatch Tanner crabs due to the morphological similarity of snow and Tanner crabs and because bycatch Tanner crabs also tend to be males > 101 mm CW (D. Tracy, ADF&G, pers. comm). Because snow crabs are typically kept in holding tanks for one to three weeks prior to offloading at processors (R. Morrison, ADF&G, pers. comm.), high rates of deadloss would be expected in the deliveries if on-deck wind chill exposure resulted in mortality rates comparable to those experienced by Tanner crabs in the laboratory study. Commercial catch statistics from the 1990 through 1998 snow crab seasons, however, indicate that the annual deadloss averaged only 1.3% of the total delivered snow crabs and ranged from 0.7% to 2.0%. Such low rates of deadloss, despite the low temperatures and high winds that can occur in the Bering Sea during the snow crab fishery, may be reflective of features of fishing vessels and fishing practices that serve to protect captured and sorted crabs from windchill exposure. Shelter decks, storm walls, use of totes, and leeward alignment of vessels during gear retrieval, for example, would all tend to protect crabs from windchill exposure during sorting. Additionally, observer data collected during the 1998 and 1999 snow crab seasons indicate that sorted bycatch typically is returned to the sea in less time than the 5 minutes that crabs were exposed to windchill during the laboratory study (D. Tracy, ADF&G, pers. comm). Data on limb autotomies collected from bycatch Tanner crabs by onboard observers during the 1999 snow crab season also indicate that the effects of windchill in practice is less than that predicted from laboratory studies and prevailing weather. Examination of 1,718 bycaught bairdi prior to discarding during the 1999 season indicates a limb autotomy rate of only 0.3% -- well below the limb autotomy rates seen in the laboratory study for windchills associated with high mortality rates. In summary, although it has been conclusively shown that windchill can effect high rates of mortality in Tanner crabs, there is also evidence that exposure of captured crabs to such windchill may not be common during actual fishing.

Catching mortality is ascribed to those crabs that enter a pot and are eaten by other pot inhabitants before the pot is retrieved. Catching mortality likely occurs during the molting period, when crabs are more susceptible to cannibalism. Most 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 unassessed.

Mortality is also caused by ghost fishing of lost crab pots and groundfish pots. Ghost fishing is the term used to describe continued fishing by lost or derelict gear. The impact of ghost fishing on crab stocks remains unknown. It has been estimated that 10% to 20% of crab pots are lost each year (Meyer 1971, Kruse and Kimker 1993). Based on skipper interviews, about 10,000 pots were estimated lost in the 1992 Bristol Bay red king, and Bering Sea Tanner and snow crab fisheries (Tracy 1994). Fewer pots are expected to be lost under pot limit regulations and shorter seasons. Bob Schofield, a major crab pot manufacturer, testified at the January 1996 Council meeting that he was making fewer pots since inception of the pot limit. He estimated that 6,461 pots were replaced in 1995. It is not known how long lost pots may persist and continue to fish, or just litter the bottom.

A sonar survey of inner Chiniak Bay (Kodiak, Alaska) found a high density of lost crab pots (190 pots) in an area of about 4.5 km^2 (Vining et al 1997). Underwater observations indicated that crabs and fish were common residents of crab pots, whether or not the pot mesh was intact. Intact pots recovered from the Chiniak Bay study area often contained crabs (primarily Tanner crabs) and octopus. High (1985) and High and Worlund (1979) observed that 20% of legal sized male red king crab and 8% of the sublegals captured by lost pots failed to escape.

Crabs captured in lost pots may die of starvation or by predation. Captured crab are subject to cannibalism (Paul et al. 1993), and predation by octopus, halibut and Pacific cod (High 1976). Crabs also have limited abilities to withstand starvation. In a simulated field study, 39% mortality of Tanner crabs was observed after 119 days of starvation (Kimker 1994). In a laboratory study, 10% of the Tanner crabs tested died of starvation in 90 days. Of the 90% that had survived 90 days, all later died even though they were freely fed (Paul et al. 1993). To reduce starvation mortality in lost pots, crab pots have been required to be fitted with degradable escape mechanisms. Regulations required #120 cotton thread from 1977-1993. Beginning in 1993, regulations required #30 cotton thread or 30-day galvanic timed release 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 galvanic timed release about 30 days to degrade. Pots fitted with an escape mechanism of #72 cotton twine had a fishable life of 3-8 years and documented retention of up to 100 crabs per lost pot (Meyer 1971). High and Wolund (1979) estimated an effective fishing life of 15 years for king crab pots. Pots without escape mechanisms could continue to catch and kill crabs for many years, however testimony from crabbers and pot manufacturers indicate that all pots currently fished in Bering Sea crab fisheries contain escape mechanisms.

Mortality of crab caused by ghost fishing is difficult to estimate with precision given existing information. Mortality caused by continuous fishing of lost pots has not been estimated, but unbaited crab pots continue to catch crabs (Breen 1987, Meyer 1971), and pots are subject to rebaiting due to capture of Pacific cod, halibut, sablefish, and flatfish. In addition to mortality of trapped crab by ghost pots, and predation by octopus and fish, pot mesh itself can kill crabs. Lost pots retrieved by NMFS trawl surveys occasionally contain dead crabs trapped in loose webbing (Brad Stevens, NMFS, pers. comm). Pot limits and escape mechanisms may have greatly minimized ghost fishing due to pot loss in recent years.

Another very minor source of human induced crab mortality is direct gear impacts. Direct gear impacts result from a pot landing on the ocean floor when it is being set, presumably damaging any crab on which it lands. With reasonable assumptions, direct gear impacts are only a very minor source of mortality, however. An estimate of this impact can be derived by multiplying the number of pot lifts, the area they occupy, and relative crab density within areas fished in the Bering Sea. Assuming that pots land on different areas after each lift, and crab pots are set non-randomly over areas with relatively high density of crabs in directed fisheries, the total number of crab impacted can be roughly estimated. For 1993 the red king crab fishery, assuming a density of 5,000 red king crab of all sizes per square mile (density data from Stevens et al. 1998), a maximum of about two thousand red king crab were impacted (NPFMC 1996). Similarly, a maximum of 9,000 Tanner crabs (assuming 10,000 crab/mile^2) and 110 thousand snow crabs (assuming 75,000 crab/mile^2) were impacted by direct gear impacts in respective crab fisheries in 1993. It is not known what proportion of these crab die when a crab pot lands on them.

Effects of longer soak times on bycatch reduction: comparison of open-access fishery with CDQ fishery.

Observer data from catcher-processor vessels during the 1998 and 1999 open-access fisheries were compared with that from catcher-only vessels during the subsequent Community Development Quota (CDQ) fisheries **(Tables 2 through 5)** to see if the increased soak times resulting from quota allocations were associated with reduced bycatch of non-retained snow crabs.

Pots sampled during the CDQ fisheries tended to have longer soak times than those sampled from the open-access fishery. Average soak time for the pot lifts sampled from the open access fishery was roughly 2 days (45 hours for the 1998 season and 48 hours for the 1999 season), whereas the average soak time for the CDQ samples was closer to 3 days (67 hours for the 1998 season and 65 hours for the 1999 season). Roughly 60% of the pots sampled from the CDQ fisheries had soak times of 48 hours or more, whereas less than 30% of the pots sampled from the open access fishery were soaked for 48 hours or more. In both 1998 and 1999, however, the pots sampled during the CDQ fishery had a higher CPUE of non-retained crabs than did those from open-access fishery (139 crabs per pot lift in the 1998 CDQ fishery versus 57 for the 1998 open-access fishery; 78 crabs per pot lift in the 1999 CDQ fishery versus 46 for the 1999 open access fishery). The bycatch of non-retained crabs in sampled pots was also higher for the CDQ fishery when expressed as the rate of non-retained crabs per retained crab (0.9 for the 1998 CDQ fishery versus 0.3 for the 1998 open-access fishery; 0.6 for the 1999 CDQ fishery versus 0.4 for the 1999 open access fishery). In both the CDQ and open-access fishery more than 90% of the non-retained crabs were legal crabs (>3.1-inches CW) that are not retained mainly due to being smaller than the market standard of 4-inches CW, to shell condition, or to injuries.

So, there was no evidence that the increased soak times associated with quota allocations resulted in bycatch reduction relative the conditions of the competitive open-access fishery. A number of possible explanations could be offered for those results, although not all of them are testable with the available data. It is possible, for example, that the escape mechanisms in use during the 1998 and 1999 fishery seasons were not sufficient to allow escape of non-retained crab, even with the extended soak times seen in the CDQ fishery. On the other hand, the higher numbers of non-retained crabs in the CDQ fishery pot samples may reflect more stringent criteria for retention of legal-sized crab during the CDQ fishery. That explanation, however, is not supported by the virtually identical size-frequency distributions for the 1998 open-access and CDQ fisheries (Moore et al. 2000). Higher bycatch rates in the CDQ fishery may also largely reflect differences in areas fished; such differences may also account for the higher catch rates of Tanner-snow crab hybrids that were observed during the 1998 CDQ fishery (Moore et al. 1998). Perhaps the most plausible explanation for the higher bycatch rates of non-retained crabs during the CDQ fishery seasons is that the CDQ fisheries followed open-access fisheries during which more than one-half of the estimated number of marketable crabs had already been harvested. Hence, comparisons of catch and bycatch between the CDQ fishery and open-access fishery may not be suitable for drawing conclusions on the effects of soak time on bycatch.

1.5.2.2 Trawl Fisheries

Crab bycatch is estimated by the National Marine Fisheries Service through the groundfish Observer Program (Queirolo et al. 1995). 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.

Bycatch (numbers) of crabs in Bering Sea groundfish trawl fisheries, 1993-1999 (through 10/30). Reported by NMFS Blend estimates.

Year	bairdi	opilio	red king
1993	3,413,642	14,631,617	248,121
1994	2,496,761	12,351,899	280,096
1995	2,212,181	5,165,555	44,934
1996	1,836,031	3,643,612	30,967
1997	1,917,736	5,276,208	50,711
1998	1,477,816	4,122,648	42,003
1999	901,619	1,544,747	84,709

Bycatch of crab in recent trawl fisheries is shown in the adjacent table; more detailed information is found in **Tables 6-8.** A total of 4.1 million snow crab were taken as bycatch in the 1998 BSAI groundfish fisheries, which was reduced to only 1.5 million in 1999. It is interesting to note that a majority of the bycatch (1,544,747 crabs) in 1999 was taken outside of the "C. Opilio Bycatch Limitation Zone" (COBLZ); the bycatch within the COBLZ was 601,451 crabs.

Most snow crab bycatch is taken in the trawl fisheries (about 90%) and to a lesser extent in the longline (3 %) and groundfish pot fisheries (7 %). Although snow crabs are bycaught in nearly every trawl fishery, the yellowfin sole fishery takes the largest share, followed by the flathead sole fishery. Bycatch has been highest in NMFS statistical areas 509 and 513; and large numbers of snow crab area have also been consistently taken in areas 517 and 521.

Examination of crab bycatch carapace width frequency suggests that most snow crab bycatch in trawl fisheries is smaller than market size (102 mm), but larger than the size of 50% maturity for females (50 mm). Width frequency data from the 1994 and 1995 trawl fisheries, examined in this report, suggest that the average size is relatively constant from year to year (**Figure 9**). A rough estimate on average width of snow crabs taken as bycatch, based on these data and total crab bycatch by regulatory area, is 75 mm for males in 1994 and 1995. A rough estimate of average width for female snow crab is 63 mm in 1993 and 1995 trawl fisheries. Narita et al. (1994) reported average carapace widths of 89 mm for males and 59 mm for females taken as bycatch in 1991 domestic BSAI groundfish fisheries.

Observer data indicate that a vast majority of snow crab taken as bycatch in trawl fisheries are males. On average, 1993-1995, about 80% of the snow crab measured by observers were male. A high male sex ratio appeared throughout the data for all statistical areas and years examined. In BSAI groundfish pot and longline fisheries nearly all snow crab measured by observers were male. Average carapace width for male snow crabs was about 90 mm in pot fisheries and 110 mm in longline fisheries.

Snow crab bycatch has been significantly reduced in recent years. A combination of factors is likely responsible for the observed reduction. First, abundance of snow crab has declined, so fewer have been available to be incidentally taken. Second, bycatch limits were established in 1997. Third, the trawl industry has implemented a voluntary bycatch avoidance program in the Bering Sea, allowing vessels to avoid fishing in crab hotspot areas (Gauvin et al. 1995). Lastly, with the implementation of the improved retention requirements, trawls have been equipped with larger mesh to reduce their incidental catch of small cod and pollock.

Bycatch limits for snow crab in trawl fisheries were established under amendment 40, which became effective in 1998. Snow crab PSC limits area apportioned among fisheries in anticipation of their bycatch needs for the year. The adjacent table shows the apportionment, and resulting bycatch observed in 1999. For some unknown reason, the yellowfin sole fishery , which was apportioned 75% of the total PSC limit, only took 8% of the available PSC in 1999. Some reasons for this may include lower yellowfin sole catches, fewer snow crabs available on the grounds, or changes in distribution of the crabs or fleet.

Bycatch of snow crabs (numbers) in 1999 Bering Sea groundfish trawl fisheries in the COBLZ. Reported by NMFS Blend estimates.

Fishery	Bycatch	PSC limit	Percent
Rock sole/Other flatfish	242,178	766,552	32%
Pacific cod	20,957	127,758	16%
Yellowfin sole	337,105	3,108,786	11%
Pollock/AMCK/Other species	1,210	74,234	2%
Rockfish	0	42,585	0%
GTRB/ARTH/SABL	0	42,585	0%
Total:	601,451	4,162,500	14%

The effect of crab bycatch on crab stocks is somewhat tempered by survival of discarded crabs. There have been numerous studies conducted on crab bycatch mortality, with each study having different objectives, methodology, and results. A summary of these studies is provided below, but many questions remain unanswered. Stevens (1990) found that 21% of the king crabs and 22% of the Tanner crabs captured incidentally in BSAI trawl fisheries survived at least 2 days following capture. Blackburn and Schmidt (1988) made observations on instantaneous mortality of crab taken by domestic trawl fisheries in the Kodiak area. They found acute mortality for softshell red king crab averaged 21%, hard shelled red king crab 1.2%, and 12.6% for Tanner crab. Another trawl study indicated that trawl induced mortalities aboard ship were 12% for Tanner crab and 19% for red king crab (Owen 1988). Fukuhara and Worlund (1973) observed an overall Tanner crab mortality of 60-70% in the foreign Bering Sea trawl fisheries. They also noted that mortality was higher in the summer (95%) than in the spring (50%). Hayes (1973) found that mortality of Tanner crab captured by trawl gear was due to time out of water, with 50% mortality after 12 hours. Natural Resource Consultants (1988) reported that overall survival of red king crab and Tanner crab bycaught and held in circulation tanks for 24-48 hours was <22%. In other analyses, the estimated mortality rate of trawl bycaught red king crab and Tanner crab was 80% (NPFMC 1993, 1995).

Not all crabs in the path of a trawl are captured. Some crab pass under the gear, or pass through the trawl meshes. Non-retained crabs may be subject to mortality from contact with trawl doors, bridles, footrope, or trawl mesh, as well as exposure to silt clouds produced by trawl and dredge gear. Only a few studies have been conducted to estimate catchability of crabs by trawl gear, and these studies are summarized below.

In one experiment to measure non-observable mortality, 169 red king crabs were tethered in the path of an Aleutian combination trawl (Donaldson 1990). The trawl was equipped with a footrope constructed of 14 inch bobbins spaced every 3 feet, separated by 6.5 inch discs. Thirty-six crabs (21.3%) were recovered onboard the vessel in the trawl. Divers recovered 46.2% of the crabs not captured by the trawl. Another 32.5% were not recovered but assumed to have interacted with the trawl. Of the 78 crabs not retained in the trawl, but captured by divers, only 2.6% were injured. If all injured crabs die, the non-observable mortality rate for trawl gear on red king crabs is estimated at 2.6% (Donaldson 1990). It should be noted that hard shelled crabs were used in this experiment; higher impacts would be expected if softshelled crabs were tested. Additionally, some areas have had higher intensity of bottom trawling than other areas, thus potentially exposing some crabs to multiple interactions with trawl gear.

In 1995, NMFS used underwater video cameras to observe the interaction of trawl gear with king and Tanner crabs (Craig Rose, NMFS, unpublished data). The experiment was conducted in Bristol Bay in an area with large red king crabs and Tanner crabs. Three types of trawl footropes were examined and they are as follows: a footrope with 3-4 foot lengths of 6" discs separated by 10" discs (called disc gear), a footrope with 24" rollers (tire gear), and an experimental float/chain footrope with the groundgear suspended about 8" off the seafloor. For disc gear, preliminary analysis indicated that all red king crab encountered entered the trawl and about 76% of the Tanner crabs were caught. Tire gear captured fewer king crabs (42%) and Tanner crabs (1%). The float/chain gear did not catch any of the crabs encountered. At the December 1995 Council meeting, excerpts of the NMFS video were shown to the Council and public. Trawl industry representatives testified that groundgear used to harvest finfish in this area depended on target species and bottom type, with tire gear type footropes used in hard bottom areas, and disc type gear used on smooth bottom areas. Testimony also indicated that there was also variability in groundgear used among vessels, but that on average, most gear used in Bristol Bay trawl fisheries would be comprised of groundgear with discs or rollers larger than the disc gear tested and smaller than the tire gear tested.

The NMFS underwater video observations were further analyzed to determine the proportion of red king crab that were injured by passage under bottom trawl footropes (Rose, 1999 unpublished manuscript). Injury rates of 5% to 10% were estimated for crabs that encountered, but were not captured, in the center section of the trawl.

Bycatch of crabs(numbers) in Bering Sea fixed gear groundfish fisheries, 1993-1999 (though 10/30). Reported by NMFS Blend estimates.

Year	bairdi	opilio	red king
1993	9,484	129,104	428
1994	48,221	130,228	928
1995	87,674	230,233	3,257
1996	279,560	267,395	75,676
1997	50,218	554,103	25,613
1998	46,552	549,139	7,012
1999	43,220	269,778	8,968

1.5.2.3 Other Groundfish Fisheries

Some crabs are caught incidentally by non-trawl gear in pursuit of groundfish, and a portion of these crabs die. No field or laboratory studies have been made to estimate mortality of crab discarded in these fisheries. However, based on condition factor information from the trawl survey, mortality of crab bycatch has been estimated and used in previous analyses (NPFMC 1993). Discard mortality rates for red king crab were estimated at 37% in longline fisheries and 37% in pot fisheries. Estimated bycatch mortality rates for Tanner crab were 45% in longline fisheries and 30% in pot fisheries. No observations had been made for snow crab, but mortality rates are likely similar to Tanner crab. In the analysis made for Amendment 37, a 37% mortality rate was assumed for red king crab taken in longline fisheries and an 8% rate for pot fisheries. Observer data on condition factors collected for crab during the 1991 domestic fisheries suggested lower mortality of red king crab taken in groundfish pot fisheries. Bycatch mortality rates used in the analysis of Amendment 37 (NPFMC 1996) for snow crabs were 45% in longline fisheries and 30% in pot fisheries, based on previous analyses.

1.5.2.4 Scallop Fishery

Bycatch of snow crab in the scallop fishery is relatively small. Although the scallop fishing grounds have remained in the same location, the fishery now encounters more snow crab than bairdi, which was previously the dominant bycatch species.

Bycatch of crabs (numbers) in Bering Sea weathervane scallop fisheries, 1993-1999 (preliminary). ADF&G Observer Program data. Note that the Bering Sea scallop fishery was closed in 1995. Opilio includes hybrids.

Year	bairdi	opilio	red king
1993	290,913	17,630	6
1994	220,710	34,866	20
1995	0	0	0
1996	16,089	104,836	0
1997	28,446	195,345	0
1998	39,363	232,911	146
1999	65,189	150,421	0

Observations from scallop fisheries across the state suggest that mortality of crab bycatch is low relative to trawl gear due to shorter tow times, shorter exposure times, and lower catch weight and volume. For crab taken as bycatch in the Gulf of Alaska weathervane scallop fishery, Hennick (1973) estimated that about 30% of Tanner crabs and 42% of the red king crabs bycaught in scallop dredges were killed or injured. Hammerstrom and Merrit (1985) estimated mortality of Tanner crab at 8% in Cook Inlet. Kaiser (1986) estimated mortality rates of 19% for Tanner crab and 48% for red king crab bycaught off Kodiak Island. Urban el al. (1994) reported that in 1992, 13-35% of the Tanner crab bycaught were dead or moribund before being discarded, with the highest mortality rate occurring on small (<40 mm cw) and large (>120 mm cw) crabs. Delayed mortality resulting from injury or stress was not estimated. Mortality in the Bering Sea appears to be lower than in the Gulf of Alaska, in part due to different sizes of crab taken. Observations from the 1993 Bering Sea scallop fishery indicated lower bycatch mortality of red king crab (10%), Tanner crab (11%) and snow crab (19%). As with observations from the Gulf of Alaska, mortality appeared to be related to size, with larger and smaller crabs having higher mortality rates on average than mid-sized crabs (D. Pengilly, ADF&G, unpublished data). Immediate mortality of Tanner crabs from the 1996 Bering Sea scallop fishery was 12.6% (Barnhart and Sagalkin 1998). Delayed mortality was not estimated. In the analysis made for Amendment 41, a 40% discard mortality rate (immediate and delayed mortality combined) was assumed for all crab species.

1.5.2.5 Total Bycatch Mortality Estimates (all fisheries)

Number of crab bycaught

Based on data discussed in previous sections, it is

Bycatch of snow crab (numbers of crab) in Bering Sea fisheries, 1994-1999.

Year	directed crab pot	groundfish trawl	groundfish fixed gear	scallop dredge	Total
1994	53,082,564	12,351,899	130,228	34,866	65,599,557
1995	48,734,000	5,165,555	230,233	0	54,129,788
1996	56,570,785	3,643,612	267,395	104,836	60,586,628
1997	75,005,446	5,276,208	554,103	195,345	81,031,102
1998	51,591,453	4,122,648	549,139	232,911	56,496,151
1999	41,666,447	1,544,747	269,778	150,421	43,631,393

possible to estimate the impacts of bycatch on the Bering Sea snow crab stock. In recent years, bycatch has declined from a high of 81 million crab in 1997 to much fewer in 1999.

Mortality of crab bycaught

These bycatch estimates can be converted into mortality estimates by applying bycatch mortality rates estimated from scientific observations, as summarized in previous sections. Discard mortality rates have been established in previous analysis (NPFMC 1999). Bycatch mortality rates for snow crab in trawl and dredge fisheries were set at 80% and 40% respectively. An estimate of 20% was applied to bycatch in fixed gear fisheries. The mortality rate of snow crabs bycaught in the snow crab and other crab fisheries was set at 24%, as an average of all crab fisheries. These bycatch mortality rate estimates reflect the need to consider new information on the potential for mortality due to windchill. The bycatch mortality rate of 25% during the snow crab fishery was used in the analysis of Amendment 11. A 20% rate for the snow crab fishery was used by Zheng and Kruse (1999) in modeling alternative harvest strategies for Tanner crab. The 20% bycatch mortality in the bairdi fishery was used in the harvest strategy analysis (Zheng and Kruse 1999), and a slightly higher number was applied to the snow crab fishery to account for increased windchill effects. These mortality rates for crab and trawl fisheries may not be the perfect number for all conditions, but represent our best estimates at this time. Applying these rates to bycatch data provides total discard mortality (in number of crabs) estimates that are useful in evaluating potential rebuilding scenarios.

Estimated bycatch mortality of snow crab (numbers of crabs) in Bering Sea fisheries, 1994-1999.

Year	directed crab pot	groundfish trawl	groundfish fixed gear	scallop dredge	Total
1994	12,739,815	9,881,519	26,046	13,946	22,661,327
1995	11,696,160	4,132,444	46,047	0	15,874,651
1996	13,576,988	2,914,890	53,479	41,934	16,587,291
1997	18,001,307	4,220,966	110,821	78,138	22,411,232
1998	12,381,949	3,298,118	109,828	93,164	15,883,059
1999	9,999,947	1,235,798	53,956	60,168	11,349,869

By incorporating the size (age) of crabs taken as bycatch, one can estimate the impacts of bycatch on a future adult population. This allows for direct comparison of adult equivalents among the various sources of mortality and so provides better estimates of impacts across fisheries. Based on information summarized in Section 1 and in the analysis of Amendment 37 to the BSAI Groundfish FMP, a simple accounting formula was used to estimate mortality in adult equivalents for males and females. Adult equivalents were calculated based on the following equation:

$$Q = (N*n*D)*(A)^t$$

where:

Q = adult equivalents, measured in number of crab of the sex and species examined
N = Number of crab bycaught of that species
n = proportion of bycatch observed to be male (of female depending on application)
D = discard mortality rate; the proportion of crab bycaught that die due to capture and handling (trawl, 0.80; longline, 0.45; groundfish pot, 0.30; scallop dredge 0.40; crab pot 0.08, 0.20, and 0.25 depending on fishery)
A =conditional annual survival rate set at 0.75, based on (e^{-M}) where M=0.30
t = years to recruitment in fishery (males) or spawning stock (females); based on average age of bycatch versus average age of crab in directed fishery (males) or average age to maturity (females).
(N*n*D) = number of crab of killed for the sex and species examined
$(A)^t$ = adjustment factor to account for age

Results of this exercise indicate that the effects of trawling and other human activities on crab mortality depend on species, sex, and year examined. Results are shown separately for 1997-1999 for male and female Bering Sea snow crab (**Tables 9-12**). Although the estimates generated by this analysis may not be precise due to numerous assumptions that have been made regarding bycatch mortality, the results should provide some indication of the effects of catch and bycatch on crab populations.

Estimated adult equivalent snow crab removals by groundfish, scallop, and crab fisheries, 1997-1999.

	1997		1998		1999	
Fishery	male	female	male	female	male	female
Groundfish	1,184,245	884,193	954,096	659,624	376,497	293,765
Scallop	58,604	0	69,873	0	45,126	0
Crab	107,708,687	266,504	191,975,900	19,748	148,513,346	510,649
Total	**108,951,535**	**1,110,697**	**192,999,869**	**679,372**	**148,934,970**	**804,414**

Estimated adult equivalent mortality of snow crab (numbers of animals) in Bering Sea fisheries, 1997-1999.

Year	directed crab pot	groundfish trawl+fixed	scallop dredge	Total
1997	107,975,191	2,068,438	58,604	110,062,232
1998	191,995,648	1,613,720	69,873	193,679,241
1999	149,023,995	670,262	45,126	149,739,383

This exercise of determining adult equivalents provided insights into the impact of crab bycatch. First, a comparison of adult equivalent mortality across fisheries is instructive for developing a crab rebuilding policy. In most years when a GHL is established, the single largest source of human induced crab mortality is removals of legal males by directed crab fisheries and associated bycatch. Crab fisheries accounted for a vast majority (98-99%) of the crab mortality. The crab fishery has a relatively smaller impact on females, but still is a source of fishing mortality for female crabs when there is a directed crab fishery. Most of the remaining removals are due to the trawl and other groundfish fisheries. In all years examined, the scallop fishery had relatively little impact on crab stocks as measured by observed bycatch. These data indicate that reductions in crab quotas for crab fisheries may have relatively more impact on rebuilding than reductions in crab bycatch in trawl or dredge fisheries.

This analysis also indicates that reducing the PSC limits for groundfish fisheries may not drastically improve or rebuild crab stocks if only this option is chosen. Because bycatch mortality caused by trawl fisheries is small relative to other sources of removals due to natural and fishing mortality, reductions in bycatch limits may not result in measurable improvements to crab stock abundance. However, any reduction in mortality would slow the decline of the Bering Sea snow crab stock and improve survival of juvenile crab. Adult equivalent removals of female spawners likely has more impact on the snow crab stock when abundance is low than when the stock is at higher levels.

1.5.3 Temporal and Spatial Aspects of Snow Crab Bycatch

1.5.3.1 Groundfish Fisheries

Bycatch of snow crab in Bering Sea groundfish fisheries was analyzed using NMFS observer program data. Official total groundfish catch and total observed bycatch of snow crab from 1995 through 1999 were queried from the observer program database and summarized by ADF&G statistical areas (½ ° latitude by 1 ° longitude blocks) based on the latitude and longitude of each haul. Observed bycatch is the number of crabs counted by observers; it is not the total estimated crab bycatch expanded to include unobserved hauls. Bycatch rate, as number of crab per metric ton of total groundfish catch, was then calculated for each statistical area. The data were separated by year and gear type and then converted to geographic format for mapping.

Figures 10-14 display total observed bycatch and observed bycatch rate for the bottom trawl fishery from 1995 through 1999. **Figures 15-19** display total observed bycatch and observed bycatch rate for the longline fishery from 1995 through 1999. **Figures 20-24** display total observed bycatch and observed bycatch rate for the pot/trap fishery from 1995 through 1999, and **Figures 25-29** display total observed bycatch and observed bycatch rate for the combined bottom and pelagic trawl fisheries from 1995 through 1999.

The bottom trawl fishery (predominately the yellowfin sole and rock sole fisheries) contributed between 89% and 96% of the total observed bycatch of snow crab from 1995 – 1999. Of the remaining contributions to snow crab bycatch, the longline fishery yielded more total observed bycatch than the pot/trap fishery, but the pot/trap bycatch rate was significantly higher than that of the longline fishery and often higher than that of the bottom trawl fishery. The pelagic trawl fishery was a very small contributor to snow crab bycatch. Because of these differences, scales are consistent on maps of a particular gear type for all years, but are considerably different between maps of different gear types.

Mapping the spatial distribution of summarized bycatch data in the bottom trawl, combined bottom and pelagic trawl, and longline fisheries revealed that several statistical areas have consistently high observed total bycatch of snow crab (particularly in the area of 57°N 165/166°W). However, the majority of these same areas has high total groundfish catch resulting in relatively low bycatch rates. The spatial distribution of high bycatch rate areas shows no apparent correlation from year to year or between gear types. In the pot/trap fishery there is evidence of positive spatial correlation between areas of high total bycatch and high bycatch rates within each particular calendar year, but there is no apparent temporal correlation of these high bycatch/high bycatch rate statistical areas during the period 1995 – 1999.

1.5.3.2 Crab Fisheries

Observers stationed on catcher-processor vessels have provided data on catch of non-retained snow crab during the commercial Bering Sea red king, blue king, Tanner, and snow crab fisheries. Observers have also been stationed on all catcher vessels participating in the Bering Sea Korean hair crab fishery. We summarize results of those data for the last five seasons, the 1995 through the 1999 seasons (sources are: Boyle et al. 1996, 1997, and L. Byrne ADF&G Kodiak pers. comm).

Bycatch of non-retained snow crabs has been observed in the snow crab fishery, the St. Matthew blue king crab fishery, the Korean hair crab fishery, the Bristol Bay red king crab fishery, and the Tanner crab fishery (see Section 1.5.2). Some bycatch of snow crabs has probably also occurred in the unobserved Pribilof king crab fisheries, but the magnitude of that bycatch is likely negligible due to the low effort in that fisheries, the distribution of that effort, and the escape mechanisms required for pots used in those fisheries. The Bristol Bay red king crab fishery has accounted for little bycatch of snow crab during the last five years due to fishery closures, distribution of the fishery effort, and, perhaps, the escape mechanisms required for pots used in that fishery. The Tanner crab and St. Matthew blue king crab fisheries can account for greater amounts of bycatch in at least some years. Total snow crab bycatch in the 1996 St. Matthew blue king crab and the Tanner crab seasons was estimated to be nearly 11 million animals during the 1996 season. It is the snow crab fishery itself, however, that is responsible for 90% to nearly 100% of the annual estimated number of snow crabs that are captured and discarded in crab fisheries.

Within the commercial snow crab fishery, female snow crabs are estimated to account for less than 1% of the retained and non-retained snow crab catch per potlift; catch per potlift of females is estimated to be 1 crab or less per pot lift. Those female snow crabs that are captured during the commercial snow crab fishery are predominately (70% to 90% of examined females, annually) mature. During most snow crab seasons, sublegal-sized male snow crabs (i.e., < 3.1-in, or 79-mm, carapace width, CW) are estimated to account for 2% or less of the retained and non-retained snow crab catch per potlift. During the 1995 and 1996 seasons, however, sublegal-sized male snow crabs accounted for 13% and 5%, respectively, of the estimated catch per potlift. A higher incidence of sublegal-sized male snow crabs, such as seen during the 1995 and 1996 seasons, can be expected one and two seasons prior to a large recruitment into the legal size class. The majority (70% to 98% depending on season) of non-retained snow crabs that are captured during the snow fishery are legal-sized crabs (> 3.1-in, or 79-mm, CW) that are discarded due to being smaller than the minimum industry standard of 4-in (102-mm) CW. Over the 1995 through 1999 fishery seasons, it is estimated that 25% to 40% of the legal-sized snow crab captured during the fishery are discarded due to being smaller than the industry standard. Close to 100% of the non-retained male snow crab that are captured during the commercial snow crab fishery are morphometrically mature, regardless of size (R.S. Otto, NMFS Kodiak, pers. comm.).

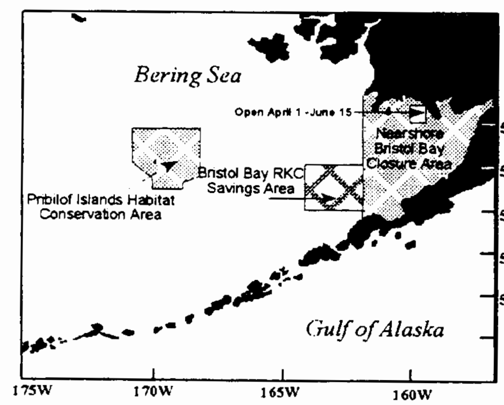
Inspection of the geographic distribution of catch per pot of females, sublegal males, non-retained legal males, and retained legal males in pot samples from catcher-processor vessels during the 1995 through 1999 snow crab seasons reveals no consistent "hotspots" of high bycatch and low directed catch. The plots for **Figures 30-34** were derived from bycatch data collected by shellfish observers deployed on catcher processors in the 1995 through 1999 snow crab fishery seasons. The area fished by all vessels participating in the fishery may be more extensive than the area fished by catcher processors which is displayed in these plots. Z-scores are used here as a relative index of harvest compared to the overall mean harvest within a single fishery season. The darker areas represent areas of higher than average catch per pot lift (CPUE). The surfaces for the snow crab fishery show z-scores calculated from mean CPUE per NMFS Eastern Bering Sea survey grid (20 x 20 nmi grid cell size). The depth contours from southeast to northwest are 200, 100 and 50 m.

1.5.4 Existing Measures to Control Crab Bycatch in Scallop and Groundfish Fisheries

The Council and the Alaska Board of Fisheries have adopted numerous regulations designed to protect habitat and minimize bycatch and bycatch mortality of crab taken incidentally in Bering Sea groundfish and scallop fisheries (Witherell and Pautzke 1997). An overview of these measures is provided below.

<u>Closure Areas</u>

Several areas of the Bering Sea have been closed to groundfish trawling and scallop dredging to reduce potential adverse impacts on the habitat for crab and other resources. Survey data have shown that Tanner crab, snow crab, and red king crab are all found in these areas. Beginning in 1995, the Pribilof Islands Conservation Area was closed to all trawling and dredging year-round to protect blue king crab habitat (NPFMC 1994). Also beginning in 1995, the Red King Crab Savings Area was established as a year-round bottom trawl and dredge closure area (NPFMC 1995). This area was known to have high densities of adult red king crab, and closure of the area greatly reduced bycatch of this species. To protect juvenile red king crab and critical rearing habitat (stalked ascidians and other living substrate), another year-round closure to all trawling was implemented for the nearshore waters of Bristol Bay.

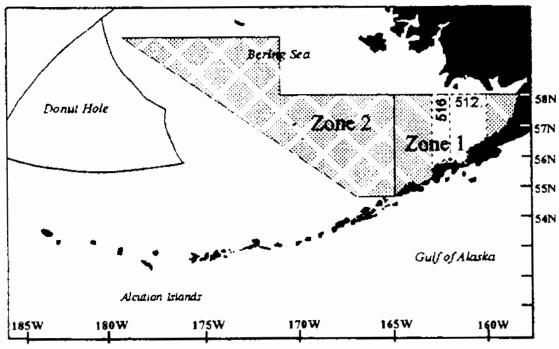


Location of trawl closure areas to protect red and blue king crab habitats.

Specifically, the area east of 162° W (i.e., all of Bristol Bay) is closed to trawling and dredging, with the exception of an area bounded by 159° to 160° W and 58° to 58°43' N that remains open to trawling during the period April 1 to June 15 each year. Because NMFS trawl surveys have shown snow crab are abundant in these areas, the existing trawl closures provide some degree of habitat protection for the snow crab stock..

Bycatch Limits

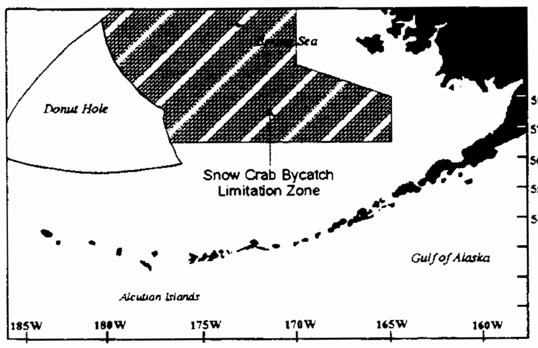
The Council has adopted numerous limits on the incidental capture of crabs taken in groundfish and scallop fisheries. Prescribed bottom trawl fisheries in specific areas are closed when prohibited species catch (PSC) limits of Tanner crab, snow crab, and red king crab are taken. Bycatch limitation zones for Tanner and red king crab PSC are shown in the figure below. Crab PSC limits for groundfish trawl fisheries are based on crab abundance as shown in the adjacent table. Note that in 1998, the Council adopted a provision to reduce bairdi crab bycatch by an additional 50,000 crabs and red king crab bycatch by 3,000 crabs as part of the regulation prohibiting the use of bottom trawl gear for pollock fisheries.



Location of the crab bycatch limitation zones.

PSC limits (numbers) for red king crab and C. bairdi Tanner crab. Note that the PSC limits are reduced by an additional 3,000 red king crab and 50,000 Tanner crab per BSAI Groundfish Amendment 57.

Species	Zone	Crab Abundance	PSC Limit
Red King Crab	Zone 1	Below threshold or 14.5 million lbs of effective spawning biomass (EBS)	35,000
		Above threshold, but below 55 million lbs of EBS	100,000
		Above 55 million lbs of EBS	200,000
Tanner Crab	Zone 1	0-150 million crabs	0.5% of abundance
		150-270 million crabs	750,000
		270-400 million crabs	850,000
		over 400 million crabs	1,000,000
Tanner Crab	Zone 2	0-175 million crabs	1.2% of abundance
		175-290 million crabs	2,100,000
		290-400 million crabs	2,550,000
		over 400 million crabs	3,000,000



Location of the C. opilio bycatch limitation zone (COBLZ).

Under Amendment 40 of the BSAI Groundfish FMP, PSC limits for snow crab taken in groundfish fisheries are based on total abundance of snow crab as indicated by the NMFS standard trawl survey (NPFMC 1996). The snow crab PSC cap is set at 0.1133% of the Bering Sea snow crab abundance index, with a minimum PSC of 4.5 million snow crabs and a maximum of 13 million snow crabs. Snow crabs taken within the "C. Opilio Bycatch Limitation Zone" (COBLZ) accrue towards the PSC limits established for individual trawl fisheries. Upon attainment of a snow crab PSC limit apportioned to a particular trawl target fishery, that fishery is prohibited from fishing within the snow crab zone. Note that in 1998, the Council adopted a provision to reduce snow crab bycatch by an additional 150,000 crabs as part of the regulation prohibiting the use of bottom trawl gear for pollock fisheries.

Crab bycatch limits have also been established by ADF&G for the Alaska scallop fisheries. Annual crab bycatch limits (CBLs) are specified for red king crab and Tanner crab species in each registration area or district thereof. In the Bering Sea, CBLs are set for "other Tanner crab" (*C. opilio* and *bairdi* x *opilio* hybrids) as 300,000 when snow crab is above MSST; 150,000 when snow crab is below MSST, and the directed snow crab fishery is open; and 75,000 when the snow crab is below MSST and the directed fishery for snow crab is closed.

Weathervane scallop registration areas, seasons, GHL's (pounds, shucked), and crab bycatch limits established for the 1999 scallop fishery, by area. Note: snow crab includes hybrids.

			Crab Bycatch Limits		
Area	GHL (pounds)	Fishing Season	king crab	Tanner crab	Snow crab
D - District 16	0 - 35,000	July 1 - Feb 15	n/a	n/a	n/a
D - Yakutat	0 - 250,000	July 1 - Feb 15	n/a	n/a	n/a
E - PWS	0 - 20,000	July 1 - Feb 15	n/a	500	n/a
H - Cook Inlet (Kamishak)	0 - 20,000	Aug 15 - Oct 31	60	24,992	n/a
Cook Inlet (Outer area)	combined	Jan 1 - Dec 31	98	2,170	n/a
K - Kodiak (Shelikof)	0 - 180,000	July 1 - Feb 15	250	42,500	n/a
Kodiak (Northeast)	0 - 75,000	July 1 - Feb 15	150	66,500	n/a
M - AK Peninsula	0 - 200,000	July 1 - Feb 15	300	75,500	n/a
O - Dutch Harbor	0 - 110,000	July 1 - Feb 15	10	10,700	n/a
Q - Bering Sea	0 - 400,000	July 1 - Feb 15	500	65,000	300,000
R - Adak	0 - 75,000	July 1 - Feb 15	50	10,000	n/a

1.5.5 Existing Measures to Control Bycatch in the Crab Fisheries

Gear modifications - Under the BSAI king and Tanner crab FMP, legal fishing gear modifications are at the discretion of the state and by empowerment, the Alaska Board of Fisheries. A number of pot gear modifications designed to inhibit bycatch in the crab fisheries have been adopted by the Board and incorporated into regulatory definitions of allowable gear. For Bering Sea red and golden king crabs and Pribilof Island red and blue king crabs, these regulations include minimum pot tunnel entrance dimensions and escape rings or mesh panels to allow egress of non-retainable crabs, including females and undersized males. Regulations for the Bering Sea Tanner and snow crab fisheries also require that pots contain egress mesh or rings, but additionally specify a maximum pot tunnel height opening of 3 inches to reduce bycatch of king crabs.

In March 2000, the Alaska Board of Fisheries passed regulations requiring that escape rings used in snow crab pots must have a minimum inside diameter of 4 inches and escape meshes, when stretched, must be at least 5 and 1/4 inches in length. All pots used in Bering Sea crab fisheries must have biodegradable twine woven into a side wall (or tunnel) to prevent "ghost fishing" whenever fished gear is lost (ADF&G 1999).

Area Closures -State regulations specify several areas closed to the commercial harvesting of king crabs in order to protect the stocks from overharvest and during biologically sensitive periods. These areas include year-round closure of 10 mile offshore zones surrounding St. Lawrence and the Little Diomede Islands and seasonal closures of two sections of Norton Sound (ADF&G 1999). The survey distribution of Bering Sea snow crabs suggests those closures do not provide discernible protection of the stock.

Bycatch limits - Non-target crab bycatch caps have not been established in state or federal regulations for Bering Sea crab fisheries. Monitoring of bycatch species and evaluation of catch rates is these fisheries is presently accomplished through varying levels of at-sea observer coverage.

Fishing Seasons - Crab fishing seasons established by the Alaska Board of Fisheries (including those for FMP crab stocks) are also scheduled to minimize the potential for excessive bycatch and associated handling mortality of molting and mating crabs. Likewise, the current timing of the Bering Sea snow crab fishery avoids harvesting during the early to mid-summer stock molting and mating

1.6 Evaluation of Alternatives and Options

1.6.1 Harvest Strategy

The Alaska Board of Fisheries (BOF) adopted as a regulation a new harvest strategy for eastern Bering Sea snow crab during their March 2000 meeting. The adopted harvest strategy includes a rebuilding component, protects against overfishing as defined for eastern Bering Sea snow crab in the BS/AI King and Tanner Crab FMP, and was closely based on the recommendations for implementing precautionary harvest strategies and rebuilding plans of Restrepo et al. (1998).

The new harvest strategy determines a guideline harvest level (GHL) for snow crabs by the application of three rules: an exploitation rate that is applied to mature male biomass; a 50% cap on the removals of "exploitable legal males", and a minimum GHL for fishery opening of 25 million pounds.

Exploitation rate on mature males. The new harvest strategy applies an exploitation rate to the estimated biomass (B) of mature male snow crab. The exploitation rate that is applied to the mature male biomass varies with the estimated spawning biomass (SB = total biomass of mature males and females) according to:

$0.75 \times 0.3 = 22.5\%$, for $SB \geq 921.6$ million pounds
$0.75 \times 22.5\% = 16.875\%$, for $SB \geq 460.8$ million pounds and $SB < 921.6$ million pounds
$(SB/460.8) \times 16.875\%$, for $SB \geq 230.4$ million pounds and $SB < 460.8$ million pounds
0% (fishery closed), when $SB < 230.4$ million pounds.

The determination of the harvest strategy is presented graphically in **Figure 35.**

The spawning biomass benchmarks, 921.6 and 460.8 million pounds, for determining the exploitation rate are the MSY biomass (B_{MSY}) and minimum stock size threshold (MSST), respectively, for eastern Bering Sea snow crab as specified in the FMP; 230.4 million pounds is one-half the MSST. The FMP defines the MSY control rule for eastern Bering Sea snow crab as a 30% exploitation of the SB. Overfishing is avoided under this harvest strategy by applying an exploitation rate < 30% only to the mature male biomass portion of the SB. Avoidance of overfishing is further assured by a maximum exploitation rate on mature male biomass of 75% of 30% -- when the SB reaches or exceeds B_{MSY}. When the SB falls below B_{MSY}, but exceeds MSST, the exploitation rate is reduced by an additional 25% to 16.875%. The exploitation rate on mature male biomass decreases linearly from 16.875% when SB is below MSST to an exploitation rate of 8.4375% when SB falls to one-half MSST. Below one-half MSST the directed snow crab fishery is closed.

50% removal cap on "exploitable legal males". Besides the determining an exploitation rate on mature male biomass, the new harvest strategy also caps the removals of "exploitable legal males" to 50%. The 50% value is based on the 50% removal cap on "exploitable legal males" that was developed for the harvest strategy in the eastern Bering Sea Tanner crab rebuilding plan (Zheng and Kruse 1999). The cap assures that removals from a single sex-size class is controlled over all population and size-frequency scenarios, avoids the sorting that can accompany high harvest rates on a single sex-size class, and adjusts for the disproportionately high harvest of new-shell males. "Exploitable legal males" for snow crab are defined for this harvest strategy on the basis of carapace width (CW) and shell age. The minimum size of "exploitable legal male" snow crabs is defined by the 4-in (102-mm) CW industry standard for processing Alaska snow crab (Morrison et al. 1999); note, however, that the minimum legal size is 3.1-in (79-mm) CW (ADFG 1999). A shell-age component to the "exploitable legal male" definition reflects the disproportionate harvest of new-shell males relative to their representation in stock assessment survey data. Hence, "exploitable legal males" for eastern Bering Sea snow crab are defined as 100% of the population estimate of new-shell males >4-in CW plus 25% of the old-shell males >4-in CW. The discounting of old-shell males in the definition of "exploitable legal males" was computed using the proportion of new-shell animals estimated for males >4-in CW in the snow crab population during the preseason surveys and the proportion of new-shell crabs in sampled deliveries for the 1991 through 1999 seasons.

25 million pound minimum GHL. The fishery season will not be opened if the GHL is less than 25 million pounds. The minimum GHL addresses the inability to adequately manage the fishery towards a low GHL under the current fleet size, pot limit conditions, in-season data collection, and end-of-season gear requirements.

Application of the new harvest strategy to historic data. Target harvest rates on males ³ 4-in CW would be generally 35% to 45%, rather than 58% as under the old harvest strategy, if the new harvest strategy for eastern Bering Sea snow crab was applied to historic population conditions **(Figure 36)**. Greater reductions would have occurred at times when spawning biomass, biomass of mature males, or numbers of exploitable legal males were low or in decline. Notably, for the stock conditions seen in 1985 and 1986 surveys, the new harvest strategy would have closed the 1986 season due to the spawning biomass being below one-half of the MSST and would have closed the 1987 season due to the computed GHL being below 25 million pounds. In reality, harvests of approximately 100 million pounds on GHLs of roughly 55 million pounds were realized during the 1986 and 1987 seasons. Likewise, the 2000 season would have been closed to fishing had the new harvest strategy because the new harvest strategy would have proscribed a GHLs below the minimum GHL of 25 million pounds. In reality, the 2000 season was opened and approximately 30 million pounds were landed on a GHL of 26.3 million pounds.

Estimates of long-term harvests, probabilities of fishery closure, and other fishery parameters of interest for the new harvest strategy as compared to the old strategy and other alternatives are provided in a previous section of this analysis. Relative to the status quo, the new harvest strategy is much more conservative, particularly at low stock sizes, and would be expected to help maintain long term stock productivity, as well as increase the probability of stock rebuilding.

Available information and conservative management. The ADF&G staff that developed this harvest strategy feel that it is highly precautionary, using conservative assumptions on natural mortality and on the influences of fishing mortality on stock dynamics. The analysts note that the time constraints for development of this rebuilding plan did not allow for this harvest strategy to be informed by thorough analyses of Bering Sea snow crab population dynamics, spawner-recruit relationships, the factors that influence year class strength, natural mortality at size and shell age, and the molting probabilities of morphometrically mature males. Assumption of a strictly terminal molt for morphometrically mature male snow crabs in the eastern Bering Sea can, for example, influence management considerations (Otto 1998). Additionally, recent information on catchability-at-size of snow crab in the NMFS eastern Bering Sea trawl survey (Somerton and Otto 1999) has not been incorporated into any analyses of population trends or into computation of the biomass estimates used to determine "overfished" levels. The conservative approach of the new harvest strategy reflects the lack of thorough analyses. The analysts urge that more thorough analyses be performed within a more realistic time frame because such analyses may justify a less conservative harvest strategy than that newly adopted by the BOF. ADF&G has indicated that once such a comprehensive analysis is completed, it would consider modifying the harvest strategy for optimal management of this fishery.

1.6.2 Bycatch Controls

Mortality associated with crab bycatch may adversely effect the recovery of the snow crab stock. Bycatch mortality was highest in 1994, with 22.6 million snow crabs killed incidentally in Bering Sea fisheries. This equated to about 0.2%of the total abundance as measured by the NMFS trawl surveys. Although the mortality was slightly lower in 1997, the impacts were somewhat higher, with bycatch mortality equating to about 0.4% of total abundance. Although removals of this magnitude may be relatively small compared with natural mortality (estimated to be about 28% per year for the same size groups measured by the survey), and fishing mortality, concerns have been expressed about controlling bycatch mortality.

Groundfish Fisheries

Crab bycatch in groundfish fisheries has ranged between 1.5 million and 15 million snow crabs during the 1993-99 period. This equates to about 0.1 % of the total stock on average. From a mortality standpoint, this is much lower than mortality associated with most other groundfish fishery PSC species such as herring (1%), halibut (1.3% trawl and longline combined), chum salmon (<1%), red king crab (0.1%),Tanner crab (1 %) and chinook salmon (2%-4%) (Witherell et al., 2000).

Bycatch of snow crabs (numbers) in Bering Sea groundfish trawl fisheries, 1993-1999 (through 10/30), and previous years survey abundance estimate.

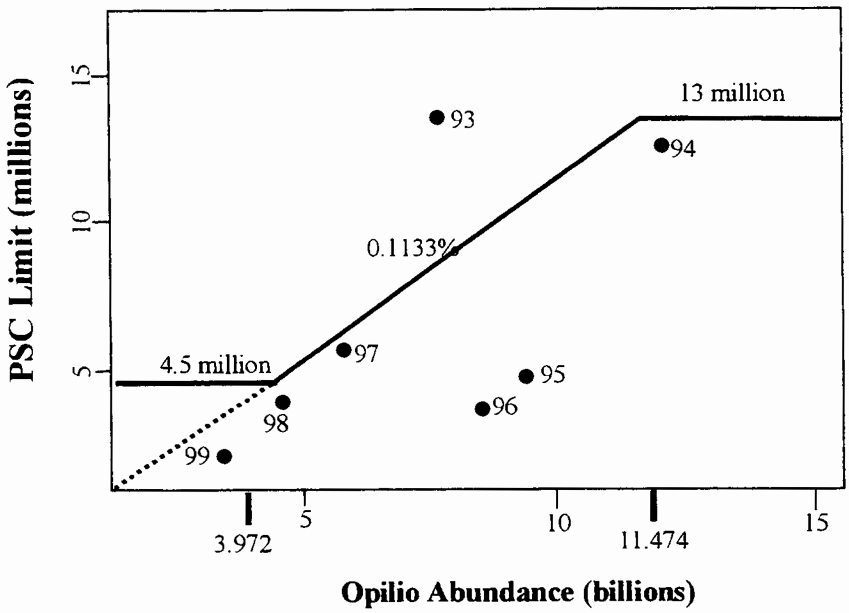
Year	PSC limit	Bycatch	Abundance (millions)	Bycatch as %
1993	-	14,631,617	7,763	0.19
1994	-	12,351,899	11,704	0.11
1995	-	5,165,555	9,446	0.05
1996	-	3,643,612	8,655	0.04
1997	-	5,276,208	5,425	0.10
1998	4,654,000	4,122,648	4,108	0.10
1999	4,350,000	1,544,747	3,233	0.05

The current snow crab bycatch limits were negotiated by an industry committee in 1996 and adopted as Groundfish Plan Amendment 40. As part of the industry agreement (**Appendix 1**), PSC limits were to be reviewed in 5 years (in 2001), so a review in this amendment package is timely.

The option to reduce the snow crab bycatch limit would maintain tighter control on the allowable bycatch of snow crabs, particularly when the stock is at low levels. Note that the current PSC regulations allow for 4.5 million snow crab PSC even if the stock collapsed to extremely low levels. However, because bycatch mortality caused by trawl fisheries is small relative to other sources of mortality, reductions in bycatch limits may not result in measurable improvements to crab stock abundance. Witherell and Harrington (1996) evaluated alternative measures to reduce the impacts of trawling and dredging on BSAI crab stocks, and concluded that a reduction in bycatch limits would conserve some crab, but would have little overall impact on crab stocks.

A shortcoming of the existing snow crab PSC limit, as based on total abundance, is due to the fact that minor changes in survey station or crab distribution can create major changes in the survey population estimate. This is because the population index is dominated by small animals and survey estimates of small crab and their distribution are highly variable from year to year. This potentially creates problems because annual PSC limits could be set disproportional to the abundance of the size of crab taken in trawl fisheries (which consists primarily of large crab). One concern is the potential for a high PSC limit generated by large numbers of juveniles. Another similar concern occurs at the opposite extreme where an artificially low PSC limit could needlessly constrain trawl fisheries.

With regards to the option to eliminate the 4.5 million "floor", trawl industry representatives have been concerned about the potential for a large year class to recruit as bycatch into to trawl fisheries before they recruit to the survey. In other words, a lot of little crabs taken as bycatch in year x+1 would count towards a PSC limit established on survey data in year x. Analysis of length frequency data from snow crab taken as bycatch in trawl fisheries, albeit based on limited sampling, suggests that such an event may be unlikely. Trawl bycatch appeared to consist of relatively large snow crabs (average size was about 70 mm cw), even when the population had a near record of small crabs (e.g., 1993). See **Section 1.5** for more information on bycatch of snow crabs in trawl fisheries. Small crabs are taken in the trawl survey due to net design (low profile footrope, small mesh) and survey locations; the trawl fisheries use larger mesh sizes (thereby letting out smaller crabs, fish, etc.) and fish in areas where the smaller snow crabs are not found (see figure on survey distribution of small crabs and trawl effort distribution). Molting to average bycatch size would probably require about 2 years (on average) after a year class is detected by the survey (year class strength appears to be well estimated when a mode reaches about 45 mm. See **Figure 2**). Barring major distributional changes or the crabs or the fishery, a large year class would not be expected to be encountered in groundfish trawl fisheries before being incorporated into the total survey abundance estimate (and consequently the PSC limit).



Snow crab bycatch and PSC limits relative to observed levels. Data points show abundance when specifications were set and the number of crabs taken the following year. Note: The actual PSC limit is reduced by 150,000 crabs per BSAI Amendment 57.

Concern has been raised about the unknown mortality of crabs caused by trawling, and reducing PSC limits may exacerbate these unobservable impacts. In an attempt to catch less crabs (via reduced bycatch limits, VIP regulations, AFA pooling, or proposed measures such as VBAs, etc.), trawl fishermen may modify their gear. Modifications to footrope design, roller size, and mesh size can result in fewer crabs being retained and counted by observers (NRC 1988). For trawl fisheries historically limited by bycatch limits, reduced bycatch rates of PSC species may result in increased effort (at least until limited by TAC of targets). In turn, increased trawl effort could result in increased unobservable impacts on crab resources, simply because more crab are encountered by trawl gear. This possibility was also raised during the Council's 1993 deliberations over trawl codend mesh size, but the benefits of reduced bycatch were felt to outweigh the possible costs of unobserved mortality due to non-retention.

Crab Fisheries

Most of the bycatch of snow crabs that occurs in the crab fisheries occurs in the snow crab fishery itself. Although catch per pot of female and sublegal male snow crab during the commercial snow crab season is low, the estimated percentage of legal-sized males that are captured but not retained has ranged from 25% to 40%. That non-retention of legal crabs during the commercial fishery is due to an industry standard minimum size of 4 inches (102 mm) in carapace width (including spines) for the purchase and processing of Bering Sea snow crab (R. Morrison, ADF&G Dutch Harbor, Alaska, pers. comm.). Given that industry standard, captured legal male snow crabs in the range of 3.1-4.0 inches carapace width (including spines) are typically discarded at sea. The spatial distribution of bycatch of submarket-sized legal snow crabs suggests no area closures for the snow crab fishery that would reduce that bycatch without significantly impacting the directed fishery.

Escape-enhancing gear requirements to address bycatch of snow crabs in the Bering Sea snow crab fishery were first developed as regulations by the BOF in March 1996 and were first implemented in the 1997 fishery season. Those regulations (5AAC 35.525; ADFG 1999) stipulated that,

> "Pots used to take Chionoecetes opilio Tanner crab must have at least one-third of one vertical surface of the pot composed of not less than five-inch stretched mesh webbing or have no less than four circular escape rings of no less than three and three-quarters inches inside diameter installed on the vertical plane to permit escapement of undersize C. opilio Tanner crab."

A survey of escape mechanisms used by fishers during the 1997 snow crab fishery indicated that escape rings, rather than escape mesh, were used in more than 95% of the pots fished in that season (Byersdorfer et al. 1997). Of those pots with escape rings, three-quarters had the rings placed mid-height or higher in the vertical panel.
More recently, during their March 2000 meeting, the BOF adopted new gear-restriction regulations for the eastern Bering Sea snow crab fishery that increased the size and coverage of escape openings with the intent of further reducing bycatch of non-retained snow crab. The newly adopted regulations require that a pot must have at least four 4-inch (inside diameter) rings within one mesh of the bottom of the pot on each of at least two sides of the pot (for a total of at least eight rings per pot) or that the pot must have at least one-half of one vertical surface be composed of not less than 5¼-inch stretched mesh.

The newly adopted escape-mechanism requirements were based on studies performed jointly by ADF&G and NMFS on Tanner (*C. bairdi*) crabs and on Industry input provided to the BOF during their March 2000 meeting. The ADF&G-NMFS research on Tanner crabs in the Bering Sea (Byersdorfer 1996) and Kodiak area (unpublished) demonstrated that escape-ring requirements are more effective if the ring placement is restricted to the lower portion of the vertical panels: Tanner crab pots with escape rings placed at mid-height on the vertical panels showed no reduction in bycatch of females and small males relative to pots without rings, whereas the catch of females was halved and the catch of sublegal males was reduced to two-thirds when rings were placed low in the side panels. The increase to a minimum 4-inch ring in the newly adopted regulations was based on studies indicating that a 4-inch ring will retain male snow crab as large or larger than the industry standard minimum size while allowing for the escape of most males below the industry standard. The increase in the minimum escape mesh was based on input from a pot manufacturer present during the March BOF meeting who indicated that 5¼ - inch stretched mesh would supply an opening equivalent to 4-inch rings.

1.6.3 Habitat Protection

Areas of important habitat for Bering Sea snow crab were determined using data collected from the NMFS eastern Bering Sea trawl survey during 1990 through 1999. In that regard, it should be noted that the NMFS eastern Bering Sea trawl survey does not cover the entire distribution of snow crabs in the Bering Sea and that areas of important snow crab habitat likely exist beyond the northern borders of the surveyed area. The life history of snow crab in the Bering Sea suggests that immigration of unknown magnitude to the survey area may occur from northern areas. Additionally, note that any data on distribution from the annual trawl survey can only reflect the distribution exhibited in the summer months. Despite those geographic and seasonal limitations, however, the eastern Bering Sea trawl survey provides the data source with the broadest geographic range of sampling locations at which size, sex, and reproductive status of snow crabs are recorded.

Two classes of snow crabs were of particular interest: juveniles (defined here as individuals < 40-mm CW) and mature females. For each survey year the catch of juveniles and the catch of mature females at each survey station were converted to z-scores. Z-scores for each station in a year were computed by subtracting the mean catch of a class (juveniles or mature females) for all stations in that year from the station's catch and then dividing that difference by the standard deviation of the catches across stations for that year. The average of each station's z-scores for the 10-year period 1990-1999 for each of the two classes was then computed and displayed as a thematic map (**Figures 37A and 37B**). Stations with high average z-scores represent areas of important habitat for a particular class of snow crab, because they tend to support higher than average densities of that class of snow crabs. **Figure 37C** provides the distribution of bottom trawl endpoints for 1990-1997 from the NMFS observer data base. **Figure 37C** is hence an index of overall effort in the various bottom trawl fisheries.

The following areas were identified as important habitat for juveniles and mature female snow crab. **Figure 37A** indicates that above average densities of juvenile snow crab tend to be found in a NW to SE band roughly 60-nm wide and 200-nm long that passes through St. Matthew Island, generally in the 50-m to 100-m depth zone. Most of high-density areas for juveniles are north of 59°30' N and between St. Matthew and Nunivak Islands or northwest of St. Matthew Island. Important areas identified for mature females were a NW-to-SE band roughly 60-nm to 100-nm wide and 425-nm long between the 100-m and 200-m depth contours and an additional smaller area directly to the east of St. Matthew Island (**Figure 37B**). **Figures 37A,B** also indicate that most areas if importance are found within the C. opilio Bycatch Limitation Zone (COBLZ). **Figure 37C** indicates that trawl fishing effort is relatively low in areas that are important for mature female and juvenile snow crab. This is particularly true in the area north and west of St. Matthew Island

Five options for protecting snow crab habitat were considered for recommendation by the analysts:

1. Status quo; i.e., no new closure areas for any Bering Sea crab or groundfish fisheries and existing prohibited species catch (PSC) limits for snow crab in the Bering Sea groundfish trawl fisheries
2. Status quo fishery closure areas with changes to the PSC limits for snow crab in the Bering Sea groundfish trawl fisheries
3. Development of new fishery closure areas for areas identified as important for juvenile snow crabs
4. Development of new fishery closure areas for areas identified as important for mature female snow crabs
5. Development of new fishery closure areas containing areas identified as important for both juvenile and mature female snow crabs; specifically, close waters north of 59° 30' N to bottom trawling.

The main goal of creating a closed area would be to protect snow crab habitat necessary to promote the rebuilding of the stock. Existing data was analyzed to determine the benefits to the stock of closing areas to bottom trawling. Existing information on the effects of trawling on the sea floor and the extent and intensity of trawling in the areas of concern was included in the analysis.

It was noted that details on the physical and biological characteristics of these areas that may make them important as habitat for juveniles and mature females – and the distribution of such characteristics within these areas – remain unknown. Without further research, it is not known why juveniles and mature females are more abundant in these areas or what the bottom type provides in terms of protection and food. The surficial sediments of these areas, like most of the Eastern Bering Sea continental shelf, have been characterized as mud, sandy mud or, muddy sand (Naidu 1988 cited in Smith and McConnaughey 1999).

Fishing is the only human activity that occurs in these areas and bottom trawling is the only fishing activity that could disrupt crab habitat. Bottom trawling can effect changes in bottom habitat through plowing of the sea floor, resuspension of sediments, and reducing habitat complexity (Vining et al. 1997). Most research shows that bottom trawling does not significantly damage mud or sandy mud bottom types (Auster and Langton 1999), although where currents are weak (e.g., at depths > 100-m), troughs caused by trawl doors may last for months or even years. Nonetheless, there was no specific information available to the analysts on what effect bottom trawling or any other fishing activities may have on the areas identified as important for juveniles or mature female snow crabs.

Plots of bottom trawl intensity in the eastern Bering Sea based on observer data (**Figure 37C**) indicate that the intensity of bottom trawling is very low in the important areas. Additionally, analysis of catch-per-unit-effort, length, and depth distributions of major groundfish species in the Bering Sea show that these are areas of marginal trawl effort (Fritz et al 1998). Likewise, observed bycatch of snow crabs in the important areas for juveniles and matures females has been low.

Based on this analysis, the analysts could not conclude that the areas identified as important for juveniles or mature female snow crabs need protection from fishing activities. The characteristics of these areas that make them important to snow crabs are not known and available information indicates that the prevailing bottom type is not vulnerable to destruction by fishing. Moreover, it is difficult to argue that the current low stock levels of Bering Sea snow crab is attributable to habitat loss when the stock has recovered from drops to similarly low levels of abundance in the recent past. For these reasons, options involving closure of areas to trawling or other fishing activities were not pursued as a component of this rebuilding plan.

Bycatch caps, particularly in fisheries that use gear that is potentially destructive to habitat, may be the most effective means to protect the habitat of stocks from fishery impacts when habitat requirements and vulnerability are poorly understood. Bycatch caps can serve to decrease effort in areas of good habitat (as indicated by high densities of the protected species) without burdening other fisheries with overly protective exclusion zones. The analysts suggest that bycatch trends be closely monitored in the future to determine if current PSC limits are negatively affecting stock recovery. In that regard, trawl bycatch staying below 0.1133% of the total snow crab population would be preferable to the 4.5 million floor when stocks are low.

Some portion of the snow crab stock is protected from trawling impacts by existing closure areas. The average distribution over the past three surveys is shown in the adjacent table. Analysis indicates that on average 4.8 % of the total stock is distributed within the trawl closure areas. Closure areas were a more protective of large males than other groups, at least during summer months in recent years. The Red King Crab Savings Area and the Nearshore Bristol Bay closure area contribute little protection for snow crab, however, the Pribilof Islands Conservation area is used by mature male snow crabs. Although most (67.6%) snow crab are

Table 1.6.1. Percentage distribution of eastern Bering Sea snow crab within year-round bottom trawl closure areas; average 1997 - 1999 NMFS surveys. Males > 77 mm and females > 49 mm in carapace width are used to represent mature crab.

Zone/area	**Males > 77 mm**	**Male Total**	**Females > 49 mm**	**Female Total**	**Species Total**
B.B Nearshore	0.2	0.1	0.0	0.0	0.0
RKC Savings	0.9	0.9	0.0	0.0	0.4
Pribilof closure	14.8	8.6	1.8	1.1	4.3
Total w/in closures	**15.9**	**9.6**	**1.8**	**1.1**	**4.8**
Outside Zone 1&2	*52.1*	*69.0*	*63.0*	*66.8*	*67.6*
Outside COBLZ	*10.4*	*7.3*	*4.1*	*2.4*	*4.4*

found outside the *bairdi* bycatch zones 1 and 2, very few (4.4%) are found outside the C. opilio bycatch limitation zone.

At present, there are no indications that human activities in the BS/AI area have had any measurable effect on the existing habitats of snow crab. The present primary human use of the offshore area is commercial fishing. While the establishment of other activities could potentially generate user conflicts, pollution, and habitat deterioration, most scientists consider that the status of the habitat in this management area is generally unaffected by other human activities at this time. Activities that could adversely affect habitat in this area, as discussed in the crab FMP include: offshore petroleum production, coastal development and filling, marine mining, ocean discharge and dumping, litter, benthic habitat damage, and discharge of wastes.

Given the current status of snow crab, it seems reasonable that the importance of snow crab EFH in maintaining stock productivity should be a priority message contained in consultations on any proposed activities. To the extent feasible and practicable, this area should be protected from adverse impacts, at least until such a time as the stock is above MSST.

1.7 Specification of the Rebuilding Time Period

In cases where a stock is overfished, Section 304(e)(4)(A) of the Magnuson-Stevens Act requires that Council action must specify a time period for stock rebuilding. Factors affecting the length of the rebuilding period include stock status and biology, interactions with other components of the ecosystem, and needs of fishing communities. The lower time limit for rebuilding is determined by the status and biology of the stock and its interactions with the marine ecosystem. It is defined as the amount of time that would be required for rebuilding if fishing mortality was eliminated entirely. If the lower limit is less than 10 years, it may be adjusted upward to 10 years if warranted to accommodate the needs of fishing communities. If the lower limit is 10 years or longer, the specified time period may be adjusted upward to accommodate needs of fishing communities within other constraints. The time period for rebuilding must be no longer than the expected rebuilding time in the absence of fishing plus the number of years corresponding to one mean generation time.

A length based simulation model was used to project the snow crab population starting from the 1999 survey population estimates. Five scenarios were used in the simulations:

1. Zero catch. No directed catch or bycatch from other crab fisheries or groundfish trawl until the population is rebuilt, then the new harvest strategy and trawl bycatch are applied.

2. Zero catch from directed fishery. Bycatch from groundfish trawl only until the population is rebuilt when the new harvest strategy is applied. Bycatch of 0.1133 % of the total number of crabs in the population with a minimum catch of 4.5 million crab and a maximum catch of 13.0 million crab. Mortality of bycaught crab was assumed to be 80%.

3. The new harvest strategy in a directed crab fishery, groundfish trawl bycatch as in scenario 2, and mortality of nonretained males and females in the directed fishery assumed to be 25%. If the estimated GHL is above 25 million lbs, then the directed fishery is opened, otherwise the fishery is closed for that year.

4. Status quo harvest policy. The directed fishery does not close if the mature biomass falls below one-half MSST. No minimum GHL. Catch is equal to 58% of the male crab over 102 mm cw. Other bycatch is equal to scenario 3.

5. Status quo harvest policy. The directed fishery closes if the mature biomass falls below one-half MSST. No minimum GHL. Catch is equal to 58% of the male crab over 102 mm cw. Other bycatch is equal to scenario 3.

Estimates of parameters such as selectivity values, molting probabilities and recruitments are not available because a full stock assessment model has not been developed at this time for snow crab. Equations used in the simulation are presented in **Table 13**. Survey selectivities have been estimated for Bering sea snow crab from trawl experiments (Somerton and Otto 1999), however, the current Bmsy and MSST values were estimated with survey selectivities assumed to be 1.0 for all sizes of crab. Survey selectivities in the simulations were assumed to be 1.0 for all sizes. Crab over 35 mm were included in the model. The fraction mature at size was estimated using a logistic function. The size at 50% mature for females was 45.4 mm with a slope of 0.28, for males the size at 50% mature was 77.9 mm with a slope of 0.054 (Otto 1998). Growth was modeled using a von Bertalanffy equation to estimate the mean width after molting given the current mean width,

$$\text{Width}_{t+1} = \text{linf}\ (1 - e^{-k}) + e^{-k}\ \text{width}_t$$

Linf was 180 mm and k was 0.125 for males and females estimated from regression equations in Otto (1998). Crab were assigned to 5mm width bins using a normal distribution with mean equal to the Width_{t+1} and variance (Quinn et al. 1998),

$$\text{var}\ iance_t = \frac{\sigma^2 (1 - e^{-k^{2t}})}{1 - e^{-k^2}} + e^{-k^{2t}} \sigma_r^2$$

σ^2 and σ_r^2 are parameters assumed to be 5.0 and 2.0, which result in a coefficient of variation for the mean length of about 0.07 to 0.1.

Natural mortality was assumed to be 0.3, which is the value used in estimating MSY and MSST levels. The number of crab in the 35 mm to 50 mm size groups from the 1980 to 1999 survey data were used to estimate the mean and variance of a lognormal distribution for simulation of recruits in the model. The parameters of the lognormal distribution were estimated by,

$$\mu = \log(mean\_recruitment) - \frac{\log(c.v.^2 + 1)}{2},$$
$$\sigma = \sqrt{\log(c.v.^2 + 1)}$$

Where c.v. is the coefficient of variation of recruitment μ was estimated as log(1.57 billion crabs) and the standard deviation was 0.759. Recruitments were generated from an autocorrelated lognormal distribution,

$$R_t = R^{1-\gamma} R_{t-1}^{\gamma} e^{\sigma\delta}$$

The autocorrelation coefficient, gamma was set at 0.73, which was the same value used in the Tanner crab rebuilding analysis. A value of gamma=0 would produce random recruits. A value of gamma=1.0 would produce a random walk, where the next recruitment is generated by using the last recruitment as the mean of the lognormal distribution. δ is a deviate from a normal distribution with mean 0 and standard deviation 1. Three recruitment scenarios were used in the simulation, 1) random recruitment (gamma=0), 2) autocorrelated recruitment (gamma=0.73) and 3) cyclic recruitment. The cyclic recruitment assumed recruitment was random at a low level for a random time period between 1 and 5 years at the beginning of the rebuilding simulation and then switched to a high recruitment for a random time period between 6 to 9 years then switched back to low recruitment for a random time between 3 and 5 years. Recruitments were drawn from a lognormal distribution where the mean was estimated from the lowest half of the observed recruitments for the low part of the cycle and using the highest half of the recruitments for the high part of the cycle.

Fishery selectivities were approximated by examination of the size of crabs caught from observer and dockside sampling. A logistic function was used to estimate selectivities. The size at 50% selected for retained males was 95 mm with a slope of 0.3. The female slope was 0.1 with 50% selected at 40 mm. The nonretained male selectivity curve was dome shaped, the ascending slope was 0.2 with 50% selected at 60mm, the descending side was equal to 1- selectivity of the retained males. Catch of nonretained males and females was estimated as a fraction of the retained male catch based on estimates from shellfish observer data from 1994 to 1998 (Tracy 1995, Boyle et al. 1996, 1997, Moore et al. 1998, Moore et al. 2000). The fraction for nonretained males was 0.67 of the retained male catch in numbers of crab and for females 0.0064 of the retained male catch. It was assumed that 25 % of the catch of nonretained males and females died as a result of handling mortality. Groundfish trawl bycatch was estimated as 0.1133 % of the total number of crabs with a minimum catch of 4.5 million crab and a maximum catch of 13.0 million crab. Selectivities were assumed to be 1.0 for all sizes for trawl bycatch.

Molting probabilities were estimated using a declining logistic function with 50% probability of molting at 45.4 mm for females, which is the same as the size at 50% mature, with a slope equal to the maturity curve slope. This approximates the terminal molt theory, resulting in crabs ceasing to molt after maturity. The male molting probabilities were estimated in the same way as females, with 50% molting at the size at 50% mature of 77.9 mm.

The population was considered rebuilt when the spawning biomass exceeded 921.6 million lbs in two consecutive years. For the zero catch harvest scenario(1) and the trawl bycatch only scenario (2), once the population was rebuilt the new harvest strategy was applied for the remainder of the time period. Each scenario was run for 2000 replications of 30 years for the random recruitment options and 40 years for the autocorrelated recruitment option. The resulting distributions of the probability of the rebuilding times are presented in **Figures 38 and 39.** Tmin is the time to reach 50% probability of rebuilding under scenario 1 (zero catch) (**Table 14**). The time to rebuild is highly dependent on the assumptions about future recruitments. Tmin was estimated at 7 years for the random recruitment option, 10 years for the autocorrelated recruitment option, and 8 years for the cyclic recruitment option. Tmax is equal to 10 years or Tmin plus one generation time, if Tmin is > 10 years. The generation time for snow crab is estimated to be 5.5 years. Tmax for the random recruitment option was 10 years and for the autocorrelated recruitment option, 15.5 years (10 years plus 5.5 years). The time to 50% rebuilding for all scenarios was less than Tmax for all recruitment options.

The time to 50% probability of rebuilding for the new harvest strategy was approximately one-half year longer than the zero catch scenario under any recruitment scenario. There was no difference in rebuilding times between the groundfish trawl bycatch scenario (2) and zero catch scenario (1) for all recruitment options.

The time to 50% probability of rebuilding was about one-half year longer for the status quo scenario (with no threshold and with a 230.4 million lb threshold) than for the new harvest policy with random and autocorrelated recruitment (**Figure 38**). The 50% probability of rebuilding for the status quo scenario with no threshold was about 0.3 years longer than the new harvest policy for the cyclic recruitment scenario.

The risk of the population falling to low levels (e.g. below one-half MSST) is important to consider in evaluating harvest strategies. For scenarios 3 and 5 the probability of going below one-half MSST is also the probability of a fishery closure. The probability that mature biomass is below one-half MSST (230.4 million lbs) was greater in the first five years (0.47) for the status quo scenario with no closure below one-half MSST, than the new harvest scenario (0.25) for the autocorrelated recruitment option. The probability that mature biomass is below one-half MSST is higher in the first few years of the rebuilding time period than the five year average (**Figures 40 through 42**). The probability of being below one-half MSST for the year 2000 with the status quo policy and no threshold was 0.72, and for the new harvest policy 0.43, for the autocorrelated recruitment option (**Figure 40**). For the random recruitment option the probability of being below one-half MSST for the year 2000 with the status quo policy and no threshold was 0.52 and for the new harvest policy 0.31 (**Figure 41**). The probability of being below one-half MSST for the cyclic recruitment option was 0.70 for the status quo with no threshold and 0.41 for the new harvest strategy. Mean yields during the first five years of rebuilding were higher for the status quo scenario than the new harvest scenario, due to closure of the fishery below one-half MSST and the 25 million lbs minimum GHL. The mean yields for the first 20 years are about 26% to 33% lower for the new harvest policy than the status quo. The mean yields for the first 10 years and first 20 years include the first few years of the rebuilding scenario when mean yields will be lower for the new harvest policy due to fishery closures. The mean yields are about 22% to 25% lower for the new harvest strategy than the status quo for the years after the stock is rebuilt for all recruitment options.

The larger commercial size of about 102 mm compared to the size at 50% mature of 78 mm for males results in a lower effect on the mature male biomass than if crabs of legal size (78 mm) were retained. Also, the low level of female bycatch results in little effect on the female spawning biomass from a directed fishery. High recruitments have been observed in the past, which have allowed the population to recover quickly from low levels of estimated spawning biomass. Past recruitments have been used to predict future recruitments, however, there is no guarantee that future recruitments will be the same as past recruitments.

Limits of model results due to lack of stock-recruitment component.

None of the recruitment models used in our analyses include any role for the effects of the spawning stock on future reproduction. That is, the recruitment models used here assume that recruitment to the stock proceeds as a random-independent, random-autocorrelated, or random-cyclic sequence without any influence from the magnitude or characteristics of the parent stock. Hence, these models do not allow for any feedback from the effects of management measures to future recruitment. The models used here may be adequate for modeling the short-term recovery of the stock, because the short-term stock dynamics will not be influenced by the present reproductive potential of the stock due to the time lag from spawning to recruiting. On the other hand, the models will not adequately represent any long-term effects due to harvesting mature males.

The lack of a stock-recruitment component in the models reflects the inability of the analysts at the current time to specify a model relating spawning stock conditions to future recruitment, rather than any conclusion on the part of the analysts that no such relationship exists. At present, no studies have been performed to identify and model the factors determining or influencing recruitment to the eastern Bering Sea snow crab stock. Physical-oceanographic factors probably have a strong influence on recruitment of snow crab in the eastern Bering Sea. Recruitment of the related *C. bairdi* in Bristol Bay, for example, is statistically related with fluctuations in water temperature and northeast winds and plausible hypothesis for the mechanisms that account for such relationships exist (Rosenkranz 1998, Rosenkranz et al. 1998). Biological factors that are unrelated to spawning stock size could also be important determinants of the strength of recruitment. In that regard, density-dependent cannibalism on early juvenile instars has been hypothesized to account for cycles of recruitment and population size of snow crab in Canada's Gulf of St. Lawrence (Lovrich and Sainte-Marie 1997, Sainte-Marie et al. 1996). The models used in the present analysis are appropriate for predicting population responses to random-independent or random-autocorrelated external forcing from the environment or to endogenous cyclic effects. Modeling effects of spawning stock on recruitment is not so easily accomplished, however, and insufficient time was available for the analysts to investigate such models. One problem for estimating the stock-recruitment model for eastern Bering Sea snow crab is the modeling of error under the assumption of a large environmental forcing or cyclic effects. The stock-recruitment relationship for Bristol Bay Tanner crab, for example, is best fit when modeled with either autocorrelated or cyclic error (Zheng and Kruse 1998). Identifying the appropriate lag time between mating and recruitment to the mature stock is another problem for estimating the stock-recruitment relationship for eastern Bering Sea snow crab. Additionally, problems remain in measuring spawning-stock size for a stock-recruitment model because of size-dependent survey catchability of snow crab (Somerton and Otto 1999). Complexities of snow crab reproductive biology – effects on reproductive performance of mature crab related to age, size, and shell age (Sainte-Marie 1993, Sainte-Marie et al. 1995, Sainte-Marie et al. 1997), for example – further complicate the identification of an appropriate index of spawning-stock size.

Given the nature of the recruitment models used here, any conservation benefits that may result from preservation of large male crabs within the spawning population through more conservative management, particularly when spawning stock is depressed due to extended periods of poor recruitment, will not be reflected in the model results. Although environmental effects may be important in effecting variation in recruitment and although the eastern Bering Sea snow crab fishery removes only the larger mature males from the stock, the possible effects on future recruitment due to the fishery should not be discounted. Relative to the snow crab stocks in the Gulf of St. Lawrence, for example, Sainte-Marie (1997, p. 498) argued that

"...although temporal heterogeneity of the environment may explain some measure of interannual variability in snow crab recruitment, ... it is certainly premature to discount the role of intrinsic or fishery-related fluctuations in the abundance of adult males for future stock condition."

Sainte-Marie (1997), for example, cited evidence for reduced or, even, abnormally low fecundity of females in exploited populations relative to virgin populations, which may possibly be attributed to "sperm limitation" resulting from insufficient numbers of large males (Sainte-Marie 1993). Orensanz et al. (1998) have also argued that size-limited, male-only crab fisheries can reduce per-capita reproductive contribution of females and, in fact, concluded that the declines of king and Tanner crab stocks in the Gulf of Alaska are attributable to overfishing. In that regard, it is important to note that the low stock levels seen for eastern Bering Sea snow crab during the 1999 survey were accompanied by indications of poor reproductive potential. Mature female snow crabs examined during the 1999 survey were barren at higher than normal rates and showed lower than normal rates of full clutches (see "Analysis of 1999 Survey Data" in Section 1.5.1.2 of this Rebuilding Plan). Sainte-Marie et al. (1995) also noted that high harvest rates on large mature males may also possibly impact reproductive potential of a stock by reducing the size of males available for breeding and cited circumstantial evidence of fishery-induced selection for reduced size or age at maturity in males. Any of these conservation concerns related to harvesting of large males would become more acute when stocks are low because of the greater impact of chance events at low stock levels.

So, important conservation consequences may result from different harvest rates applied to large males and those consequences would not be revealed in the model results for time to rebuilding or long term yield that are presented here. For that reason, equal attention should be paid to the model results for portion of years that the stocks are at a low spawning biomass as an index of relative conservation risks under the alternative harvest strategies.

1.8 Mechanisms for Monitoring Effectiveness of the Rebuilding Plan

Mechanisms are in place for monitoring the effectiveness of the rebuilding plan. The NMFS eastern Bering Sea bottom-trawl survey provides an annual assessment of the status of the eastern Bering Sea snow crab stock. ADF&G will use the results of that survey to determine openings and harvest. The annual survey will allow the BSAI Crab Plan Team to include an assessment of the snow crab stock status relative to the overfished level and its progress towards the rebuilt level in the Stock Assessment and Fishery Evaluation (SAFE) Report for the king and Tanner crab fisheries of the BSAI.

Programs exist within ADF&G and NMFS to contain levels of catch and bycatch at those prescribed in the rebuilding plan. Any catch or bycatch level that departs from that prescribed by the rebuilding plan can be assessed and will be reported in the SAFE. ADF&G will monitor catch and bycatch from the directed crab fishery and NMFS and ADF&G will monitor bycatch of snow crabs in other fisheries. Programs currently exist for reporting catch to ADF&G fishery managers during the directed crab fishery so that the harvest can be capped at the level prescribed by the harvest strategy. ADF&G currently has a dockside sampling program for monitoring landings during the commercial fishery to shoreside processors and an observer program for monitoring landings by floater-processor vessels and catcher-processor vessels. ADF&G reports the total harvest from the commercial fishery and that report will be included annually in the SAFE. The NMFS observer program provides the means by which bycatch of crabs can be monitored inseason and kept below the prescribed bycatch caps during the BSAI trawl groundfish fisheries.

The Alaska Board of Fisheries passed regulations in 1999 that allow for expansion of the state observer program for crab fisheries into the catcher-only vessel component effective July 2000. Coupled with the existing state program that provides for observer coverage on catcher-processor vessels, the expanded crab-fishery observer program will provide improved estimates of the bycatch of crabs that occurs during the crab fisheries. Estimates of bycatch in the groundfish pot and longline fisheries will be provided by the existing NMFS observer program and estimates of bycatch in the scallop fishery will be provided by the existing ADF&G program. Estimates of crab bycatch from all commercial fisheries will be reported annually in the SAFE and the BSAI Crab Plan Team will assess that bycatch relative to the expectations and assumptions of the rebuilding plan.

2.0 NEPA REQUIREMENTS: ENVIRONMENTAL IMPACTS OF THE ALTERNATIVES

The snow crab fisheries occur in the Bering Sea in the U.S. EEZ from 56° N to 65°N, concentrating between the 100 and 200 meter contour lines. Descriptions of the affected environment are given in the FSEIS for the groundfish fisheries (NMFS 1998). Substrate is described at section 3.1.1, water column at 3.1.3, temperature and nutrient regimes at 3.1.4, currents at 3.1.5, marine mammals at 3.4, seabirds at 3.5, benthic infauna and epifauna at 3.6, prohibited species at 3.7, and the socioeconomic environment at 3.10. The projections for fishing year 1999, as well as the status of the stocks and history of the fishery, are contained in the 1999 BSAI crab SAFE report (NPFMC 1999).

An EA is required by the National Environmental Policy Act of 1969 (NEPA) to determine whether the action considered will result in significant impact on the human environment. If the action is determined not to be significant based on an analysis of relevant considerations, the EA and resulting finding of no significant impact (FONSI) would be the final environmental documents required by NEPA. An environmental impact statement (EIS) must be prepared for major Federal actions significantly affecting the human environment. This section contains the discussion of the environmental impacts of the alternatives including impacts on threatened and endangered species and marine mammals.

The environmental impacts generally associated with crab fishery management actions are effects resulting from (1) harvest of crab stocks which may result in changes in food availability to predators and scavengers, changes in the population structure of target stocks, and changes in the marine ecosystem community structure; (2) changes in the physical and biological structure of the marine environment as a result of fishing practices, e.g., effects of pot gear use; and (3) entanglement/entrapment of non-target organisms in active or inactive fishing gear.

The rebuilding plan would reduce the environmental consequences of the snow crab fishery by possibly enacting the following: 1) prohibiting fishing some years, and 2) allowing fishing at a reduced harvest rate during other years. For the rebuilding plan, the Council may adopt the new harvest strategy for snow crab adopted by the Board in March 2000. The harvest strategy is intended to improve management of the snow crab fishery and improve long term stock productivity, as well as increase the probability of stock rebuilding. The harvest strategy will be implemented by ADF&G. The harvest strategy will close the snow crab fishery when abundance is low, allow a fishery at a reduced harvest level when abundance has increased, and a establish sustainable harvest rate, which is less that the status quo, when the stock is rebuilt.

2.1 Trophic Interactions

The marine food-web of North Pacific marine fishes are complex (Livingston and Goiney 1983). Numerous species of plankton, phytoplankton, invertebrates, mollusks, crustaceans, forage fish, demersal, mid-water, and pelagic fish, marine mammals, seabirds, and humans combine to comprise the food-web present in the BSAI and GOA. Environmental changes as well as human exploitation patterns can effect changes to trophic interactions. Fishing causes direct changes in the structure of benthic communities by reducing the abundance of target or by-catch species, then these reductions may lead to responses in non-target species through changes in competitive interactions and predator prey relationships. Indirect effects of fishing on trophic interactions in marine ecosystems may also occur. Current debates on these topics include comparing relative roles of "top down" (predator) or "bottom up" (environmental and prey) control in ecosystems and the relative significance of "donor controlled" dynamics (in which victim populations influence enemy dynamics but enemies have no significant effect on victim populations) in the food webs (Jennings and Kaiser 1998.)

Snow crab feed on an extensive variety of benthic organisms including bivalves, brittle stars, crustaceans (including other snow crab), polychaetes and other worms, gastropods, and fish. In turn, they are consumed by a wide variety of predators including bearded seals, Pacific cod, halibut and other flat fish, eel pouts, sculpins, and skates. Predators consume primarily age 0 and 1 juvenile snow crab less than 7 cm carapace width. Flathead sole, rock sole, and yellowfin sole are important predators in terms of numbers of small crab. Larval predators include salmon, herring, and jellyfish. The rate of cannibalism may be high among juvenile crabs.

Predation of crabs by groundfish removes large numbers of young snow crab. For snow crabs, estimates of annual consumption by groundfish from May through September ranged from 9 billion to 31 billion crabs (Livingston et al. 1993). Snow crabs consumed were primarily age 1, and to a lesser extent age 2 and 3 crabs. Pacific cod is a primary predator of snow crab, particularly softshell female and juvenile crab (Livingston 1989). Flathead sole, yellowfin sole, and rock sole also prey on young snow crabs (Livingston et al. 1993).

Predation of other crab species also occurs. Annual consumption of Tanner crabs by groundfish ranged from 10 billion to 153 billion crabs, consisting primarily of Age 0 and Age 1 crabs (Livingston et al. 1994). Yellowfin sole and flathead sole were found to be the primary consumers of small Tanner crabs, whereas Pacific cod preyed on the larger juveniles. Although yellowfin sole and Pacific cod are known predators of juvenile and molting red king crab (Livingston 1989), data suggest that mortality caused by groundfish predators on adult red king crab may be low during summer months. It has been estimated that Pacific cod consumed about 1.4% to 3.8% of the female red king crab stock during the early 1980's, which suggested to Livingston (1989), that these rates were not the major factor behind the Bristol Bay red king crab stock crash. In the late 1980's, consumption by Pacific cod was estimated at 3.8% to 14.3 % of the female red king crab stock (Livingston et al. 1994). Although it has been hypothesized that juvenile sockeye salmon may impact recruitment of red king crab in Bristol Bay, subsequent analysis has failed to support this theory (Tyler and Kruse (1996).

Crab predators and competitors have been at relatively high levels through the 1980's and 1990's. Biomass of crab competitors (inshore benthic infauna consumers such as starfish and flatfish) increased about 40% from 1979-1993 (Livingston et al. 1994). 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, and to a lesser extent a decrease in average bottom temperature (Livingston et al. 1994).

Popular opinion has been that predation by groundfish has been a major source of natural mortality for juvenile and molting crabs in the Bering Sea, particularly in years of high abundance of predators. Competition with groundfish may also lead to slower growth, as well as reduced resistance to disease and predation. A recent analysis concluded that changes in Bering Sea crab and groundfish populations were not related (Kruse and Zheng 1999). That is, it does not appear from statistical analysis that groundfish predation caused declines in crab populations. To better illustrate this for snow crabs, Kruse and Zheng (1999) noted that although snow crabs are heavily preyed upon by Pacific cod, strong year classes of snow crabs co-occurred with high cod biomass resulting in positive correlations.

None of the Alternatives or options considered in this analysis would be expected to significantly alter the trophic interactions in the Bering Sea beyond the natural variability of the ecosystem.

2.2 Impacts on Habitat

Inclusively all the marine waters and benthic substrates in the management areas comprise the habitat of all marine species. Additionally the adjacent marine waters outside the EEZ, adjacent State waters inside the EEZ, shoreline, freshwater inflows, and atmosphere above the waters, constitutes habitat for prey species, other life stages, and species that move in and out of, or interact with, the fisheries' target species, marine mammals, seabirds, and the ESA listed species.

This section contains analyses of potential fishing gear impacts on benthic substrate attributable to the snow crab fishery. The habitat impacts of the snow crab fishery will not increase due to this proposed action because the proposed action does not increase the amount of crab harvested or change the location of the fishery. In fact, under the rebuilding plan harvest strategy, the fishery will have no habitat impacts in the years that the fishery is closed and will have a decreased habitat impacts when the harvest level is reduced. Further, once the stock is rebuilt, the new harvest strategy will ensure that the harvest rate remains below the status quo harvest rate. Summaries and assessments of habitat information for BSAI king and Tanner crab are provided in the "Essential Fish Habitat Assessment Report for the Bering Sea and Aleutian Islands King and Tanner Crabs" dated March 31, 1998 (available from the NPFMC).

2.2.1 Direct Impacts of Fishing Gear on Habitat

Pot Gear

The snow crab fishery uses pot gear. This gear type likely affects habitat during setting and retrieval of pots; however, no research quantifying the impacts has been conducted to date. Whatever the direct effects of setting and pulling pot gear on the benthic environment, they appear to be small in comparison to the potentially large-scale effects of "ghost-fishing" by derelict pots. Lost by the fishery, these pots may continue to entrap animals until their netting or escape panels disintegrate. Inasmuch as they are unbaited, the primary attraction of derelict pots is their physical structure, which adds complexity and vertical relief to a generally featureless environment. No additional pot loss is expected under the proposed action. Under the rebuilding plan, no pot loss will occur in years when the fishery is closed.

Like other fisheries, pot fisheries incur some bycatch of incidental fish and crab. Bycatch in crab pot fisheries includes crabs, octopus, Pacific cod, halibut, and other flatfish (Tracy 1994). Crab bycatch in the snow crab fishery includes females of target species, sublegal males of target species, and non-target crabs, primarily Tanner crab. Section 3.1.2.3 of the groundfish FSEIS (NMFS 1998) provides a detailed description of the impacts of pot gear on the seas floor. Section 4.2 of this document provides a detailed description of bycatch in the snow crab fishery and bycatch of snow crab in other fisheries.

Trawl Gear

Options considered under Alternative 2 could reduce bottom trawl effort targeting flatfish in particular, so any potential impacts to bottom substrates would be reduced. Nevertheless, fisheries for these flatfish species occurs on soft bottom (sand/silt/mud). These impacts would be minimal relative to trawling on hard bottom or living substrates (see literature reviews in the EFH analysis: NPFMC 1999).

Some general conclusions drawn from studies of trawling worldwide can be applied to Alaska. Actions that affect one species adversely may benefit another species. In a review of 22 studies worldwide, Auster and Langton (1999) found that despite their wide geographic range, from tropical to boreal, all studies showed similar classes of impacts. They found that mobile fishing gear reduced habitat complexity in three ways: (1) the epifauna is removed or damaged; (2) sedimentary bedforms are smoothed and bottom roughness is reduced, and (3) taxa are removed which produce structure, including burrows and pits. These findings are consistent with the findings of the studies in the North Pacific detailed above. Also applicable to the Alaska situation is the idea that environmental variables, including the make-up of the bottom, depth of the water column, oxygen content in bottom layers (Krost 1993), and natural wind stress (Riemann and Hoffman 1991), will play a role in determining the severity and direction of impacts.

In order to study the long-term effects of trawling on the benthos in the eastern Bering Sea, in 1996 a study was conducted on megafauna populations in a shallow, soft-bottom area of the eastern Bering Sea (McConnaughey et al., 1999). The researchers collected samples of 92 taxa at 84 shallow (48-m average), soft-bottom, heavily fished sites, each one square nautical mile in size, and all straddling the boundary of a closed area, Crab and Halibut Protection Zone 1. The following generalizations were drawn from running multi- and univariate statistical tests and examining raw patterns in the data: (1) sedentary megafauna (e.g., anemones, soft corals, sponges, whelk eggs, ascidians), neptunid whelks and empty shells were more abundant in the unfished (UF) area; (2) mixed responses were observed in motile groups (e.g., crabs, sea stars, whelks); and (3) overall diversity and niche breadth of sedentary organisms (e.g., sponges, anemones, soft corals, stalked tunicates) indicates that long-term exposure to bottom trawling, at least in the experimental area, reduces diversity and increases patchiness of this epibenthic community. Some of the physical effects of trawling, and their potential impacts on the North Pacific, are discussed in more detail below:

Resuspension of sediments

Trawling an area kicks up both inorganic and organic sediments, contributing significantly to the average suspended sediment load in the trawled area, especially at depths where bottom stress due to tidal and current action is weak (Churchill 1989). Compared to the Gulf of Alaska, the Bering Sea has relatively weak currents but relatively strong tidal action, accounting for up to 95% of all flow as deep as 200 m. Unlike the Gulf of Alaska, which has a greater variety of bottom types, the Bering Sea has a bottom mostly comprised of sand and mud.

Sediment resuspension can have a long-term effect on benthic communities. An increase of sediment reduces light levels on the seabed, can smother the benthos when it resettles, create anaerobic conditions near the seabed, and reintroduce toxins that may have settled out of the water column (Churchill 1989, Jones 1992, Messieh et al. 1991). Sediment resuspension may also have the beneficial effect of enhancing the food supply to the water column (Churchill 1989). Effects both beneficial and negative would probably be greater in the deep ocean where the bottom is relatively unaffected by natural disturbances, but minimal in areas with significant current or tidal transport, because organisms in such areas are adapted to such events (International Council for the Exploration of the Sea 1988, Jones 1992). The eastern Bering Sea with its winter storms, whose effects are in some ways similar to that of trawling, falls in the latter category, especially in the shallower areas.

The resuspension of sediments can lead to a recomposition of the ocean floor, in an effect called winnowing. In winnowing, small particles which are resuspended by a trawl pass may move with the currents to another area instead of resettling, so that the texture of the bottom coarsens. Again, areas subject to storm activity may naturally experience this phenomenon, so that trawling would not make much difference, especially in shallower waters. But in waters at a depth exceeding storm-related effects, the resuspension caused by trawls could have a stronger impact on the composition of the bottom.

Alteration of the seabed due to contact with the gear

The extent to which the gear penetrates the substrate depends on the makeup of the bottom, the speed with which the gear is being towed, the strength of tides and currents, the gear configuration, and the component of the gear encountered. Otter trawl doors can penetrate the substrate as little as 1 cm, on sand and rock substrata, or as much as 30 cm in some mud strata (Jones 1992). Heavier doors create deeper troughs.

The length of time that the benthic troughs last is also variable. In sand or mud substrata with strong tidal action or currents, the troughs can be washed away within a few hours or days (Caddy 1973, Jones 1992). But in very deep seabeds (deeper than 100 m) with weak currents and a mud or sandy-mud substrate, the troughs can last for much longer, from a few months to over five years (Brylinsky et al. 1994, Jones 1992, Krost et al. 1990). The impacts can vary depending upon the scale of the fishery (Thrush et al. 1998).

While trawl doors cause the most intensive effects over relatively narrow paths (< 3 m wide), the sweeps and footropes may have a more profound effect on the environment, as they impact a much larger area, due to their greater width (Jones 1992, Kaiser and Spencer 1996b, Reise 1982). Different types of footropes cause different levels of disruption. Footropes designed to skim over the seafloor, which are typically used in the BSAI on soft bottoms, cause little physical alteration aside from smoothing of the substrate and minor compression. However, if the area is trawled repeatedly, by the same vessel or different vessels, the cumulative effect of these minor compressions can cause a "packing" of the substrate (Schwinghammer et al. 1996). This packing effect can be further exacerbated when the net fills up and the codend is dragged along the bottom.

Alteration of species mix

The survival of benthic organisms in the path of trawl gear is also very variable. Factors include the species, age, and size of the organism, type of gear, component of gear encountered, size of the haul, substrate morphology, and ocean conditions. The sedentary organisms living in the upper 5 cm of the seabed are especially vulnerable (Rumohr and Krost 1991). Thin-shelled bivalves and starfish tend to sustain heavy damage from the trawl doors, while thick-shelled bivalves are less likely to be damaged. Diatoms, nematodes and polychaetes have been found to be affected by the passage of trawls (Brylinsky et al. 1994). Hard-shelled red king crab seem to fare better; in one experiment the crab were tethered in the path of an Aleutian combination trawl, and only 2.6% of the crabs that interacted with the trawl, but were not retained, were injured (Donaldson 1990). In another experiment, an estimate was made of the rate of injuries sustained by red king crabs passing under three types of bottom trawl footropes commonly used in the bottom trawl fisheries of the eastern Bering Sea. Injury rates of 5%, 7% and 10% were estimated for crab passing under the three types of commercial footropes (Rose in press).

Some studies have found that recolonization in disturbed habitat can occur over a relatively short period. Brylinsky et al. (1994) found that nematodes and polychaetes returned to their pre-trawled levels in less than seven weeks, and diatoms increased in abundance in trawl troughs within 80 days; in a study by Rumohr and Krost (1991), small epibenthic species recovered to pre-trawl densities in 24 hours.

Several studies have observed increases in scavenging in the wake of beamtrawls. These short-term changes in individual species distribution, however, are not likely to affect the ecosystem in any profound sense. The more important question is whether bottom trawl fishing causes long-term changes in the benthic community structure. Intensive fishing in an area can possibly result in such changes by promoting populations of opportunistic fish species that migrate into fished areas in order to feed on animals that have been disturbed in the wake of a trawl tow (Caddy 1973, Kaiser and Spencer 1994, 1996a).

Cumulative and long-range effects from bottom trawl gear

Some evidence exists that the effect of trawling on both bedforms and invertebrates who live on them is cumulative. Some studies (e.g., Prena et al. 1999) indicate that invertebrate "habitat organisms" become more patchy and decrease in abundance with multiple trawls. The smoothing caused by multiple trawls removes patchy biogenic depressions, which are important habitat features for juvenile fish. It also moves boulders, which are an important characteristic in the GOA, but not the Eastern Bering Sea. Multiple trawls in an area also pack down the substrate and reduce its complexity, which is likely to reduce the exchange capacity and may lead to less species diversity (Jones 1992, Kaiser and Spencer 1996b, Reise 1982). The probability of a particular spot being dragged over by a full net might also increase in a densely trawled area. Finally, multiple trawls in an area could increase the cumulative effect of the winnowing phenomenon described above.

Studies of the long-range effects of trawling are in their early stages. In their review of trawl studies, Auster and Langton (1999) caution that it is not easy to characterize the long-term effects of fishing on the benthic community structure. The authors write: "The pattern that does appear to be emerging from the available literature is that communities that are subject to variable environments and are dominated by short-lived species are fairly resilient. Depending on the intensity and frequency of fishing, the impact of such activity may well fall within the range of natural perturbations. In communities that are dominated by long-lived species in more stable environments, the impact of fishing can be substantial and longer term."

Little work has been done showing a direct connection between the effects of trawling on habitat complexity and the population of managed fish. None has been done in the North Pacific. A study in western Australia (Sainsbury 1988) concluded that alteration of the area of different types of habitat would be likely to alter community composition. This conclusion was based on an analysis of the catch per unit effort of certain fish species in the paths of photographed trawl paths which had classified into habitat types by cluster analysis of the presence and approximate size of the epibenthic fauna in each photograph.

More research is needed in three areas, according to Auster and Langton: (1) the spatial extent of fishing-induced disturbances; (2) the effects of specific gear types, along a gradient of effort, on specific habitat types; and (3) the role of seafloor habitats in the population dynamics of fishes. A fourth area of needed research involves investigating the life histories of affected non-commercial invertebrates, their relationships to one another, and to managed stocks of fish and shellfish. Little is known about these invertebrates. Until more is known, it is difficult to judge the affects of observed reductions in diversity and structural heterogeneity on the mortality, growth, and recruitment rates of important species.

2.2.2 Impacts on Essential Fish Habitat

Section 303(a)(7) of the Magnuson-Stevens Act requires all FMPs to describe and identify EFH , which it defines as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." In addition, FMPs must minimize effects on EFH caused by fishing and identify other actions to conserve and enhance EFH. Groundfish and snow crab fisheries occur within essential fish habitat (EFH) for a number of fish and invertebrate species. In the Bering Sea, EFH includes those identified for pollock, Pacific cod, many flatfish species, other groundfish species, red king crab, Tanner crab, and snow crab. Additional information on EFH can be found in the EA for Amendments 55/55/8/5/5 (NPFMC 1999 - copies of this document can be obtained from the Council office upon request). Actions taken to protect snow crab habitat could potentially benefit groundfish and other crab stocks in the area. None of the proposed alternatives would affect areas identified as habitat areas of particular concern.

Given the current status of snow crab, it seems reasonable that the importance of snow crab EFH in maintaining stock productivity should be a priority message contained in consultations on any proposed activities. To the extent feasible and practicable, this area should be protected from adverse impacts. The interim final rule for EFH states the following in the case of an overfished stock: *"If a species is overfished, and habitat loss or degradation may be contributing to the species being identified as overfished, all habitats currently used by the species should be considered essential in addition to certain historic habitats that are necessary to support rebuilding the fishery and for which restoration is technologically and economically* *feasible. Once the fishery is no longer considered overfished, the EFH identification should be reviewed, and the FMP amended, if appropriate."* Therefore, EFH for BSAI Tanner crab should be considered as all habitats used by this stock, at least until such a time as the stock is above MSST. Additional and updated information on snow crab habitat was provided in this analysis.

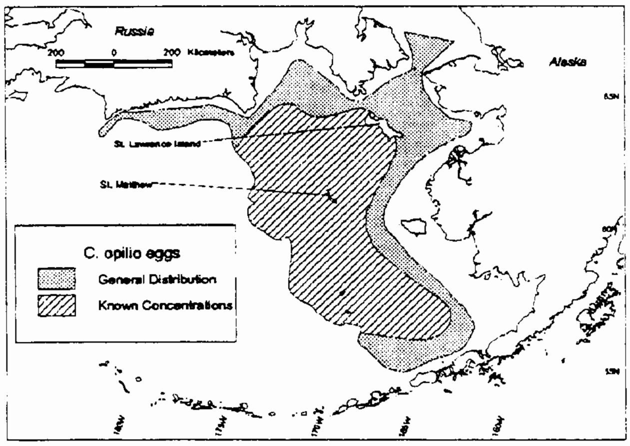
The snow crab fishery occurs in the Bering Sea, concentrating in the region between the 100 meter and 200 meter contour line, north of 58°N. lat and south of 60°N. lat. According to the EA for Amendment 8 to Crab FMP, it is reasonable to assume that the snow crab fisheries may impact the EFH of the following species: yellowfin sole, Greenland turbot, arrowtooth flounder, rock sole, Alaska Place, flathead sole, sablefish, northern rockfish, dusky rockfish, skates, sculpins, golden king crab, scarlet king crab, Tanner crab, and Triangle Tanner crab. Insufficient data exists to determine the extent of the impacts on EFH, beyond the fact that the snow crab fishery occurs in the species general distribution. No evidence suggests that the snow crab fishery impacts the EFH of salmon. The Tanner crab fishery does not occur on any areas designated as Habitat Areas of Particular Concern (HAPC). This proposed action will not change the location of the snow crab fishery.

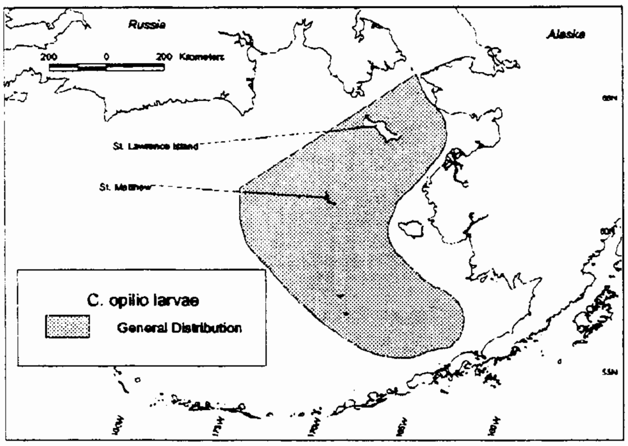
The rebuilding plan reduces the harvest rate from status quo and provides for decreased harvest if the stock is below the minimum stock size threshold and provides for no fishing when the stock is at very low levels of abundance. The action proposed by this regulatory amendment will not increase the amount of harvest, the intensity of harvest, or the location of harvest, therefore, this action is presumed not to increase the impacts of the fishery to EFH. Based on the above, this action, in the context of the fishery as a whole, will not adversely affect EFH for species managed under the five North Pacific FMPs. As a result of this determination, an EFH consultation is not required.

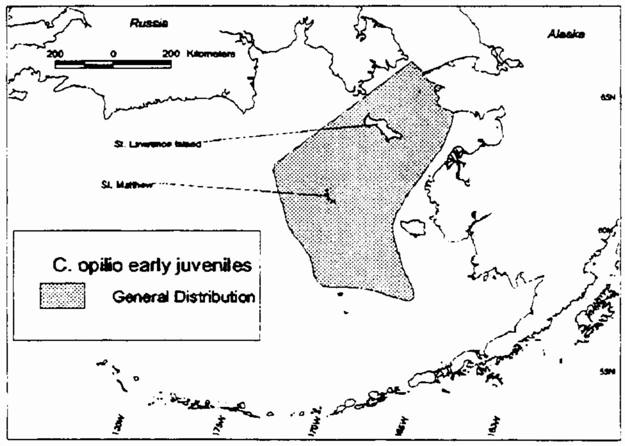
On January 20, 1999, the Council's five FMPs (BSAI and GOA groundfish, salmon, crab, and scallops) were amended to incorporate EFH provisions. These provisions included identification and description of EFH including habitat areas of particular concern, identification of research and information needs, and identification of potential adverse effects on EFH due to fishing and non-fishing activities. Additional information on EFH can be found in the EA for Amendments 55/55/8/5/5 (NPFMC 1999 - copies of this document can be obtained from the Council office upon request). The EFH definitions adopted for snow crab life stages are listed below.

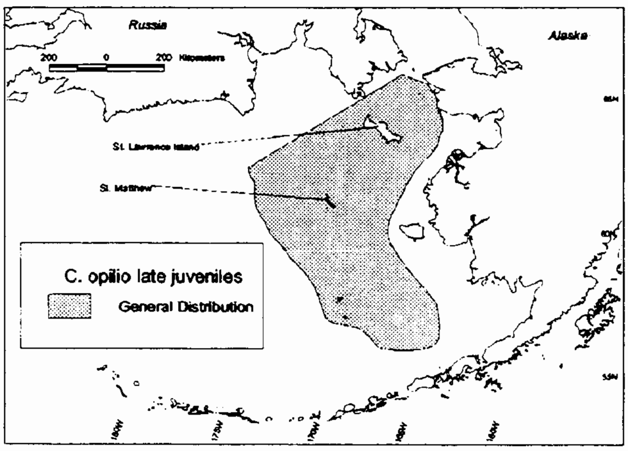
Egg - Level 2 See Mature. Essential habitat for eggs is known for the stocks of *C. opilio* snow crabs in the Eastern Bering Sea based on general distribution (level 1) and density (level 2) of egg bearing female crabs.
Larvae - Level 1 Larvae of *C. opilio* snow crab are found in early summer and exhibit diel migration. The last of 3 larval stages settles onto bottom in nursery areas. Essential habitat is based on general distribution (level 1) of *C. opilio* snow crab larvae of the Eastern Bering Sea stock.
Early Juvenile - Level 1 Shallow water areas of the Eastern Bering Sea are considered nursery areas for *C. opilio* snow crabs and are confined to the mid-shelf area due to the thermal limits of early and late juvenile life stages. Essential habitat is identified as the general distribution (level 1) of early juvenile crabs of the Eastern Bering Sea stock of *C. opilio* snow crabs.
Late Juvenile - Level 2 A geographic cline in size of *C. opilio* snow crabs indicates a large number of morphometrically immature crabs occur in shallow waters less than 80 m. Essential habitat is based on the general distribution (level 1) and density (level 2) of juvenile crabs of the Eastern Bering Sea stock of *C. opilio* snow crabs.
Mature - Level 2 Female *C. opilio* snow crabs are acknowledged to attain terminal molt status at maturity. Primiparous female snow crabs mate January through June and may exhibit longer egg development period and lower fecundity than multiperous female crabs. Multiparous female snow crabs are able to store spermatophores in seminal vesicles and fertilize subsequent egg clutches without mating. At least two clutches can be fertilized from stored spermatophores, but the frequency of this occurring in nature is not known. Females carry clutches of approximately 36,000 eggs and nurture the embryos for approximately one year after fertilization. However, fecundity may decrease up to 50% between the time of egg extrusion and hatching presumably due to predation, parasitism, abrasion or decay of unfertilized eggs. Brooding probably occurs in depths greater than 50 m. Changes in proportion of morphometrically mature crabs by carapace width have been related to an interaction between cohort size and depth.

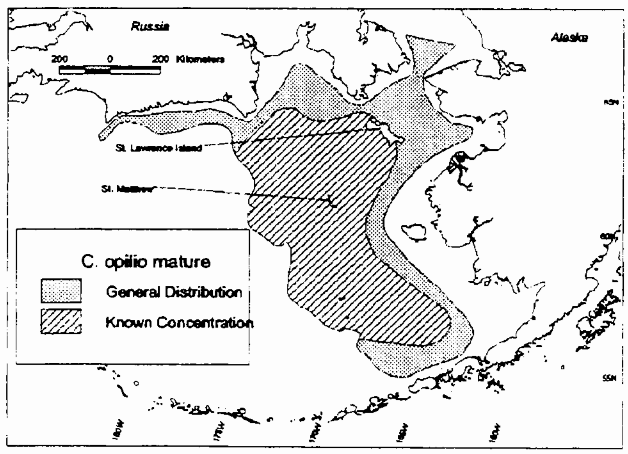
EFH Maps for snow crab by life history stage are shown in the adjacent figures.











2.3 Biological Diversity

The concept of biological diversity is generally used to denote the variety of living things in an ecosystem. The definition of biological diversity considers three levels: genetic, species, and ecosystem diversity. There is potential for other ecological impacts of this proposal. Reduced bottom trawl and crab pot effort may result in reduced unobserved mortality on fish, crabs, and other benthic organisms. This issue, and other potential ecological effects of trawling and pot fishing, has been thoroughly discussed in previous analyses (e.g., EFH amendment analyses, NPFMC 1999, Livingston 1999).

Adoption of Alternative 2 is expected to allow the Bering Sea Snow crab stock to rebuild to the Bmsy level within 10 years. Adoption of the revised harvest strategy should result in more spawning biomass as more larger male crab would be conserved. This higher spawning biomass would be expected to produce good year-classes when environmental conditions are favorable. Protection of habitat and/or reduction of bycatch would be expected to reduce mortality on juvenile crabs, allowing a higher percentage of each year-class to contribute to spawning (and future landings). Any or all of these actions proposed under Alternative 2 would be expected to improve the status of this stock, thus promoting biological diversity.

2.4 Bycatch Impacts

Analysis of PSC limits for groundfish trawl fisheries indicates that bycatch of snow crab in groundfish fisheries in small relative to total abundance. Bycatch mortality due to groundfish fisheries has ranged between 1.2 million and 9.9 million crabs during the 1994-98 period. This equates to a very low percentage (0.1%) of the total snow crab stock. From a mortality standpoint, this is lower than mortality associated with other groundfish fishery PSC species such as herring (1%), halibut (1.3% trawl and longline combined), chum salmon (<1%), red king crab (0.1%), tanner crab (1.0%), and chinook salmon (2%-4%) (Witherell et al., 2000).

The option to reduce the snow crab limit would maintain tighter control on the allowable bycatch, particularly when the stock is at low levels. However, because bycatch mortality caused by trawl fisheries is small relative to other sources of mortality, reductions in bycatch limits may not result in measurable improvements to crab stock abundance. Witherell and Harrington (1996) evaluated alternative measures to reduce the impacts of trawling and dredging on BSAI crab stocks, and concluded that a reduction in bycatch limits would conserve some crab, but would have little overall impact on crab stocks.

2.5 Endangered Species Act Considerations

The Endangered Species Act of 1973 as amended (16 U.S.C. 1531 *et seq*; ESA), provides for the conservation of endangered and threatened species of fish, wildlife, and plants. The program is administered jointly by the NMFS for most marine mammal species, marine and anadromous fish species, and marine plant species and by the USFWS for bird species, and terrestrial and freshwater wildlife and plant species.

The designation of an ESA listed species is based on the biological health of that species. The status determination is either threatened or endangered. Threatened species are those likely to become endangered in the foreseeable future [16 U.S.C. § 1532(20)]. Endangered species are those in danger of becoming extinct throughout all or a significant portion of their range [16 U.S.C. § 1532(20)]. Species can be listed as endangered without first being listed as threatened. The Secretary of Commerce, acting through NMFS, is authorized to list marine fish, plants, and mammals (except for walrus and sea otter) and anadromous fish species. The Secretary of the Interior, acting through the USFWS, is authorized to list walrus and sea otter, seabirds, terrestrial plants and wildlife, and freshwater fish and plant species.

In addition to listing species under the ESA, the critical habitat of a newly listed species must be designated concurrent with its listing to the "maximum extent prudent and determinable" [16 U.S.C. § 1533(b)(1)(A)]. The ESA defines critical habitat as those specific areas that are essential to the conservation of a listed species and that may be in need of special consideration. Federal agencies are prohibited from undertaking actions that destroy or adversely modify designated critical habitat. Some species, primarily the cetaceans, which were listed in 1969 under the Endangered Species Conservation Act and carried forward as endangered under the ESA, have not received critical habitat designations.

Federal agencies have an affirmative mandate to conserve listed species (Rohlf 1989). One assurance of this is Federal actions, activities or authorizations (hereafter referred to as Federal action) must be in compliance with the provisions of the ESA. Section 7 of the Act provides a mechanism for consultation by the Federal action agency with the appropriate expert agency (NMFS or USFWS). Informal consultations, resulting in letters of concurrence, are conducted for Federal actions that have no adverse affects on the listed species. Formal consultations, resulting in biological opinions, are conducted for Federal actions that may have an adverse affect on the listed species. Through the biological opinion, a determination is made as to whether the proposed action poses "jeopardy" or "no jeopardy" of extinction to the listed species. If the determination is that the action proposed will cause jeopardy, reasonable and prudent alternatives may be suggested which, if implemented, would modify the action to no longer pose the jeopardy of extinction to the listed species. These reasonable and prudent alternatives must be incorporated into the Federal action if it is to proceed. A biological opinion with the conclusion of no jeopardy will contain an incidental take statement if a likelihood exists of any taking[1] occurring during promulgations of the action. The incidental take statement is appended to a biological opinion and provides for the amount of take that is expected to occur from normal promulgation of the action. An incidental take statement is not the equivalent of a permit to take. Further, if incidental take is expected, then reasonable and prudent measures are specified that are necessary or appropriate to minimize the impact of the take (50 CFR 402.14(i)). A biological opinion with the conclusion of no jeopardy may contain a series of conservation recommendations intended to further reduce the negative impacts to the listed species. These management measures are advisory to the action agency (50 CFR 402.14(j)).

The regulations state: "Re-initiation of formal consultation is required and shall be requested by the Federal agency or by the Service, where discretionary Federal involvement or control over the action has been retained or is authorized by law and: (a) If the amount or extent of taking specified in the incidental take statement is exceeded; (b) If new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; (c) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion; or (d) If a new species is listed or critical habitat designated that may be affected by the identified action." (50 CFR 402.16).

Currently, 10 marine species occur in the BSAI crab management area are listed as endangered or threatened under the ESA. The group includes seven great whales, one pinniped, two seabirds, and one albatross. NMFS is the expert agency for ESA listed marine mammals. The USFWS is the expert agency for ESA listed seabirds.

[1] the term "take" under the ESA means "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct" [16 U.S.C. § 1538(a)(1)(B)].

Table 2.5.1 Species listed as endangered or threatened under the ESA and occur in the BSAI crab management areas.

Common Name	Scientific Name	ESA Status
Northern Right Whale	*Balaena glacialis*	Endangered
Bowhead Whale	*Balaena mysticetus*	Endangered
Sei Whale	*Balaenoptera borealis*	Endangered
Blue Whale	*Balaenoptera musculus*	Endangered
Fin Whale	*Balaenoptera physalus*	Endangered
Humpback Whale	*Megaptera novaeangliae*	Endangered
Sperm Whale	*Physeter macrocephalus*	Endangered
Short-tailed Albatross	*Diomedia albatrus*	Endangered
Steller Sea Lion	*Eumetopias jubatus*	Endangered and Threatened [1]
Spectacled Eider	*Somateria fishcheri*	Threatened
Steller's Eider	*Polysticta stelleri*	Threatened

[1] Steller sea lion are listed as endangered west of Cape Suckling and threatened east of Cape Suckling.

Section 7 Consultations. Because crab fisheries are federally regulated activities, any negative effects of the fisheries on listed species or critical habitat and any takings that may occur are subject to ESA section 7 consultation.

Seabirds:
In 1994, NMFS prepared a Biological Assessment for the king and Tanner crab FMP, which analyses the potential takes of listed seabirds in these fisheries and conducted an informal Section 7 consultation with USFWS. According to the Biological Assessment, the crab fisheries are not known to result in any significant impact to the short-tailed albatross, Steller's eider, or Spectacled eider. Nor do the fisheries compete for any crab species commonly preyed upon by marine birds. NMFS determined that the crab fisheries will have no adverse impact on any listed seabird nor will they delay in any way the recovery of those species, except the snow crab fishery which may adversely impact the Spectacled Eider.

Section 7 consultations have been made to determine the effects of the snow crab fishery on the spectacled eider. The snow crab fishery was the only crab fishery that NMFS and FWS determined through informal consultation had the potential to impact this species. Spectacled Eider (*Somateria fischeri*), a threatened seaduck, feed on benthic mollusks and crustaceans taken in shallow marine waters or on pelagic crustaceans. The marine range for spectacled eider is not known, although Dau and Kitchinski (1977) review evidence that they winter near the pack ice in the northern Bering Sea. Spectacled eider are rarely seen in U.S. waters except in August through September when they molt in northeast Norton Sound and in migration near St. Lawrence Island. The lack of observations in U.S. waters suggests that, if not confined to sea ice polyneas, they likely winter near the Russian coast (FWS 1993).

Since 1994, NMFS has consulted with the USFWS annually on the crab FMP, which includes the winter Bering Sea snow crab fishery, pursuant to section 7 of the ESA (FWS 1996a, 1996b). In the past, section 7 consultations on this fishery have been formal because it was perceived that the fishery was likely to adversely affect spectacled eiders. This perception of a likelihood of an adverse effect resulted from: (1) a lack of knowledge concerning the at-sea range of spectacled eiders and; (2) a lack of knowledge of the species of eiders that have struck, or were likely to strike crabbing vessels.

Beginning in 1995, observers aboard crabbing vessels received training in bird identification and reporting. Observers were instructed to report all sightings of spectacled eiders to the USFWS either directly or through ADF&G. To date, no take of spectacled eiders associated with this fishery has been reported.

Since the initial determination that this fishery was likely to adversely affect spectacled eiders, the USFWS has learned much about the at-sea distribution of spectacled eiders. Satellite telemetry data and 3 years of late winter aerial surveys indicate that spectacled eiders spend the winter in exposed waters between St. Matthew and St. Lawrence Islands, or in open leads slightly west of the inter-island area. Snow crab fishing has been largely concentrated around the Bering Sea continental shelf, which in the Bering Sea, runs from Unimak Island to the northwest, passing well south and west of St. Matthew Island. Crabbing occurs along the shelf because this is where the greatest snow crab concentrations occur, and not because of fishing ground access restrictions imposed by sea-ice conditions between January and March. Thus, even if sea ice conditions were to make it possible for crabbing vessels to venture into the waters used by wintering spectacled eiders, they would not likely do so, due both to the time and expense of vessels traveling that far and the relatively fewer number of snow crabs present there.

Crab fishery observers will continue to be placed aboard the catcher-processor vessels participating in this fishery, and in the future, these catcher-processor vessel observers will continue to receive training and refresher training in seabird identification and seabird reporting procedures.

Therefore, in 1998, USFWS concurred with NMFS's determination that the snow crab fishery is not likely to adversely affect threatened or endangered species under the jurisdiction of the USFWS, including the threatened spectacled eider (FWS 1998).

None of the alternatives under consideration would affect the prosecution of the crab fisheries of the BSAI in a way not previously considered in the above consultations. The proposed alternatives are designed to improve the effectiveness of the management of BSAI crab fisheries. None of the alternatives would affect takes of listed species. Therefore, none of the alternatives are expected to have a significant impact on endangered or threatened species.

2.6 Marine Mammal Protection Act Considerations

The king and Tanner crab fisheries in the Bering Sea/Aleutian Islands are classified as Category III fisheries under the Marine Mammal Protection Act. A fishery that interacts only with non-strategic stocks and whose level of take has an insignificant impact on the stocks is placed in Category III. An observer program has been in existence since 1988 for the Alaskan crustacean pot fisheries. No marine mammal species have been recorded as taken incidentally in the fisheries according to records that date back to 1990.

2.7 Coastal Zone Management Act

Implementation of each of the alternatives would be conducted in a manner consistent, to the maximum extent practicable, with the Alaska Coastal Management Program within the meaning of Section 30(c)(1) of the Coastal Zone Management Act of 1972 and its implementing regulations.

2.8 Conclusions or Finding of No Significant Impact

None of the alternatives for Amendment 14, a rebuilding plan for snow crab, are likely to significantly affect the quality of the human environment, and the preparation of an environmental impact statement for the proposed action is not required by Section 102(2)(C) of the National Environmental Policy Act or its implementing regulations.

______________________________ ______________________

Assistant Administrator for Fisheries, NOAA Date

3.0 ECONOMIC AND SOCIOECONOMIC IMPACTS OF THE ALTERNATIVES

This section provides information about the economic and socioeconomic impacts of the alternatives including identification of the individuals or groups that may be affected by the action, the nature of these impacts, and, if possible, quantification of the economic impacts.

3.1 Description of Fleet, Fishery, & Industry

A description of the crab fishery and fishing industry is provided in the Crab FMP, the Crab Stock Assessment and Fishery Evaluation (SAFE) report (e.g., NPFMC 1998), and the annual area management reports produced by ADF&G. The 1999 Groundfish Economic SAFE contains the latest information on the groundfish fishing industry. Copies of these documents are available on request from the Council office.

The most recent description of the groundfish fishery is contained in the Economic Status of the Groundfish Fisheries Off Alaska (Hiatt and Terry 1999). The report includes information on the catch and value of the fisheries, the numbers and sizes of fishing vessels and processing plants, and other economic variables that describe or affect the performance of the fisheries. Catch of groundfish in the Bering Sea has remained relatively stable over the past 10 years, averaging about 1.8 million metric tons, consisting primarily of pollock. About 2,000 vessels fish for groundfish in the BSAI and GOA each year. Catch in the domestic groundfish fisheries off Alaska totaled 1.9 million metric tons in 1998, worth $385 million in ex-vessel value. The value of resulting products after primary processing was over $1 billion.

The economics of BSAI crab fisheries are summarized in ADF&G's Annual Area Management Reports and the BSAI Crab SAFE. Total value of the three major Bering Sea crab fisheries in the late 1990's was about $180 million to $260 million per year. Most vessels that participate in snow crab fisheries also participate in the Tanner crab (*C. bairdi*) and Bristol Bay red king crab fisheries. Since 1982, the snow crab fishery has generated much higher values than the other crab fisheries. Although snow crab landings had dropped drastically since the peak in 1991 (325 million lbs.), price increased such that average gross ex-vessel value increased to over $710,000 per vessel in the 1995 snow crab fishery. The 2000 fishery opened with a guideline harvest level of only 28.5 million pounds. The estimated value of the regular commercial fishery in 2000 is $55 million, which equals an average gross ex-vessel value of approximately $238,000 per vessel.

The Bering Sea snow crab fleet is made up of vessels ranging in size from 58 to 180 feet in overall length. Approximately 65% are less than 125 feet in length. From 1995 to 1999 the fleet size numbered from 226 to 253 vessels, including up to 19 catcher processors. In addition, as many as 15 floating processors also participate in this fishery.

The following tables present data summarizing the number of vessels by gear and area that harvested Alaska groundfish and crab in recent years. More recent data were not readily available. However, the number of vessels participating in 2000 would be expected to be less than, but not significantly different from the number of vessels participating in the years shown in the adjacent tables. More detailed information on projected fleet size can be found in the License Limitation Program analysis (NPFMC 1998).

Number of vessels that caught crab in the BSAI area in 1996, by vessel length class (measured by length overall (LOA) in feet), catcher type, and gear.

	Catcher vessels			Catcher/
	<60'	60-124'	>125'	proc.s
Bristol Bay red king	0	130	62	4
Bering Sea Tanner	0	102	40	4
Bering Sea Snow crab	0	154	70	15
Norton Sound red king	41	0	0	0

Number of vessels that caught groundfish in the BSAI area in 1998, by vessel length class (measured by length overall (LOA) in feet), catcher type, and gear.

	<60'	60-124'	>125'	Total
Catcher vessels				
Hook and line	39	38	0	77
Pot	4	46	21	71
Trawl	6	78	34	118
	<125'	125-164'	>165'	Total
Catcher/processors				
Hook and line	16	15	12	43
Pot	2	4	2	8
Trawl	8	4	39	51

The snow crab fishery in the Bering Sea takes place in waters north of the latitude of Cape Sarichef at 54°36' N. lat., south of the latitude of Cape Romanzof at 61° 49' N. lat., and east of the U.S.-Russian Convention Line of 1867. The Bering Sea snow crab fishery dates back to the mid 1970's, with the first recorded landings in 1977, incidental to the harvest of Tanner (*C. bairdi*) crabs. Declining catches of Tanner crabs in the late 1970s focused the fleet's attention on snow crabs, resulting in a harvest of over 50 million pounds by 1981. From 1982 through 1984, the harvest of snow crabs declined to less than 30 million pounds, then climbed steadily to a peak harvest of 328.6 million pounds by 1991. Although snow crab stocks subsequently declined, the harvest remained over 100 million pounds through the 1994 season. In 1996, the harvest was 65.7 million pounds, the lowest in the preceding eleven seasons. By 1997 however, strong recruitment resulted in a harvest of 119.5 million pounds. In 1998, high population levels yielded a harvest of 243.3 million pounds in the open access fishery. An additional 8.9 million pounds was harvested by 21 vessels in the newly implemented Community Development Quota (CDQ) fishery. In 1999, as recruit strength began to wane, the total harvest (open access and CDQ) declined to just under 196 million pounds. Continued recruitment failure and overall declines in all size classes of both male and female crabs, necessitated a more conservative harvest rate and a significantly reduced GHL of only 28.5 million pounds for the 2000 season, from April 1 to April 8.

Given the current status of stock, which is expected to continue to decline, the Bering Sea snow crab fishery may remain closed for the 2001 season. We will not know the estimated abundance of snow crab for the 2001 season until the analysis of the 2000 NMFS trawl survey.

Detailed economic information on the BSAI crab fisheries is available in ADF&G's Annual Area Management Reports (e.g., Morrison et al. 1997). Total value of the three major Bering Sea crab fisheries in recent years is about $180 million to $260 million per year. The Bristol Bay red king crab fishery did not open in 1995 or 1996. The Tanner crab fishery did not open in 1997, 1998, or 1999. Exvessel values had averaged about $100,000 to $500,000 per vessel for Tanner crab during the early 1990's when the stock was abundant.

Catch, effort, and economic data from the Bering Sea snow crab fishery, 1989-2000 (catch includes CDQ, other columns do not). Catch (millions of lbs) includes deadloss.

Year	Catch	# of vessels	# of days	# of pots	price per lb	total value
1989	149.5	168	112	663,442	0.75	$ 110,700,000
1990	161.8	189	148	911,613	0.64	$ 102,300,000
1991	328.6	220	159	1,391,583	0.50	$ 162,600,000
1992	315.3	250	97	1,281,796	0.50	$ 156,500,000
1993	230.8	254	59	971,046	0.75	$ 171,900,000
1994	149.8	273	45	716,524	1.30	$ 192,400,000
1995	75.3	253	33	506,802	2.43	$ 180,000,000
1996	65.7	234	45	520,651	1.33	$ 85,600,000
1997	119.5	226	65	754,140	0.79	$ 92,600,000
1998	243.3	229	64	891,268	0.56	$ 134,650,000
1999	194.0	241	66	899,043	0.88	$ 162,390,000
2000	33.6	231	8	173,000	1.85	$ 55,000,000

In evaluating the alternatives to the status quo, it is informative to know what crab bycatch in groundfish and crab fisheries costs the directed crab fisheries. The answer to this question can be derived from the adult equivalent exercise made in a previous section of this document. On the basis of the assumptions made in the exercise (e.g., bycatch mortality rates), if groundfish fisheries caught no crab incidentally, the crab fishery may increase total ex-vessel revenues by about $1.2 million to $2.0 million. Similarly, if crab fisheries caught no crab incidentally, the crab fishery may increase total ex-vessel revenues by about $4.0 million to $7.6 million. These estimates do not include losses due to unobserved mortality.

This represents an estimate of opportunity costs. Assuming there are about 275 crab vessels, these crab would equate to about $19,000 to $35,000 per vessel in gross ex-vessel value all else equal. Potential costs of proposed alternative crab PSC limits for trawl fisheries and reductions in crab bycatch in crab fisheries can be measured against the potential benefits to directed snow crab fisheries.

Eliminating all snow crab bycatch from groundfish trawl fisheries in the Bering Sea would eliminate all groundfish catch, and therefor incur costs to that industry. For example, groundfish landings by trawl vessels in the Bering Sea / Aleutian Islands area were valued at $332.4 million exvessel in 1997. The previous table showed that the adult equivalent value of crabs taken as bycatch in groundfish trawl fisheries was $1.96 million in 1997. Therefore, eliminating BSAI groundfish trawl fisheries would have a net exvessel cost of over $330 million. The bottom line is that reducing crab bycatch limits would likely impose substantial costs to the groundfish trawl industry.

Value of snow crab bycatch in groundfish and crab fisheries to directed crab fisheries, based on 1997 and 1998 data.

Fishery	Equivalents	weight	price/lb	value ($)
1997				
Groundfish	2,068,438	1.2	0.79	1,960,879
Crab	7,999,652	1.2	0.79	7,583,670
			Total =	**$9,544,455**
1998				
Groundfish	1,613,720	1.3	0.56	1,174,788
Crab	5,451,913	1.3	0.56	3,968,993
			Total =	**$5,143,781**

The Crab Vessel License Limitation Program (LLP)

The Council approved LLPs for its Groundfish and Crab FMPs on June 17, 1995. The Secretary of Commerce approved the proposed rule implementing the Groundfish and Crab LLPs on September 12, 1997. The final rule was approved on October 1, 1998. Fishing under the final LLPs began in January 2000. In 1998, the Crab LLP was further amended to include changes in the basic eligibility criteria for crab, in the form of additional recent participation criteria. These changes were adopted by the Council as Amendment 10 to the Crab FMP in October, 1998. The Secretary has yet to approved Amendment 10.

Under the original qualifying criteria, 365 vessels are projected to qualify for crab licenses in areas excluding Norton Sound. Of the total projected qualifiers, Alaskans currently own 125 vessels and 240 are currently owned by residents of other states. Participation declined from 349 vessels in 1995 to 299 in 1996 and 282 in 1997. Throughout the recent period a total of 410 unique vessels have participated: 19 vessels as catcher processors and 391 as catcher vessels. The largest decline appears for seine combination catcher vessels. The number of participants reported in the data dropped from 70 in 1995 to 7 in 1997. The numbers of participants in other vessel classes varied within a much narrower range. The number of Alaskan residents participating in the crab fisheries has declined throughout the period, while the number of participating residents of other states fell in 1996 and then rose in 1997. The number of crab vessels with endorsements for the BSAI Tanner crab fishery under the original LLP was 323 vessels.

In 1998 the Council adopted Amendment 10 to the Crab FMP, which would require recent participation in the BSA king and Tanner crab fisheries in order to qualify for a license under the Crab LLP. The recent participation requirement would apply to the general license only; if a vessel satisfies the recent participation criteria chosen, it would receive its original license and all of the species/area endorsements for which it qualified under the original criteria. No new species/area endorsements could be earned during the recent qualification. The specific alternative adopted by the Council in October, 1998, was Alternative 9, which required participation at least once between 1996 and February 7, 1998 (NPFMC 1998). The Council also included the following four exemptions to this requirement:

1. Vessels with only a Norton Sound Endorsement

2. All vessels that are < 60' LOA and are qualified under the original LLP

3. Vessels that made landings in the Bering Sea and Aleutian Islands crab fishery in 1998, on or before February 7, 1998, and for which the owner acquires license limitation rights from a vessel that meets the general qualification period (GQP) and endorsement qualification period (EQP) landings requirements. The owner must have acquired these rights or entered into a contract to acquire the rights by 8:36 a.m. Pacific time on October 10, 1998.

4. A vessel that was lost or destroyed and which made a landing (or its replacement vessel) in the Bering Sea and Aleutian Islands crab fishery from the time it left the fishery and January 1, 2000, would be deemed to have met the recent participation criteria and would be issued the general license and all species/area endorsements earned under the original crab LLP.

The table below shows the potential number of endorsements for crab vessels that qualified under proposed Amendment 10. A total of 265 vessels will be endorsed for the Tanner crab fishery (both *C. opilio* and *C. bairdi*), if this amendment is adopted by the Secretary. Note that this is not be the actual number of vessels that apply for and receive endorsements for crab licences. Also, individual licenses may contain more than one endorsement.

Table. Potential number of endorsements for crab fishing licenses under the crab license limitation program, adopted by the Council as Amendment 10, October 1998. The BSAI Tanner endorsement includes both C. opilio and C. bairdi fisheries.

	BSAI Tanner	Adak Brown	Adak Red	Bristol Bay Red	Dutch H. Brown	Pribilofs Blue/Red	St. Matt. Blue/Red
Factory Trawlers	6		1	5		2	2
Other Fixed-gear Cps	28	5	2	28	3	14	20
Pot CVs 125'+	42	5	5	42	5	22	35
Pot CVs 60'-124'	132	10	16	132	8	84	96
Seine Combination Cvs	1			1		2	
Trawl CVs 125'+	13	1	1	12	1	5	5
Trawl CVs 60'-124'	43		2	43		14	20
CV / CP Licenses							
Catcher Vessels	249	18	26	248	15	136	170
Catcher Processors	16	3	1	15	2	7	8
Grand Total	**265**	**21**	**27**	**263**	**17**	**143**	**178**

3.2 Expected Effects of Each Alternative

Alternative 1 - Under this alternative, no action would be taken to rebuild the snow crab stock. Adoption of this alternative would result in a violation of Magnuson-Stevens Act requirements. Presumably, costs are associated with this, as lawsuits could result, and courts could potentially close fisheries. Also, allowing a high harvest rate on the declining stock may jeopardize rebuilding causing the stock to remain at low levels. The fleet would then suffer long-term economic losses from a depressed stock.

Alternative 2A, Option 1 - Under this option, the harvest rates for snow crab would not be changed from the rate used in recent years. Although this is considered status quo, the Board recently adopted a new harvest strategy for the snow crab stock. Nevertheless, establishment of GHLs is a category 2 measure under the FMP, and the FMP could be amendment to restrict the allowable harvest rate range to accomplish FMP objectives.

As shown in previous sections of this analysis, the harvest rate under Alternative 2A, Option 1 may result in rebuilding, but at a slower rate. The costs associated with this alternative include the potential for more years when no fishery occurs. Also, this alternative poses unknown risks to the long-term productivity of the stock and could result in a permanent stock decline. The effects of high harvest rates on low crab populations are not understood. Crab populations do crash and remain at very low levels for extended periods of time, as we have seen in the Gulf of Alaska.

Alternative 2A, Option 2 - Under this option, the new harvest strategy adopted by the Board would be employed to generate annual GHLs for the snow crab fishery. Positive benefits to the crab fleet would be realized when snow crab stocks rebuild to stock sizes that can produce MSY. Nevertheless, proposed actions that reduce crab harvests relative to the status quo would be expected to result in short term losses to the fleet.

Alternative 2B, Option 1 - Under this option, bycatch control measures that were implemented in the past would remain the same. No additional regulations to reduce snow crab bycatch in crab fisheries would be implemented. Costs of adopting this option may be those associated with forgone yield due to discards, longer rebuilding times, and reduced survival of pre-recruit snow crabs.

Alternative 2B, Option 2 - Under this alternative, the PSC limits for snow crab taken incidentally in Bering Sea trawl fisheries would be modified, such that there is no minimum number specified. As such, when the population of snow crab gets very small, the PSC limits also get small.

The groundfish trawl fisheries would be impacted under alternatives that impose more restrictive snow crab bycatch limits. This can occur even if the overall PSC limit is not reduced below what is currently taken. This is because bycatch limits are apportioned among fisheries pre-season, and reaching one of these limits shuts down a fishery for the remainder of the season. In a perfect world, managers could know exactly how much crab would be taken in each fishery, and could apportion the PSC limit exactly. This is far from possible, however. In the end, some fisheries are apportioned more PSC than required, and other fisheries are not apportioned enough. Although groundfish trawl fisheries can potentially be impacted under the current PSC limits, the excess PSC allows for some error in the preseason specification of the allocation. A reduction in the PSC limit would increase the possibility of a mis-allocation. A mis-allocation implies costs imposed on the groundfish fleets in the form of premature closures, forgone catch, revenue losses, and potential market impacts due to reduced supplies.

So the question is: how much would a mis-allocation cost, and what sector of the fishery would likely bear these costs. Most likely, it would be the flatfish target trawl fisheries that would be impacted by any decrease in snow crab PSC caps, although all groundfish trawl target fisheries could potentially be impacted. Note that the flatfish fisheries account for over 90% of the snow crab PSC, so this is the sector that would likely be most impacted. The 1996 BSAI flatfish catch was worth $ 47 million (most recent data from November 1999 Economic SAFE). About one third of the flatfish are caught in the COBLZ area based on preliminary examination of observer data. So the flatfish in COBLZ would have an exvessel value of about $ 15.7 million. If we further assume that 80% is taken in directed flatfish fisheries, then the directed flatfish fishery in COBLZ is worth $ 12.5 million exvessel. This figure can be used to estimate costs to the fishery. For example, a PSC mis-allocation of 10% may cost the flatfish fleet $ 1.2 million exvessel if the catch could not be made up outside the COBLZ. Note however, that flatfish are taken at high CPUE outside the snow crab bycatch zone (Fritz et al. 1998), and the flatfish fishery generally shuts down when halibut PSC limits are achieved.

Alternative 2B, Option 3 - Under this option, bycatch control measures that were implemented in the past would remain the same. Regulations to reduce snow crab bycatch in crab fisheries would be expected to have added costs; however the GHL for these other stocks would still be expected to be harvested. In this specific case, fishermen would not incur additional costs associated with installing new escape rings in their pots.

The Board adopted new regulations for escape rings in March 2000, and these will be required in future snow crab fisheries. Note that gear modifications is a category 3 measure (at the discretion of the State), so the Council and NMFS cannot directly establish gear regulations, only request that these be made by the State to conform with the objectives of the FMP.

Alternative 2C, Option 1 - Under this option, no additional changes would be made to the existing habitat protection measures. Costs associated with this option are that marginal habitats would not be protected in the course of EFH consultations made with NMFS by federal agencies for proposed activities that could be harmful to this habitat. Habitat loss would be expected to reduce the overall productivity of the stock and result in lower harvests.

Alternative 2C, Option 2 - Under this option, EFH for snow crab would be defined as those areas currently and historically used by the Bering Sea snow crab stock, and the importance of snow crab habitat to productivity could be emphasized in consultations. For agency consultation purposes, highlight the importance of snow crab EFH in maintaining stock productivity. To the extent feasible and practicable, this area should be protected from adverse impacts due to non-fishing activities. The costs associated with this alternative would be borne by those proposing such activities, as they would be required to respond in writing to NMFS concerns, if any, to the effects of these activities on snow crab EFH.

3.3 Impacts on Communities

National Standard 8 of the Magnuson-Stevens Act mandates that conservation and management shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to provide for the sustained participation of such communities, and to the extent practicable, minimize adverse economic impacts on such communities.

Changes to BSAI crab fishery regulations to rebuild snow crab may impact communities in the North Pacific region. Changes to the harvest strategy would effect the crab fishermen from Seattle, Dutch Harbor, Kodiak, Homer, and other communities. However, these impacts would be expected to be short lived, as some fishing on the stock will be allowed during the rebuilding period (see section 1.7), and the stock is projected, with a 50% probability, to reach rebuilt status in less than 10 years. This fishery generated $80 million to $192 million (exvessel) annually during the last 10 years. The costs of reduced fishing opportunities during the rebuilding period may be more than offset by benefits gained from rebuilding the snow crab stock to its MSY level. Note that ADF&G does not allow directed snow crab fisheries when the stock is at low abundance, so exvessel value would be $0. Once the stock is rebuilt, these coastal communities would once again have expanded opportunities (both fishing and processing) in this potentially lucrative fishery.

Costs of rebuilding will be borne by communities supporting BSAI crab industries (all of those listed in Section 3.3) due to reduced harvest rates. On the other hand, benefits of a rebuilt crab stock will be gained primarily by those communities supporting the snow crab industry.

Many of the coastal communities participate in the crab fisheries in one way or another, whether it be processing, support businesses, have port facilities, or as home to fishermen and processing workers. Shore-based processing plants which purchase, process and sell Bering Sea snow crabs are located in the ports of Dutch Harbor (7), Akutan (1), King Cove (1) and St. Paul, on the Pribilof Islands (3). Additional processors in ports as far away as Kodiak and Juneau occasionally purchase and process snow crabs from the Bering Sea. These same ports also process groundfish catch from the Bering Sea. Additionally, Seattle, Washington is home port to many catcher and catcher-processor vessels from all of the potentially effected fleets.

The economic impact to communities where snow crabs are landed and processed may be significant if the snow crab stocks fail to rebuild. In the five year period from 1995 to 1999, the ports of Dutch Harbor and St. Paul both received an average of 24% of the annual snow crab harvest. These landings were worth an average of $32 million ex-vessel annually to each port. During this same period, the ports of Akutan, King Cove and Kodiak received a combined average of 7.5% of the harvest worth almost $ 10 million ex-vessel, while the catcher processor component of the fleet received an average of 8.7% of the annual snow crab harvest, worth $ 11.3 million ex-vessel. The largest percentage of the harvest, during the most recent five years, has gone to the floating processor component of the fleet. These floating factories, operating on the fishing grounds, received almost 42% of the yearly harvest worth almost $ 54 million ex-vessel annually.

The State of Alaska collects a 3 percent fish tax on all fish processed and landed in Alaska. Fifty percent of this fish tax is shared with the local communities. The fish tax provides the majority of revenue for the local governments of the Bering Sea communities. As you can see, in years with large snow crab harvests, tax revenue from snow crab comprises a significant portion of the fish tax revenue received by Bering Sea communities. Fish tax revenue would decrease significantly in years with limited or no snow crab harvest.

The portion of State fish tax revenues from snow crab received by communities, 4 year averages 1995-1998.

	total fish tax	tax from snow crab	snow crab as a % of total
AEB	$1,221,139	$20,707	1.70%
Akutan	$376,438	$116,769	31.02%
King Cove	$293,232	$104,173	35.53%
St. George	$211,825	$98,416	46.46%
St. Paul	$1,158.450	$709,308	61.23%
Unalaska	$4,759,867	$553,512	11.63%

Source: Alaska Department of Community and Economic Development

In the past five years, from 1995 to 1999, $640 million worth of snow crab were landed and/or processed in Bering Sea communities. Communities receive a large portion of their income from revenue and employment from crab processors, and secondary income from things like harbor usage, sale of goods and services, transportation, and fuel tax. Communities use this revenue for basic services, such as electricity, operating budgets, education, and health care. Reduced harvest of snow crab would result in a loss of revenue, causing a decline in employment, loss in services, and increased difficulty in maintaining harbor and other facilities. Community representative have also expressed the concerns that this decrease in employment and local revenue would cause an increase in social problems such as depression and alcoholism.

On May 11, 2000, the Secretary issued a determination of a commercial fishery failure affecting the 2000 Bering Sea snow crab fishery. This determination enabled Congress to appropriate relief money to the State of Alaska to distribute to the affected fishing communities under section 312 of the Magnuson-Stevens Act. The determination of a commercial fishery failure recognized the economic hardships the fishing communities endure while the snow crab stock is depressed.

Total pounds and value of snow crab landed and/or processed in Alaska from 1995-1999, and percent of the total value of snow crab landed and processed, by community.

	pounds	value	% of total value
AEB	29,030,997	$22,520,994	3.44%
Akutan	44,336,564	$41,666,460	6.36%
King Cove	36,035,796	$36,723,336	5.60%
St. George	48,632,428	$48,133,533	7.34%
St. Paul	264,722,362	$285,148,060	43.51%
Unalaska	225,102,051	$205,745,339	31.39%
Other	13,570,090	$15,469,714	2.36%
Total	661,430,288	$655,407,436	100%

Notes: 'Other' includes: the Alaskan communities of Juneau, Kodiak, Togiak; unknown landing locations; snow crab transited out, and at-sea processing in State waters.
Source: Alaska Department of Community and Economic Development

To explain more about the individual communities, summary information on these communities is provided below. More detailed information about Alaskan fishing communities is provided in the "Faces of the Fisheries" (NPFMC 1994).

St. Paul -St. Paul is a supply and processing port for a portion of the Bering Sea groundfish and crab fleets. Major improvements to the harbor, including a dock expansion and breakwater, have allowed continual development of this community as a shipping and fishing town. There are fish processing plants, along with cold storage and warehouse facilities. The local fleet fishes primarily for halibut; local processor produce crab and several species of groundfish.

In addition to seafood harvesting and processing, employment on Saint Paul includes government administration, education, native corporation , and other service related jobs. The community is also developing tourism; visitors come from all over to see fur seals and sea bird rookeries. Subsistence hunting, fishing and gathering has always been an important part of life on the Pribilof Islands. Processing of snow crab and fleet support in St. Paul has provided jobs and revenue for the City. On January 31, 2000, the City of St. Paul requested the Secretary to declare a commercial fishery failure under Section 312 of the Magnuson-Stevens Act.

Of all the coastal communities, Saint Paul is most effected by low stock sizes of snow crab because it is primarily dependent on snow crab processing, and thus may suffer relatively larger economic impacts than other communities during the rebuilding period.

Dutch Harbor/Unalaska -Dutch Harbor/Unalaska has been called "... *the most prosperous stretch of coastline in Alaska.*" With 27 miles of ports and harbors and several hundred local businesses, most of them servicing, supporting, or relying on the seafood industry, this city is the heart of the Bering Sea fisheries. Dutch Harbor is not only the top ranked fishing port in terms of the tonnage of fish landed in Alaska, but has held that distinction for the Nation, as a whole, each year since 1989, and ranked at or near the top in terms of value of fish landed over the same period.

Historically, Dutch Harbor was principally dependent upon non-groundfish (primarily king and Tanner crab) landings and processing for the bulk of its economic activity. These non-groundfish species continue to be important components of a diverse processing complex in Dutch Harbor. In 1997, for example, nearly 2 million pounds of salmon, more than 1.7 million pounds of herring, and 34 million pounds of crabs were reportedly processed in this port. Since the mid-1980s, groundfish and particularly pollock has accounted for the vast majority of landings in Dutch Harbor/Unalaska. Again, utilizing 1997 catch data, over 93.5% of total pounds landed and processed in this port were groundfish, 83% of which were pollock.

The facilities and related infrastructure in Dutch Harbor/Unalaska support fishing operations in the eastern Bering Sea, Aleutian Islands and GOA management areas. At least eight shore-based processors in this port receive and process fish caught in all three areas, and the wider community is linked to, and substantially dependent upon, serving both the inshore and at-sea sectors of the fishing industry. While Dutch Harbor has been characterized as one of the world's best natural harbors, it offers few alternative opportunities for economic activity beyond fisheries and fisheries support. Its remote location, limited and specialized infrastructure and transportation facilities, and high cost make attracting non-fishery related industrial and/or commercial investment doubtful, at least in the short-run.

Akutan -Akutan ranks as the second most significant landings port for groundfish, most of which is pollock, on the basis of tons delivered and has been characterized as a unique community in terms of its relationship to the BSAI fisheries. According to a recent social impact assessment, prepared for the Council, while Akutan is the site of one of the largest of the onshore pollock processing plants in the region, the community is geographically and socially separate from the plant facility.

While the community of Akutan derives economic benefits from its proximity to the large Trident Seafoods shore plant (and a smaller permanently moored processing vessel, operated by Deep Sea Fisheries, which handles only crab), the entities have not been integrated in the same manner as other landings ports and communities. The community derives some economic benefits from the fisheries, including a 1% raw fish tax from the nearby plant. Alternative economic opportunities of any kind are extremely limited.

Kodiak -Kodiak supports at least nine processing operations which receive pollock harvested from the GOA and, to a lesser extent, the eastern Bering Sea and Aleutian Islands management areas, and four more which process exclusively non-groundfish species. The port also supports several hundred commercial fishing vessels, ranging in size from small skiffs to large catcher/processors and everything in between. According to data supplied by the City, "The Port of Kodiak is 'home port' to 770 commercial fishing vessels. Not only is Kodiak the state's largest fishing port, it is also home to some of Alaska's largest trawl, longline, and crab vessels."

Kodiak has a diversified seafood processing sector. The port historically was very active in the crab fisheries and, although these fisheries have declined from their peaks in the late-1970s and early-1980s, Kodiak continues to support shellfish fisheries, as well as significant harvesting and processing operations for groundfish (particularly flatfish and pollock) Pacific halibut, herring, sablefish, and the five Pacific salmon species.

Kodiak often ranks near the top of the list of U.S. fishing ports, on the basis of landed value, and is frequently regarded as being involved in a wider variety of fisheries than any other community on the North Pacific coast. In 1997, for example, the port recorded salmon landings of just under 44 million pounds, with an estimated exvessel value of over $12 million. Approximately 4.3 million pounds of Pacific herring were landed in Kodiak with an exvessel value of more than $713,000. Crab landings exceeded 1.1 million pounds and were valued exvessel at more than $2.7 million.

In addition to seafood harvesting and processing, the Kodiak economy includes sectors such as transportation (being regarded as the transportation hub for southwest Alaska), federal/state/local government, tourism, and timber (the forest products industry, based upon Sitka spruce, is an important and growing segment of the Kodiak economy). The community is also home to the largest Coast Guard base in the U.S.

Sand Point and King Cove - Sand Point and King Cove, like Akutan, are part of the Aleutians East Borough. Both Sand Point and King Cove have had extensive historical linkages to commercial fishing and fish processing, and currently support resident commercial fleets delivering catch to local plants. These local catches are substantially supplemented by deliveries from large, highly mobile vessels, based outside of the two small Gulf of Alaska communities. King Cove possesses a deep water harbor which provides moorage for approximately 90 vessels of various sizes, in an ice-free port. Sand Point, with a 25 acre/144 slip boat harbor and marine travel-lift, is home port to what some have called " the largest fishing fleet in the Aleutians" (NPFMC, 1994).

For decades, each of these the two communities has concentrated principally on salmon fisheries. For example, in 1997, both Sand Point and King Cove recorded salmon landings of several million pounds. In addition, King Cove had significant landings of Pacific herring and crabs. Recently, each community has actively sought to diversify its fishing and processing capabilities. Few employment alternatives to commercial fishing and fish processing exist, within the cash-economy, in these communities. However, subsistence harvesting is an important source of food, as well as a social activity, for local residents in both Sand Point and King Cove.

Groups

Alaska's Community Development Quota (CDQ) program was designed to promote the revitalization of rural communities in Western Alaska by providing those communities access to nearby fishery resources. The 1996 Amendments to the Magnuson Stevens Act required that the Secretary establish western Alaska CDQ program for Bering Sea crab fisheries, to be phased in as follows: 3.5 % of the GHLs for 1998; 5% of the GHLs for 1999; and 7.5% for 2000 and beyond, unless modified after October 2001. In years of low GHLs, the CDQ quotas for snow crab would be very small, even with a 7.5 % allocation. Snow crabs will generate much higher incomes for CDQ groups when the stock is rebuilt and GHLs are increased.

Criteria for eligible Alaska communities are defined in the Act. Sixty-five communities formed six geographical groups, in order to pool their efforts in producing Community Development Plans and managing the CDQ harvest. The six groups are: Aleutian Pribilof Island Community Development Association; Bristol Bay Economic Development Corporation; Central Bering Sea Fisherman's Association; Coastal Villages Fisheries Cooperative; Norton Sound Economic Development Corporation; and Yukon Delta Fisheries Development Association.

Allocation of snow crab among the CDQ groups for the year 2000.

CDP	Percent
APICDA	10 %
BBEDC	19 %
CBSFA	19 %
CVRF	17 %
NSEDC	18 %
YDFDA	17 %

A crab CDQ program was formally adopted as Amendment 5 to the FMP (64 FR 42826), which became effective on September 7, 1999. In 2000, the CDQ reserve was 7.5% of Bering Sea crab stocks GHLs. The 2000 snow crab CDQ was 2,518,760 pounds, of which 2,516,508 pounds were harvested. Thirteen vessels participated in the CDQ fishery. Average ex-vessel price per pound in the 2000 fishery was $1.79, slightly less than the price per pound of $1.85 in the regular commercial fishery. The ex-vessel fishery value to the CDQ fleet was $4.5 million. The fishery value to the CDQ groups is estimated to be 20-30% of the fleet fishery value. Two shorebased processors participated in the fishery, one is St. Paul and one in Akutan.

4.0 REFERENCES

ADF&G (Alaska Department of Fish and Game). 1999. Commercial shellfish fishing regulations 1999-2000 edition. Alaska Department of Fish and Game, Division of Commercial Fisheries Management and Development, Juneau.

Auster, P.J. and R.W. Langton. 1999. The effects of fishing on fish habitat. P150-187 *in* L.R. Benaka, ed. Fish habitat: essential fish habitat and rehabilitation. Ma. Fish. Soc. Symp. 22, Bethesda, MD.Auster, P. J. and R. W. Langton. 1999. The effects of fishing on fish habitat. In: L. Benaka (ed), Fish habitat: Essential Fish Habitat and Rehabilitation. American Fisheries Society. Bethesda, MD.

Barnhart, J.P., and N. Sagalkin. 1998. Summary and analysis of onboard collected data from the 1996/97 statewide commercial weathervane scallop fishery. Alaska Department of Fish and Game Commercial Fisheries, Regional Information Report. Kodiak.

Blackburn, J. and D. Schmidt. 1988. Injury and apparent mortality rates from incidental trawl catches of halibut, king crab, and Tanner crab in the Kodiak area, 1977-81. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K88-21.

Boyle, L., L.C. Byrne, and H. Moore. 1997. Alaska Department of Fish and Game Summary of the 1996 Mandatory Shellfish Observer Program Database. Regional Information Report 4K97-51. Kodiak. 165 pp.

Boyle L., L.C. Byrne, H. Moore, and D. Pengilly. 1996. Alaska Department of Fish and Game summary of the 1995 Mandatory Shellfish Observer Program database. Regional Information Report No. 4K96-47. ADF&G, Kodiak.

Breen, P.A. 1987. Mortality of Dinginess crabs caused by lost traps in the Fraser River estuary, British Columbia. North American Journal of fisheries Management 7:429-435.

Brylinsky, M., J. Gibson and D. C. Gordon, Jr. 1994. Impacts of flounder trawls on the intertidal habitat and community of the Minas Basin, Bay of Fundy. Canadian Journal of Fisheries and Aquatic Science.. 51:650-661.

Byersdorfer, S., and L.J. Watson. 1992. A summary of biological data collected during the 1991 Bristol Bay red king crab tagging study. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 92-14.

Byersdorfer, S., and L.J. Watson. 1993. A summary of biological data collected during the 1992 Bristol Bay red king crab test fishery. Alaska Department of Fish and Game, Division of Commercial Fisheries, Technical Fishery Report 92-14.

Byersdorfer, S. 1996. A summary of biological data collected during the 1996 Bristol Bay red king crab test fishery. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 4k96-55, Kodiak.

Byersdorfer, S., D. Pengilly, and D. Tracy. 1997. A survey of escape mechanisms and ring placements on commercial crab pots fished during the 1997 Bering Sea snow crab fishery, *Chionoecetes opilio*, season. Alaska Department of Fish Game, Division of Commercial Fisheries, Regional Information Report No. 4k97-45, Kodiak.

Caddy, J. F. 1973. Underwater observations on tracks of dredges and trawls and some effects of dredging on a scallop ground. Journal of the Fisheries Research Board of Canada 30: 173-180.

Carls, M.G., and C.E. O'Clair. 1989. Influence of cold air exposures on ovigerous red king crabs (Paralithodes camtschatica) and Tanner crabs (Chionoecetes bairdi) and their offspring. Proceedings of the International Symposium on King and Tanner Crabs. Alaska Sea Grant College Program Report No. 90-04.

Caswell, H. 1989. Matrix population models. Sinauer Associates, Sunderland, MA. 328 p.

Churchill, J. H. 1989. The effect of commercial trawling on sediment resuspension and transport over the Middle Atlantic Bight continental shelf. Continental Shelf Research. 9:841-864.

Dau, C.P., and S.A. Kitchinski. 1977. Seasonal movements and distribution of the Spectacled Eider. Wildfowl 28:65-75.

Donaldson, W.E. 1990. Determination of experimentally induced non-observable mortality on red king crab. Alaska Department of Fish and Game Regional Information Report 4K90-13.

Fritz, L.W., A. Greig, and R.F. Reuter. 1998. Catch-per-unit-effort, length, and depth distributions of major groundfish and bycatch species in the Bering Sea, Aleutian Islands, and Gulf of Alaska regions based on groundfish fishery observer data. NOAA Technical Memorandum NMFS-AFSC-88.

Fukuhara, F.M., and D. Worlund. 1973. Incidence of halibut and Tanner crab in catches by the eastern Bering Sea mothership trawl fishery and independent trawlers. NOAA/NMFS/NAFC Report to the International North Pacific Fisheries Commission.

FWS, 1993.Alaska Seabird Management Plan. Report of the US Fish and Wildlife Service. Anchorage: USDA FWS.

FWS 1996a. Letter from Ann Rappoport, FWS, to Steve Pennoyer, NMFS re: section 7 consultation on the King & Tanner Crab FMP and the 1996 winter Bering Sea opilio crab fishery. January 23, 1996.

FWS 1996b. Letter from Ann Rappoport, FWS, to Steve Pennoyer, NMFS re: section 7 consultation on the King & Tanner Crab FMP and the 1997 winter Bering Sea opilio crab fishery. December 20, 1996.

FWS. 1997. Letter from Ann Rappoport, FWS to Steve Pennoyer, NMFS re: section 7 consultation on the effects of the 1997 TAC specifications of the GOA and BSAI groundfish fisheries on the short-tailed albatross, February 19, 1997.

FWS 1998. Letter from Ann Rappoport, FWS, to Steve Pennoyer, NMFS re: reinitiation of section 7 consultation for the Opilio crab fishery. January 13, 1998.

Gauvin, J. R., K. Haflinger, and M. Nerini. 1995. Implementation of a voluntary bycatch avoidance program in the flatfish fisheries of the Eastern Bering Sea. In: Solving Bycatch: considerations for today and tomorrow, p. 79-85. Alaska Sea Grant Coll. Rep. 96-03. University of Alaska, Fairbanks.

Gish, R.K. 1999. Bering Sea Community Development Quota (CDQ) program fisheries, 1998, Report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 499-14.

Goodyear, C. P. 1995. Red snapper in U.S. waters in the Gulf of Mexico. NMFS/SEFSC Contribution MIA-95/96-05.

Hammerstrom, L.F., and M.F. Merritt. 1985. A survey of Pacific weathervane scallops (Patinopecten caurinus) in Kamishak Bay, Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Information Leaflet 252.

Hayes, M.L. 1973. Survival of Tanner crab (Chionoecetes bairdi) after capture in trawls and subsequent handling and storage aboard fishing boats. NOAA/NMFS report to the International North Pacific Fisheries Commission.

Hennick, D.P. 1973. Sea scallop, Patinopecten caurinus, investigations in Alaska. Alaska Department of Fish and Game, Division of Commercial Fisheries, Completion Report 5-23-R.

High, W.L. 1976. Escape of Dinginess crabs from pots. Marine fisheries review 38(4):19-23.

High, W.L. 1985. Some consequences of lost fishing gear. Pages 430-437 in R.S. Shomura and H.O. Yoshida, editors. Proceedings of the workshop on the fate and impact of marine debris. NOAA/NMFS/SWFC Technical Memorandum 54.

High, W.L., and D.D. Worlund. 1979. Escape of king crab (Paralithodes camtschaticus), from derelict pots. NOAA/NMFS/SSRS Technical Report 734.

Hill, P.S., DeMaster, D.P., and R.J. Small. 1997. Alaska marine mammal stock assessments, 1996. NOAA Technical Memorandum NMFS-AFSC-78. 154 p.

Hiatt, T. and J. Terry. 1999. Stock Assessment and Fishery Evaluation Report for the Groundfish Fisheries of the Gulf of Alaska and Bering Sea/Aleutian Island area: Economic status of the groundfish fisheries off Alaska, 1998. Unpubl. Manuscr. AFSC, NMFS, 7600 Sand Point Way N.E., BIC C15700, Seattle, WA 98115. 68p.

International Council for the Exploration of the Sea. 1988. Report of the Study Group on the Effects of Bottom Trawling. In CM 1988/B International Council for the Exploration of the Sea.

Jennings, S. and M. J. Kaiser. 1998. The effects of fishing on Marine Ecosystems. Advances in Marine Biology 34:201-352.

Jones, J. B. 1992. Environmental impact of trawling on the seabed: a review. New Zealand Journal of Marine and Freshwater Research. 26:59-67.

Kaiser, R.J. 1986. Characteristics of the Pacific weathervane scallop (Patinopecten caurinus) fishery in Alaska 1967-1981. Alaska Department of Fish and Game, Division of Commercial Fisheries (Unpublished Report, Catalog RUR-5J86-01).

Kaiser, M. J. and Spencer, B. E.. 1994. Fish scavenging behaviour in recently trawled areas. Marine Ecology Progress Series 112: 41-49.

Kaiser, M. J. and B. E. Spencer. 1996a. Behavioural responses of scavengers to beam trawl disturbance. In: Greenstreet, S. P. R. and M. L. Tasker (eds). Aquatic predators and their prey. Blackwell Scientific, Oxford, pp. 117-123.

Kaiser, M. J. and Spencer, B. E. 1996b. The effects of beam-trawl disturbance on infaunal communities in different habitats. Journal of Animal Ecology. 65:348-358.

Kimker, A. 1994. Tanner crab survival in closed pots. Alaska Fishery Research Bulletin 1(2):179-183.

Krost, P., M. Bernhard, F. Werner, and W. Hukriede. 1990. Otter trawl tracks in Kiel Bay (Western Baltic) mapped by side-scan sonar. Meereforschung 32: 344-353.

Kruse, G.H., and A. Kimker. 1993. Degradable escape mechanisms for pot gear: a summary report to the Alaska Board of Fisheries. Alaska Department of Fish and Game Regional Information Report 5J93-01.

Kruse, G. H., and J. Zheng. 1999. Are changes in Bering Sea crab and groundfish populations related? Ecosystem Approaches for Fisheries Management. Alaska Sea Grant College Program AK-SG-99-01:143-148.

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.

Livingston, P.A. L-L Low, and R.J. Marasco. 1994. Eastern Bering sea ecosystem trends. Unpublished paper presented at the Symposium on Large Marine Ecosystems of the Pacific. October 11, 1994. Qingdao, China.

Livingston, P. A., and Goiney, B. J. 1983. "Food habits literature of North Pacific marine fishes: A review and selected bibliography." in *NOAA Technical Memorandum NMFS F/NWC-54* U.S. Department of Commerce, NOAA. 81 p.

Livingston, P. 1999. Ecosystems Considerations for 2000. In: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. Compiled by the Plan Team for the Groundfish Fisheries (2000 SAFE). North Pacific Fisheries Management Council, 605 W. 4th Ave. Anchorage, AK 99501.

Lovrich, G.A. and B. Sainte-Marie. 1997. Cannibalism in the snow crab, Chionoecetes opilio (O. Fabricus) (Brachyura: Majidae), and its potential importance to recruitment. J. Exp. Mar. Biol. Ecol. 211:225-245.

MacIntosh, R.A., B.G. Stevens, and J.A. Haaga. 1996. Effects of handling and discarding on mortality of Tanner crabs, Chionoecetes bairdi. Proceedings of the International Symposium on Biology, Management, and Economics of Crabs from High Latitude Habitats. Alaska Sea Grant College Program Report 96-05:577-590.

McConnaughey, R. A., K. L. Mier and C. B. Dew. 1999. An examination of chronic trawling effects on soft-bottom benthos of the eastern Bering Sea. ICES J. Mar. Sci. (in press).

Messieh, S. N., T. W. Rowell, D. L. Peer and P. J. Cranford. 1991. The effects of trawling, dredging and ocean dumping on the eastern Canadian continental shelf. Cont. Shelf Res. 11:1237-1263.

Meyer, R.M. 1971. A study concerning the problem of derelict pots in the king crab fishery. NOAA/NMFS unpublished manuscript.

Moore, H., L.C. Byrne, and D. Connolly. 1998. Alaska Department of Fish and Game summary of the 1997 Mandatory Shellfish Observer Program database. Regional Information Report No. 4K98-50. ADF&G, Kodiak.

Moore, H., L.C. Byrne, and D. Connolly. 2000. Alaska Department of Fish and Game summary of the 1998 Mandatory Shellfish Observer Program database. Regional Information Report No. 4K00-21. ADF&G, Kodiak.

Morrison, R., R.K. Gish, and N.H. Sagalkin. 1997. Annual management report for the shellfish fisheries of the Bering Sea Area. Pages 120-210 *In* Annual management report for the shellfish fisheries of the Westward region, 1996. Alaska Department of

Fish and Game, Division of Commercial Fisheries Management and Development, Regional Information Report No. 4K97-41. Kodiak.

Morrison, R., F. Bowers, R. Gish, E. Wilson, M. Schwenzfeier, and R. Alinsunurin. 1999. Annual management report for the shellfish fisheries of the Bering Sea. Pp 133-247, *in:* Annual management report for the shellfish fisheries of the Westward Region, 1998. Regional Information Report No. 4k99-49.

Murphy, M.C. and G.H. Kruse. 1995. An annotated bibliography of capture and handling effects on crabs and lobsters. Alaska Fishery Research Bulletin 2(1):23-75.

Naidu, A.S. 1988. Marine surficial sediments. Section 1.4 in C.N. Ehler, D.J. Basta, T.F. LaPointe, and G.C. Ray (editors). Bering, Chukchi, and Beaufort Seas coastal and ocean zones strategic assessment: Data atlas. U.S. Dep. Commer., NOAA, Nat'l Ocean Ser., Off. Oceanog. And Mar. Assess., Ocean Assess. Div., Str. Assess. Br. Silver Spring, MD.

Narita, R., M. Guttormsen, J. Gharrett, G. Tromble, and J. Berger. 1994. Summary of observer sampling of domestic groundfish fisheries in the Northeast Pacific Ocean and Eastern Bering Sea, 1991. US Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-48.

NMFS. 1999. Environmental Assessment/Regulatory Impact Review for an Emergency Rule to Implement Reasonable and Prudent Steller Sea Lion Protection Measures in the Pollock Fisheries of the Bering Sea and Aleutian Islands Area and the Gulf of Alaska (January 1999, FONSI signed January 14, 1999.) Available from NMFS, Alaska Regional Office, P.O. Box 21668, Juneau, AK 99801. 89 pg.

NMFS. 1998. Final Supplemental Environmental Impact Statement: Groundfish Total Allowable Catch Specifications and Prohibited Species Catch Limits Under the Authority of the Fishery Management Plans for the Groundfish Fishery of the Bering Sea and Aleutian Islands Area and Groundfish of the Gulf of Alaska. December 1998. National Marine Fisheries Service, P.O. Box 21668, Juneau, Alaska 99802. 692 pp + Appendices and Comments.

NPFMC (North Pacific Fisheries Management Council). 1998. Stock assessment and fishery evaluation report for the king and Tanner crab fisheries of the Bering Sea and Aleutian Islands Regions. 238 p.

NPFMC (North Pacific Fishery Management Council). 1993. Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility Analysis alternatives to allocate the Pacific cod total allowable catch by gear and/or directly change the seasonality of the cod fisheries: Amendment 24 to the Fishery Management Plan for the groundfish fishery of the Bering Sea and Aleutian Islands area. October 1993.

NPFMC (North Pacific Fishery Management Council). 1994. Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility analysis for Amendment 21a to the Fishery Management Plan for the Scallop Fishery of the Bering Sea and Aleutian Islands area.

NPFMC (North Pacific Fishery Management Council). 1995. Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility analysis for red king crab bycatch in the Bering Sea trawl fisheries and alternatives for closure areas.

NPFMC (North Pacific Fishery Management Council). 1996. Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility analysis for Amendment 37 to the Fishery Management Plan for Bering Sea and Aleutian Islands Groundfish.

NPFMC (North Pacific Fishery Management Council). 1998. Analysis of Proposed License Limitation Amendment Package. Draft for Public Review. August 21, 1998.

NPFMC (North Pacific Fishery Management Council). 1999. Environmental Assessment/Regulatory Impact Review/ Initial Regulatory Flexibility analysis for Amendment 11 to the Fishery Management Plan for Bering Sea and Aleutian Islands King and Tanner Crabs.

NRC (Natural Resources Consultants). 1988. Minimization of King and Tanner crab by-catch in trawl fisheries directed at demersal groundfish in the Bering Sea. February 1988.

Orensanz, J.M., J. Armstrong, D. Armstrong, and R. Hilborn. 1998. Crustacean resources are vulnerable to serial depletion – the multifacted decline of crab and shrimp fisheries in the greater Gulf of Alaska. Reviews in Fish Biology and Fisheries 8:117-176.

Otto. R.S. 1998. Assessment of the eastern Bering Sea snow crab, *Chionoecetes opilio*, stock under the terminal molting hypothesis. *In* Proceedings of the North Pacific Symposium on Invertebrate Stock Assessment and Management. *Edited by* G.S. Jamieson, and A. Campbell. Can. Spec. Publ. Fish. Aquat. Sci. 125 pp. 109-124.

Owen D. 1988. A bottom trawl survey on the west side of Kodiak Island: Viekoda Bay, Spiridon Bay, and Kupreanof Strait. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K88-28.

Paul, J.M., A.J. Paul, and A. Kimker. 1993. Starvation resistance in Alaska crabs: interim report. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A93-03.

Pengilly, D., and D. Schmidt. 1995. Harvest strategy for Kodiak and Bristol Bay red king crab and St. Matthew Island and Pribilof blue king crab. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division Special Publication Number 7.

Powers. J.E. 1996. Benchmark requirements for recovering fish stocks. North American Journal of Fisheries Management 16:495-504.

Prena, J., P. Schwinghammer, T. W. Rowell, D. C. Gordon, Jr., K. D. Gilkinson., W. P. Vass, and D. L. McKeown. 1999. Experimental otter trawling on a sandy bottom ecosystem of the Grand Banks of Newfoundland: analysis of trawl bycatch and effects on epifauna. Marine Ecology Progress Series, 181:107-124.

Queirolo, L.E., L.W. Frita, P.A. Livingston, M.R. Loefflad, D.A. Colpo, and Y.L. deReynier. 1995. Bycatch, Utilization, and Discards in the Commercial Groundfish Fisheries of the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands. NOAA Technical Memorandum NMFS-AFSC-58.

Quinn, T.J. , C.T. Turnbull and C. Fu. 1998. A Length-based population model for hard-to-age invertebrate populations. Fishery stock assessment models Alaska Sea Grant College Program. AK-SG-98-01, 1998. pp. 531-556.

Reise, K. 1982. Long-term changes in the macrobenthic invertebrate fauna of the Wadden Sea: are polychaetes about to take over? Netherlands Journal of Sea Research. 16:29-36.

Restrepo, V.R., G. G. Thompson, P. M. Mace, W. L. Gabriel, L. L. Low, A. D. MacCall, R. D. Methot, J. E. Powers, B. L. Taylor, P. R. Wade, and J. F. Witzig. 1998. Technical guidance on the use of precautionary approaches to implementing national standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31.

Riemann, B. and Hoffmann E. 1991. Ecological consequences of dredging and bottom trawling in the Limfjord, Denmark. Marine Ecology Progress Series 69(1-2): 171-178.

Rohlf, D.J. 1989. The Endangered Species Act, A Guide to its Protections and Implementation. Stanford Environmental Law Society, Stanford Law School, Stanford, CA. 207 p.

Rose, C. S. 1999. Injury rates of red king crab, Paralithodes camtschaticu, passaging under bottom trawl footropes. Mar. Fisher. Review.

Rosenberg, A.A., and V.R. Restrepo. 1994. Uncertainty and risk evaluation in stock assessment advice for U.S. marine fisheries. Can. J. Fish. Aquat. Sci. 51:2715-2720.

Rosenkranz, G.E. 1998. Statistical modeling of Tanner crab recruitment in Bristol Bay, Alaska. M.S. thesis, University of Alaska Fairbanks, Fairbanks.

Rosenkranz, G.E., A.V. Tyler, G.H. Kruse, and H.J. Neibauer. 1998. Relationship between wind and year class strength of Tanner crabs in the southeastern Bering Se4a. Alaska Fishery Research Bulletin 5(1): 18-24.

Rumohr, H. and P. Krost. 1991. Experimental evidence of damage to benthos by bottom trawling with special reference to Artica islandica. Meeresforschung. 33:340-345.

Sainsbury, K. J. The ecological basis of multispecies fisheries in tropical Australia. In: Fish Population Dynamics, the Implications for Management. Guilland, J. A. (ed), 1988, John Wiley and Sons.

Sainte-Marie, B. 1993. Reproductive cycle and fecundity of primiparous and mulitparous female snow crabs, Chionoecetes opilio, in the northwest Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 50: 2147-2156.

Sainte-Marie, B. 1997. Comment – An improved link between industry, management and science: review of case history of the southwestern Gulf of St. Lawrence snow crab fishery. Can. J. Fish. Aquat. Sci. 54: 496-500.

Sainte-Marie, B., S. Raymond, and J.-C. Brethes. 1995. Growth and maturation of the benthic stages of male snow crab, Chionoecetes opilio (Brachyura: Majidae). Can. J. Fish. Aquat. Sci. 52: 903-924.

Sainte-Marie, B. J.-M. Sevigny, B.D. Smith, and G.A. Lovrich. 1996. Recruitment variability in snow crab (Chionoecetes opilio): pattern, possible causes, and implications for fishery management. Pp. 451-478 in: High Latitude Crabs: Biology, Management, and Economics. Alaska Sea Grant Program Report No. 96-02, University of Alaska Fairbanks.

Sainte-Marie, B.J., J.-M. Sevigny, and Y. Gauthier. 1997. Laboratory behavior of adolescent and adult males of the snow crab (Chionoecetes opilio) (Brachyura: Majidae) mated noncompetitively and competitively with primiparous females. Can. J. Fish. Aquat. Sci. 54: 239-248.

Schwinghammer, P., J. Y. Guigne, and W. C. Siu. 1996. Quantifying the impact of trawling on benthic habitat structure using high resolution acoustics and chaos theory. Canadian Journal of Fishery and Aquatic Science 53: 288-296.

Shirley, T.C. 1998. Appendix D: Crab handling mortality and bycatch reduction. In King and Tanner crab research in Alaska: Annual report for July 1, 1997 though June 30, 1998. Alaska Department of Fish and Game Regional Information Report No. 5J98-07.

Smith, K.R. and R.A. McConnaughey. 1999. Surficial sediments of the eastern Bering Sea continental shelf: EBSSED database documentation. NOAA Technical Memorandum NMFS-AFSC-104. U.S. Department of Commerce, National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA.

Somerton, D. A. 1981. A computer technique for estimating the size of sexual maturity in crabs. Can. J. Fish. Aquat. Sci. 37: 1488-1494.

Somerton, D. and L.L. Low. 1977. Determination of minimum size and yield limits for Tanner crabs in the eastern Bering Sea. Northwest and Alaska Fisheries Center Processed Report, April 1977. National Marine Fisheries Service, NWAFC, Seattle WA.

Somerton, D.A. and R.S. Otto. 1999. Net efficiency of a survey trawl for snow crab, *Chionoecetes opilio*, and Tanner crab, *C. bairdi*. Fish. Bull. 97:617-625.

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

Stevens, B.G., and R.A. MacIntosh. 1993. Survival of crabs discarded from commercial pot fisheries. Cited in Queirolo et al. 1995. Bycatch, Utilization, and Discards in the Commercial Groundfish fisheries of the Gulf of Alaska, Eastern Bering Sea, and Aleutian Islands. NOAA Technical Memorandum NMFS-AFSC-58.

Stevens, B.G., J.A. Haaga, and R.A. MacIntosh. 1998. Report to the industry on the 1998 Eastern Bering Sea crab survey. NOAA/NMFS-AFSC Processed Report 98-07.

Thrush, S. F., J. E. Hewitt, V. J. Cummings, P. K. Dayton, M. Cryer, S. J. Turner, G. A. Funnell, R. G. Budd, C. J. Milburn, and M. R. Wilkinson. 1998. Disturbance of the marine benthic habitat by commercial fishing: impacts at the scale of the fishery. Ecological Applications, 8(3), pp. 866-879.

Tracy, D.A. 1994. Biological summary of the 1992 mandatory shellfish observer program database. Alaska Department of Fish and Game. Regional Information Report 4K94-10.

Tracy, D.A. 1995. Alaska Department of Fish and Game Summary of the 1994 Mandatory Shellfish Observer Program Database. Alaska Department of Fish and Game. Regional Information Report 4K95-32.

Tyler, A.V., and G.H. Kruse. 1996. Conceptual modeling of brood strength of red king crabs in the Britol Ba region of the Bering Sea. High Latitude Crabs: Biology, Management and Economics. University of Alaska Sea Grant College Program Report No. 96-02: 511-543.

Urban, D., D. Pengilly, and I. Vining. 1994. The scallop observer program and statewide data analysis summary to the Board of Fisheries. Alaska Department of Fish and Game Report 4K94-28.

Vining, I., S. Byersdorfer, W. Donaldson, B. Stevens, and G. Edwards. 1997. Lost crab and cod pot recovery and ghost fishing in Chiniak Bay and other areas in the waters around Kodiak Island, Alaska. Alaska Department of Fish and Game, Regional Information Report No. 4K97-42.

Vining, I., D. Witherell, and J. Heifetz. 1997. The effects of fishing gear on benthic communities. In: 1998 Ecosystem Chapter of SAFE Report.

Watson, L.J., and D. Pengilly. 1994. Effects of release method on recovery rates of tagged red king crabs (Paralithodes camtschaticus in the 1993 Bristol Bay commercial fishery. Alaska Department of Fish and Game, Commercial Fisheries Management and Development Division, Regional Information Report 4K94-40.

Witherell, D., and G. Harrington. 1996. Evaluation of alternative management measures to reduce the impacts of trawling ad dredging on Bering Sea crab stocks. Pages 41-58. In: High Latitude Crabs: Biology, Management, and Economics. Alaska Sea Grant College Program. AK-SG-96-02.

Witherell, D., and C. Pautzke. 1997. A brief history of bycatch management measures for Eastern Bering Sea groundfish fisheries. Marine Fisheries Review 59(4):15-22.

Witherell, D., C. Pautzke, and D. Fluharty. 2000. An ecosystem-based approach for Alaska groundfish fisheries. ICES Journal of Marine Science. In press.

Zheng, J. M.C. Murphy, and G.H. Kruse. 1995. Overview of population estimation methods and robust long-term harvest strategy for red king crabs in Bristol Bay. Alaska Department of Fish and Game Regional Information Report No. 5J95-21.

Zheng, J. and G.H. Kruse. 1998. Stock-recruitment relationships for Bristol Bay Tanner crab. Alaska Fishery Research Bulletin 5(2):116-130.

Zheng, J., and G.H. Kruse. 1999. Overview of population dynamics and recommended harvest strategy for Tanner crabs in the eastern Bering Sea. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J99-04, Juneau.

Zhou, S. and T.C. Shirley. 1995. Effects of handling on feeding, activity, and survival of red king crabs, Paralithodes camtschaticus (Tilesius, 1815). Journal of Shellfish Research 14:173-177.

Zhou, S. and T.C. Shirley. 1996. Is handling responsible for the decline of the red king crab fishery? Proceedings of the International Symposium on Biology, Management, and Economics of Crabs from High Latitude Habitats. Alaska Sea Grant Program Report 96-02:591-611.

Zhou, S. and G.H. Kruse. 1998. Appendix C: Crab handling mortality and bycatch reduction. In King and Tanner Crab Research in Alaska: Annual Report for July 1, 1997 through June 30, 1998. Alaska Department of Fish and Game Regional Information Report No. 5J98-07.

5.0 AGENCIES AND INDIVIDUALS CONSULTED

NMFS-AKRO: Mary Furuness, Lew Queirolo
ADF&G: Wayne Donaldson, Shareef Siddeek
UAF: Josh Greenberg

Public: John Gauvin, Francine Bennis, Arni Thomson, David Hillstrand, Simeon Swetzoff, Mateo Paz-Soldan

Advisory Groups: BSAI Crab Plan Team, Alaska Board of Fisheries, NPFMC Scientific and Statistical Committee, NPFMC Advisory Panel

6.0 LIST OF PREPARERS

NPFMC: Dave Witherell
ADF&G: Rance Morrison, Gordon Kruse, Doug Pengilly, Jie Zheng, Larry Byrne, Kristin Mabry
NMFS: Bob Otto, Jack Turnock, Gretchen Harrington
UAF: Tom Shirley

7.0 Tables

Table 1 Annual abundance estimates (millions of crabs) for eastern Bering Sea snow crabs (*C. opilio*) from NMFS surveys (all districts combined).

	Males				Females			
	Small	Large	V. Large		Small	Large		
Carapace Width(mm)	<102[1]	≥102[1]	≥110		<50	≥50		Grand
Width(in)	<4.0	≥4.0	≥4.3	Total	<2.0	≥2.0	Total	Total
1980	2502.3	115.2	57.8	2617.6	1827.2	4144.5	5971.7	8589.3
1981	1889.1	54.5	22.2	1943.6	668.6	2607.6	3276.2	5219.8
1982	2003.0	70.2	21.7	2073.2	402.6	2255.8	2658.4	4731.7
1983	1782.8	75.3	22.1	1858.1	673.1	1228.4	1912.6	3771.0
1984	1237.4	153.2	73.9	1390.6	610.5	581.7	1192.2	2582.9
1985	547.8	74.9	40.7	622.7	258.2	123.5	381.7	1004.3
1986	1179.0	83.1	45.9	1262.1	790.6	422.0	1212.5	2474.5
1987	4476.0	144.3	66.4	4620.3	2903.0	2795.0	5698.0	10318.3
1988	3467.2	171.0	90.1	3638.2	1235.3	2322.7	3556.0	7194.2
1989	3646.1	187.1	81.2	3833.2	1922.8	3790.7	5713.4	9546.6
1990	2860.4	420.3	188.7	3280.7	1463.3	2798.1	4261.4	7542.1
1991	3971.2	484.1	323.0	4455.3	3289.0	3575.0	6863.9	11319.2
1992	3158.4	256.4	163.8	3414.8	2433.9	1914.3	4348.2	7763.0
1993	5596.6	135.0	77.9	5731.5	3989.8	1982.6	5972.4	11703.9
1994	4282.5	71.6	39.9	4354.0	3417.6	1674.3	5091.8	9445.9
1995	4086.8	68.8	30.9	4155.6	2090.3	2409.4	4499.7	8655.3
1996	2700.1	171.6	64.8	2871.7	1189.0	1364.2	2553.2	5424.9
1997	1490.8	305.7	160.9	1796.6	927.9	1383.1	2311.0	4107.5
1998	1014.7	254.6	139.2	1269.3	803.0	1160.8	1964.0	3233.3
1999	517.0	94.2	55.8	611.1	315.5	474.3	789.8	1401.0
East(%)[2]	59.5	70.3	73.9	61.1	38.0	45.3	42.4	50.6
Limits[3]								
Lower	398.1	72.5	40.2	488.9	186.1	265.6	481.8	970.7
Upper	635.9	115.8	71.4	733.4	444.8	683.0	1097.8	1831.2
±%	23	23	28	20	41	44	39	31

[1] Values prior to 1984 are interpolated from 5 mm width classes.

[2] Percent of size group in Eastern District (east of 173°).

[3] Mean ± 2 standard errors for most recent year.

Table 2. Estimated CPUE of snow crabs by soak hours from 2,128 pot lifts sampled from 12 catcher-processors during the 1998 Bering Sea snow crab open access fishery (Moore et al. 2000).

	Pots Sampled		CPUE				
Soak Hours	Number	Percent	Legal Retained	Legal Not Retained	Sublegal	Female	Total Crabs
1-12	73	3.4	61	38	2	<1	100
13-24	496	23.3	132	59	2	<1	193
25-36	590	27.7	154	56	3	<1	212
37-48	412	19.4	199	63	3	<1	265
49-60	194	9.1	245	63	2	<1	310
61-72	91	4.3	176	49	2	<1	227
73-84	66	3.1	172	23	1	<1	197
85-96	51	2.4	212	42	3	<1	257
97-108	33	1.6	240	45	2	<1	287
109-120	31	1.5	274	81	3	0	357
121-132	24	1.1	298	37	1	0	336
133-144	19	0.9	254	22	1	<1	277
145-156	6	<0.1	298	24	1	0	322
157-168	11	0.5	229	21	0	0	251
169-180	1	<0.1	48	6	0	0	54
181-192	5	<0.1	93	14	2	0	108
193-204	0	0.0	0	0	0	0	0
205-216	13	0.6	105	12	0	0	117
217-228	3	<0.1	266	48	2	0	315
229-240	2	<0.1	77	11	0	0	88
241-252	2	<0.1	162	18	1	0	180
253-276	0	0.0	0	0	0	0	0
277-288	2	<0.1	34	24	0	0	58
289-300	2	<0.1	90	5	1	0	96
301-312	2	<0.1	303	40	4	0	346
mean soak: 45 hours		Overall CPUE:	171	55	2	<1	229

Table 3. Estimated CPUE of snow crabs by soak hours from 1,719 pot lifts sampled from 20 catcher-only vessels during the 1998 Bering Sea snow crab Community Development Quota fishery (Moore et al. 2000).

	Pots Sampled		CPUE				
Soak Hours	Number	Percent	Legal Retained	Legal Not Retained	Sublegal	Female	Total Crabs
0-23	61	3.5	113	108	3	2	228
24-47	650	37.8	126	124	4	2	257
48-71	440	25.6	146	128	6	3	284
72-95	219	12.7	179	144	5	2	332
96-119	146	8.5	182	137	8	4	332
120-143	82	4.8	179	144	9	3	335
144-167	48	2.8	220	159	5	1	386
168-191	34	2.0	226	179	6	5	417
192-215	10	0.6	182	185	6	0	373
216-239	2	0.1	238	341	9	1	590
240-263	6	0.3	157	102	5	1	266
264-287	6	0.3	36	17	2	0	56
288-311	8	0.5	116	128	2	0	246
312-359	0	0.0	0	0	0	0	0
360-383	6	0.3	149	75	2	0	228
384-407	0	0.0	0	0	0	0	0
408-431	1	0.1	202	285	12	0	500
Mean Soak: 67 hours		Overall CPUE:	150	131	5	3	290

Table 4. Estimate CPUE of snow crabs by soak hours from 1,507 pot lifts sampled from 10 catcher-processor vessels during the 1999 Bering Sea snow crab open-access fishery (Data from ADF&G).

	Pots Sampled		Catch Per Sampled Pot				
Soak Hours	Number	Percent	Legal Retained	Legal Not Retained	Sublegal	Female	Total Crabs
1-24	293	19.4	87	49	1	<1	137
25-48	811	53.8	133	45	1	<1	180
49-72	209	13.9	126	45	1	<1	172
73-96	67	4.4	118	34	1	0	152
97-120	44	2.9	171	50	1	0	222
121-144	41	2.7	142	30	<1	0	173
145-168	19	1.3	124	58	1	0	183
169-192	7	0.5	130	73	1	0	205
193-216	5	0.3	31	5	0	0	36
217-240	1	0.1	203	13	1	0	217
241-264	2	0.1	101	26	0	0	127
265-288	0	0.0	0	0	0	0	0
289-312	0	0.0	0	0	0	0	0
313-336	0	0.0	0	0	0	0	0
337-360	0	0.0	0	0	0	0	0
361-384	0	0.0	0	0	0	0	0
385-408	1	0.1	0	0	0	0	0
409-432	3	0.2	241	38	2	<1	281
433-456	2	0.1	296	34	4	1	333
457-480	2	0.1	293	43	1	0	337
Mean Soak: 48 hours	Overall CPUE:		124	45	1	<1	170

Table 5. Estimate CPUE of snow crabs by soak hours from 783 pot lifts sampled from 20 catcher-only vessels during the 1999 Bering Sea snow crab Community Development Quota fishery (Data from ADF&G).

	Pots Sampled		CPUE				
Soak Hours	Number	Percent	Legal Retained	Legal Not Retained	Sublegal	Female	Total Crabs
1-24	11	1.4	63	37	1	0	101
25-48	305	39.0	116	67	2	<1	185
49-72	295	37.7	131	80	3	<1	214
73-96	109	13.9	149	70	3	<1	222
97-120	31	4.0	144	69	2	<1	216
121-144	9	1.1	153	78	4	0	234
145-168	6	0.8	182	118	5	0	305
169-192	5	0.6	172	148	14	<1	333
193-216	4	0.5	227	112	7	0	346
217-240	0	0.0	0	0	0	0	0
241-264	0	0.0	0	0	0	0	0
265-288	0	0.0	0	0	0	0	0
289-312	0	0.0	0	0	0	0	0
313-336	0	0.0	0	0	0	0	0
337-360	0	0.0	0	0	0	0	0
361-384	1	0.1	533	261	8	0	802
385-408	3	0.4	168	166	9	0	343
409-432	4	0.5	244	290	17	0	550
Mean Soak: 65 hours		Overall CPUE:	130	75	3	<1	208

Table 6 Bycatch of crab in 1997 BSAI groundfish fisheries by species, gear type, target, and regulatory area. Note that the "other Tanner crab" category is primarily C. opilio.

1997 crab bycatch data		red king	bairdi	o.Tanner
by gear and target				
Hook & Line				
	P. cod	4,465	11,428	140,624
	other	12	14	622
	Total all targets	4,477	11,442	141,246
Groundfish Pot				
	P. cod	21,102	38,775	412,859
	other	0	0	0
	Total all targets	21,102	38,775	412,859
Trawl	Atka mackerel	0	0	0
	bottom pollock	137	10,723	127,563
	P. cod	2,211	246,281	465,172
	other flatfish	71	35,731	72,553
	midwater pollock	0	6,525	88,589
	rock sole	38,405	469,948	568,631
	flathead sole	0	146,481	582,386
	yellowfin sole	9,886	1,000,633	3,365,135
	other	1	1,415	6,179
	Total all targets	50,711	1,917,737	5,276,208
Total all gears/targets		76,290	1,967,954	5,830,313

1997 crab bycatch data		red king	bairdi	o.Tanner
by area (all gears/targets)				
Regulatory Area				
	508	0	0	0
	509	15,956	844,510	1,304,240
	512	8,761	488	4
	513	3,161	803,065	3,441,822
	514	2,601	6,119	31,216
	516	45,623	12,259	1,331
	517	79	244,454	775,358
	518	43	756	136
	519	10	3,549	3,949
	521	83	33,307	190,709
	523	0	343	2,151
	524	0	15,881	79,292
	530	0	0	0
	541	1	3,170	58
	542	7	51	40
	543	0	0	4
Total all gears/targets		76,325	1,967,952	5,830,310

Table 7 Bycatch of crab in 1998 BSAI groundfish fisheries by species, gear type, target, and regulatory area. Note that the "other Tanner crab" category is primarily C. opilio.

1998 crab bycatch data		red king	bairdi	o.Tanner
by gear and target				
Hook & Line				
	P. cod	3,006	5,907	152,453
	other	13	36	1,393
	Total all targets	3,019	5,943	153,846
Groundfish Pot				
	P. cod	3,993	40,609	395,290
	other	0	0	3
	Total all targets	3,993	40,609	395,293
Trawl	Atka mackerel	0	121	1,084
	bottom pollock	5,078	19,314	68,449
	P. cod	3,646	106,692	259,027
	other flatfish	28	31,881	70,155
	midwater pollock	9,276	37,742	56,165
	flathead sole	1,761	208,536	672,140
	rock sole	13,246	214,264	477,327
	yellowfin sole	8,738	851,866	2,476,741
	other	230	7,400	41,560
	Total all targets	42,003	1,477,816	4,122,648
Total all gears/targets		49,015	1,524,368	4,671,787

1998 crab bycatch data		red king	bairdi	o.Tanner
by area (all gears/targets)				
Regulatory Area				
	508	0	0	0
	509	36,509	545,828	1,078,032
	512	558	33	0
	513	1,717	575,995	2,503,323
	514	1,059	1,088	57,317
	516	7,255	31,342	14,859
	517	181	284,807	623,813
	518	3	574	45
	519	28	21,801	39,931
	521	894	51,136	340,034
	523	4	172	3,978
	524	55	10,231	10,284
	530	0	0	0
	541	4	1,230	139
	542	624	126	24
	543	125	6	10
Total all gears/targets		49,015	1,524,369	4,671,789

Table 8 Bycatch of crab in 1999 BSAI groundfish fisheries by species, gear type, target, and regulatory area. Note that the "other Tanner crab" category is primarily C. opilio.

1999 crab bycatch data		red king	bairdi	o.Tanner	o. king
by gear and target					
Hook and Line					
	P. cod	7,981	2,782	90,582	1,624
	other	8	18	756	1,724
	Total all targets	7,989	2,800	91,338	3,348
Groundfish pot					
	P. cod	979	40,402	177,673	14,511
	other	0	18	767	23,761
	Total all targets	979	40,420	178,440	38,272
Trawl					
	Greenland turbot	0	5,828	3,032	1,811
	P. cod	7,697	127,242	278,899	4,066
	rock sole	62,619	306,775	451,338	3,075
	yellowfin sole	14,304	455,527	739,812	2,890
	other targets	89	6,247	71,666	7,380
	Total all targets	84,709	901,619	1,544,747	19,222
Total all gears/targets		93,677	944,839	1,814,525	60,842

1999 crab bycatch data		red king	bairdi	o.Tanner	o. king
by area (all gears/targets)					
Regulatory area					
	509	48,032	291,353	450,943	1,843
	512	2,420	46	45	14
	513	915	284,478	855,019	3,447
	514	895	4,589	78,317	1,963
	516	40,623	81,718	11,655	2,864
	517	66	214,088	234,937	4,690
	518	4	4,741	210	923
	519	34	18,344	41,511	438
	521	405	31,661	126,322	11,517
	523	5	327	5,654	8
	524	77	7,740	9,212	4,985
	541	196	5,497	677	19,693
	542	5	245	22	4,438
	543	0	10	0	4,018

Table 9 Mortality of male snow crabs, as measured by adult equivalents, using 1997 and 1998 bycatch data.

1997 male snow crab

Fishery	Gear or Target	Total number impacted	Number MALES impacted	Ave. width (mm)	Approx. average age (years)	Discard mortality rate	Number killed	Approx. years to recruit (males)	Mortality in adult equivalents
Groundfish	Trawl	5,276,208	4,220,966	75	8	0.80	3,376,773	4	1,068,432
	Hook&line	141,246	141,246	110	12	0.45	63,561	0	63,561
	Pot	412,859	412,859	90	9	0.30	123,858	3	52,252
						total	3,564,192		1,184,245
Scallop	Dredge	195,345	195,345	100	11	0.40	78,138	1	58,604
Crab	Snow crab harvest	99,975,539	99,975,539	110	12	1.00	99,975,539	0	99,975,539
	BB red king (bycatch)	21,296	0	90	9	0.08	0	3	0
	EBS Tanner (bycatch)	0	0	90	9	0.20	0	3	0
	EBS Snow (bycatch)	74,040,000	73,020,000	90	9	0.25	18,255,000	3	7,701,328
	Pribilof Hair (bycatch)	994,150	942,800	90	9	0.08	75,424	3	31,820
	Prib red/blue (bycatch)			90	9	0.08	0	3	0
						total	118,305,963		107,708,687
					Totals		121,948,293		108,951,535

1998 male snow crab

Fishery	Gear or Target	Total number impacted	Number MALES impacted	Ave. width (mm)	Approx. average age (years)	Discard mortality rate	Number killed	Approx. years to recruit (males)	Mortality in adult equivalents
Groundfish	Trawl	4,122,648	3,298,118	75	8	0.80	2,638,495	4	834,836
	Hook&line	153,846	153,846	110	12	0.45	69,231	0	69,231
	Pot	395,293	395,293	90	9	0.30	118,588	3	50,029
						total	2,826,313		954,096
Scallop	Dredge	232,911	232,911	100	11	0.40	93,164	1	69,873
Crab	Snow crab harvest	186,543,734	186,543,734	110	12	1.00	186,543,734	0	186,543,734
	BB red king (bycatch)	16,692	16,337	90	9	0.08	1,307	3	551
	EBS Tanner (bycatch)	0	0	90	9	0.20	0	3	0
	EBS Snow (bycatch)	51,464,874	51,464,874	90	9	0.25	12,866,219	3	5,427,936
	Pribilof Hair (bycatch)	109,886	108,987	90	9	0.08	8,719	3	3,678
	Prib red/blue (bycatch)			90	9	0.08	0	3	0
						total	199,419,978		191,975,900
					Totals		202,339,456		192,999,869

Table 10 Mortality of male snow crabs, as measured by adult equivalents, using 1999 bycatch data.

Fishery	Gear or Target (1999 male snow crab)	Total number impacted	Number MALES impacted	Ave. width (mm)	Approx. average age (years)	Discard mortality rate	Number killed	Approx. years to recruit (males)	Mortality in adult equivalents
Groundfish	Trawl	1,544,747	1,235,798	75	8	0.80	988,638	4	312,811
	Hook&line	91,338	91,338	110	12	0.45	41,102	0	41,102
	Pot	178,440	178,440	90	9	0.30	53,532	3	22,584
						total	1,083,272		376,497
Scallop	Dredge	150,421	150,421	100	11	0.40	60,168	1	45,126
Crab	Tanner crab harvest	143,296,568	143,296,568	110	12	1.00	143,296,568	0	143,296,568
	BB red king (bycatch)	16,692	13,496	90	9	0.08	1,080	3	455
	EBS Tanner (bycatch)	0	0	90	9	0.20	0	3	0
	EBS Snow (bycatch)	51,464,874	49,427,332	90	9	0.25	12,356,833	3	5,213,039
	Pribilof Hair (bycatch)	109,886	97,294	90	9	0.08	7,784	3	3,284
	Prib red/blue (bycatch)			90	9	0.08	0	3	0
						total	155,662,264		148,513,346
					Totals		156,805,705		148,934,970

Table 11 Mortality of female snow crabs, as measured by adult equivalents, using 1997 and 1998 bycatch data.

Fishery	Gear or Target	Total number impacted	Number FEMALES impacted	Ave. width (mm)	Approx. average age (years)	Discard mortality rate	Number killed	Approx. years to maturity fem.	Mortality in adult equivalents
	1997 female snow crab								
	-								
Groundfish	Trawl	5,276,208	1,055,242	63	7	0.80	844,193	0	844,193
	Hook&line	141,246	0	63	7	0.45	0	0	0
	Pot	412,859	0	63	7	0.30	0	0	0
						total	844,193		844,193
									0
Scallop	Dredge	195,345	0	100	10	0.40	0	0	0
									0
Crab	Snow crab harvest	99,975,539	0	50	6	0.25	0	0	0
	BB red king (bycatch)	21,296	0	65	7	0.08	0	0	0
	EBS Tanner (bycatch)	0	0	65	7	0.20	0	0	0
	EBS Snow (bycatch)	74,040,000	1,020,000	65	7	0.25	255,000	0	255,000
	Fribilof Hair (bycatch)	994,150	143,800	65	7	0.08	11,504	0	11,504
	Prib red/blue (bycatch)			65	7	0.08	0	0	0
						total	266,504		266,504
					Totals		1,110,697		1,110,697

Fishery	Gear or Target	Total number impacted	Number FEMALES impacted	Ave. width (mm)	Approx. average age (years)	Discard mortality rate	Number killed	Approx. years to maturity fem.	Mortality in adult equivalents
	1998 female snow crab								
Groundfish	Trawl	4,122,648	824,530	63	7	0.80	659,624	0	659,624
	Hook&line	153,846	0	63	7	0.45	0	0	0
	Pot	395,293	0	63	7	0.30	0	0	0
						total	659,624		659,624
									0
Scallop	Dredge	232,911	0	100	10	0.40	0	0	0
									0
Crab	Tanner crab harvest	186,543,734	0	50	6	1.00	0	0	0
	BB red king (bycatch)	16,692	355	65	7	0.08	28	0	28
	EBS Tanner (bycatch)	0	0	65	7	0.20	0	0	0
	EBS Snow (bycatch)	51,464,874	78,592	65	7	0.25	19,648	0	19,648
	Pribilof Hair (bycatch)	109,886	899	65	7	0.08	72	0	72
	Prib red/blue (bycatch)			65	7	0.08	0	0	0
						total	19,748		19,748
					Totals		679,372		679,372

Table 12 Mortality of female snow crabs, as measured by adult equivalents, using 1999 bycatch data.

	1999 female snow crab								
Fishery	Gear or Target	Total number impacted	Number FEMALES impacted	Ave. width (mm)	Approx. average age (years)	Discard mortality rate	Number killed	Approx. years to maturity fem.	Mortality in adult equivalents
Groundfish	Trawl	1,836,031	367,206	63	7	0.80	293,765	0	293,765
	Hook&line	17,543	0	63	7	0.45	0	0	0
	Pot	262,016	0	63	7	0.30	0	0	0
						total	293,765		293,765
									0
Scallop	Dredge	17,000	0	100	10	0.40	0	0	0
									0
Crab	Tanner crab harvest	143,296,568	0	50	6	0.25	0	0	0
	BB red king (bycatch)		3,196	65	7	0.08	256	0	256
	EBS Tanner (bycatch)		0	65	7	0.20	0	0	0
	EBS Snow (bycatch)		2,037,542	65	7	0.25	509,386	0	509,386
	Pribilof Hair (bycatch)		12,592	65	7	0.08	1,007	0	1,007
	Prib red/blue (bycatch)			65	7	0.08	0	0	0
						total	510,649		510,649
					Totals		804,414		804,414

Table 13 Model equations describing the populations dynamics used in the simulation.

$Y_t = \sum_{l=1}^{L} w_l C_{t,l}$	$1 \le t \le T$ $1 \le l \le L$	Yield
$N_{t+1,l} = N_{t,l} e^{-Z_{t,l}}$	$1 < t \le T$ $1 \le l < L$	Numbers at length l and time t+1.
$N_{ln} = N_{ln} - \eta_{ln} N_{ln} + \sum_{l=1}^{L} N_l \eta_l p_{ln,l}$		Numbers in length bin ln are equal to the numbers in length bin ln that did not molt, plus the numbers that grow from other length bins, where $p_{ln,l}$ is the proportion of animals in length bin l that grow to length bin ln. $p_{ln,l}$ is estimated from a normal distribution with the mean length and variance of the ln th length bin.
$SB_t = \sum_{l=1}^{L} w_l \phi_l N_{t,l}$		Mature biomass, estimated separately for males and females
$Z_{t,l} = F_{t,l} s_l + M$		Total Mortality
$\phi_l = \frac{1}{(1+e^{-\alpha(l-\beta)})}$		Logistic maturity function
$\eta_l = 1 - \frac{1}{(1+e^{-\alpha(l-\beta)})}$		Molting probabilities – a descending logistic function
$s_l = \frac{1}{(1+e^{-\alpha(l-\beta)})}$		Logistic fishery selectivity function.
$l_{t+1} = l\inf(1-e^{-k}) + e^{-k} l_t$		Mean length at time t+1 given length at time t. k and linf are von Bertalanffy growth parameters.
$\text{var}\,iance_l = \frac{\sigma^2(1-e^{-k^{2l}})}{1-e^{-k^2}} + e^{-k^{2l}} \sigma_r{}^2$		Variance of mean length. k is the growth parameter, σ^2 is the variance at the largest length bin, and σ_r^2 is the variance at the smallest length bin.
$R_t = R^{1-\gamma} R_{t-1}^{\gamma} e^{\sigma\delta}$		Recruitment at time t, using an autocorrelated lognormal distribution with mean R and standard deviation σ. δ is from a standard normal distribution. γ is the autocorrelation parameter.

Table 14 Results of rebuilding simulation for five scenarios, zero catch until rebuilt (1), trawl bycatch only(2), a directed fishery with the new harvest strategy(3), the status quo harvest policy with no msst or minimum GHL (4), and the status quo harvest policy with an msst of 230.4 million lbs (5). Each scenario was run with random recruitment, autocorrelated recruitment and the low-high recruitment options.

	Years to rebuild for probabilities of 10%,50% and 90%			Probability of mature biomass below one-half MSST			Mean annual yield(million lbs)		
Random recruitment									
Scenario	10%	50%	90%	5yr	10yr	20yr	5 yr	10 yr	20 yr
1	4	6.6	12	0.04	0.02	0.01	4.5	31.5	57.4
2	4	6.6	12	0.04	0.02	0.01	4.5	31.5	57.1
3	5	7.2	15	0.08	0.04	0.02	10.7	38.0	61.7
4	5	7.6	16	0.16	0.08	0.04	25.0	57.7	83.4
5	5	7.6	16	0.12	0.06	0.03	26.3	59.3	84.2
Autocorrelated recruitment									
Scenario									
1	6	9.9	22	0.17	0.11	0.06	1.06	18.3	59.2
2	6	9.9	22	0.19	0.12	0.07	1.0	17.5	61.0
3	6	10.4	25	0.25	0.16	0.09	5.8	24.5	61.2
4	6	11.1	26	0.47	0.28	0.16	20.2	43.1	92.2
5	6	11.1	26	0.38	0.23	0.13	17.7	41.1	88.5
Low-High recruitment									
1	6	7.1	10	0.10	0.05	0.02	0.9	28.6	65.1
2	6	7.1	10	0.09	0.05	0.02	1.1	28.9	65.3
3	6	7.3	10	0.16	0.08	0.04	6.6	33.8	68.4
4	6	7.6	10	0.33	0.17	0.08	20.5	52.1	92.7
5	6	7.4	10	0.26	0.13	0.07	20.0	52.9	93.0

8.0 Figures

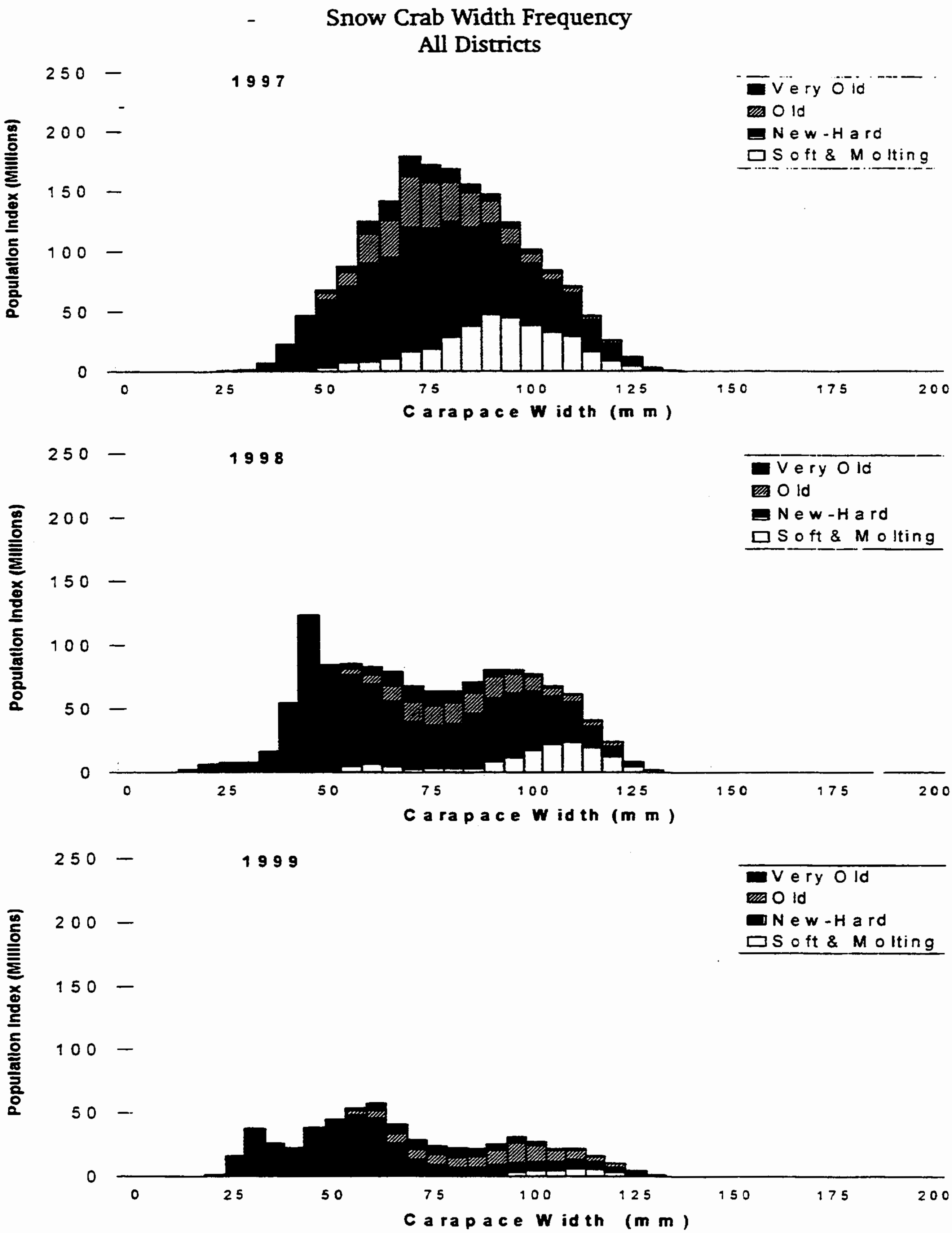


Figure 1 Size-frequency of male snow crab (*C. opilio*), all districts combined, by 5 mm width classes, 1997-1999.

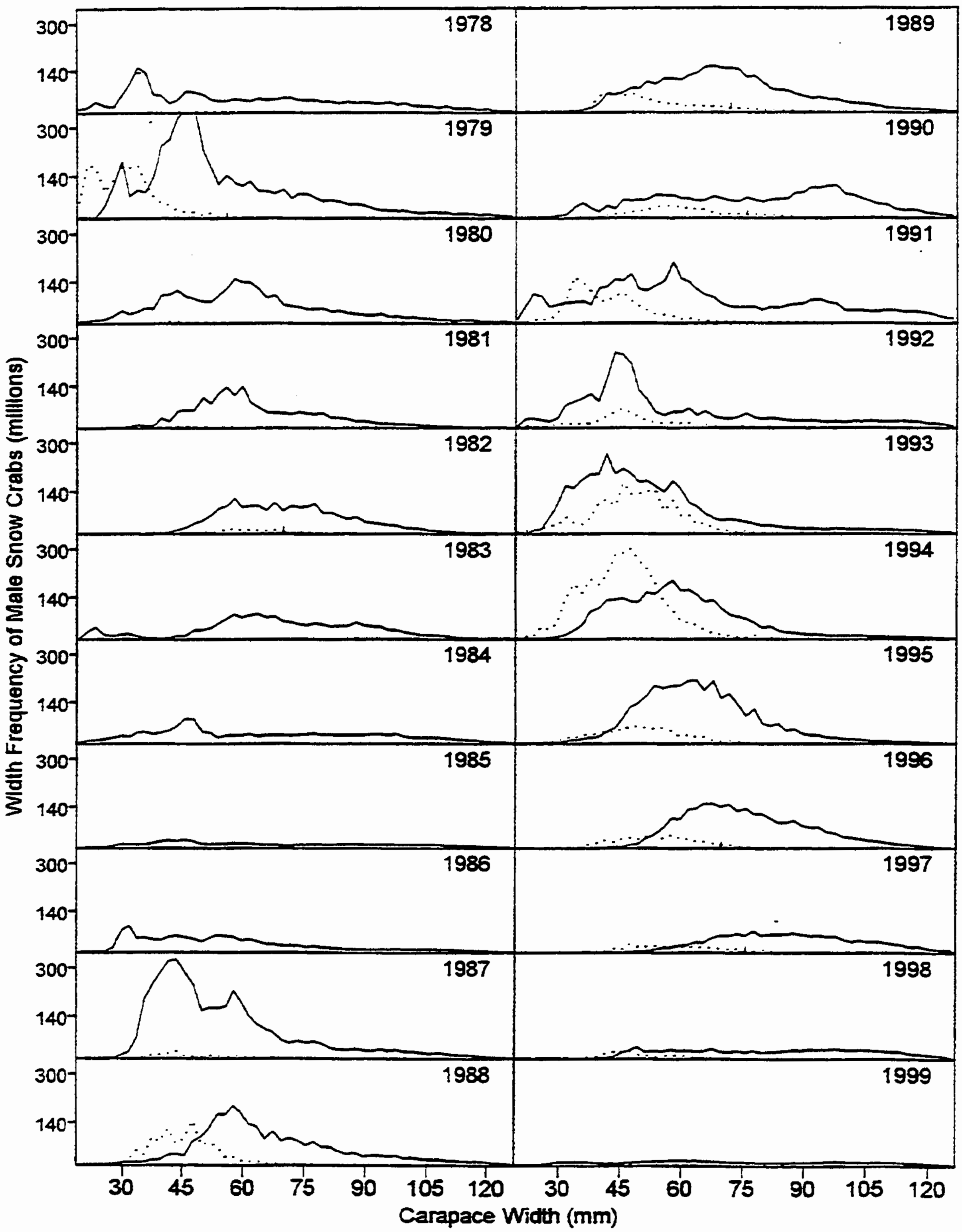


Figure 2 Width frequency of area-swept estimates of male snow crab abundance in the eastern Bering Sea. Solid lines—south of 61.2°N, and dotted lines—north of 61.2°N.

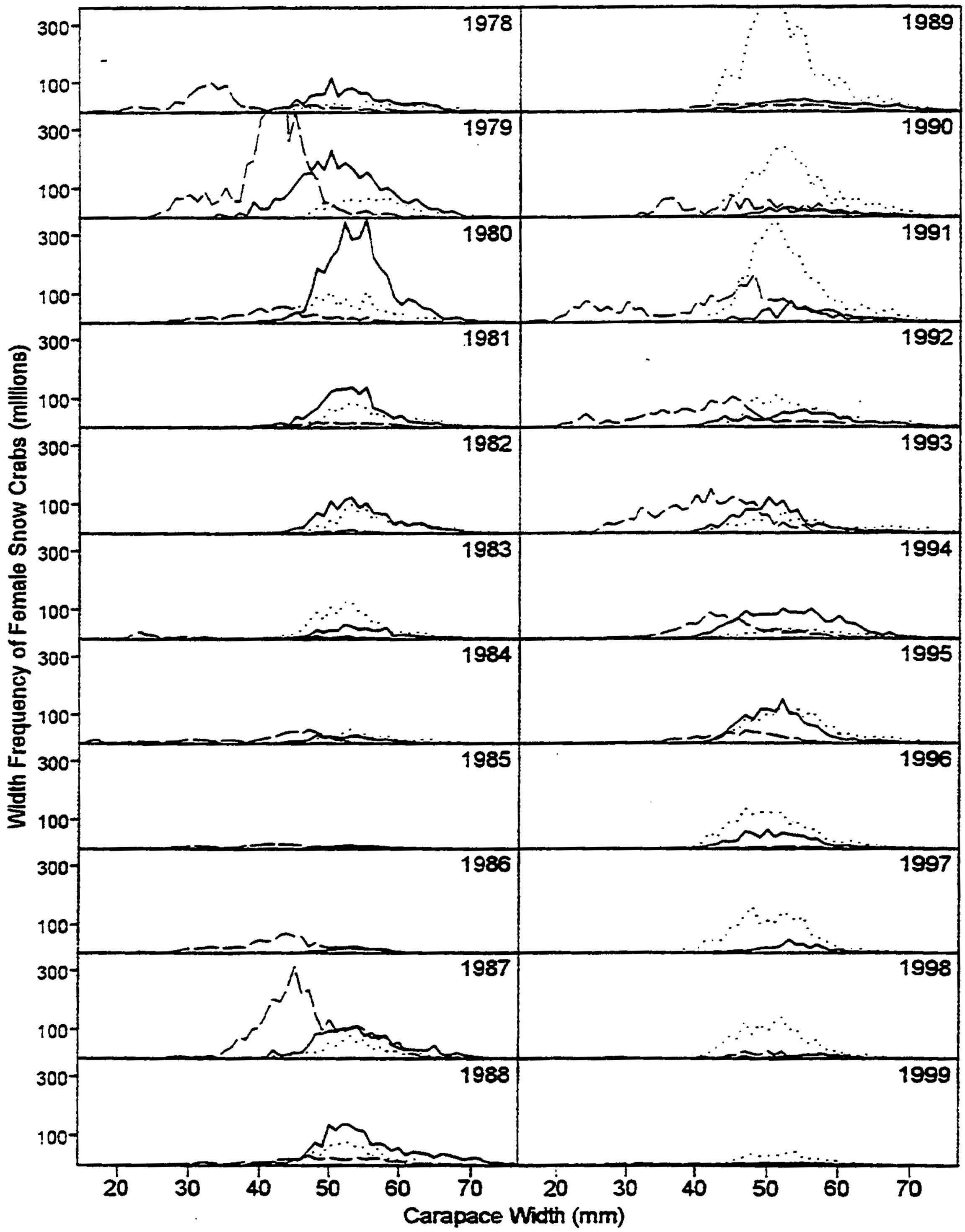


Figure 3 Width frequency of area-swept estimates of female snow crab abundance south of 61.2°N in the eastern Bering Sea. Dashed lines—immature crabs, solid lines—newshell mature crabs, and dotted lines—oldshell mature crabs.

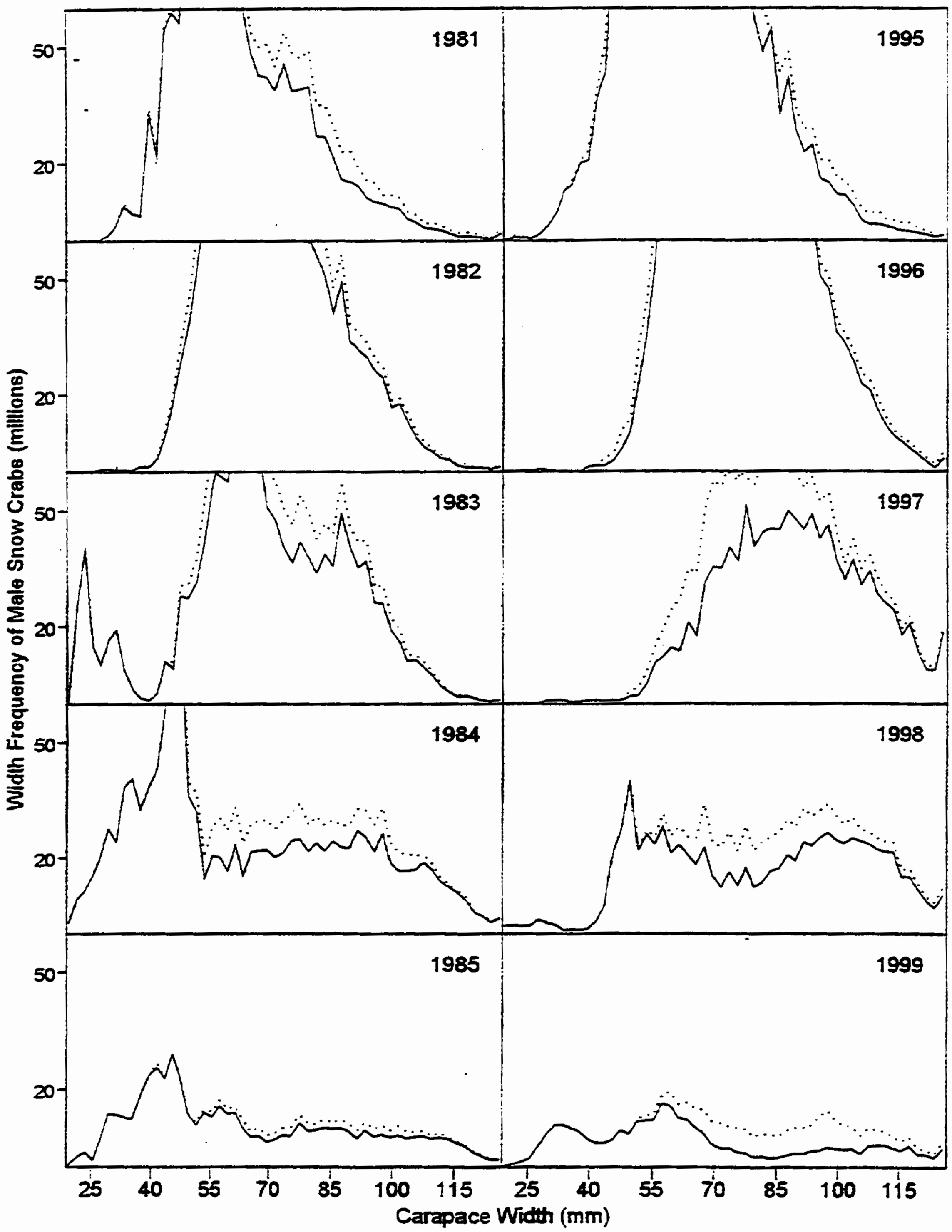


Figure 4 Comparison of width frequency of male snow crab abundance south of 61.2^{0}N in the eastern Bering Sea from 1981 to 1985 and from 1995 to 1999. Solid lines—newshell crabs, and differences between dotted and solid lines—oldshell crabs.

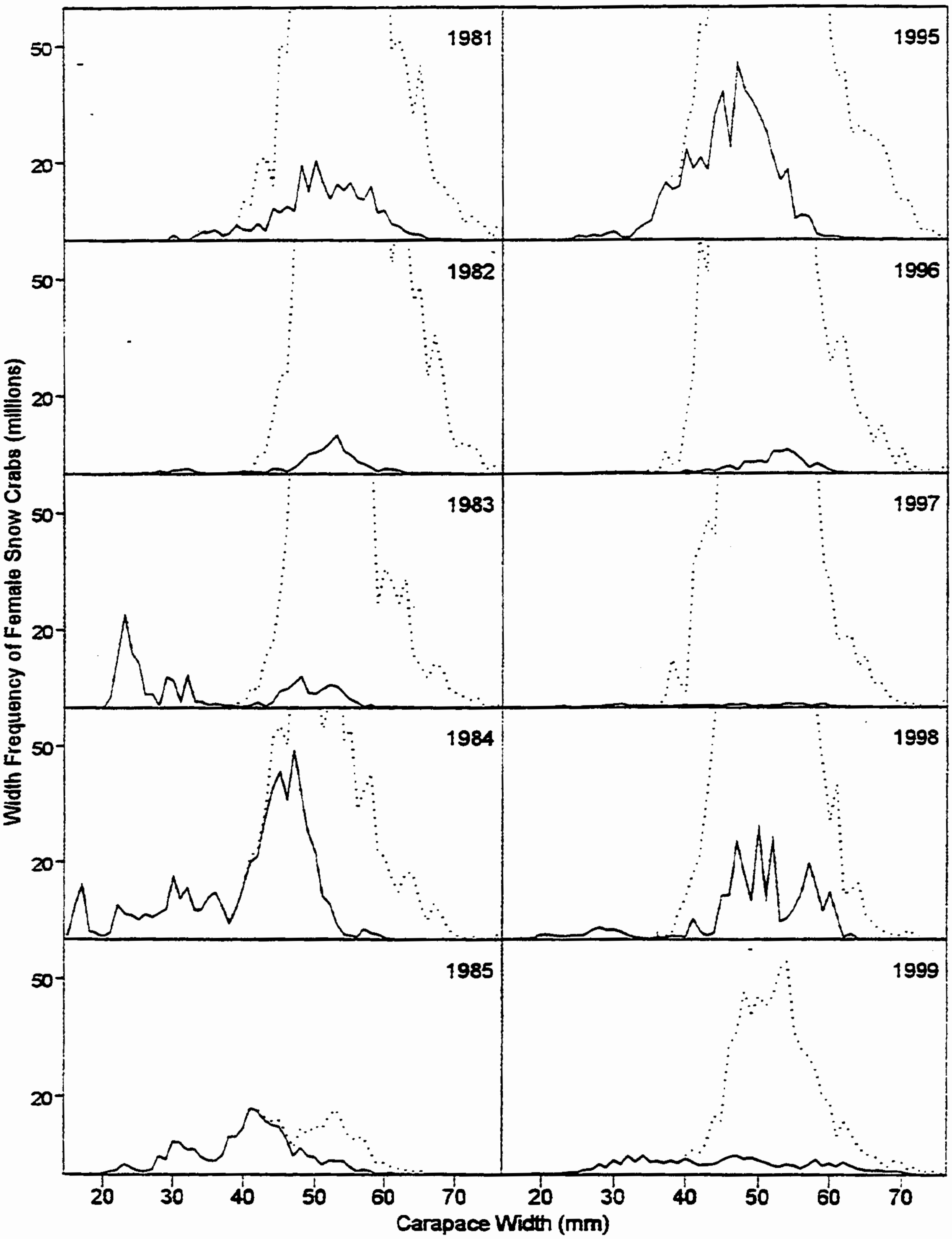


Figure 5 Comparison of width frequency of female snow crab abundance south of 61.2°N in the eastern Bering Sea from 1981 to 1985 and from 1995 to 1999. Solid lines — immature crabs, and differences between dotted and solid lines—mature crabs.

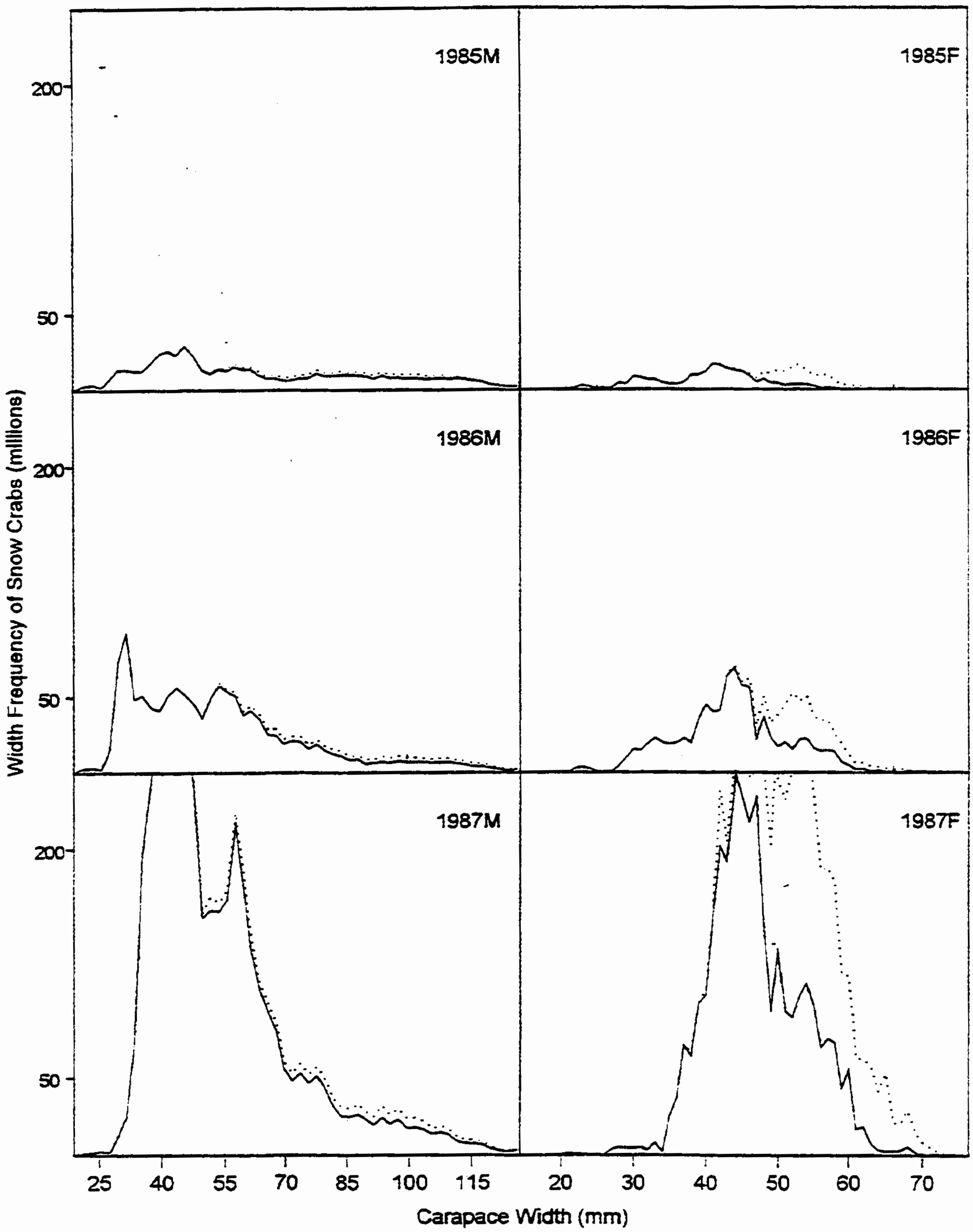


Figure 6 **Comparison of width frequency of male (M) and female (F) snow crab abundance south of 61.2°N in the eastern Bering Sea from 1985 to 1987. Solid lines—newshell male or immature female crabs, and differences between dotted and solid lines—oldshell male or mature female crabs.**

Figure 7 **Incidence of barren mature female EBS snow crab by shell age: 1990-1999**

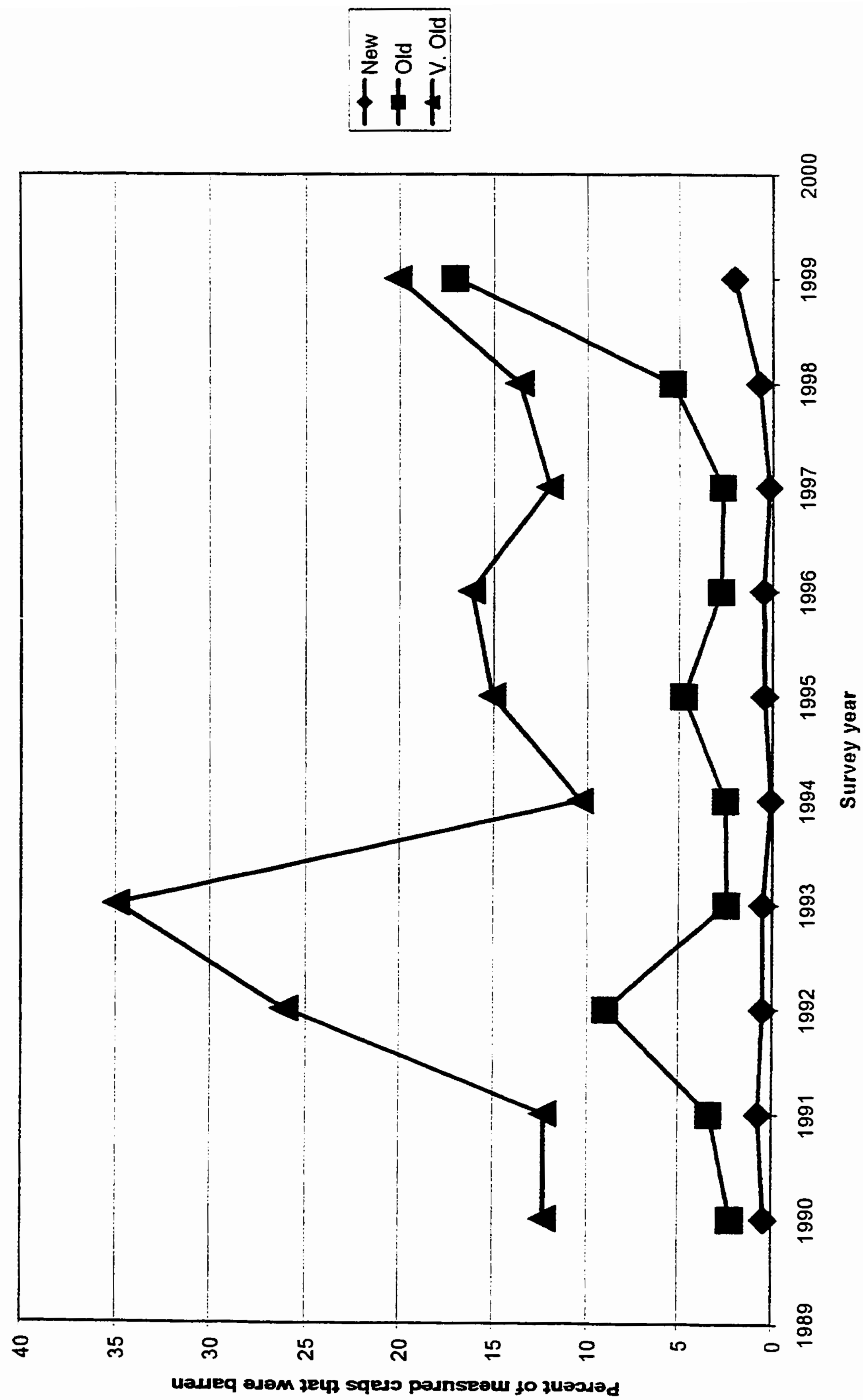


Figure 8 **Incidence of full clutches in mature female EBS snow crab by shell age: 1990-1999**

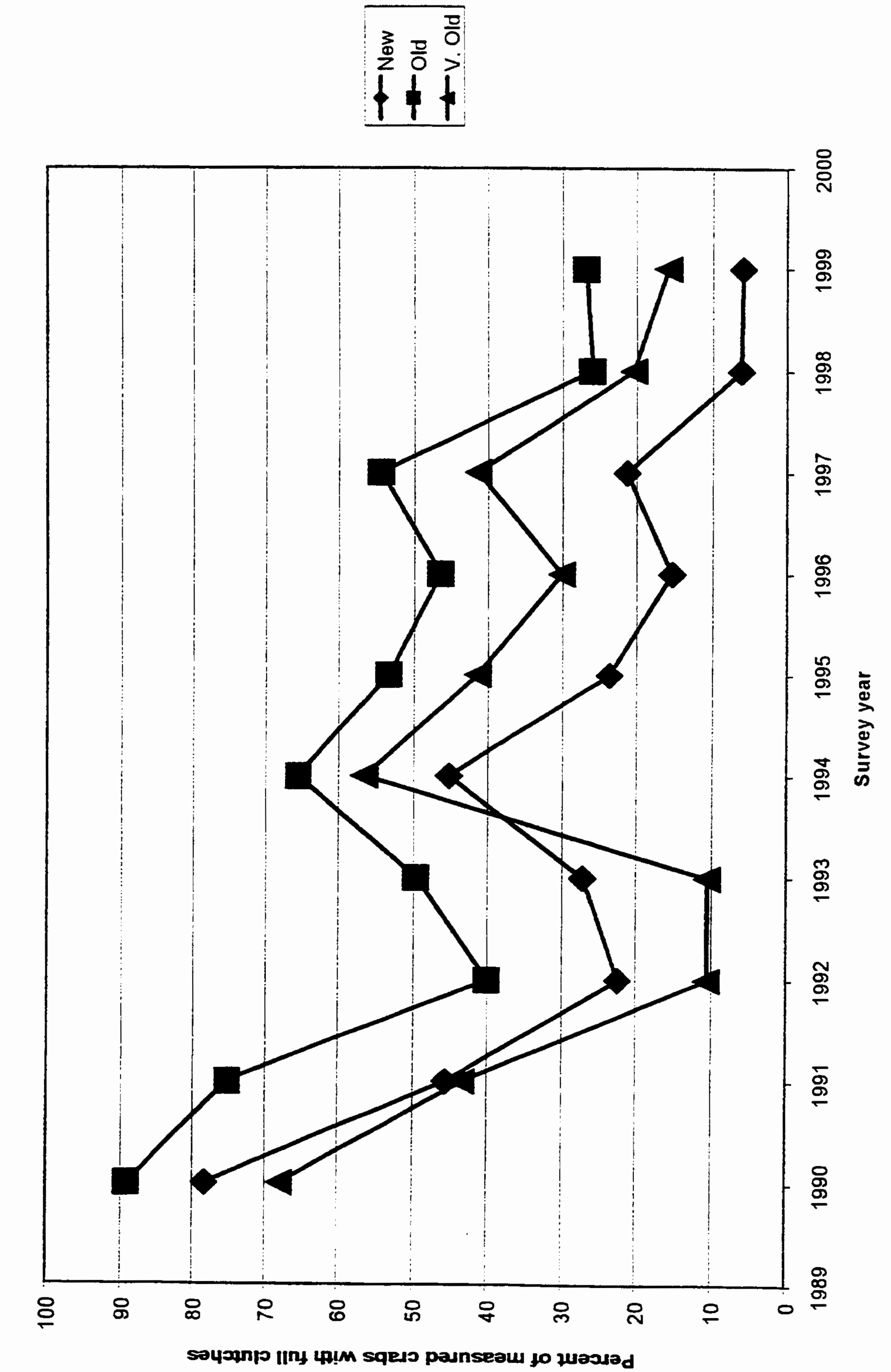


Figure 9 Carapace width frequency of Eastern Bering Sea snow crab (C.opilio) taken incidentally in trawl fisheries, by regulatory area, 1994 and 1995. Note that 1995 data are not complete; additional data are being compiled. Source: NMFS Observer Program.

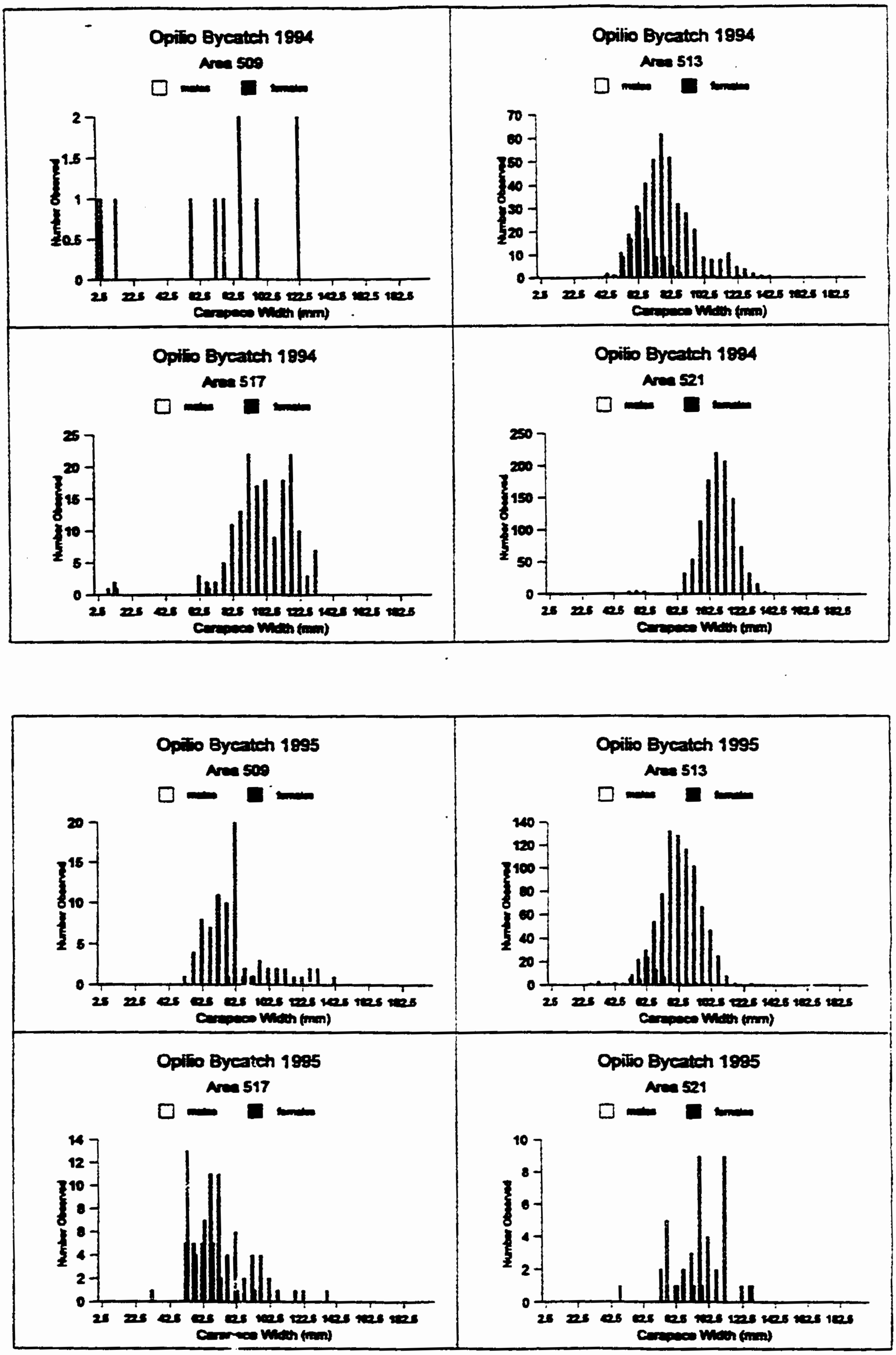
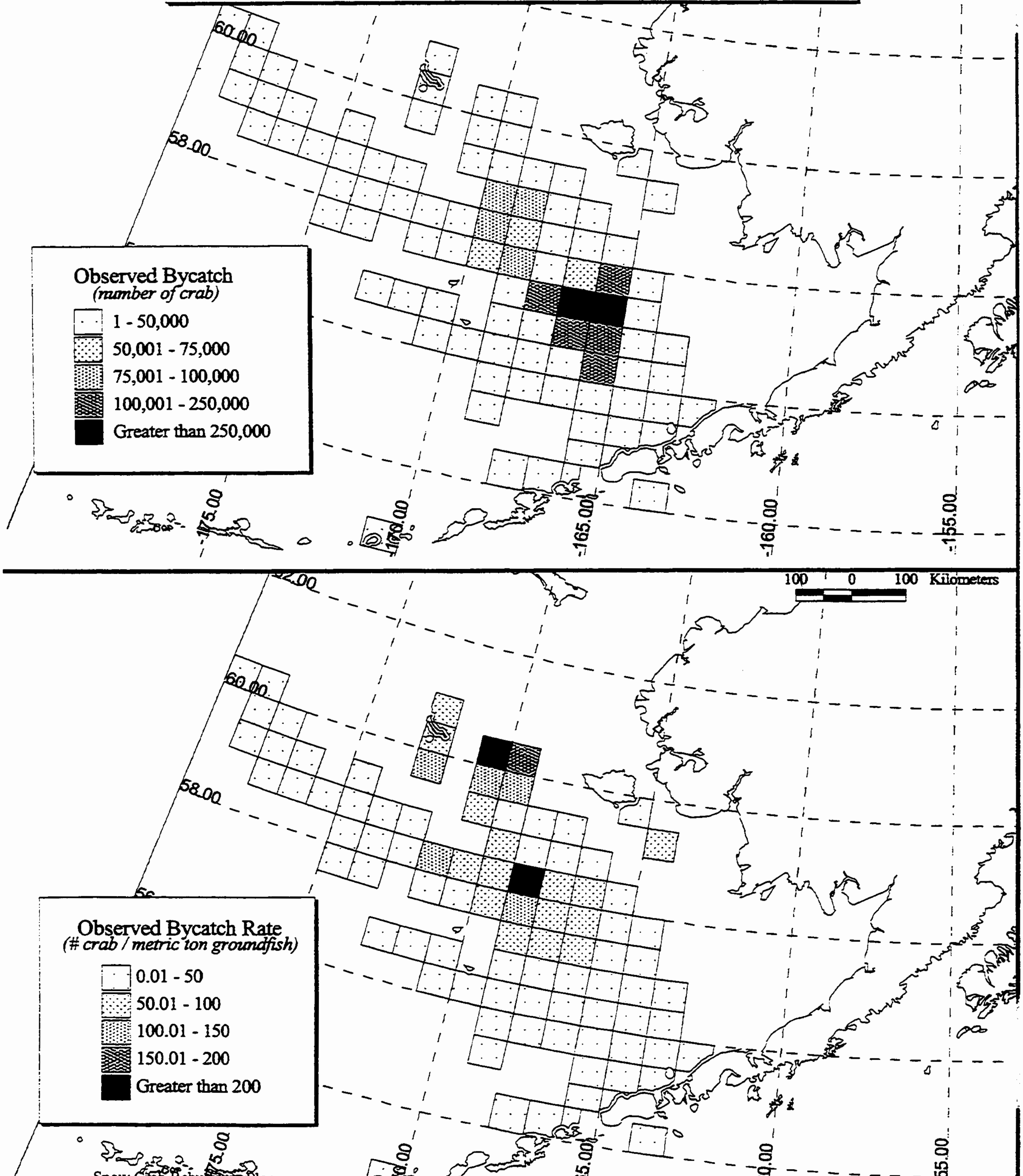


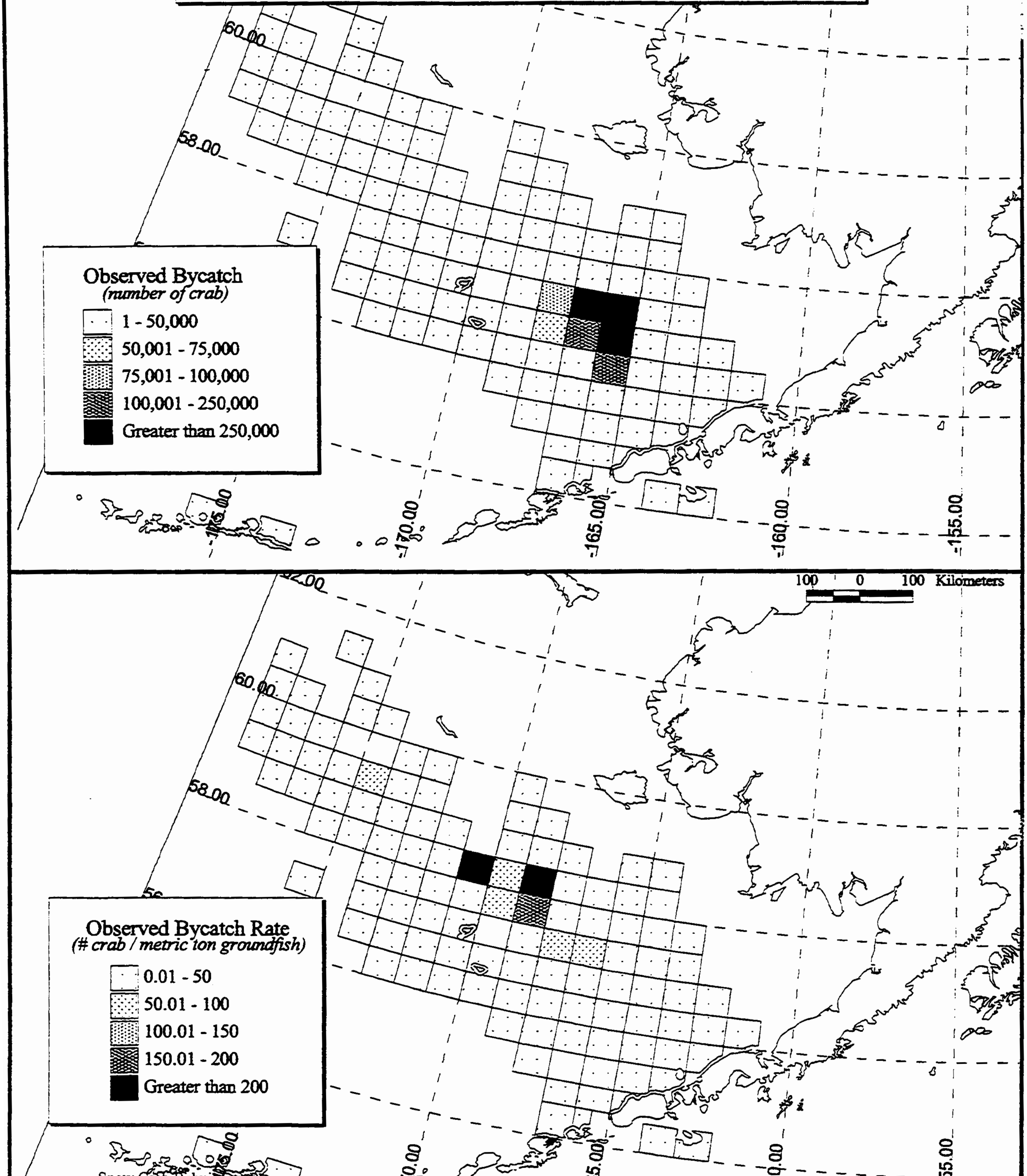
Figure 10

C. opilio observed bycatch in bottom trawl fisheries 1995



Snow Crab Rebuilding Plan

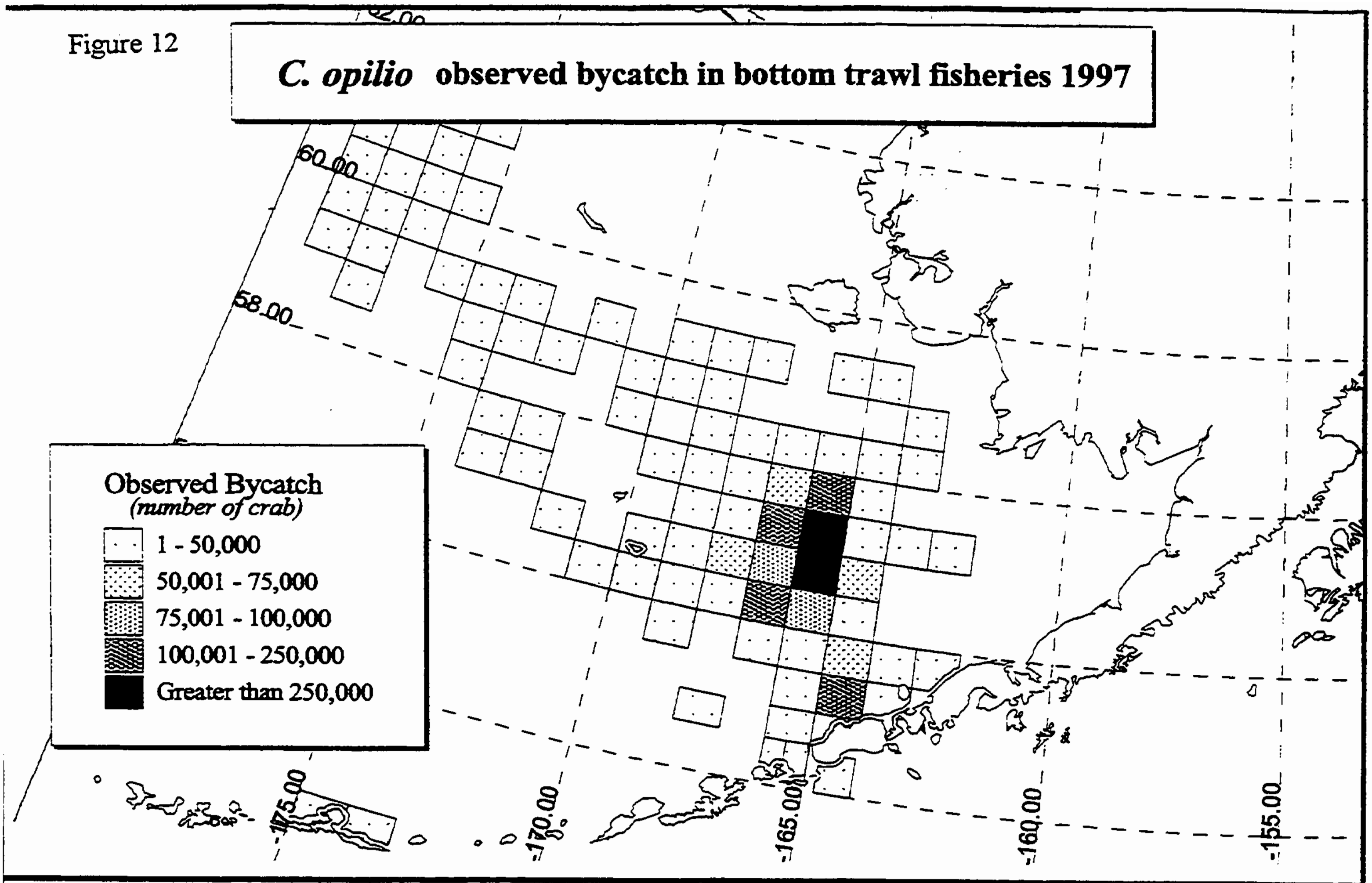
Figure 11 ***C. opilio* observed bycatch in bottom trawl fisheries 1996**



Snow Crab Rebuilding Plan

Figure 12

C. opilio observed bycatch in bottom trawl fisheries 1997



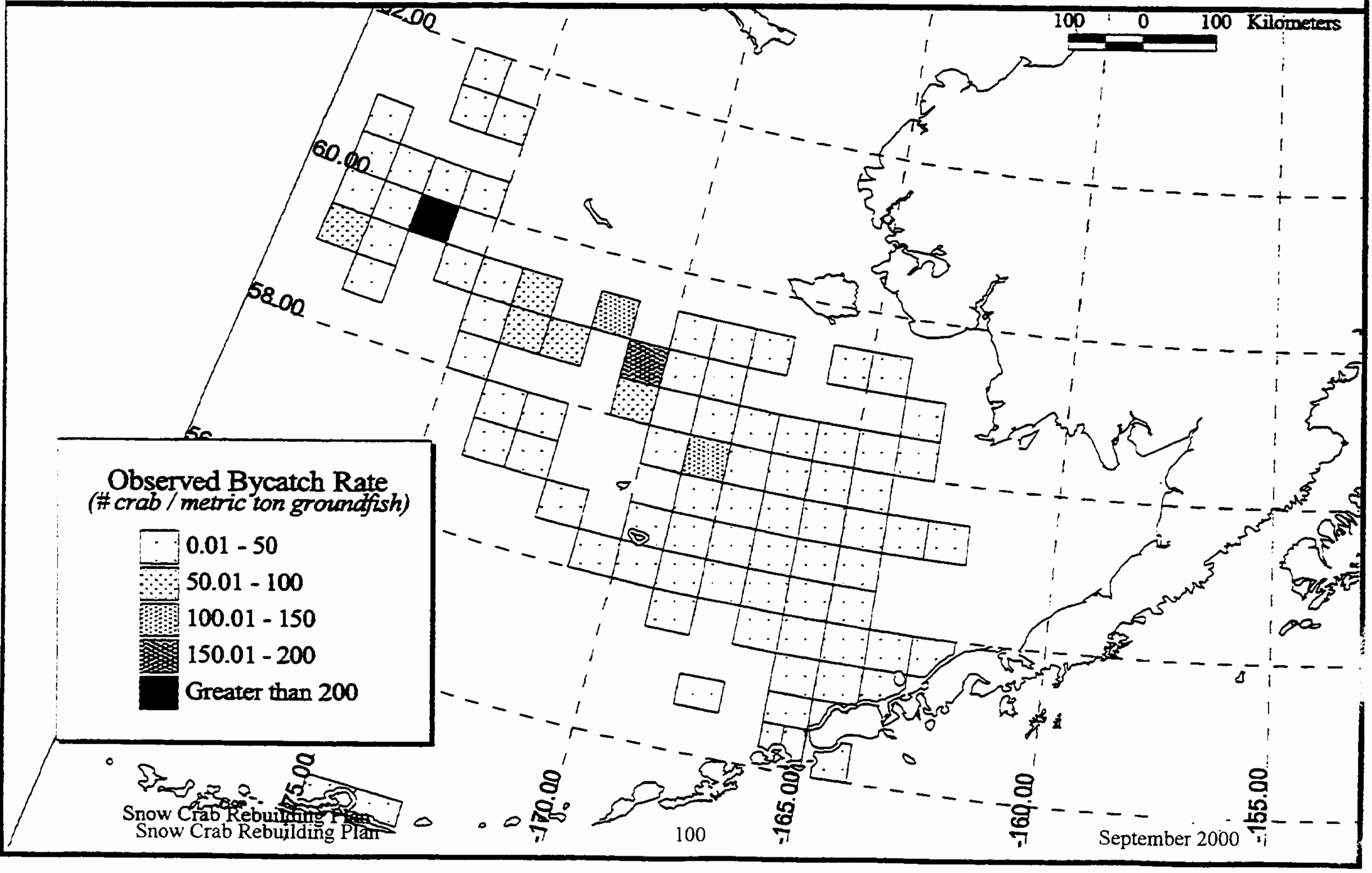


Figure 13

C. opilio observed bycatch in bottom trawl fisheries 1998

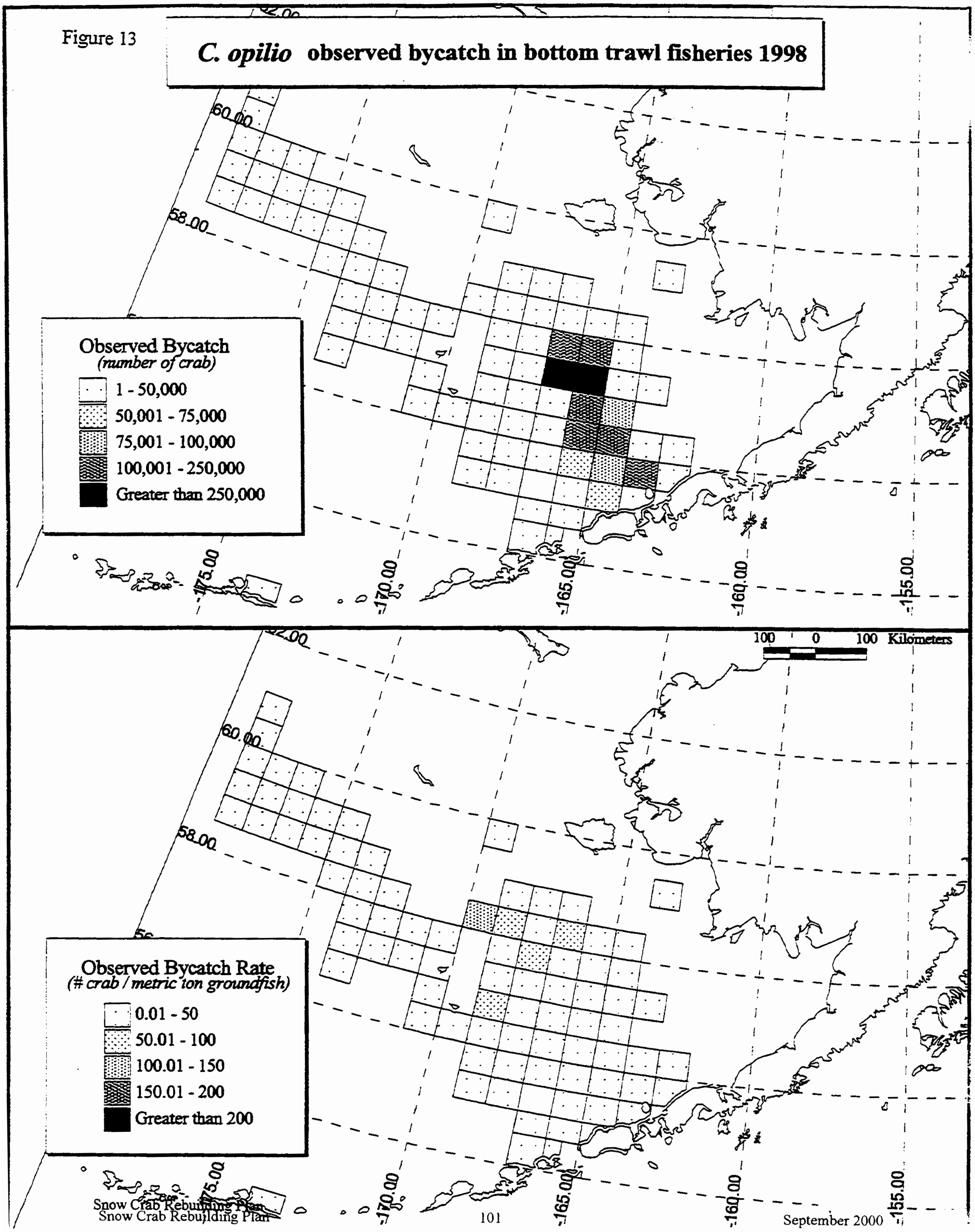
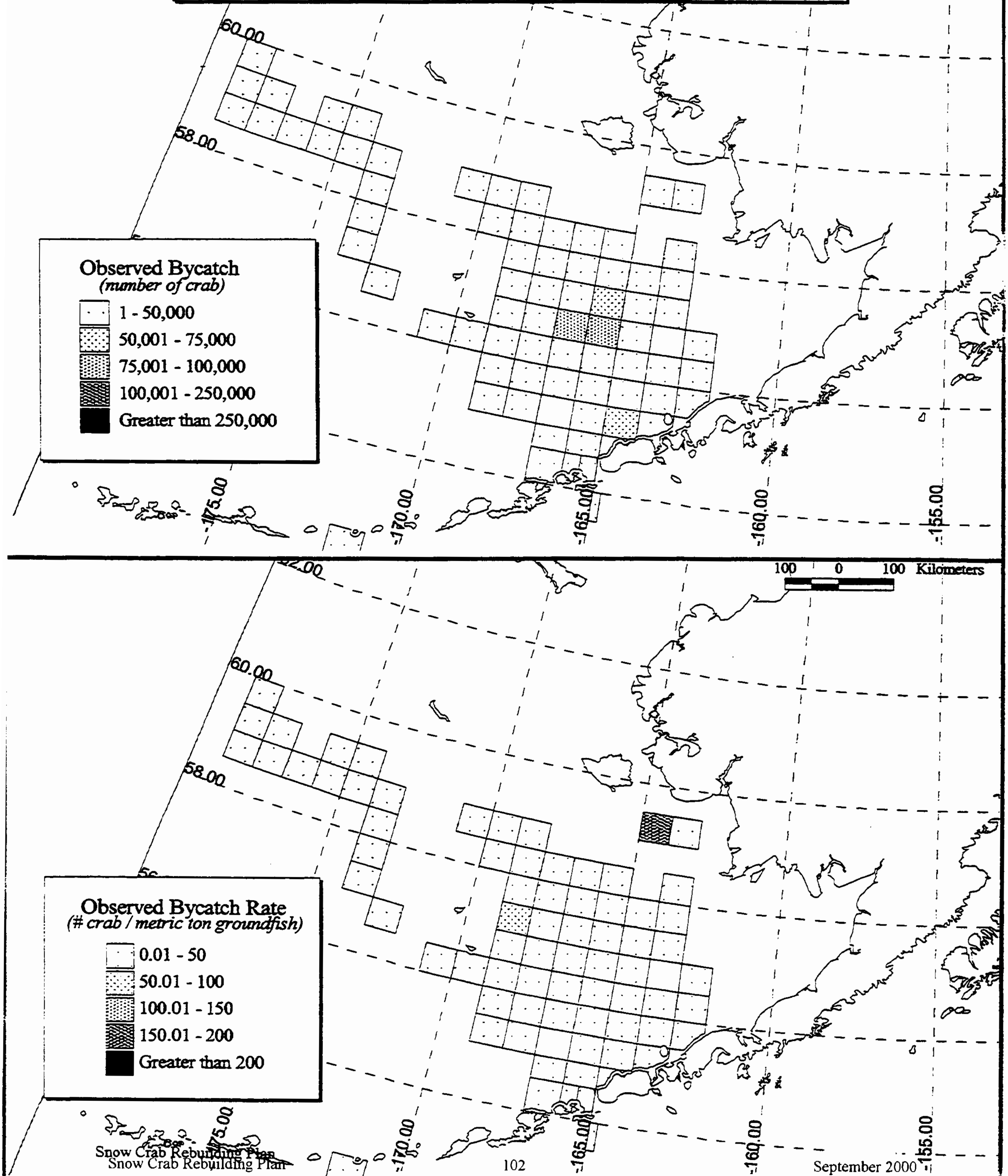


Figure 14

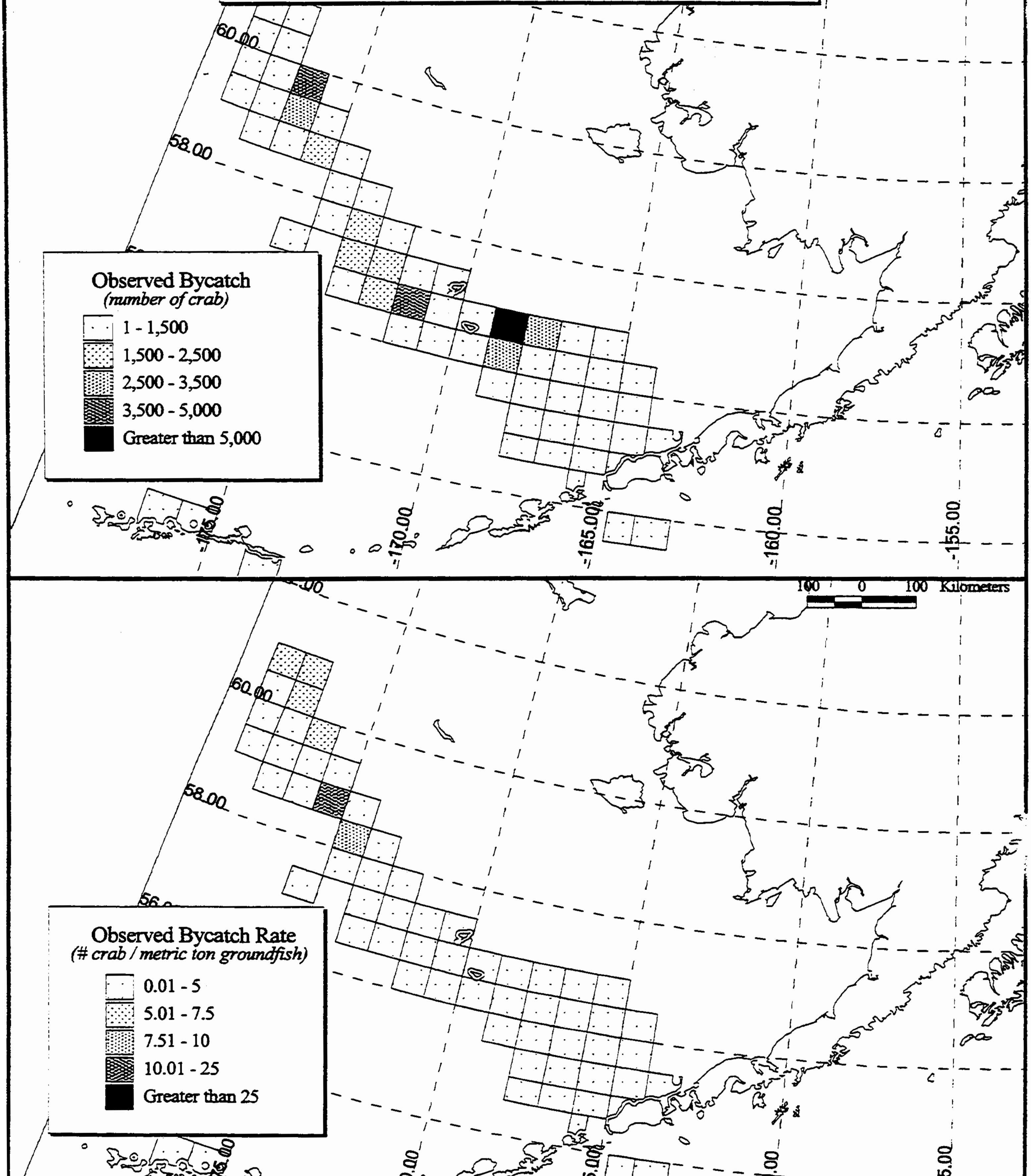
C. opilio observed bycatch in bottom trawl fisheries 1999



Snow Crab Rebuilding Plan

Figure 15

C. opilio observed bycatch in longline fisheries 1995



Snow Crab Rebuilding Plan

Figure 16

C. opilio observed bycatch in longline fisheries 1996

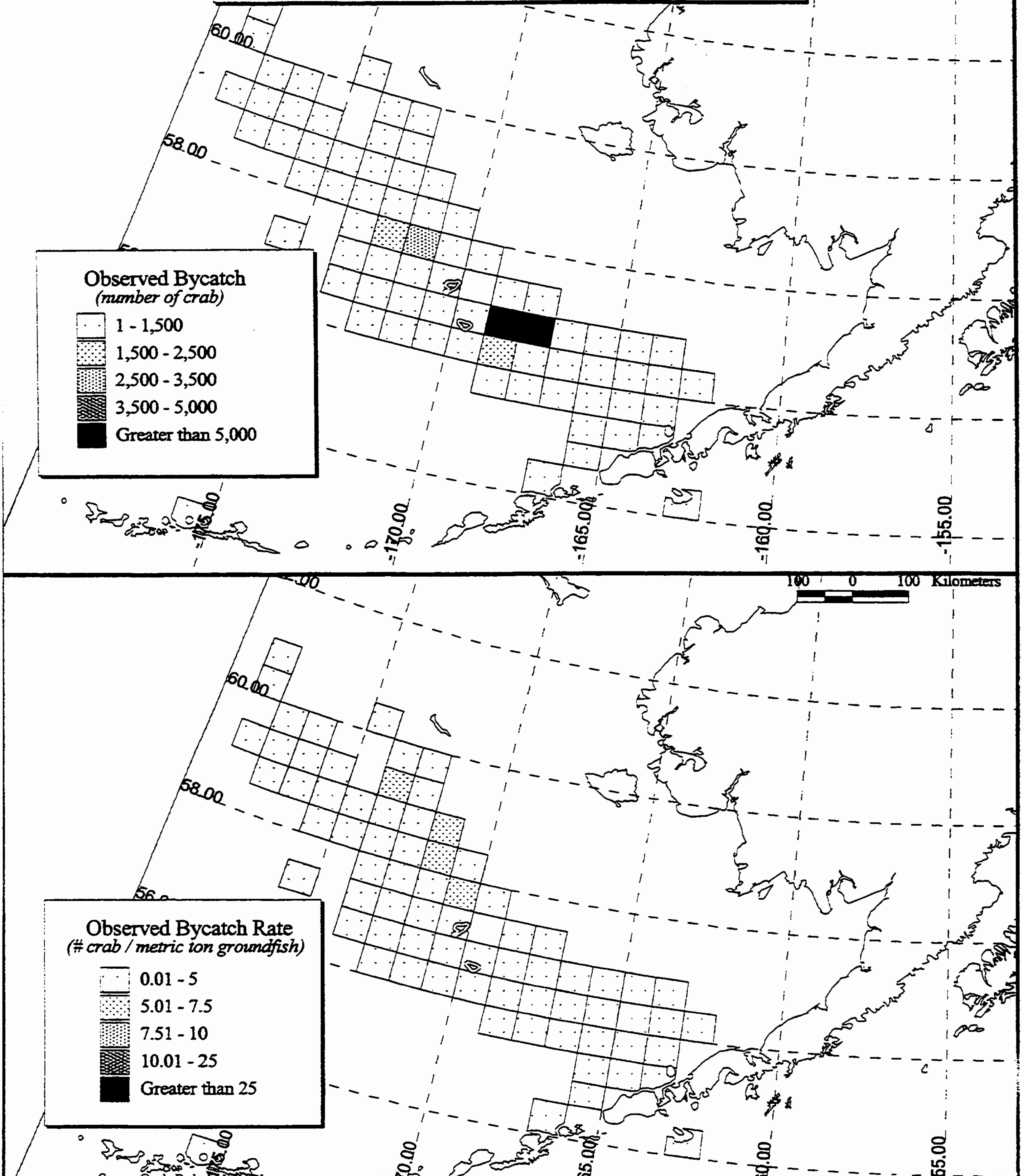
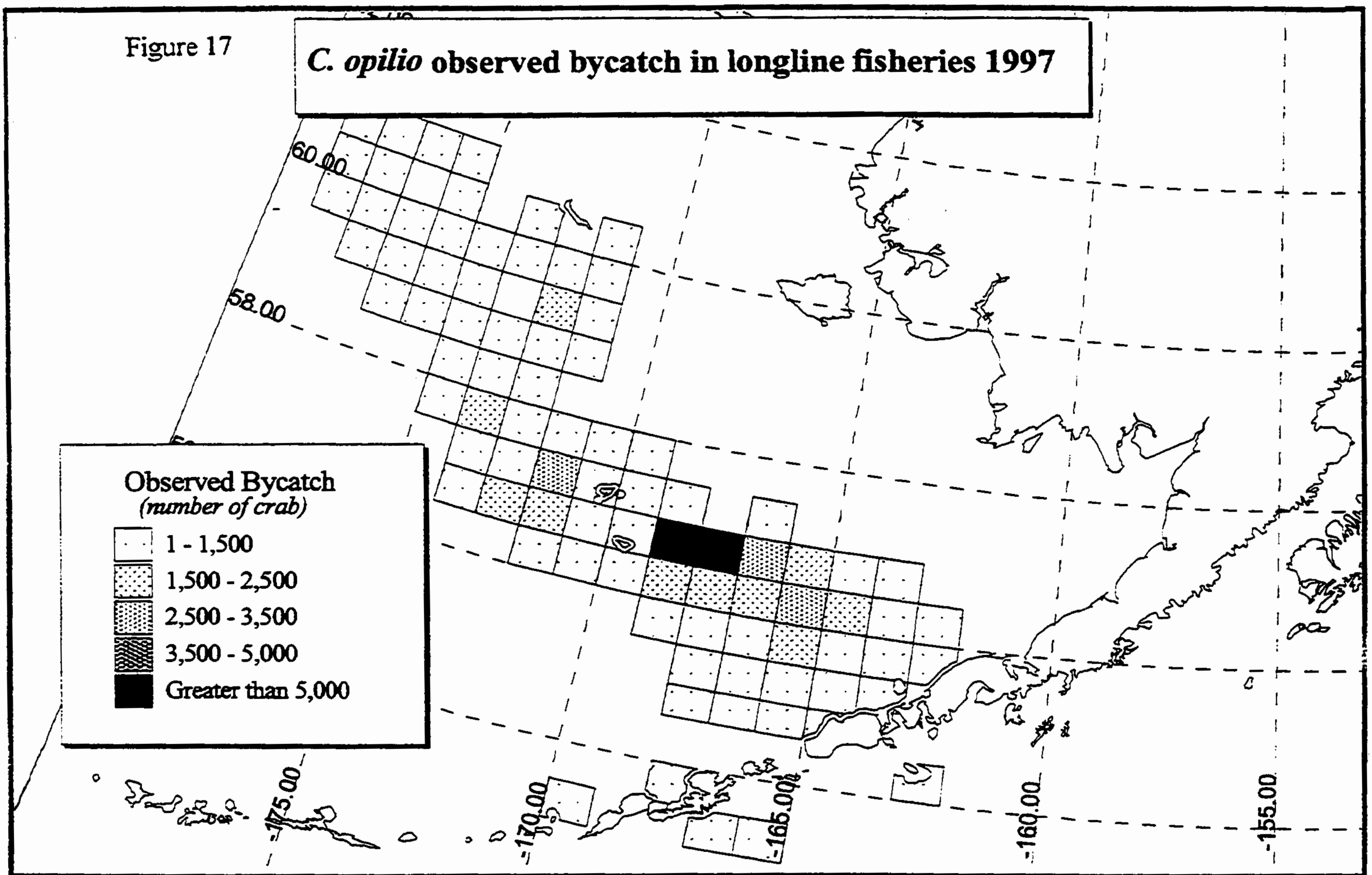


Figure 17

C. opilio observed bycatch in longline fisheries 1997



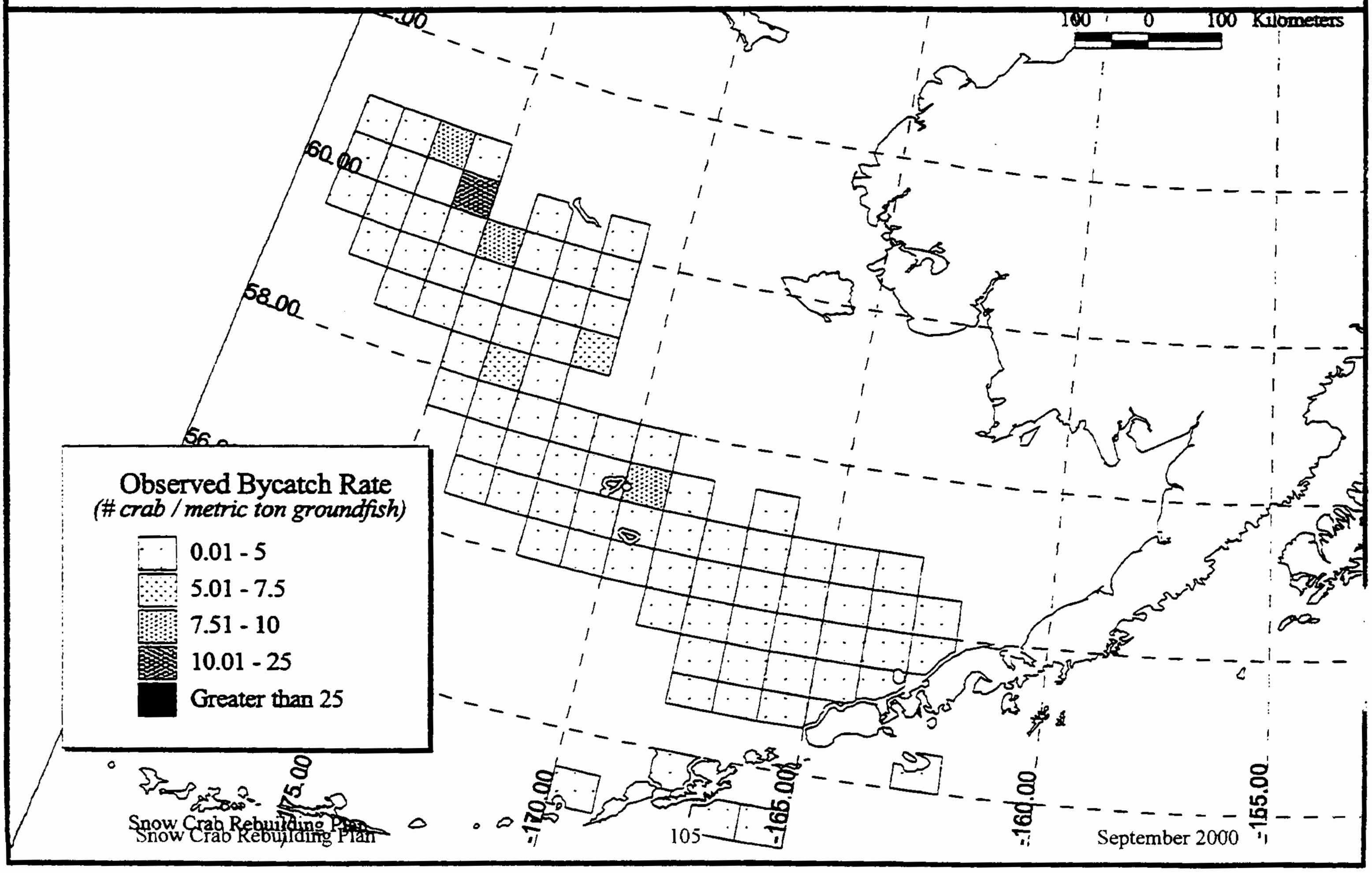
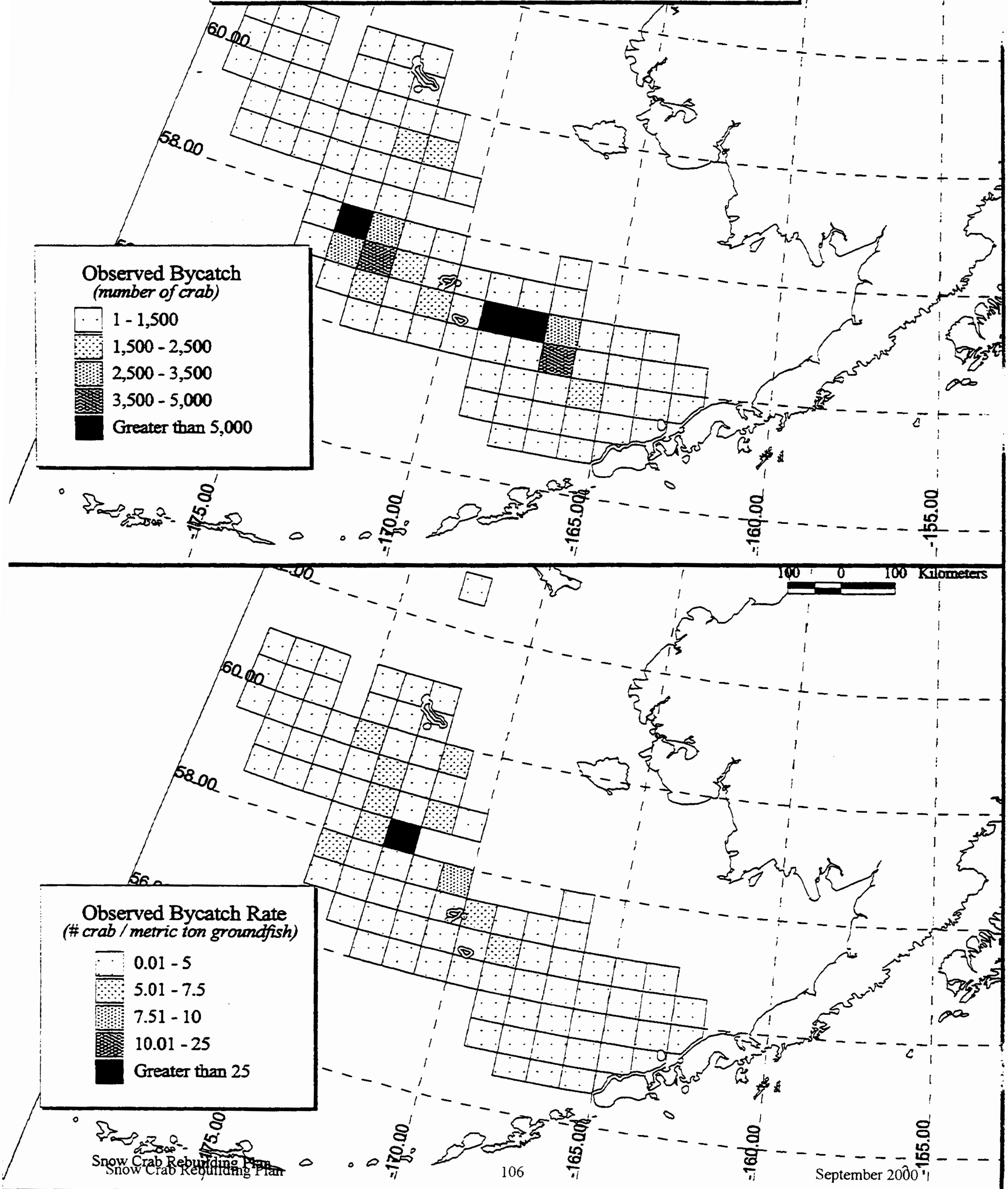


Figure 18

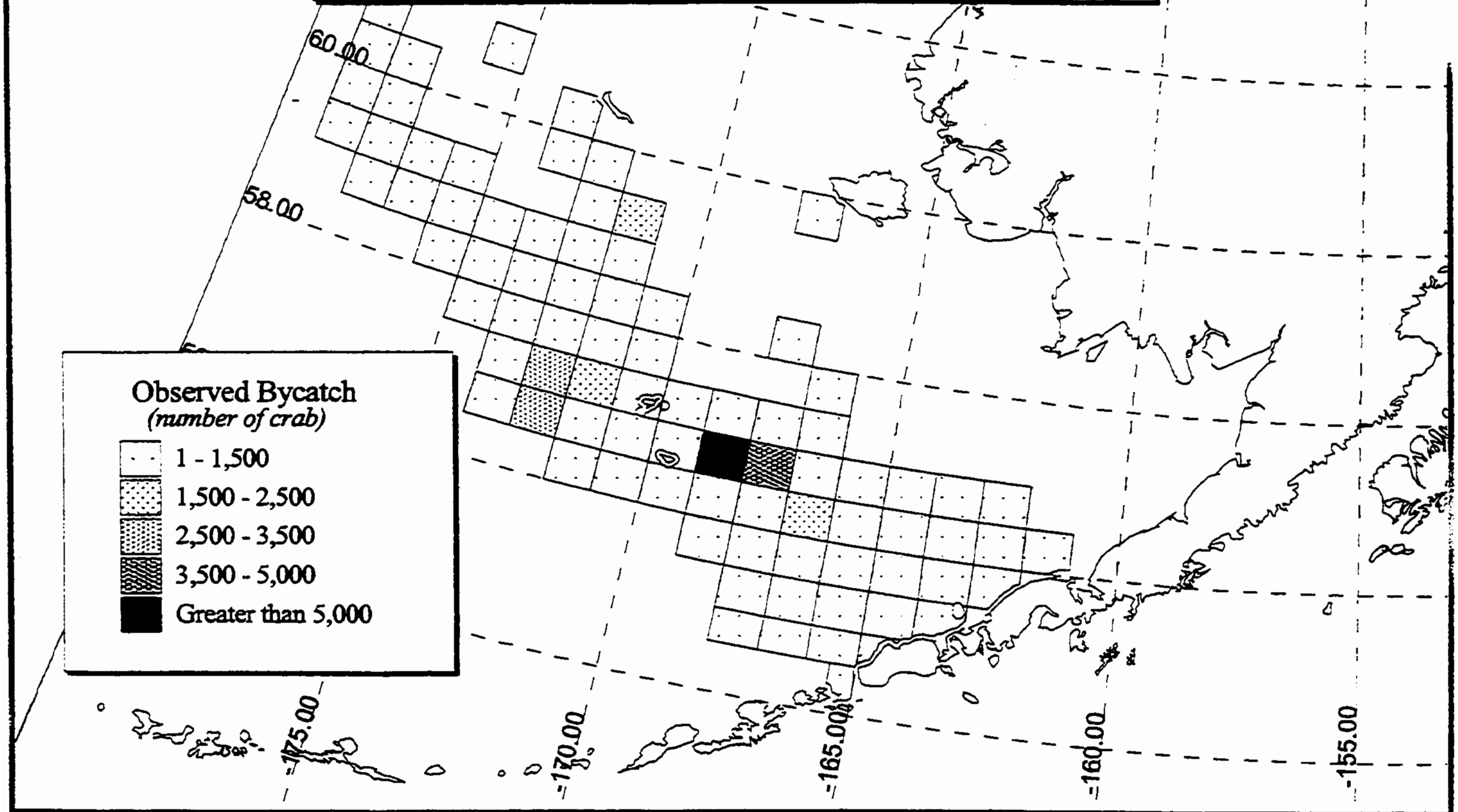
C. opilio observed bycatch in longline fisheries 1998

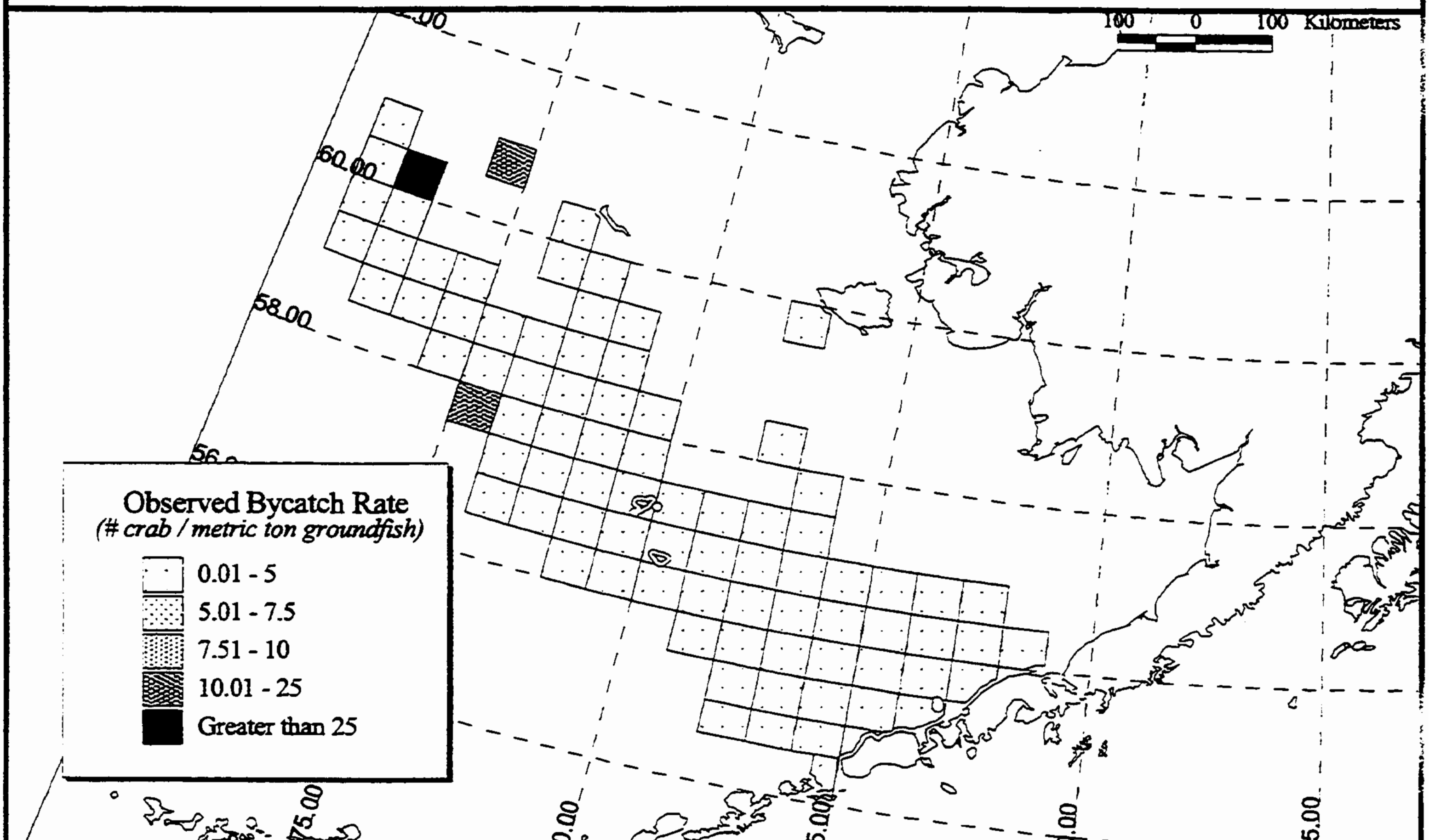


Snow Crab Rebuilding Plan

Figure 19

C. opilio observed bycatch in longline fisheries 1999

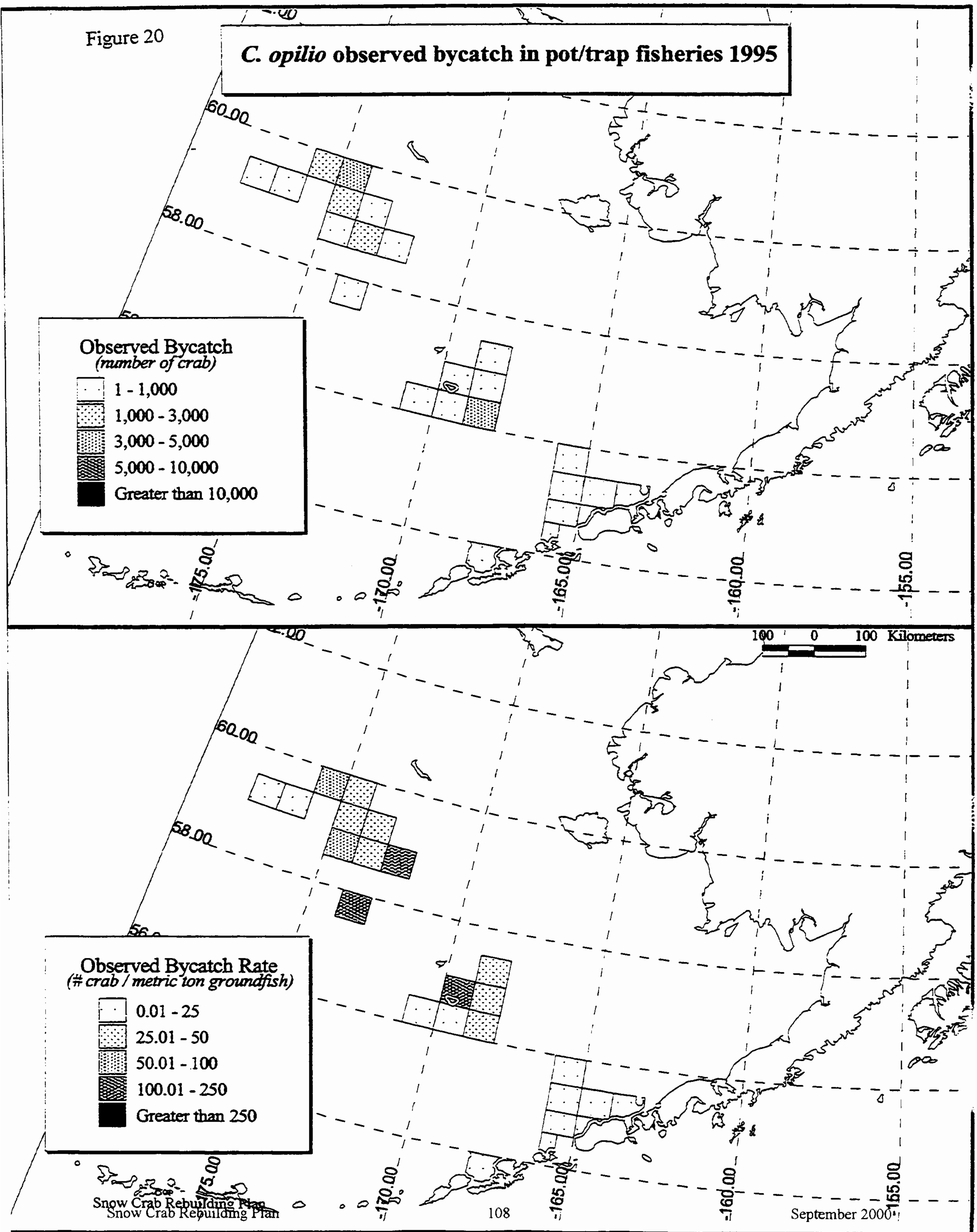




Snow Crab Rebuilding Plan

Figure 20

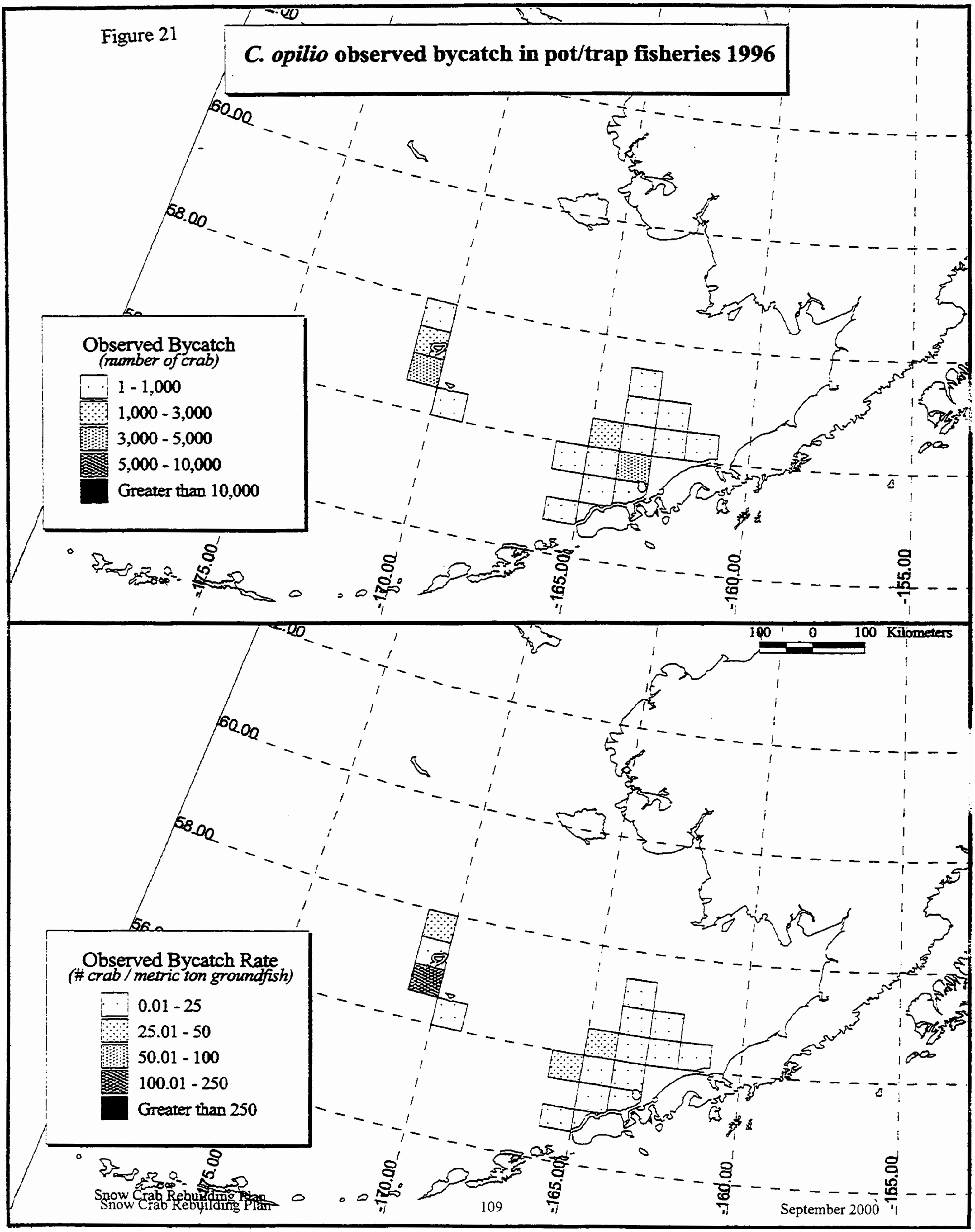
C. opilio observed bycatch in pot/trap fisheries 1995



Snow Crab Rebuilding Plan

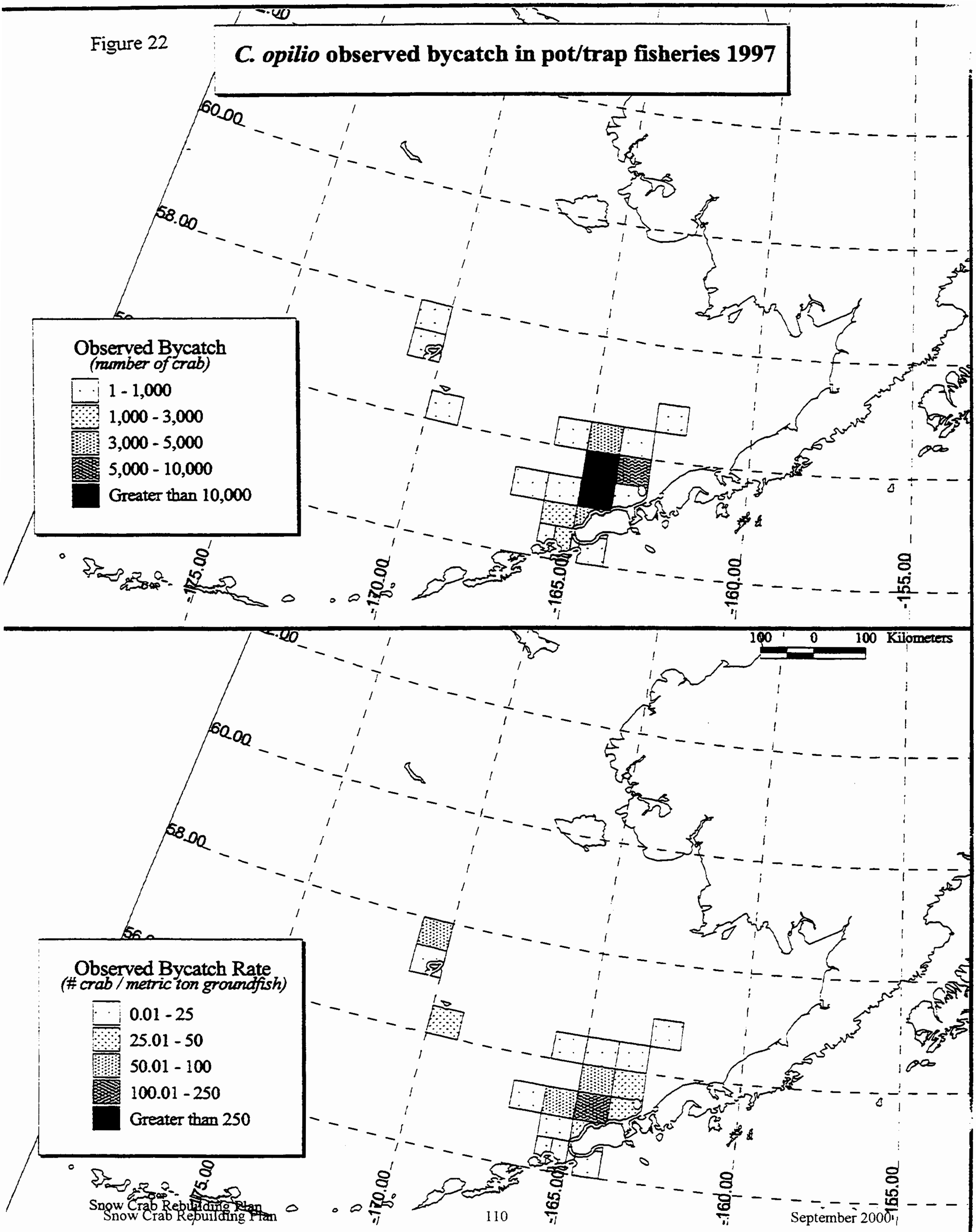
Figure 21

C. opilio observed bycatch in pot/trap fisheries 1996



Snow Crab Rebuilding Plan

Figure 22



Snow Crab Rebuilding Plan

Figure 23

C. opilio observed bycatch in pot/trap fisheries 1998

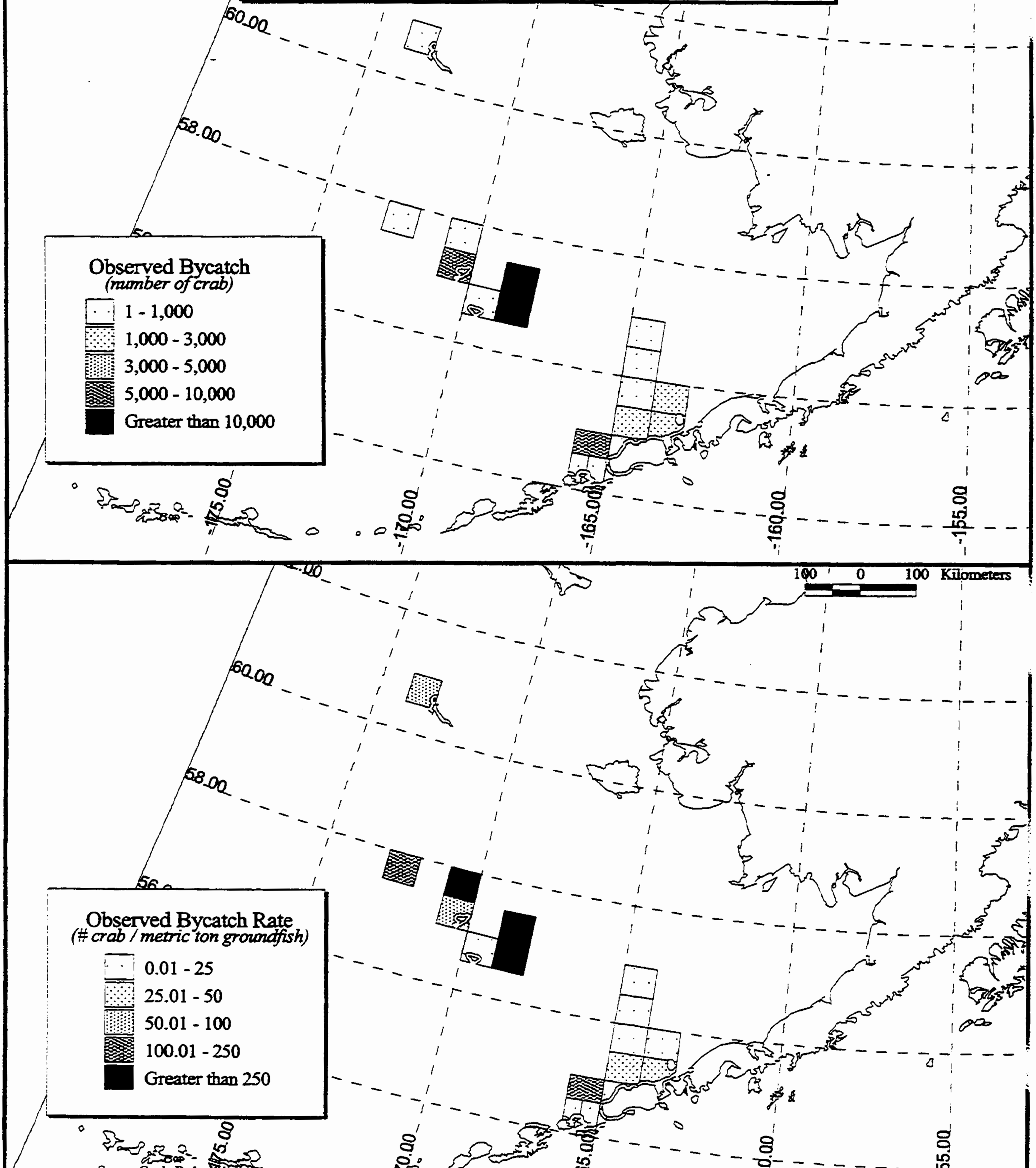
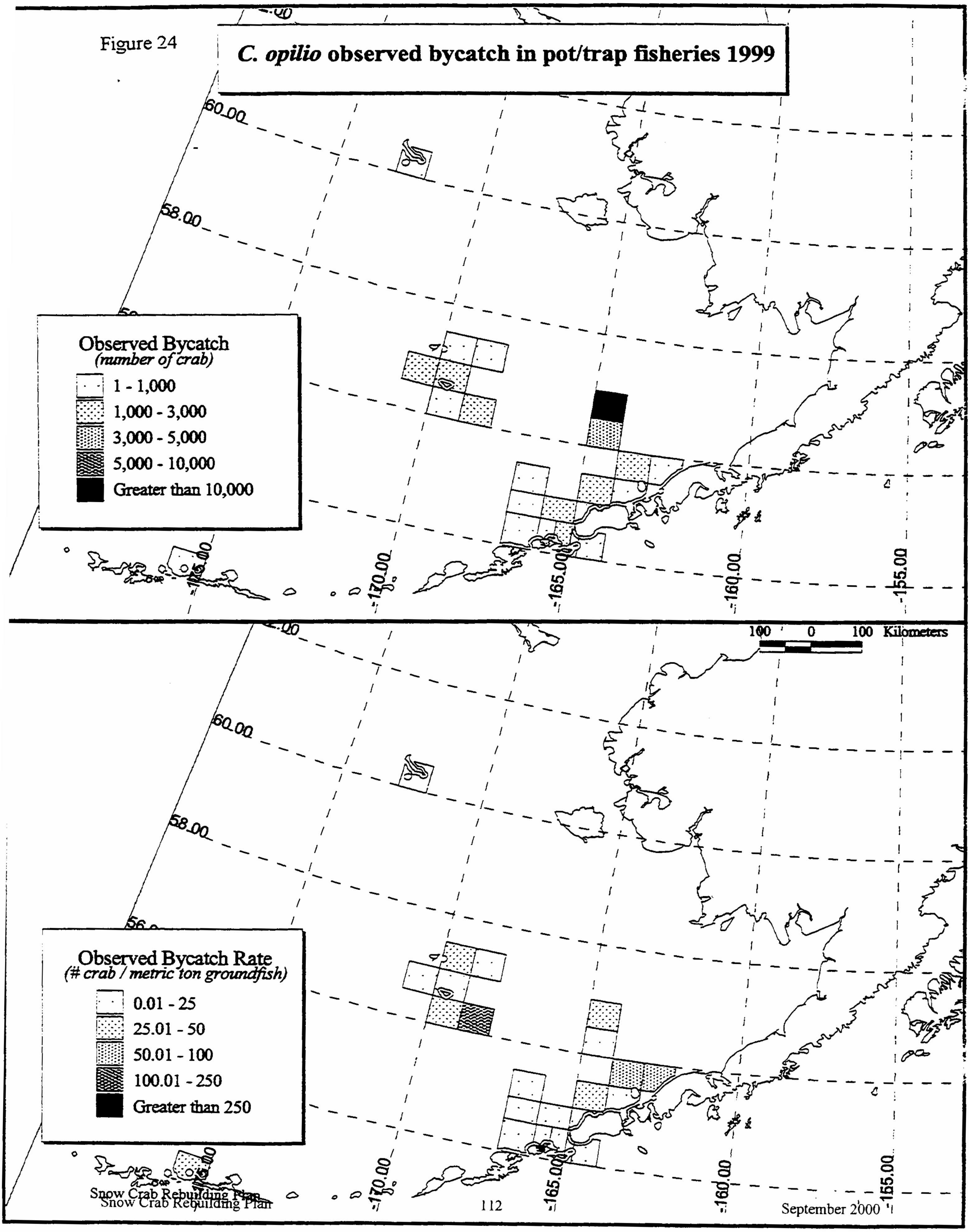


Figure 24

C. opilio observed bycatch in pot/trap fisheries 1999



Snow Crab Rebuilding Plan

Figure 25

C. opilio observed bycatch in bottom and pelagic trawl fisheries 1995

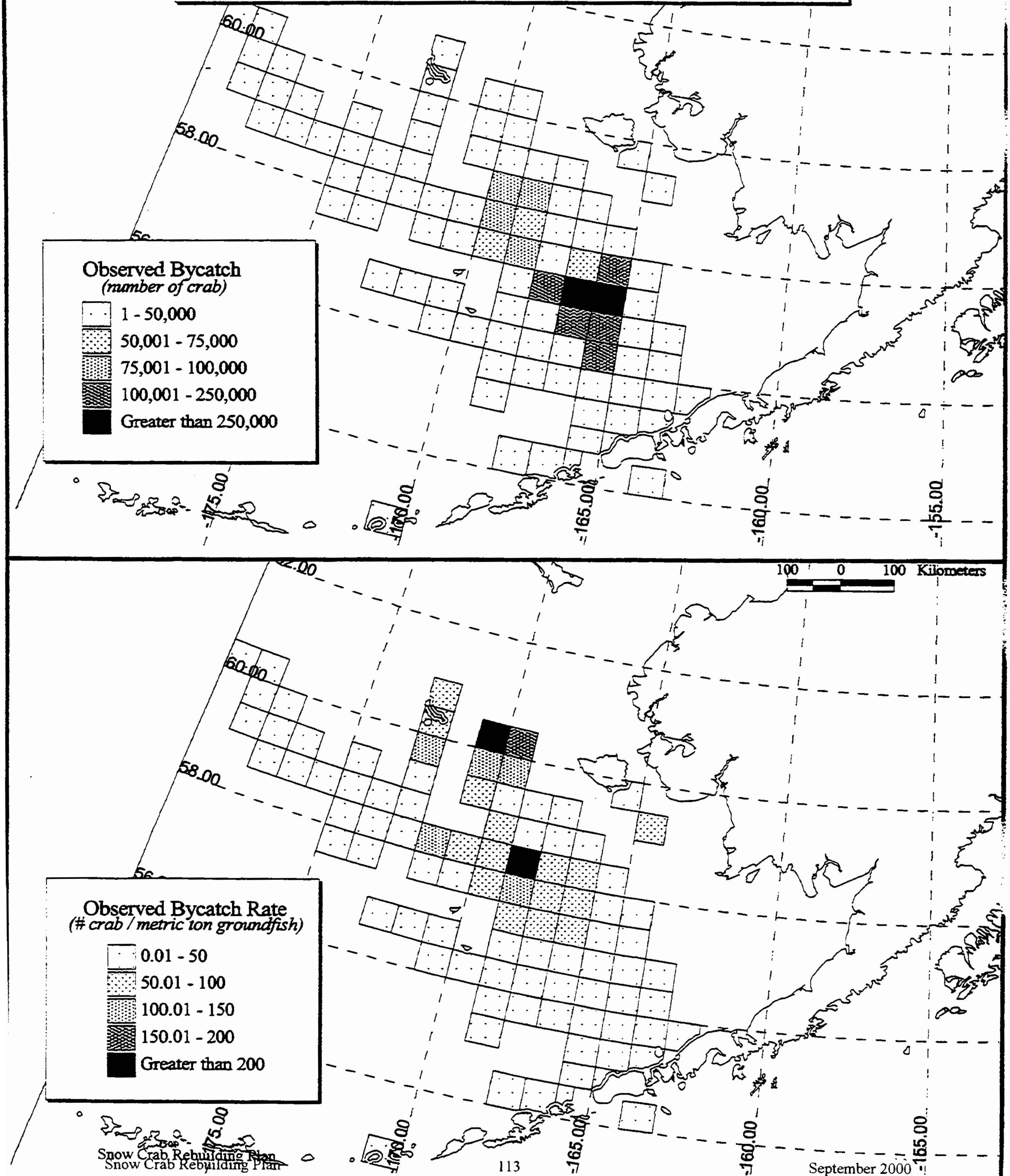


Figure 26

C. opilio **observed bycatch in bottom and pelagic trawl fisheries 1996**

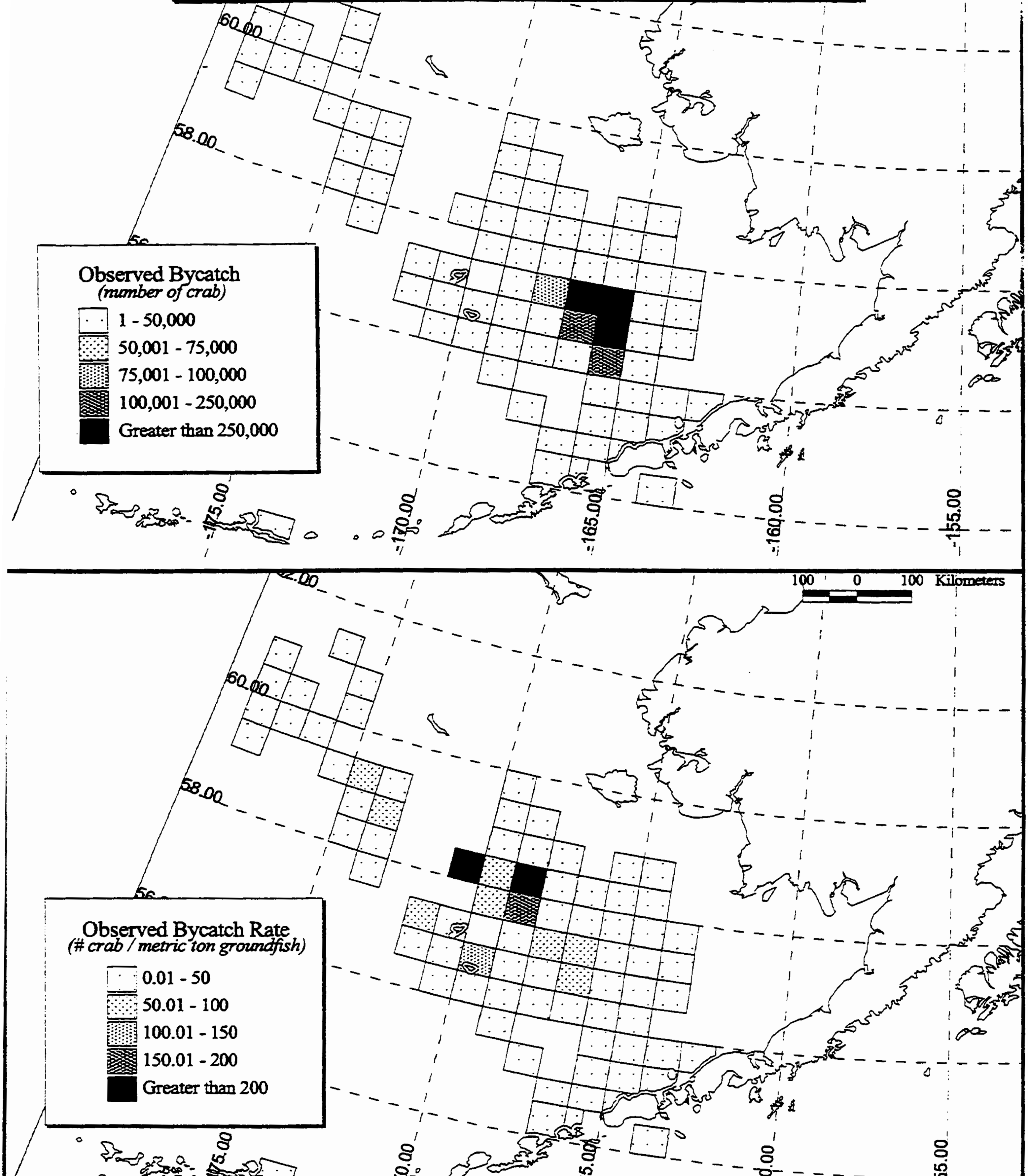
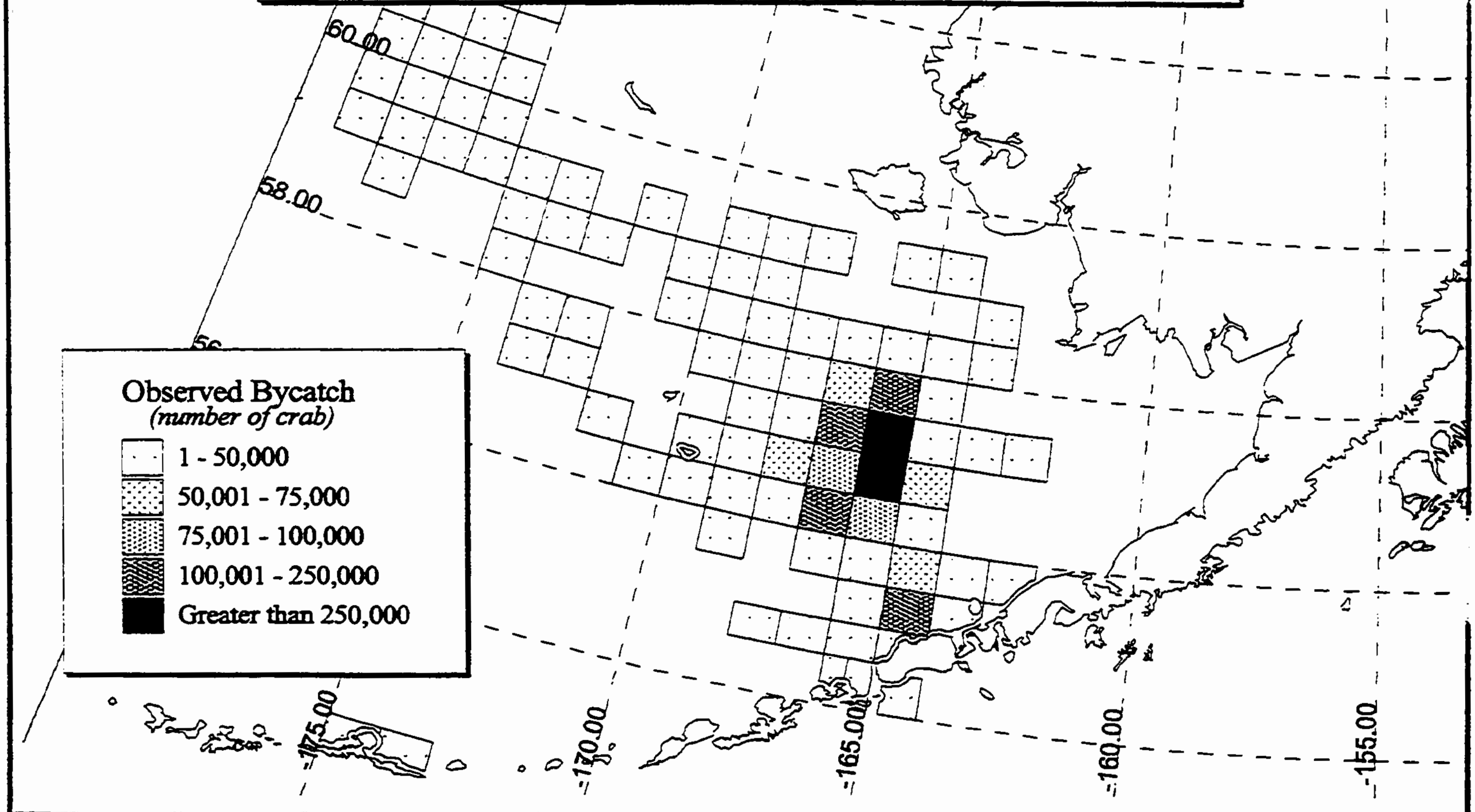


Figure 27

C. opilio observed bycatch in bottom and pelagic trawl fisheries 1997



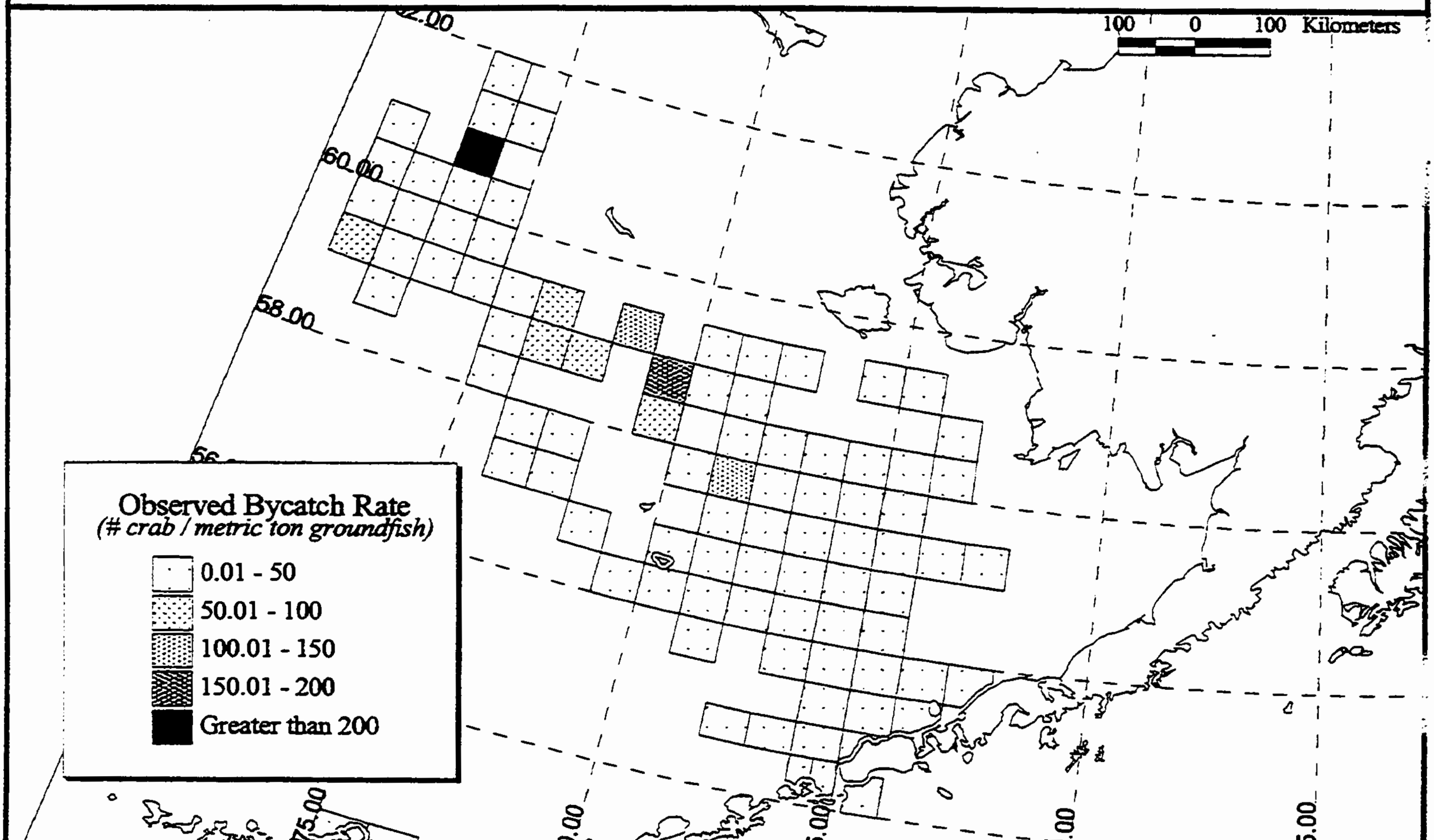
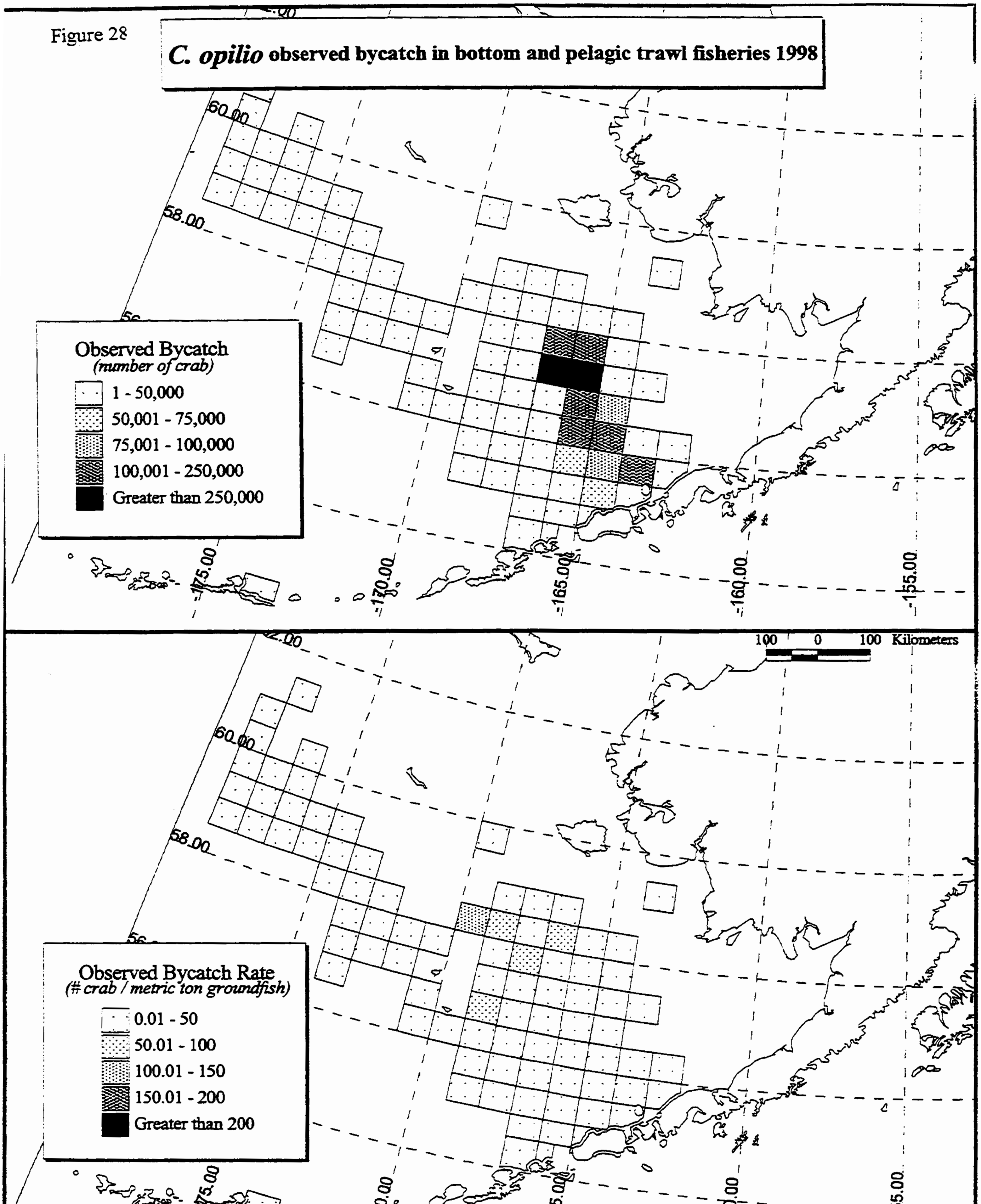


Figure 28

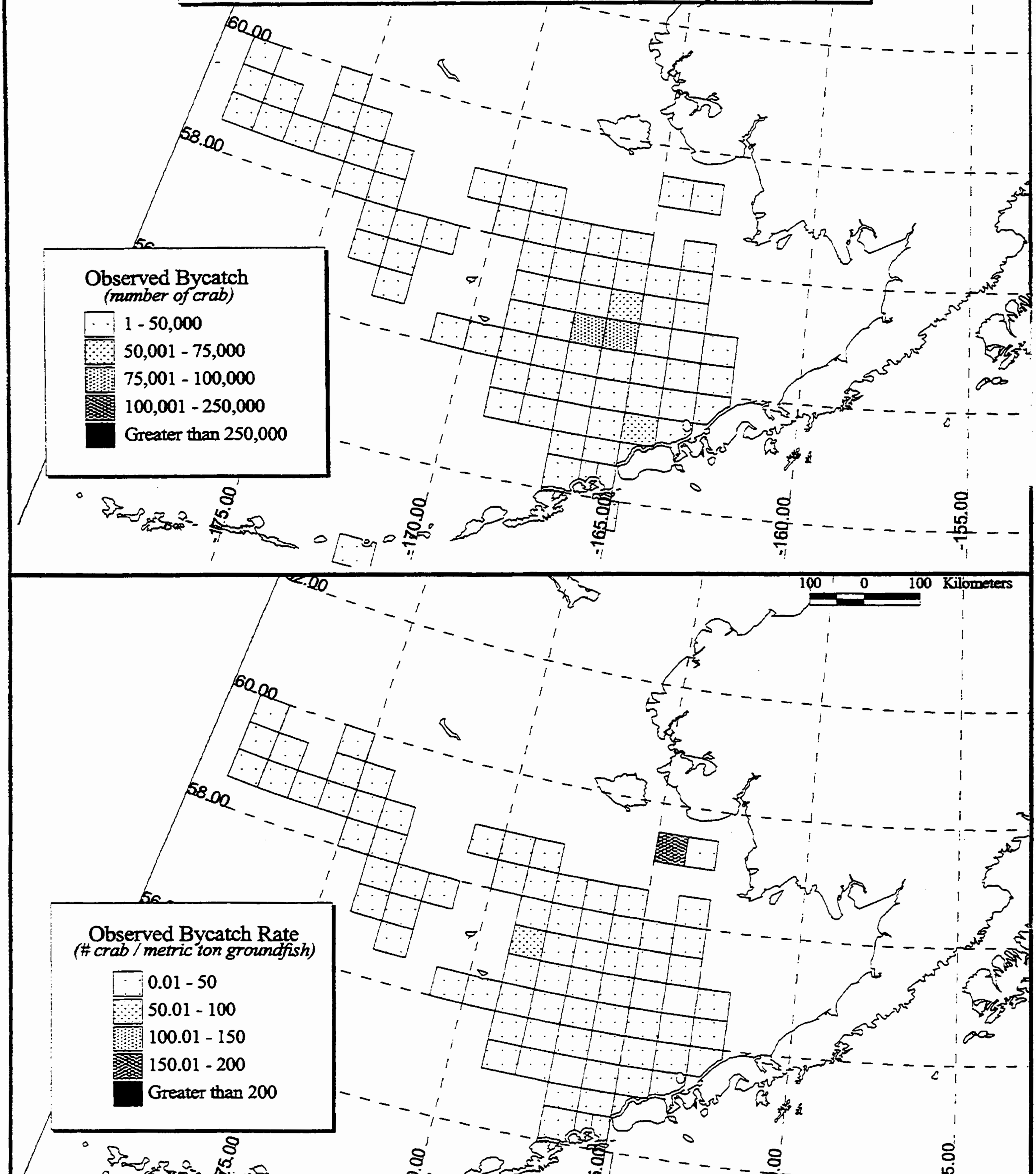
C. opilio observed bycatch in bottom and pelagic trawl fisheries 1998



Snow Crab Rebuilding Plan

Figure 29

C. opilio observed bycatch in bottom and pelagic trawl fisheries 1999



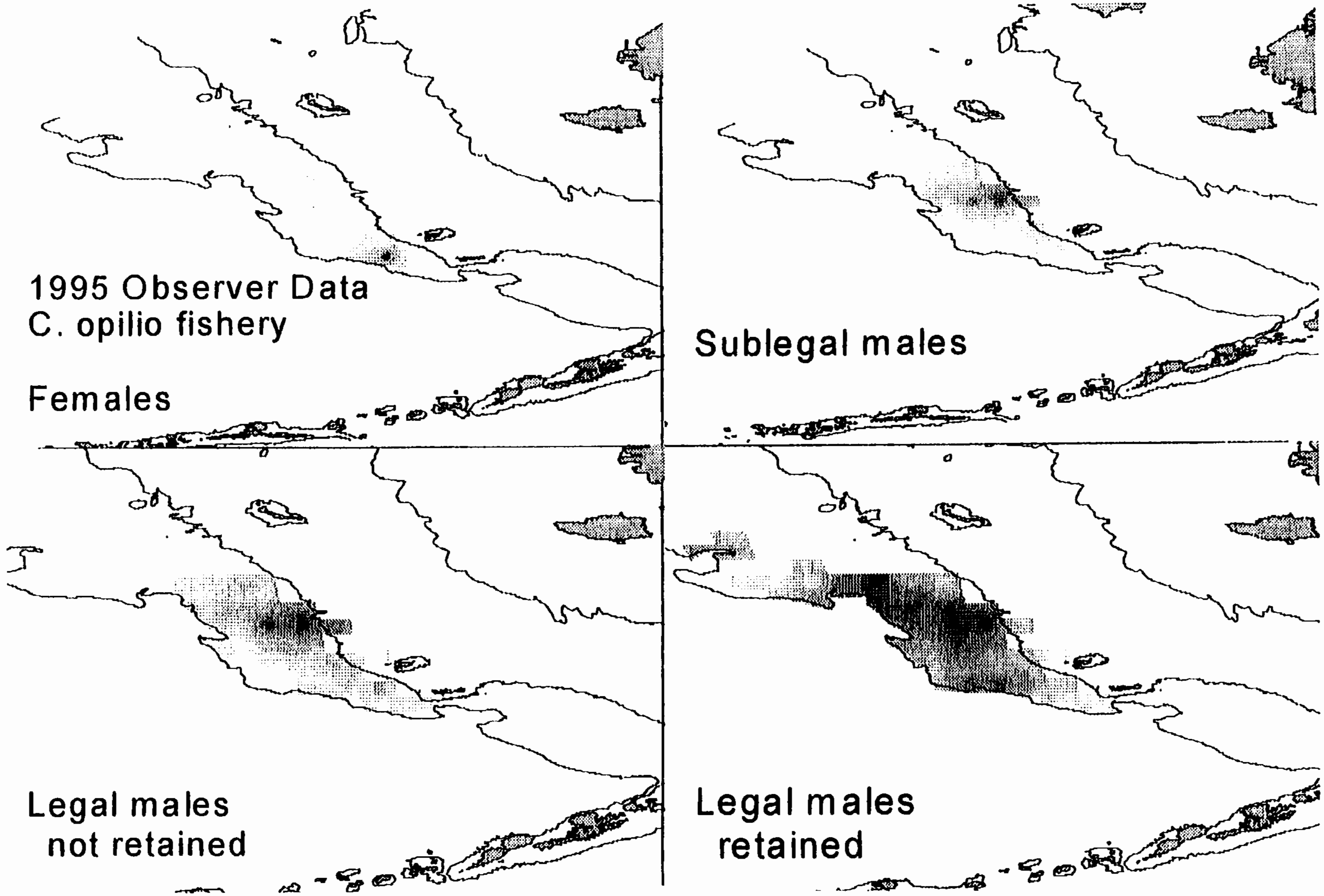


Figure 30 Z-score surfaces of mean CPUE for *C. opilio* from the Bering Sea 1995 *C. opilio* fishery. Data is from 1,529 pots sampled by observers on 17 catcher processors participating in the fishery.

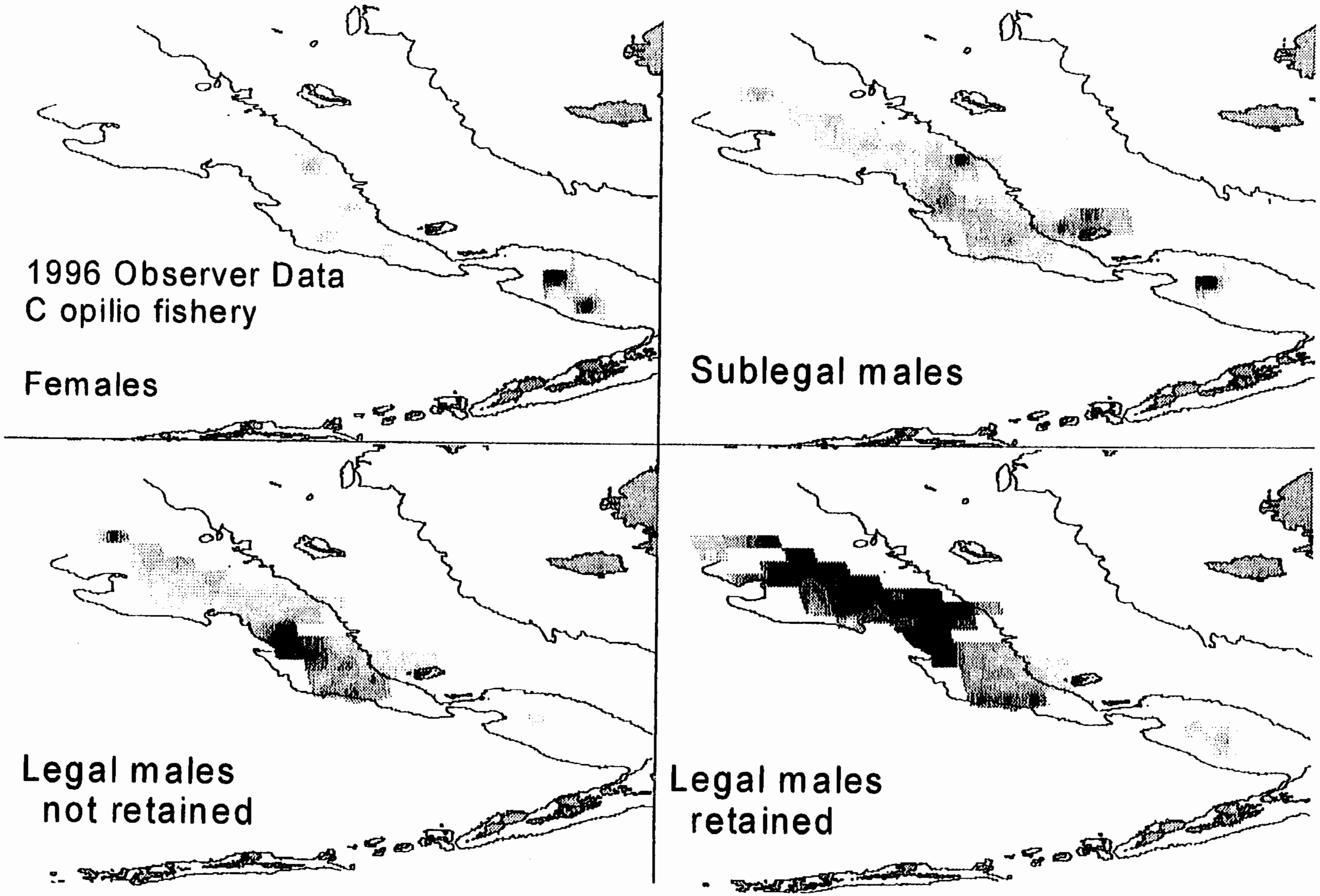


Figure 31 Z-score surfaces of mean CPUE for *C. opilio* from the Bering Sea 1996 *C. opilio* fishery. Data is from 1,384 pots sampled by observers on 15 catcher processors participating in the fishery.

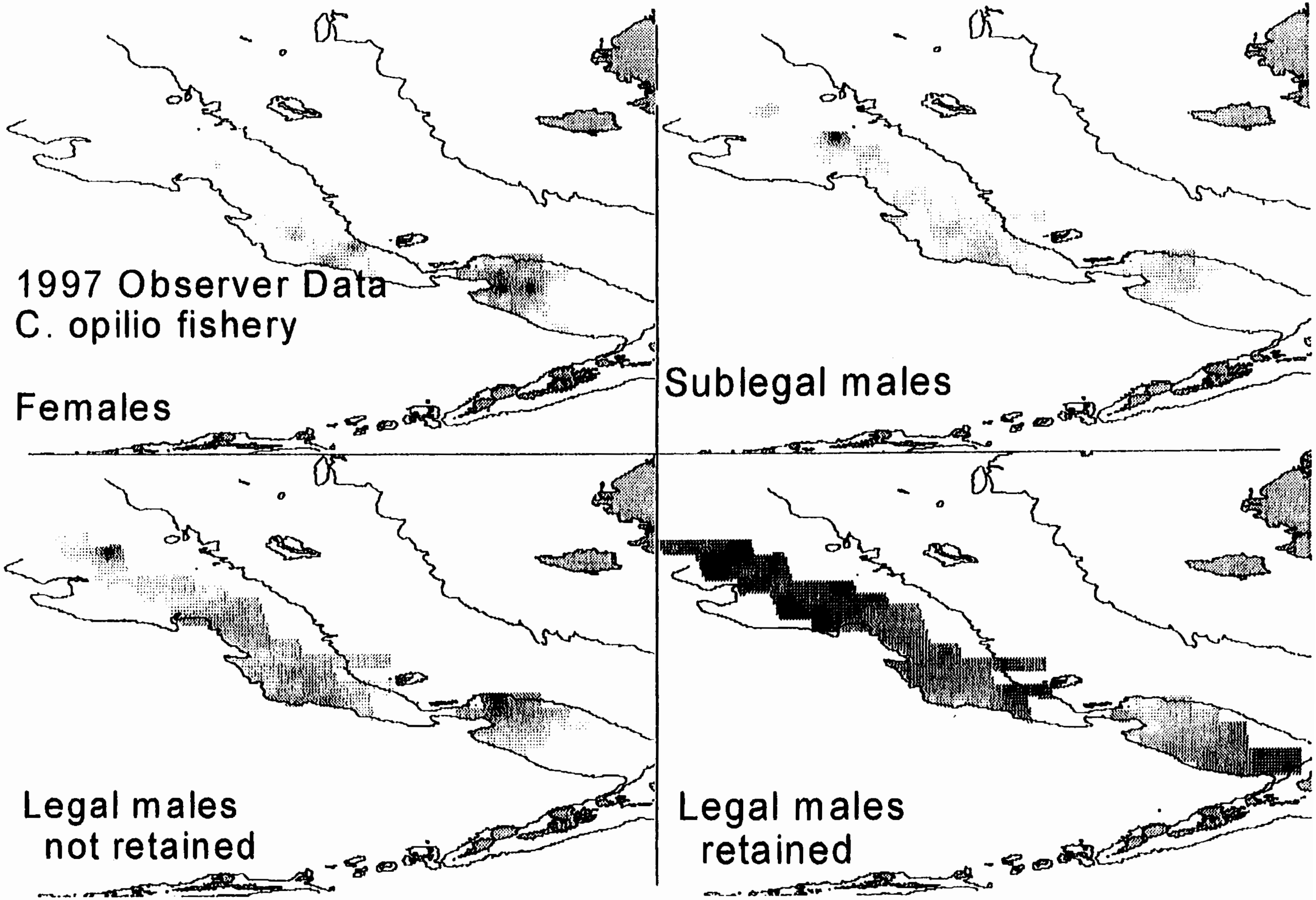


Figure 32 Z-score surfaces of mean CPUE for *C. opilio* from the Bering Sea 1997 *C. opilio* fishery. Data is from 1,733 pots sampled by observers on 13 catcher processors participating in the fishery.

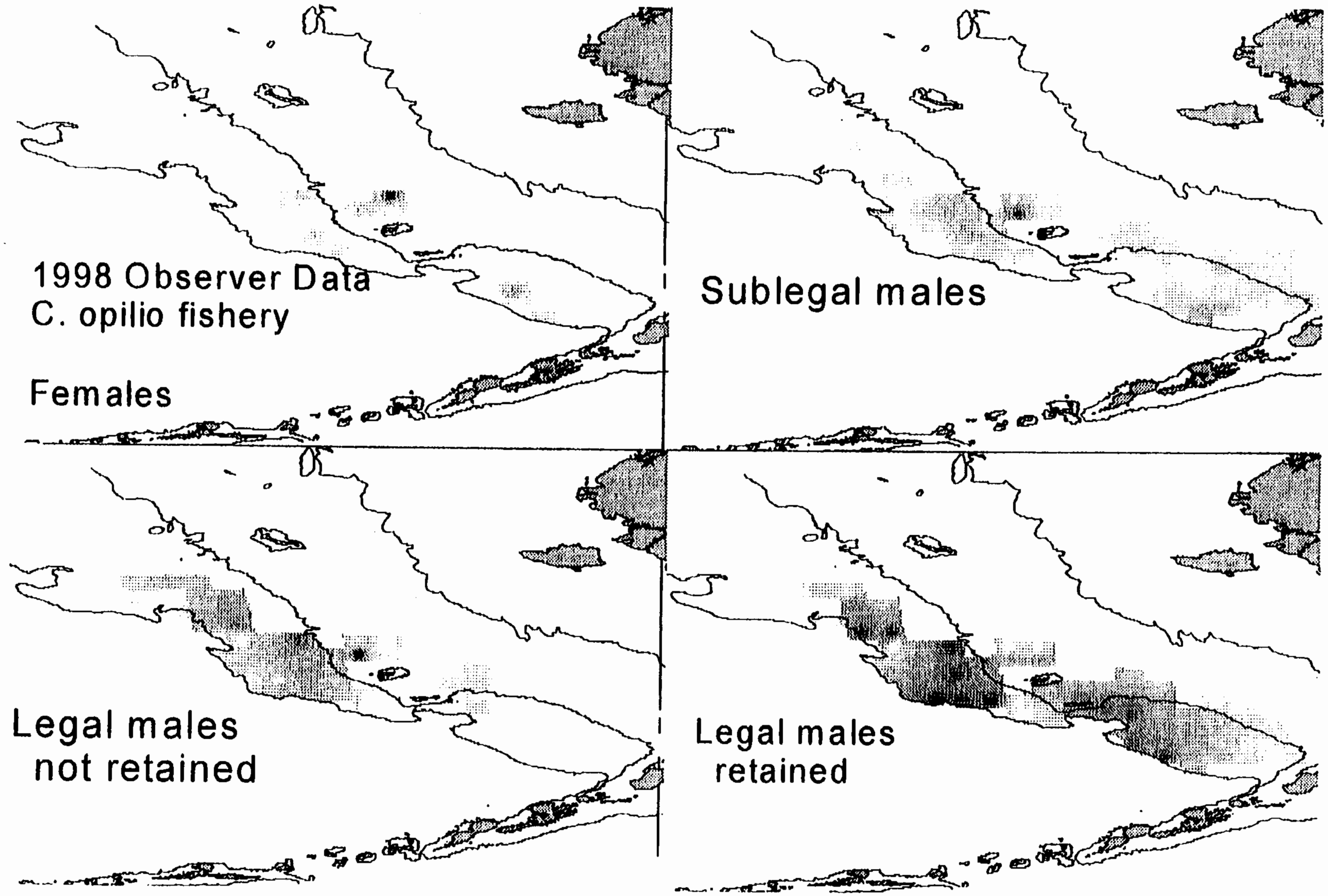


Figure 33 Z-score surfaces of mean CPUE for *C. opilio* from the Bering Sea 1998 *C. opilio* fishery. Data is from 1,782 pots sampled by observers on 10 catcher processors participating in the fishery.

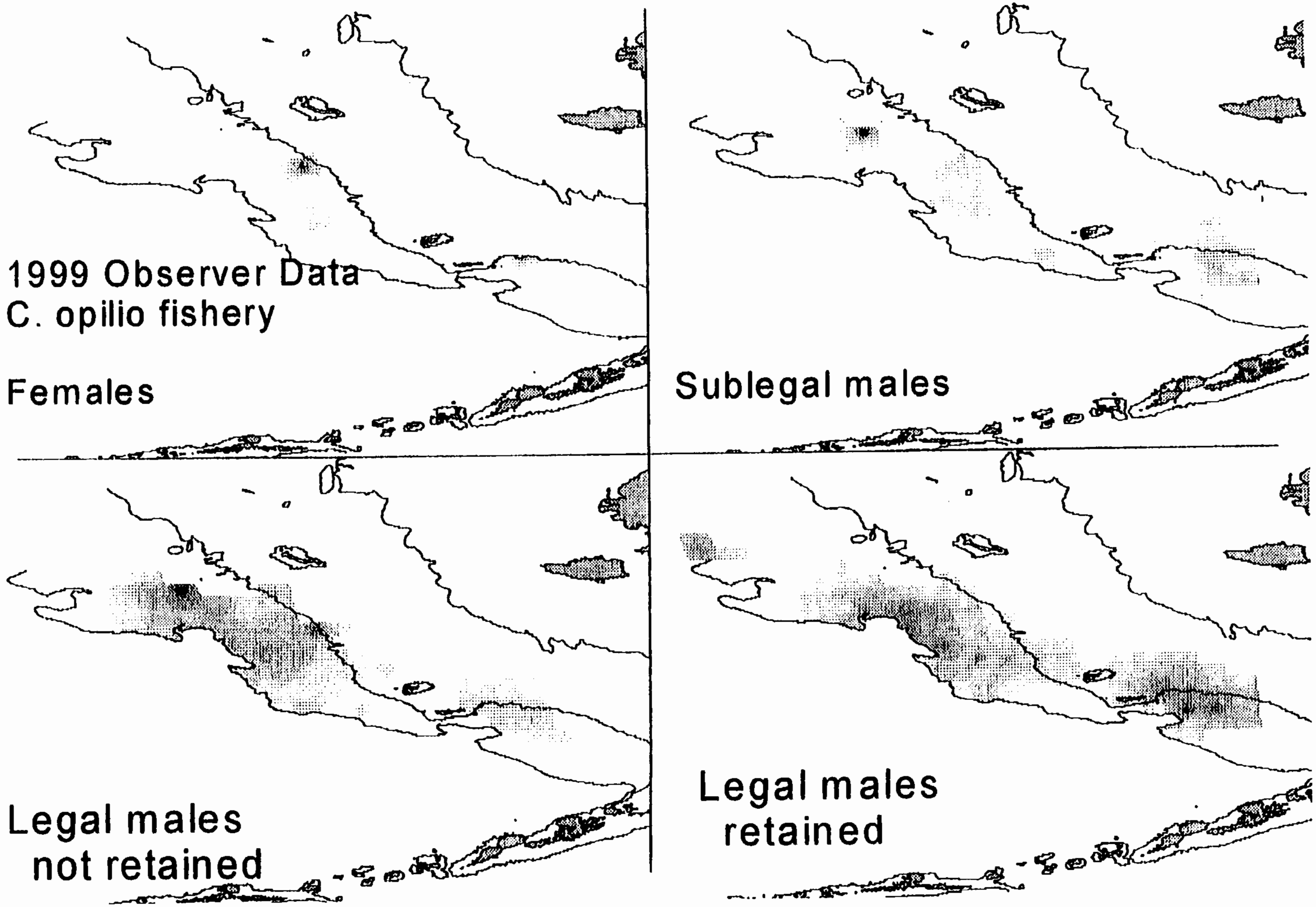


Figure 34 Z-score surfaces of mean CPUE for *C. opilio* from the Bering Sea 1999 *C. opilio* fishery. Data is from 1,506 pots sampled by observers on 10 catcher processors participating in the fishery.

Figure 35 **EBS snow crab harvest strategy adopted by BOF, March 2000: Determination of exploitation rate on mature male biomass**

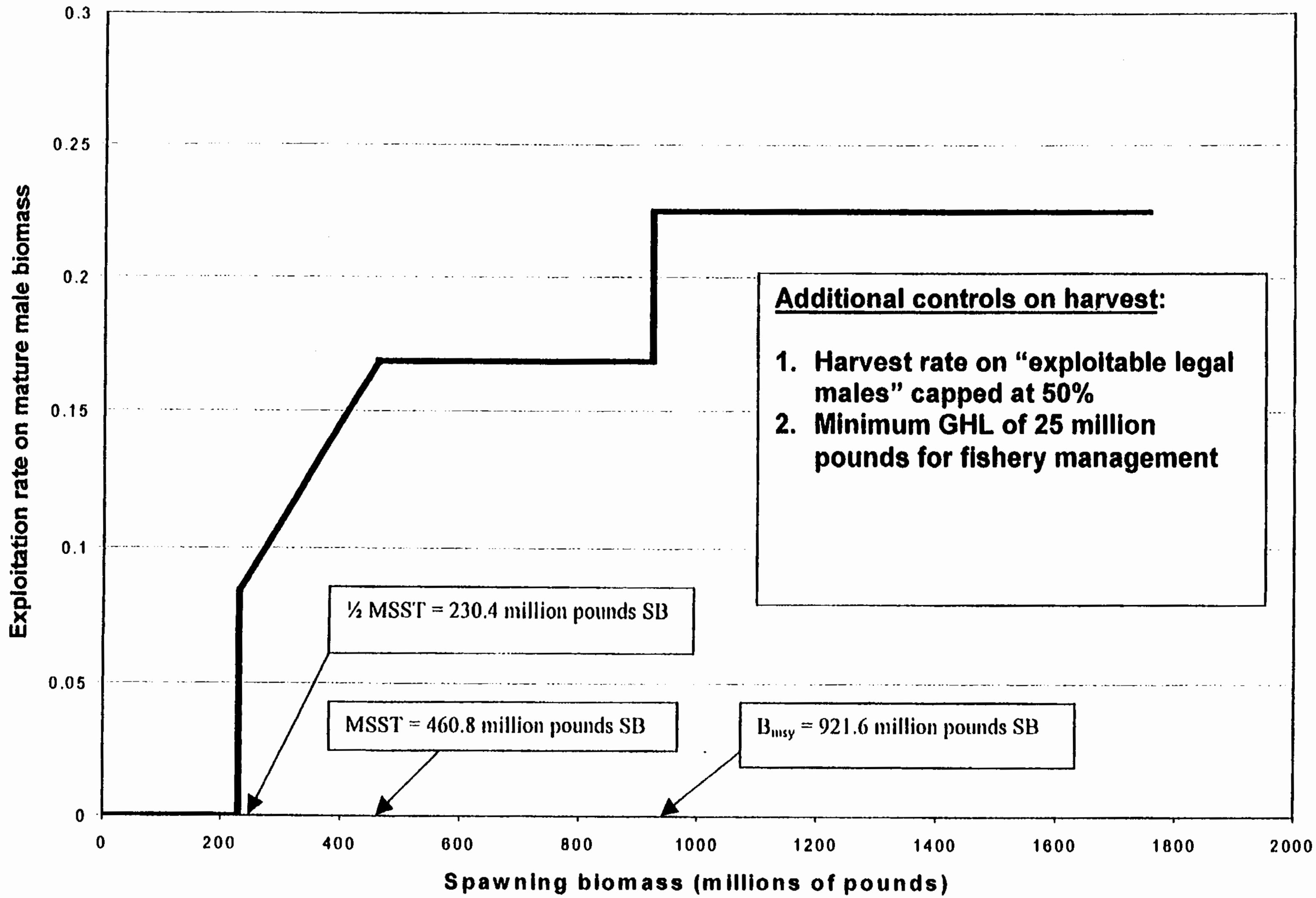


Figure 36

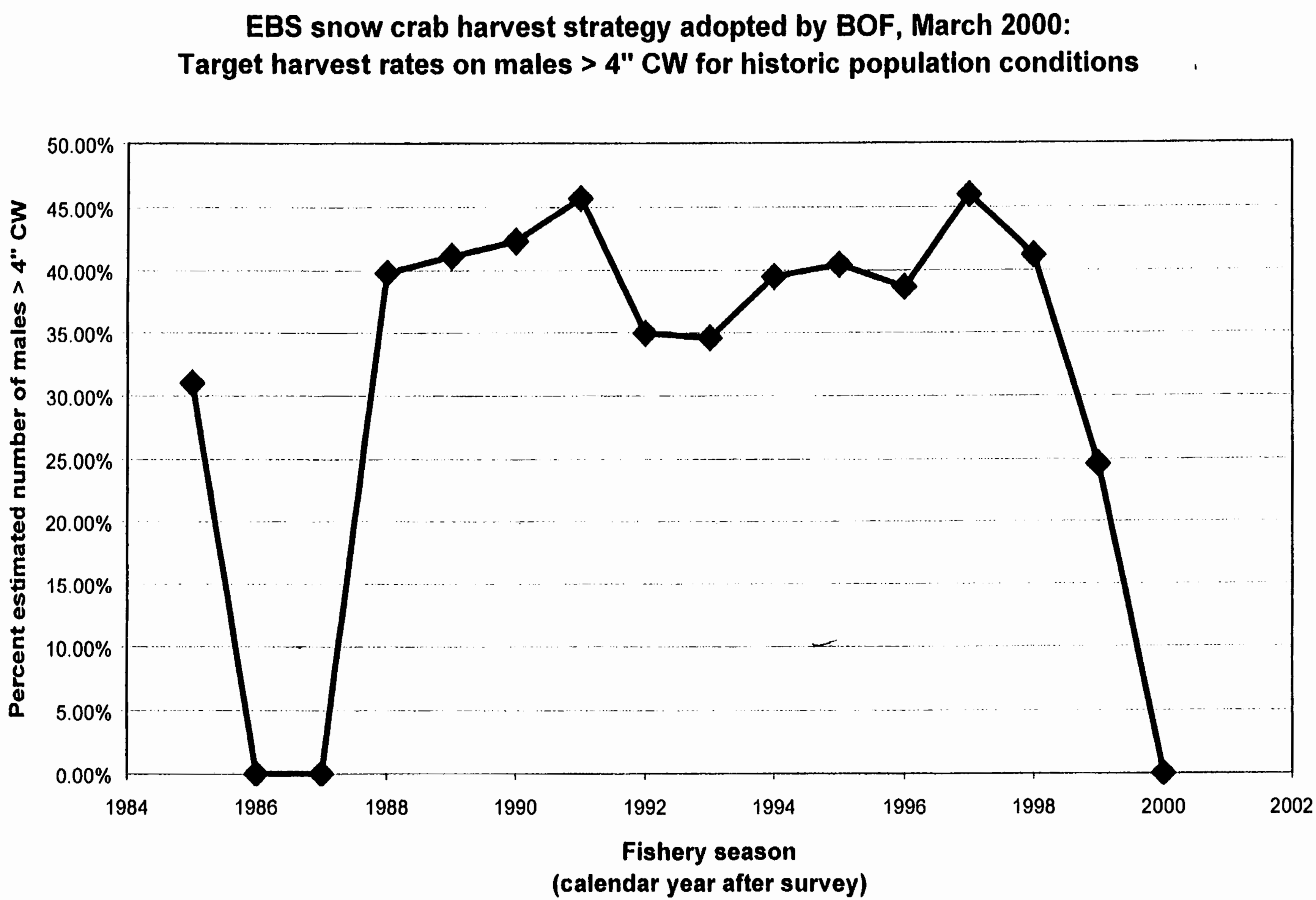
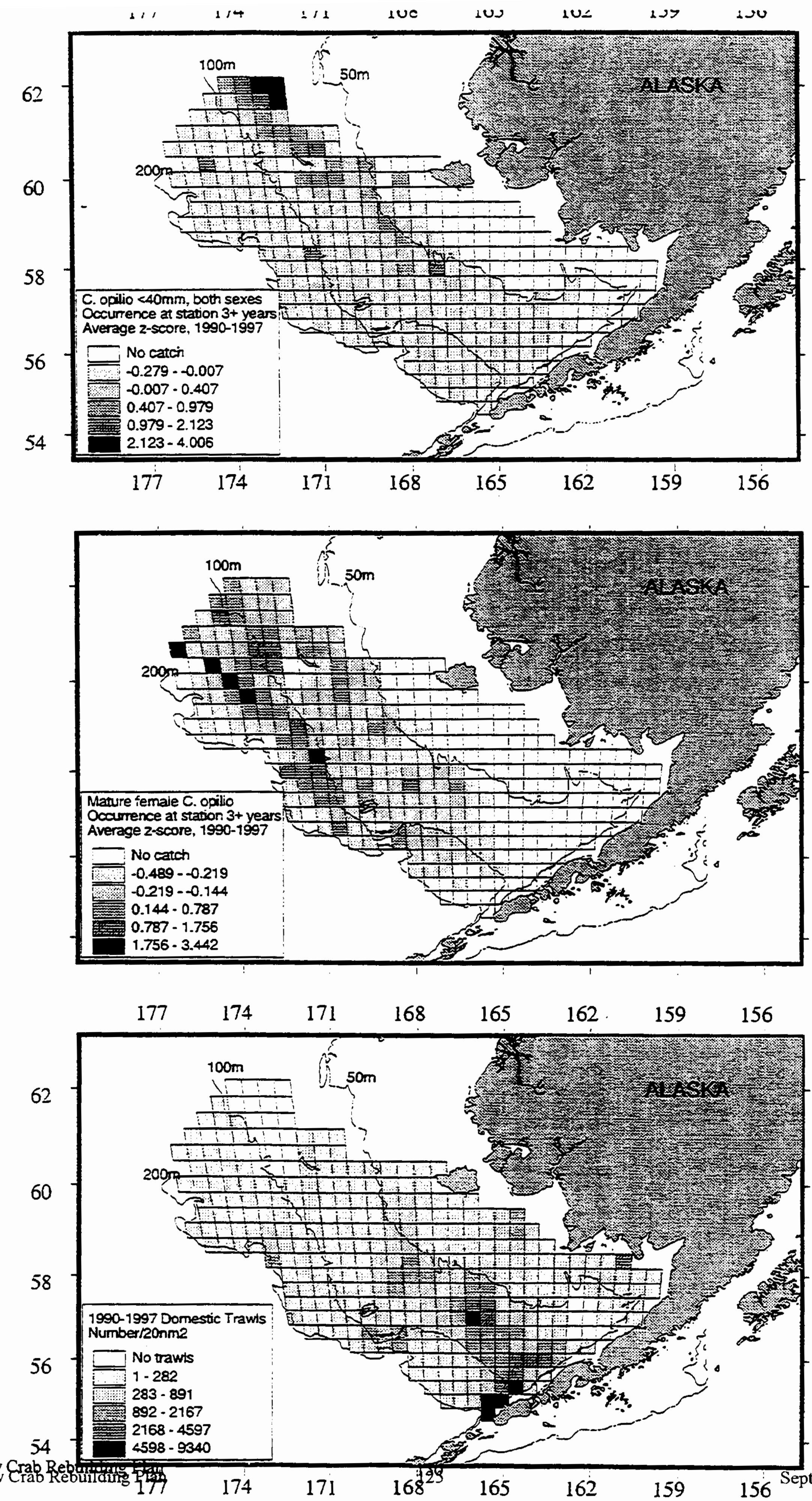

EBS snow crab harvest strategy adopted by BOF, March 2000:
Target harvest rates on males > 4" CW for historic population conditions
Percent estimated number of males > 4" CW
50.00%
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Fishery season
(calendar year after survey)

Figure 37



Snow Crab Rebuilding Plan 125

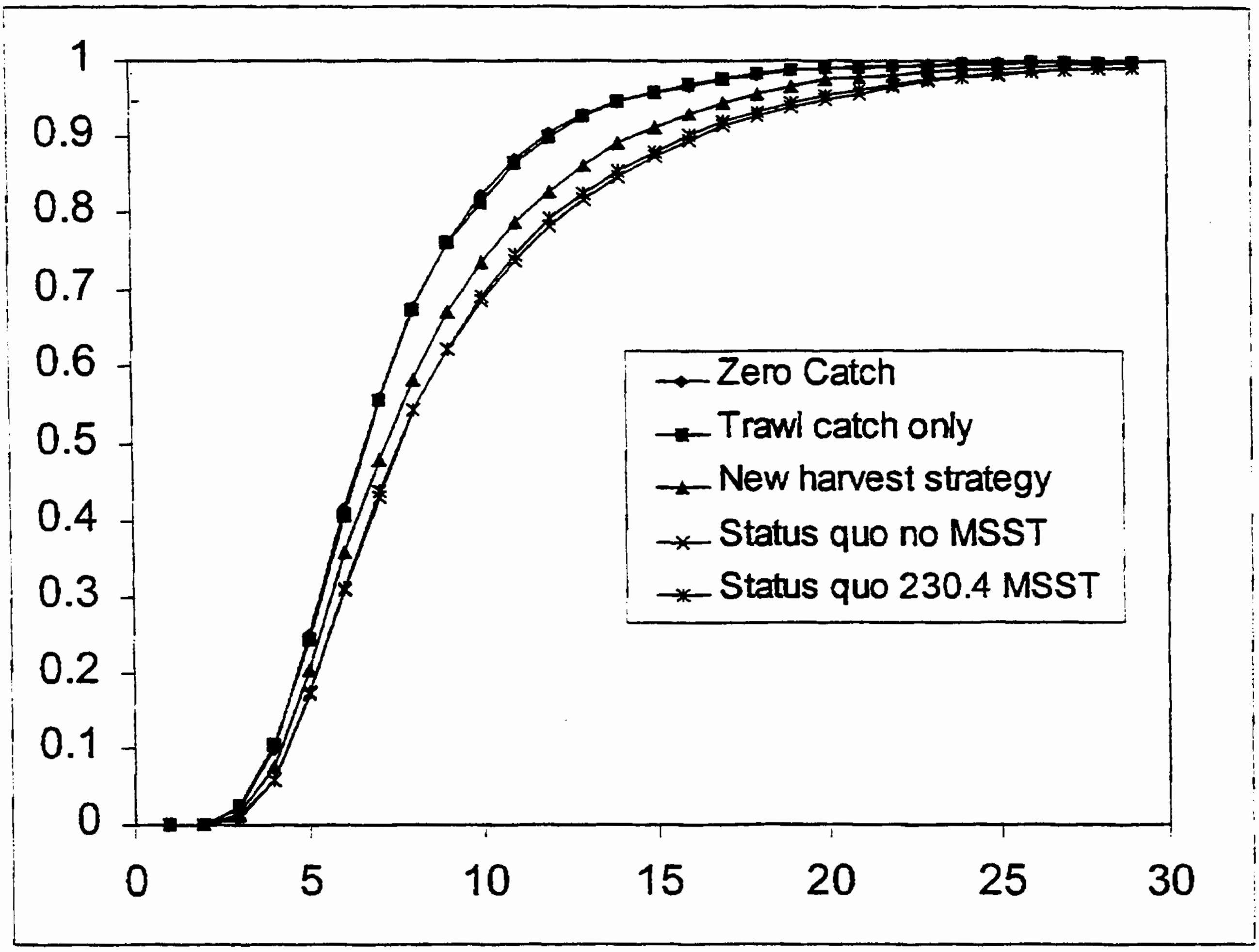


Figure 38 Probability of rebuilding by year for various catch scenarios with random recruitment. Year 1 corresponds to year 2000.

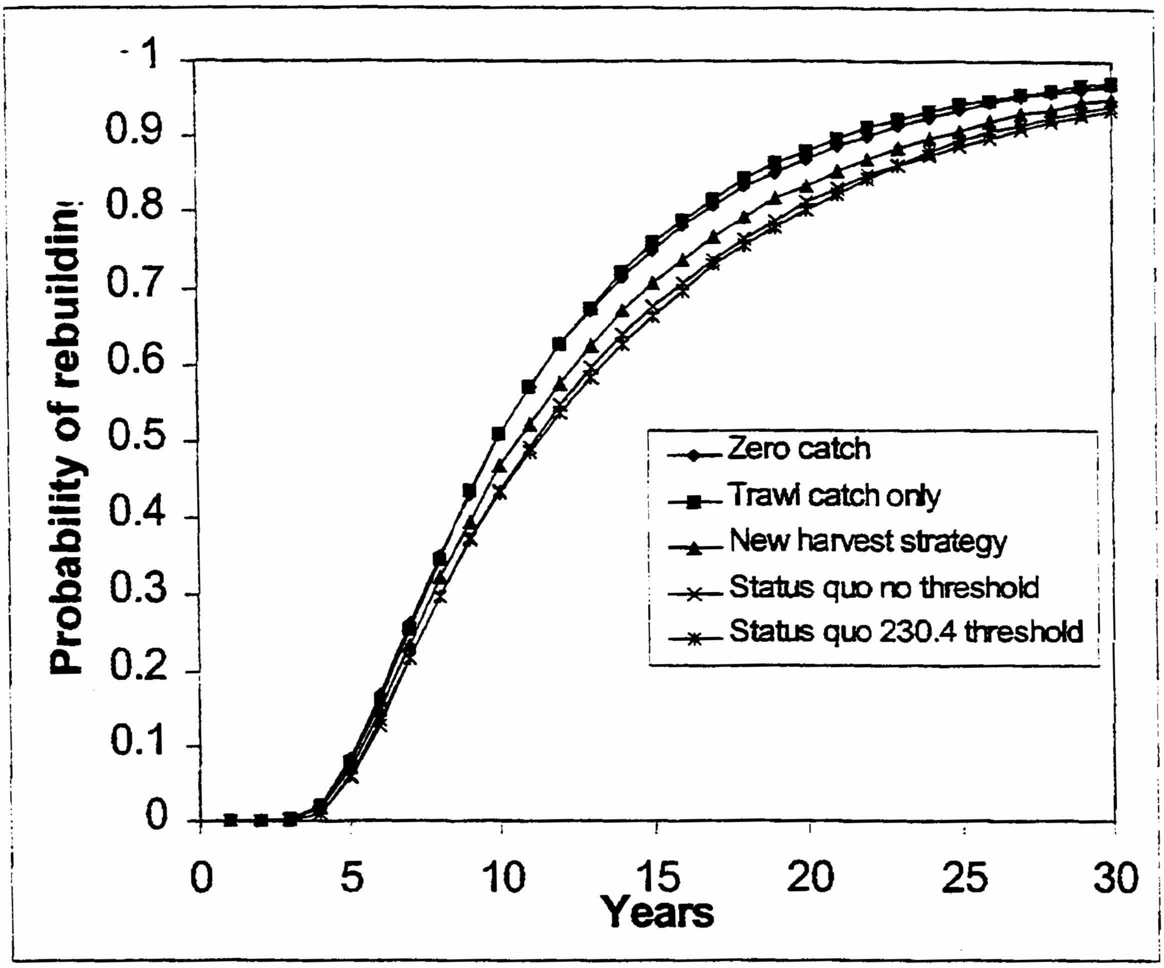


Figure 39 Probability of rebuilding by year for various catch scenarios with autocorrelated recruitment. Year 1 corresponds to year 2000.

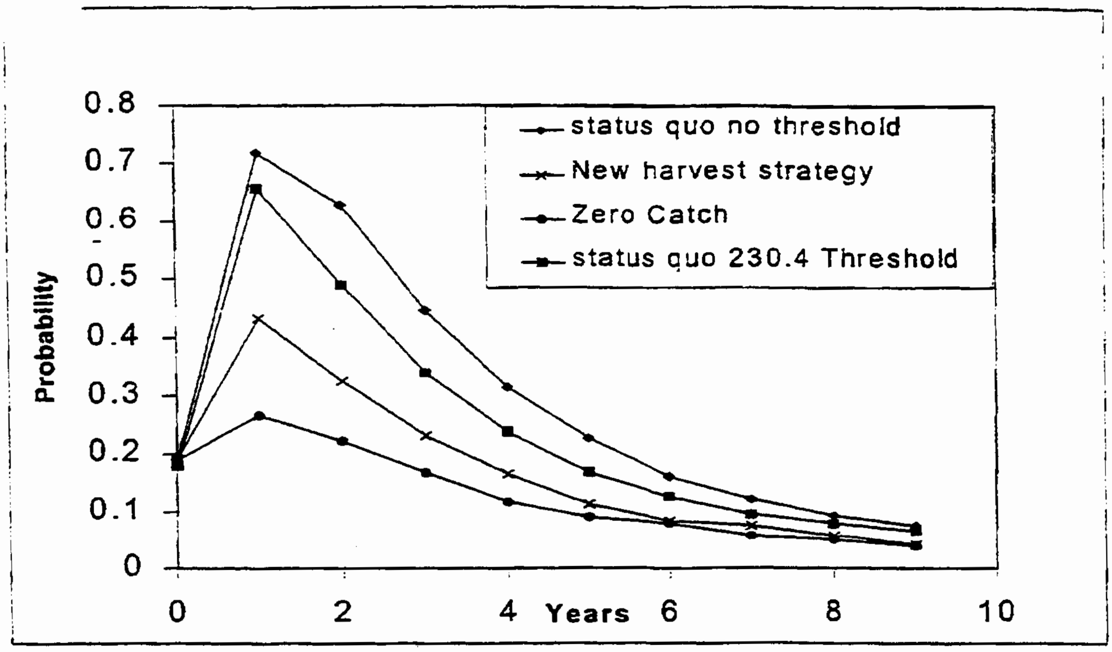


Figure 40 Probability of mature biomass being below one-half MSST (230.4 million lbs) by year the autocorrelated recruitment option. Year 0 corresponds to the 1999 survey and year 1 corresponds to the 2000 survey.

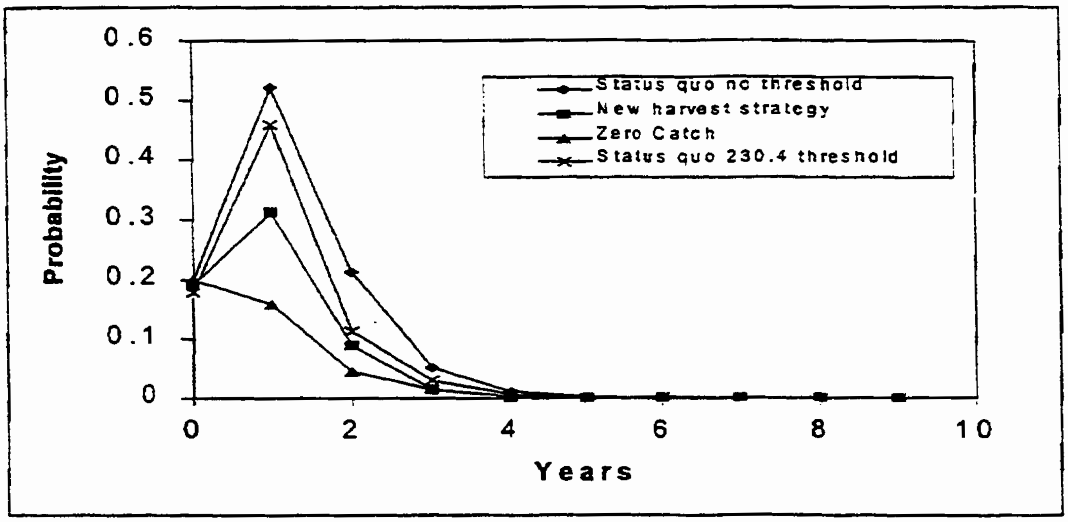


Figure 41 Probability of mature biomass being below one-half MSST (230.4 million lbs) by year the random recruitment option. Year 0 corresponds to the 1999 survey and year 1 corresponds to the 2000 survey.

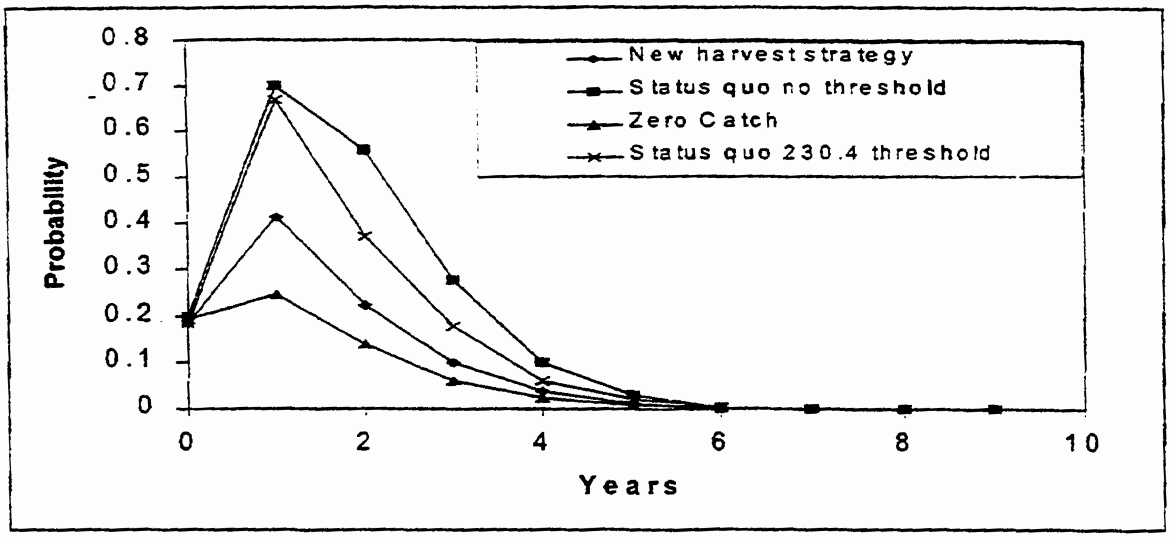


Figure 42 Probability of mature biomass being below one-half MSST (230.4 million lbs) by year the cycle recruitment option. Year 0 corresponds to the 1999 survey and year 1 corresponds to the 2000 survey.

Appendix 1 The 1996 Industry Agreement on Snow Crab PSC Limits

On November 7, 1996, the following agreement was reached by the negotiating committee on PSC caps for C. opilio in the Bering Sea trawl fisheries.

PSC caps for C. opilio

The PSC limit for snow crab (*C. opilio*) taken in Bering Sea trawl fisheries will be based on total abundance of C. opilio as indicated by the NMFS annual bottom trawl survey. **The PSC cap will be set at 0.1133% of the total Bering Sea abundance, with a minimum PSC of 4.5 million snow crabs and a maximum PSC of 13 million snow crabs.** Snow crab taken within the "Snow Crab Bycatch Limitation Zone" (SCBLZ) would accrue towards the PSC limits established for individual trawl fisheries. Upon attainment of a snow crab PSC limit apportioned to a particular trawl target fishery, that fishery would be prohibited from fishing within the SCBLZ.

Coordinates of the Snow Crab Bycatch LimitationZone, as agreed upon by the negotiating committee.

North latitude	West longitude
56°30'	Donut Hole
56°30'	165°00'
58°00'	165°00'
59°30'	170°00'
US-Russia Line	170°00'

Note that this agreement would yeild a snow crab PSC limit of 6,147,000 snow crab for 1997. This number is 0.1133% of the total 1996 NMFS survey abundance of 5,424,886,000 snow crab (both sexes, all size groups).

Caveats and Recommendations:

1. If area 517 bycatch exceeds 500,000 snow crab in any one year, the Council should consider moving the southern boundary of the snow crab bycatch limitation zone from 56°30' to 56°00'.

2. These snow crab PSC limits will be subject to a 5 year review.

Industry Support:

All parties here below signed will support this agreement at the North Pacific Fishery Management Council meeting through Secretarial review and approval. The Committee strongly recommends that the NPFMC approve this agreement without change. Any substantive change from this agreement releases the parties from supporting said agreement.