Regional Information Report No. 4K21-13

Updated Tanner Crab Harvest Strategies for Kodiak, Chignik, and South Peninsula Districts: A Report to the Alaska Board of Fisheries

by

Kally Spalinger

Nathaniel Nichols

and

Michael Knutson

December 2021

Alaska Department of Fish and Game **Divisions of Commercial Fisheries**

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used without definition in the following reports by the Divisions of Sport Fish and of Commercial Fisheries: Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications. All others, including deviations from definitions listed below, are noted in the text at first mention, as well as in the titles or footnotes of tables, and in figure or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	E
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	′
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	″
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

REGIONAL INFORMATION REPORT 4K21-13

UPDATED TANNER CRAB HARVEST STRATEGIES FOR KODIAK, CHIGNIK, AND SOUTH PENINSULA DISTRICTS: A REPORT TO THE ALASKA BOARD OF FISHERIES

by
Kally Spalinger, Nathaniel Nichols and Michael Knutson

Alaska Department of Fish and Game, Division of Commercial Fisheries, Kodiak

Alaska Department of Fish and Game
Division of Commercial Fisheries
351 Research Court
Kodiak, AK 99615

December 2021

The Regional Information Report Series was established in 1987 and was redefined in 2007 to meet the Division of Commercial Fisheries regional need for publishing and archiving information such as area management plans, budgetary information, staff comments and opinions to Alaska Board of Fisheries proposals, interim or preliminary data and grant agency reports, special meeting or minor workshop results and other regional information not generally reported elsewhere. Reports in this series may contain raw data and preliminary results. Reports in this series receive varying degrees of regional, biometric and editorial review; information in this series may be subsequently finalized and published in a different department reporting series or in the formal literature. Please contact the author or the Division of Commercial Fisheries if in doubt of the level of review or preliminary nature of the data reported. Regional Information Reports are available through the Alaska State Library and on the Internet at: http://www.adfg.alaska.gov/sf/publications/.

Product names used in this publication are included for completeness and do not constitute product endorsement. The Alaska Department of Fish and Game does not endorse or recommend any specific company or their products.

Kally Spalinger, Nathaniel Nichols, and Michael Knutson
Alaska Department of Fish and Game, Division of Commercial Fisheries,
351 Research Court, Kodiak, AK 99615, USA

This document should be cited as follows:
Spalinger, K., N. Nichols, and M. Knutson. 2021. Updated Tanner crab harvest strategies for Kodiak, Chignik, and South Peninsula Districts: A report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K21-13, Kodiak.

The Alaska Department of Fish and Game (ADF&G) administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act (ADA) of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility please write:
ADF&G ADA Coordinator, P.O. Box 115526, Juneau, AK 99811-5526
U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, MS 2042, Arlington, VA 22203
Office of Equal Opportunity, U.S. Department of the Interior, 1849 C Street NW MS 5230, Washington DC 20240

The department's ADA Coordinator can be reached via phone at the following numbers:
(VOICE) 907-465-6077, (Statewide Telecommunication Device for the Deaf) 1-800-478-3648,
(Juneau TDD) 907-465-3646, or (FAX) 907-465-6078

For information on alternative formats and questions on this publication, please contact:
ADF&G, Division of Sport Fish, Research and Technical Services, 333 Raspberry Rd, Anchorage AK 99518 (907) 267-2375

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

The Alaska Department of Fish and Game (ADF&G) recommends updating harvest strategies for the Tanner crab *Chionoecetes bairdi* fisheries in the Kodiak, Chignik and South Peninsula Districts. Proposed harvest strategies will update minimum regulatory thresholds used to determine fishery openings and use similar framework and rationale to the harvest strategy recently adopted for Bering Sea Tanner crab. The proposed harvest strategies account for fluctuations in both mature male and female abundance and produce guideline harvest levels (GHLs) in line with historical management practices.

Key words: Tanner crab, *Chionoecetes bairdi*, harvest strategy, commercial fishery, management, Kodiak, Chignik, South Peninsula, guideline harvest level, Board of Fisheries

INTRODUCTION

The Kodiak District for Tanner crab *Chionoecetes bairdi* is subdivided into eight sections: Northeast, Eastside, Southeast, Southwest, Semidi Island Overlap, Westside, North Mainland, and South Mainland (5 AAC 35.505(a)(1–8). The South Peninsula District is divided into two sections, Eastern and Western, by long 162° W. The Chignik District is managed as a single unit (Figure 1).

BACKGROUND

Kodiak, Chignik, and South Peninsula District Tanner crab fisheries developed in the 1970s and were managed by ADF&G until December 1978 when a federal fishery management plan (FMP) was adopted. Under the FMP, ADF&G managed Tanner crab in state waters (0–3 nmi offshore) and the federal government managed Tanner crab in federal waters (3–200 nmi offshore). Joint jurisdiction occurred until 1987, when the state again assumed full management authority (Bevaart and Phillips 2021).

In the early 1980s, Tanner crab abundance and commercial harvests began a decline that continued through the 1990s. No formal guidelines existed for determining when areas should remain closed or when they could reopen to fishing. In response, ADF&G developed new harvest strategies with conservative management measures that were aimed at preventing overharvest and localized depletion (Bevaart and Phillips 2021; Urban et al. 1999). In 1999, the Alaska Board of Fisheries (BOF) adopted 5 AAC 35.507 *Kodiak, Chignik, and South Peninsula Districts* C. bairdi *Tanner crab harvest strategies*, which currently guides the fisheries.

The harvest strategies specify both biological and management thresholds. The biological threshold requires mature male[1] abundance within the district, or sections within a district, to meet or exceed 50% of the long-term average abundance of mature male crab. The management threshold requires guideline harvest levels (GHLs) to meet section and/or district minimum GHL thresholds. If mature male abundance and minimum GHL thresholds are met, a commercial fishery may occur in that management unit (Urban et al. 1999). Tanner crab area-swept abundance estimates are collected annually during the ADF&G bottom trawl survey on the R/V *Resolution* (Spalinger and Knutson 2021).

The initial long-term average abundance estimates used to establish biological thresholds were determined for each district, or section within a district, using a combination of four different methods; Leslie depletion, catch survey analysis, catch expansion, and area-swept (Urban and Vining 1999). Because there were only 11 years of trawl survey area-swept abundance estimates available in 1999, combining these methods was considered the best way to create a long-term

[1] Male Tanner crab > 114 mm carapace width (Donaldson et al. 1981, Knutson *in prep*)

time series. It was recognized that since the trawl survey area-swept method was being used to estimate abundance in the areas, any similarities between the results of the trawl survey and the other methods would provide insight into the accuracy of the various estimates.

The harvest strategies implemented in 1999 replaced a fixed 40% exploitation rate on legal males (used through 1998) with stair-step exploitation rates of 10% or 20% of molting mature males[2] and a cap at 30% of legal males. Tanner crab populations are known to undergo quasi-periodic fluctuations in population abundance (Zheng and Kruse 2000). While this was not evident in the trawl survey data prior to the implementation of the 1999 harvest strategies, since 2000 the Kodiak, Chignik, and South Peninsula Districts have shown 4 major abundance pulses at 5–6 year intervals (Figure 2). Under such conditions a fixed exploitation rate is not the most effective strategy for implementing BOF policies on managing Tanner crab populations. Studies comparing a fixed (40%) exploitation rate on legal crab to strategies in which the exploitation rate varies with stock productivity found that when coupled with an appropriate population threshold and maximum exploitation rate, the variable exploitation rate strategy provides better conservation of reproductive potential and balance between long-term and annual yield (Heller-Shipley et al. 2021; Zheng and Kruse 1999).

Updated harvest strategies were developed using an additional 23 years of survey estimates, subsequent management decisions, and review of harvest strategy analyses performed for the Bering Sea (Daly et al. 2020). They allow for flexible exploitation rates that better reflect the productivity of the population, would maintain consistency with fishery management practices, and prevent overexploitation of the resource.

PURPOSE

The purpose of this report is to recommend updated Tanner crab harvest strategies for the Chignik District and for each section of the Kodiak and South Peninsula Districts (Figure 1). The proposed harvest strategies update the abundance assessment time series, apply a new harvest control rule (HCR), and include fishery management measures that best promote successful fisheries. We provide an overview of the fishery management goals and objectives, the need for updated harvest strategies, describe the harvest strategies evaluated, and provide our recommendations.

MANAGEMENT GOALS AND OBJECTIVES

The BOF adopted fishery management policies for king and Tanner crabs in March 1990 with the goal to maintain and improve crab resources for the greater overall benefit to Alaska and the nation (ADF&G 1990; ADF&G 2017). Achievement of this goal is constrained by the need to minimize 1) risk of irreversible adverse effects on reproductive potential, 2) harvest during biologically sensitive periods, 3) adverse effects on non-targeted portions of the stock, and 4) adverse interactions with other stocks and fisheries. The policy endeavors to maintain a healthy stock, provide for a sustained and reliable supply of high-quality product that leads to substantial and stable employment, and provide for subsistence and personal use of the resource. These policies are outlined in detail in Appendix A.

Our goal is to update the harvest strategies to be consistent with those policies while using the most recent biological information available to develop thresholds for opening fisheries, consider

[2] Molting mature males are defined as 100% of new shell and 15% of old and very old shell Tanner crab that are >114 mm in carapace width

female abundances in setting exploitation rates, and closely align those rates with current management practices.

HARVEST STRATEGY REVISION NEED

When the 1999 harvest strategies were implemented, a framework was provided to incorporate future improvements in determination of stock thresholds, reference levels for rebuilding and rebuilt stocks, criteria for defining mature males, optimal harvest rates, and caps on the harvest of legal crabs (Urban et al. 1999).

Since 1999, improvements have been made to the calculation of trawl survey area-swept abundance estimates for Tanner crab. Survey stations and areas have been standardized so that area-swept expansion calculations are consistent and provide comparable abundance estimates for all years the survey has been conducted since 1988 (Spalinger and Knutson *In prep*). There are 34 years of abundance estimates using this updated method. We propose to update the biological thresholds used to determine fishery openings, using only data from the trawl survey area-swept abundance estimates, for the years 1988–2021.

In addition, 17 years of fishery data are available to evaluate the existing harvest strategies. While the basic framework promotes conservation, when exploitation rates on legal crab were generally set higher than 20% of the legal crab abundance estimate, the fisheries often resulted in long seasons with low CPUEs (Figure 3). The updated strategies reduce the maximum exploitation rate on legal crab from 30% to 20% of the estimated abundance for that year.

The use of a molting mature male calculation was implemented in 1999, prior to broad scientific acceptance in 2005 of the concept that both female and male Tanner crab have a terminal molt to maturity (i.e. crab will never molt and grow after the molt to maturity; Tamone et al. 2005, 2007; Zheng et al. 2011). Eliminating use of molting mature males is believed to be appropriate based on the current knowledge of Tanner crab biology.

The existing harvest strategies do not incorporate a measure of mature female abundance when considering fishery openings or determining maximum exploitation rates, although the survey provides those estimates for each area annually. Given the importance of mature females for reproductive potential (Knutson 2020; NPFMC 2013; Orensanz et al. 1998; Sainte-Marie et al 2008; Webb et al. 2016; Webb and Bednarski 2009), all Bering Sea and Aleutian Islands crab harvest strategies consider mature females for stocks which there is reliable mature female abundance data. These data suggest that a reduction in exploitation on males is appropriate when mature female abundance is relatively low to provide for adequate overlap between newly recruited mature females and mature males from the previous cohort. Furthermore, lowering exploitation on mature males for 1–2 years prior to a population decline could preserve males for harvest in subsequent fisheries, buffering the rate of population decline (Daly et al. 2020).

We propose adding a female control rule, similar to the rule recently implemented in the Bering Sea (Daly et al. 2020), that would reduce the legal male exploitation rate on a sliding scale when mature female abundance falls below the long-term average abundance index.

ELEMENTS OF THE UPDATED HARVEST STRATEGY

The harvest strategies proposed for Kodiak, Chignik, and South Peninsula District Tanner crab follow the framework and rationale used in the harvest strategy for Bering Sea Tanner crab (Daly et al. 2020) and include 3 core elements.

1) A minimum stock size threshold for fishing to occur, based on area-swept abundance estimates from the ADF&G bottom trawl survey.
2) A harvest control rule that incorporates both mature female and mature male abundance to determine maximum fishery exploitation rates and applies those rates to legal male crab abundance to determine GHLs.
3) A minimum GHL requirement that must be met for a fishery to open.

Mature Male Abundance Thresholds

Minimum abundance thresholds were updated for the Chignik District and for each section within the Kodiak and South Peninsula Districts, apart from the Semidi Island Overlap and South Mainland Sections. Trawl survey stations and station areas were standardized across all years (1988–2021) to develop an abundance index directly comparable to current assessment methodology.

No thresholds were established for Semidi Island Overlap and South Mainland Sections because of the lack of fishery and stock abundance data available from those areas. Currently, these two sections only open when adjacent areas open, and close on the regulatory closure date of March 31. Proposed opening criteria would remain the same and closures would occur on February 15. In these areas, seasons are used in place of GHLs and this date will ensure that an opening would not be substantially longer than openings in adjacent areas that have more stock information available. This will provide opportunity for vessels to explore the area but eliminate protracted, low-CPUE fisheries, which have generally been associated with high exploitation rates in other areas (Figure 3).

Threshold Level Determination

Mature male abundance estimates from 1988 to 2021 were used to generate a linear trendline of abundance for each management unit (Spalinger and Knutson *In prep*; Appendix B). The abundance data was categorized as having an increasing or decreasing (slope greater than ±25,000 crab year^{-1}) or stable (slope less than ±25,000 crab year^{-1}) abundance trend. For areas where the long-term trend of mature male abundance is increasing a threshold level of 50% of the long-term average abundance of mature males will remain in place. For areas where the long-term trend of mature male abundance is decreasing or stable, a more conservative threshold level of 100% of the long-term average abundance of mature males will be established to protect the reproductive potential of the stock. Only the Northeast, Westside and North Mainland Sections of the Kodiak District currently fall into this category, and abundance estimates in those areas have shown no sign of improvement since the prior fishery collapse in the late 1980s (Spalinger and Knutson *In prep*). Table 1 provides the long-term average and the updated threshold based on mature male abundance trends.

When estimated mature male abundance is greater than the applicable threshold, the district/section may be considered for a commercial fishery opening. When the estimate of mature male abundance is less than the applicable threshold, the district/section will remain closed to commercial fishing until the mature male abundance surpasses the threshold.

Harvest Control Rule (HCR)

For areas where the mature male abundance is above threshold, the mature female abundance ratio (current year relative to the long-term average from 1988 to 2021) will be determined. If the abundance is more than the long-term average the sloping HCR will be set to the maximum level of exploitation. If the abundance is less than the long-term average the sloping HCR will be adjusted using the female ratio to reduce the maximum legal male exploitation rate (Figure 4). Should the ratio fall below 0.4 the HCR will be set to the minimum legal male exploitation rate.

When the sloping HCR has been determined based on the mature female ratio, the mature male abundance ratio (current year relative to the long-term average from 1988 to 2021) will be calculated. According to the ratio, the location on the sloping HCR will be determined and the resulting maximum exploitation rate applied towards legal males (Figure 4).

The product of the maximum exploitation rate and the estimated number of new and old shell legal males is multiplied by the average weight of legal-sized crabs, as determined from trawl survey data, to compute the maximum GHL in pounds. Very old shell legal males are not included in GHL calculation. Relative to other shell conditions, a higher proportion of very old shell crab are expected to die due to natural mortality between a summer survey and a winter fishery and are generally not targeted during the fishery.

Additional Precautionary Measure

The harvest strategy updates for the Kodiak, Chignik, and South Peninsula Districts contain additional precautionary measures. The Chignik or South Peninsula Districts will remain closed if the calculated GHL is below 200,000 pounds. Any section of the Kodiak District will remain closed if the calculated GHL is below 100,000 pounds.

Proposed minimum GHLs remain the same as the existing harvest strategy for the Chignik District and the sections of the South Peninsula District. For the Kodiak District we are proposing to remove the district GHL minimum requirement of 400,000 pounds and the requirement that at least 2 sections must open for a fishery to occur. Communication between managers and the fishing fleet have greatly improved since 1999. In the last 3 Tanner crab seasons in Kodiak, most fishing vessels communicated with managers daily via satellite dispatch radio, satellite phone, or satellite texting services. This allows managers to make more informed and timely decisions than was previously possible, allowing for smaller GHLs to be managed effectively. Additionally, on several occasions in the recent past (e.g., 2017 and 2021), the Kodiak District fishery has not opened because the district minimum GHL criteria of 400,000 pounds was not met, although an individual section met all other regulatory requirements. Staff agreed that smaller fisheries could be both manageable and biologically appropriate, according to all other aspects of the harvest strategies.

COMPARISONS OF THE UPDATED STRATEGIES WITH HISTORICAL MANAGEMENT PRACTICES

To understand how the proposed strategies may affect annual harvest and the frequency of fishery openings we provide year-by-year comparisons of what those strategies would have meant at a given stock level relative to what occurred under current management practices. However, we have not attempted to reconstruct the historical stock levels that would have occurred under hypothetical fishing pressure had the updated harvest strategies been implemented at some time in the past.

Two important aspects of the harvest strategies are the abundance levels at which fisheries are closed, and the GHLs that the strategies produce for a given stock level.

The difference in threshold levels (50% or 100%) between management units replaces the previous use of "rebuilding" and "rebuilt" from the 1999 harvest strategy. It was noted that while abundance in some areas has increased to levels comparable to that seen prior to fishery collapses in the late 1980s and early 1990s, in others abundance has shown no sign of improvement. For those areas a threshold of 50% of the long-term average could allow fisheries that would jeopardize stock recovery. Consistent with observed abundance trends, thresholds will be increased in 3 management units (Northeast Kodiak, Eastside Kodiak, and Southeast Kodiak) and decreased in 6 management units (Southwest Kodiak, Westside Kodiak, North Mainland Kodiak, Chignik, Eastern South Peninsula, and Western South Peninsula). Using area-swept abundance estimates generated from the trawl survey data (2000–2021), comparing the frequency of fishery openings that would have occurred using updated thresholds with the actual frequency of openings indicate that the updated strategies result in fisheries more frequently than the existing strategies in 2 areas (Southwest Kodiak and Westside Kodiak), less frequently in 5 areas (Northeast Kodiak, Eastside Kodiak, Southeast Kodiak, Eastern South Peninsula, and Western South Peninsula), and equal numbers of openings in 2 areas (North Mainland Kodiak and Chignik; Table 1).

Using trawl survey data from 2000 to 2021, retrospective comparison between the existing and updated harvest strategies show that the updated strategy produced GHLs lower than the actual GHLs for years from 2001 to 2009, but generally higher GHLs for years 2010–present (Figures 5–9). During the first few seasons the existing strategies were in place, managers recognized that the fleet was not able to catch the full GHLs set using the maximum exploitation rates specified by the newly adopted harvest strategies. Subsequently, managers adjusted exploitation rates (i.e., GHLs were set lower than the maximum) in an attempt to better scale fishery removals to stock and fishery conditions at the time. In all areas, except for the Westside Section of Kodiak District, the total maximum GHLs determined using the updated strategies are closer to actual harvests than total maximum GHLs determined using the existing harvest strategies (Table 2), indicating that the updated strategies yield maximum GHLs that reflect recent historical harvest rates.

A district level summary of the retrospective comparison between actual fishery harvest and updated harvest strategies shows that the updated strategies result in increased annual average harvest in each district from 2001 to 2022 (Table 3). In the Kodiak District, annual average harvest suggested using the updated harvest strategies increased by 5%, but the number of fishery openings decreased from 17 to 16, resulting in a 1% decrease to overall harvest compared to what was actually caught. In the Chignik District, the updated harvest strategy suggested an annual average harvest that was 54% higher than actual average harvest and the number of fishery openings was the same, resulting in a 54% increase in overall harvest. In the South Peninsula District, annual average harvest suggested by the updated harvest strategies was 109% higher, while the number of fishery openings decreased from 11 to 7; the result was a 46% increase in overall harvest compared to what was actually caught in the fisheries (Table 3).

CONCLUDING REMARKS

The harvest strategies proposed here build upon recent advances in our understanding of Tanner crab biology and management, and incorporate a 34-year trawl survey time series and 17 years of fishery data that were not available when the existing harvest strategies were implemented. This data allows yearly comparisons of female abundance estimates, which were also not available

when existing harvest strategies were developed. Knowledge gained through the management of fisheries prosecuted under the existing harvest strategies were used to inform maximum harvest rates believed to yield better-performing fisheries. These harvest strategies are designed to be more responsive to quasi-periodic abundance fluctuations evident within these stocks and are simplified by consistently applying a harvest rate to legal males only and removing molting mature male calculations. The design of the updated harvest strategies resembles that approved by the BOF and implemented in Bering Sea Tanner crab fisheries (Daly et al. 2020).

These strategies improve upon the framework implemented in 1999 and should be regularly reevaluated to incorporate future improvements in determination of stock thresholds, criteria for defining mature males, and optimal harvest rates. If the updated harvest strategies are adopted by the BOF, future changes should be well documented (as required by 5 AAC 35.080) and reviewed by the BOF prior to implementation.

REFERENCES CITED

ADF&G (Alaska Department of Fish and Game). 1990. Policy on king and Tanner crab resource management. ICES Document 90-04-FB.

ADF&G (Alaska Department of Fish and Game). 2017. 2017-2019 King and Tanner Crab Commercial Fishing Regulations.

Bevaart, K., and K. Phillips. 2021. Annual management report for shellfish fisheries in the Kodiak, Chignik, and South Peninsula Districts, 2020. Alaska Department of Fish and Game, Fishery Management Report No. 21-29, Anchorage.

Daly, B., M. Heller-Shipley, M. Stichert, W. Stockhausen, A. E. Punt, and S. Goodman. 2020. Recommended harvest strategy for Bering Sea Tanner crab. Alaska Department of Fish and Game, Fishery Manuscript Series No. 20-03, Anchorage.

Donaldson, W. E., R. T. Cooney, and J. R. Hilsinger. 1981. Growth, age and size at maturity of Tanner crab, *Chionoecetes bairdi* M. J. Rathbun, in the northern Gulf of Alaska (Decapoda, Brachyura). Crustaceana 40(3): 286-302.

Heller-Shipley, M. A., W. T. Stockhausen, B. J. Daly, A. E. Punt, and S. E. Goodman. 2021. Should harvest control rules for male-only fisheries include reproductive buffers? A Bering Sea Tanner crab (*Chionoecetes bairdi)* case study. Fisheries Research 243(2021): 106049.

Knutson, M. R. 2020. Reproductive potential of eastern Bering Sea Tanner crab. Master's thesis, College of Fisheries and Ocean Sciences, University of Alaska, Fairbanks.

Knutson, M. *In prep.* Evaluation of mature size of Tanner crab *(Chionoecetes bairdi)* from the Kodiak District large-mesh trawl survey, 1996–2019. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

NPFMC. 2013. North Pacific Fishery Management Council's five-year research priorities: 2013 through 2017 (as adopted in June 2013). Anchorage, AK.

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

Sainte-Marie, B., T. Gosselin, J. M. Sevigny, and N. Urbani. 2008. The snow crab mating system: Opportunity for natural and unnatural selection in a changing environment. Bulletin of Marine Science, 83(1):131-161.

Spalinger, K., and M. Knutson. 2021. Large-mesh bottom trawl survey of crab and groundfish: Kodiak, Chignik, South Peninsula, and Eastern Aleutian Management Districts, 2020. Alaska Department of Fish and Game, Fishery Management Report No. 21-05, Anchorage.

Spalinger, K., and M. Knutson. *In prep*. Historical abundances of Tanner crab *Chionoecetes bairdi* for Kodiak, Chignik, South Peninsula, and Eastern Aleutian Districts from standardized large-mesh trawl surveys, 1988–2020. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report, Kodiak.

Tamone, S. L., M. M. Adams, and J. M. Dutton. 2005. Effect of eyestalk-ablation on circulating ecdysteroids in hemolymph of snow crabs, *Chionoecetes opilio*: physiological evidence for a terminal molt. Integrative and Comparative Biology 45(1): 166-171.

Tamone, S. L., S. J. Taggart, A. G. Andrews, J. Mondragon, and J. K. Nielsen. 2007. The relationship between circulating ecdysteroids and chela allometry in male Tanner crabs: Evidence for a terminal molt in the genus *Chionoecetes*. Journal of Crustacean Biology 27(4): 635-642.

Urban, D., and I. Vining. 1999. Reconstruction of historic abundances of Kodiak, Chignik, and South Peninsula Tanner crab, report to the Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K99-17, Kodiak.

Urban, D., D. Pengilly, D. Jackson, and I. Vining. 1999. A Tanner crab harvest strategy for Kodiak, Chignik, and the South Peninsula Districts, report to the Board of Fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 4K99-21, Kodiak.

REFERENCES CITED (CONTINUED)

Webb, J. B., L. M. Slater, G. L. Eckert, and G. H. Kruse. 2016. The contribution of fecundity and embryo quality to reproductive potential of eastern Bering Sea snow crab (*Chionoecetes opilio)*. Canadian Journal of Fisheries and Aquatic Sciences 73:1800-1814.

Webb, J. B., and J. Bednarski. 2009. Variability in reproductive potential among exploited stocks of Tanner crab (*chionoecetes bairdi*) in southeastern Alaska. Pages 295-317 [*In*] G.H. Kruse, G.L. Eckert, R.J. Foy, R.N. Lipcius, B. Sainte-Marie, D.L. Stram, and D. Woodby, editors. Biology and Management of Exploited Crab Populations under Climate Change. Alaska Sea Grant, University of Alaska Fairbanks.

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.

Zheng, J. and G. H. Kruse. 2000. Recruitment patterns of Alaskan crabs and relationships to decadal shifts in climate and physical oceanography. ICES Journal of Marine Science, 57: 438-451.

Zheng, J., L. Slater, J. Webb, and G. Bishop. 2011. The current status of biological knowledge relating to the management of fisheries for Tanner (*Chionoecetes Bairdi* (Rathbun, 1924)) and snow crabs (*Chionoecetes Opilio* (Fabricius, 1788)) in Alaskan waters. Pages 127-138 [*In*] A. Asakura, editor. New frontiers in crustacean biology: proceedings of the TCS Summer Meeting, Tokyo, 20-24 September 2009. Brill, Leiden, The Netherlands.

TABLES

Table 1.–Long-term (1988–2021) average of mature male Tanner crab abundance, updated threshold levels to open the fishery, and the percent of years from 2001 to 2022 when a fishery would have opened under the updated harvest strategies compared to actual fishery openings.

					Threshold		Fishery opening %	
District	Section	Long-term average	Abundance trend	Threshold level	Updated (2022)	Existing (1999)	Actual fisheries	Updated strategy
Kodiak								
	Northeast	1,367,699	decreasing	100%	1,368,000	1,123,000	50%	32%
	Eastside	5,166,563	increasing	50%	2,583,000	1,552,000	77%	64%
	Southeast	1,687,419	increasing	50%	844,000	733,000	45%	27%
	Southwest	1,108,774	increasing	50%	554,000	1,236,000	27%	32%
	Westside	504,878	stable	100%	505,000	764,000	0%	18%
	North Mainland	650,932	decreasing	100%	651,000	1,469,000	0%	0%
Chignik		1,787,130	increasing	50%	894,000	973,000	23%	23%
South Peninsula								
	Eastern	1,670,642	increasing	50%	835,000	2,015,000	32%	18%
	Western	2,479,676	increasing	50%	1,240,000	1,250,000	45%	32%

Table 2.–Total amount of Tanner crab harvest (pounds) that could have been allowed under the existing (1999) and updated (2022) harvest strategies compared to the actual harvest from 2001 to 2022, and the average exploitation rate of those fisheries on the estimated abundance of legal male crab.

		Maximum guideline harvest levels (totals 2001–2022)			Average legal male exploitation rate (years eligible to open only)		
District	Section	1999 Harvest strategy	2022 Updated harvest strategy	Actual fishery harvest (2001–2022[a])	1999 Harvest strategy	2022 Updated harvest strategy	Actual fishery exploitation rate (2001–2022)
Kodiak							
	Northeast	3,761,549	2,004,414	2,118,628	29%	18%	15%
	Eastside	17,402,901	7,696,180	8,648,501	21%	12%	12%
	Southeast	4,079,241	1,825,393	1,697,456	25%	14%	14%
	Southwest	2,305,779	1,709,399	1,384,566	17%	13%	11%
	Westside	0	511,804	0	0%	18%	0%
	North Mainland	0	0	0	0%	0%	0%
Chignik		5,597,226	3,028,885	2,098,479	28%	17%	14%
South Peninsula							
	Eastern	5,376,465	3,666,149	2,496,643	20%	17%	11%
	Western	10,464,989	7,588,091	5,191,956	26%	18%	14%

[a] 2022 harvest was estimated based on 2022 guideline harvest levels.

Table 3.–Total and average annual Tanner crab harvest (pounds) that could have been allowed under the updated (2022) harvest strategy compared to the actual harvest from 2001 to 2022, and the number of fishery openings, by district.

		Actual fishery harvest (2001–2022[a])	2022 Updated harvest strategy	Percent difference
Kodiak District				
	Total harvest	13,849,151	13,747,190	-1%
	Avg annual	814,656	859,199	5%
	Num. fishery openings	17	16	-6%
Chignik District				
	Total harvest	2,098,479	3,227,490	54%
	Avg annual	419,696	645,498	54%
	Num. fishery openings	5	5	0%
South Peninsula District				
	Total harvest	7,688,599	11,254,240	46%
	Avg annual	768,860	1,607,749	109%
	Num. fishery openings	11	7	-36%

[a] 2022 harvest was estimated based on 2022 guideline harvest levels.

FIGURES

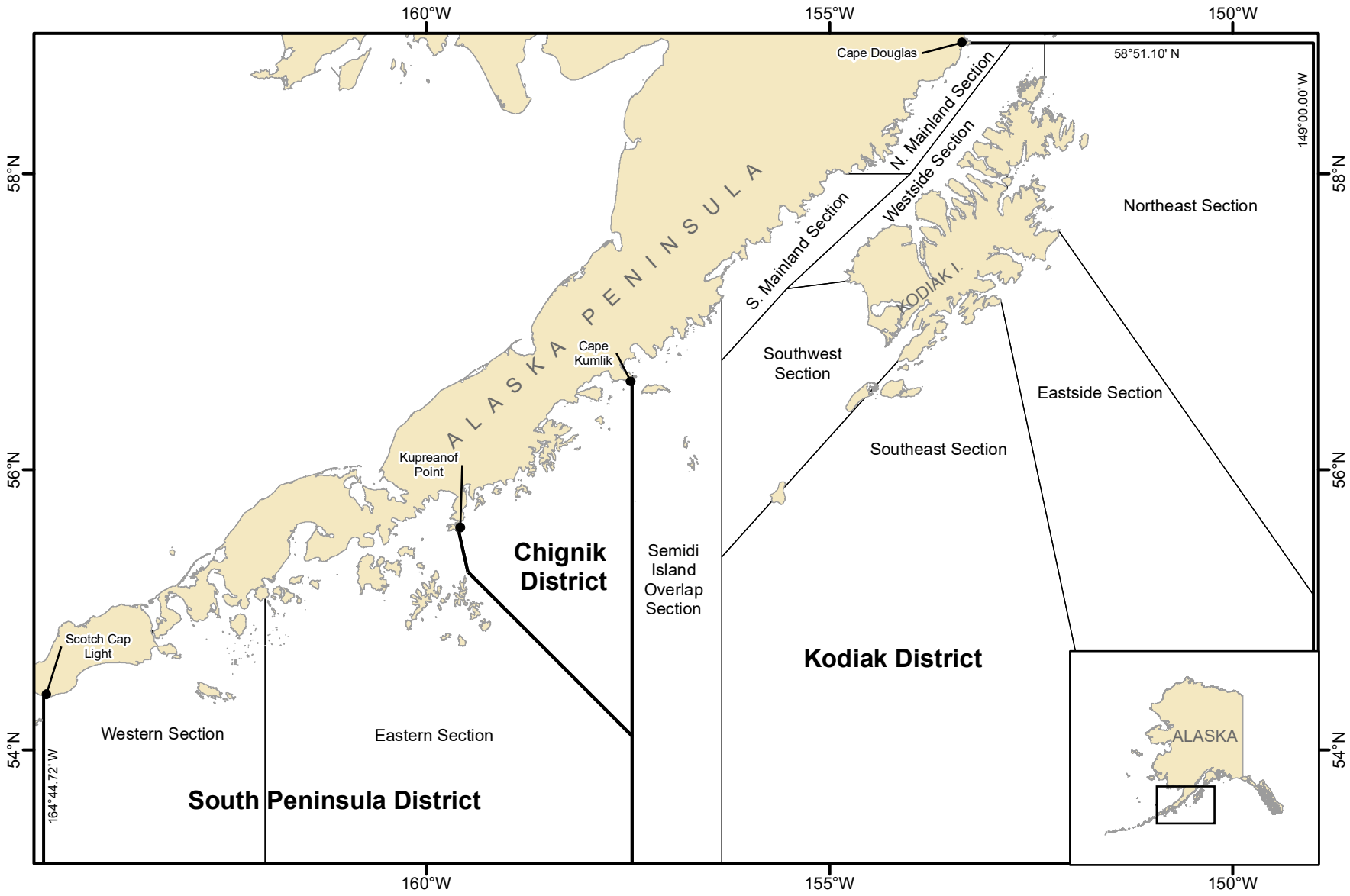


Figure 1.–Kodiak, Chignik, and South Peninsula Tanner crab management districts and sections.

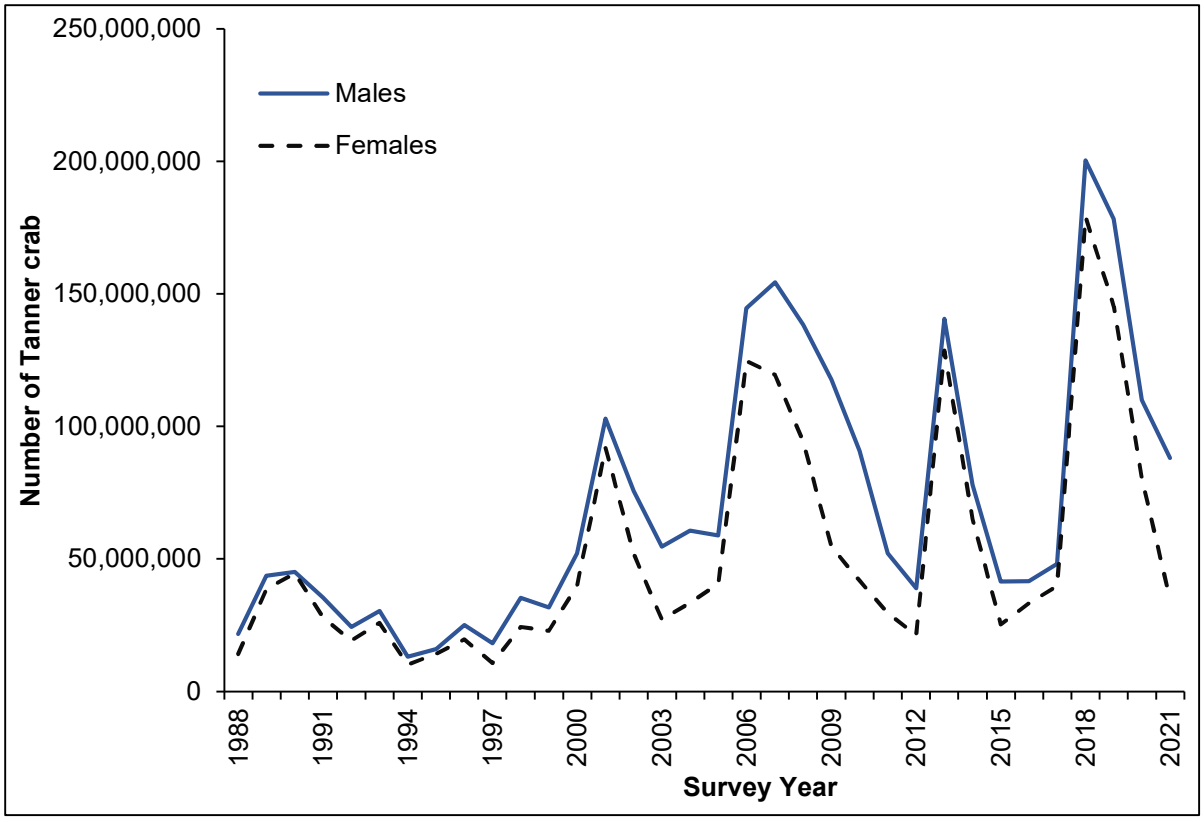


Figure 2.–Total Tanner crab abundance estimated from trawl surveys in the Kodiak, Chignik, and South Peninsula Districts, 1988–2021. Highly episodic recruitment became evident in 2000, the year after the existing harvest strategy was implemented.

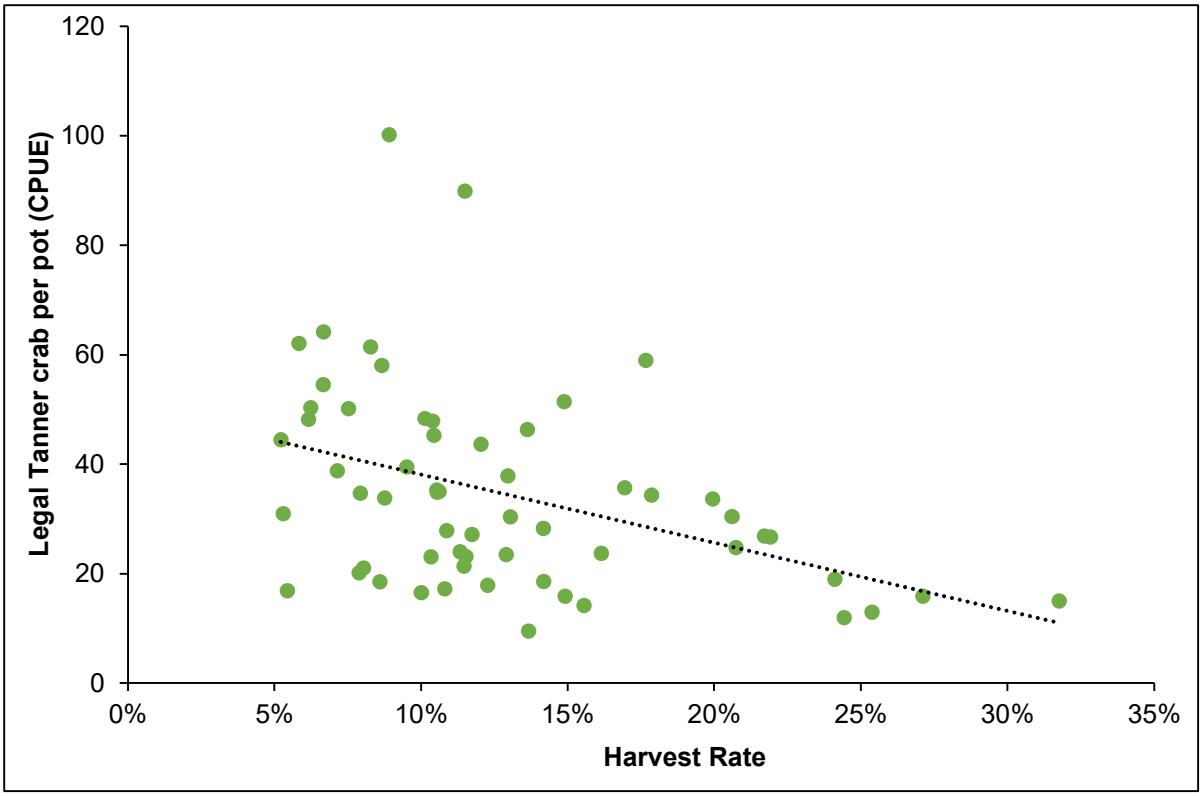


Figure 3.–Harvest rate of legal Tanner crab compared to fishery CPUE in all open management areas, 2001–2021, and the linear trendline.

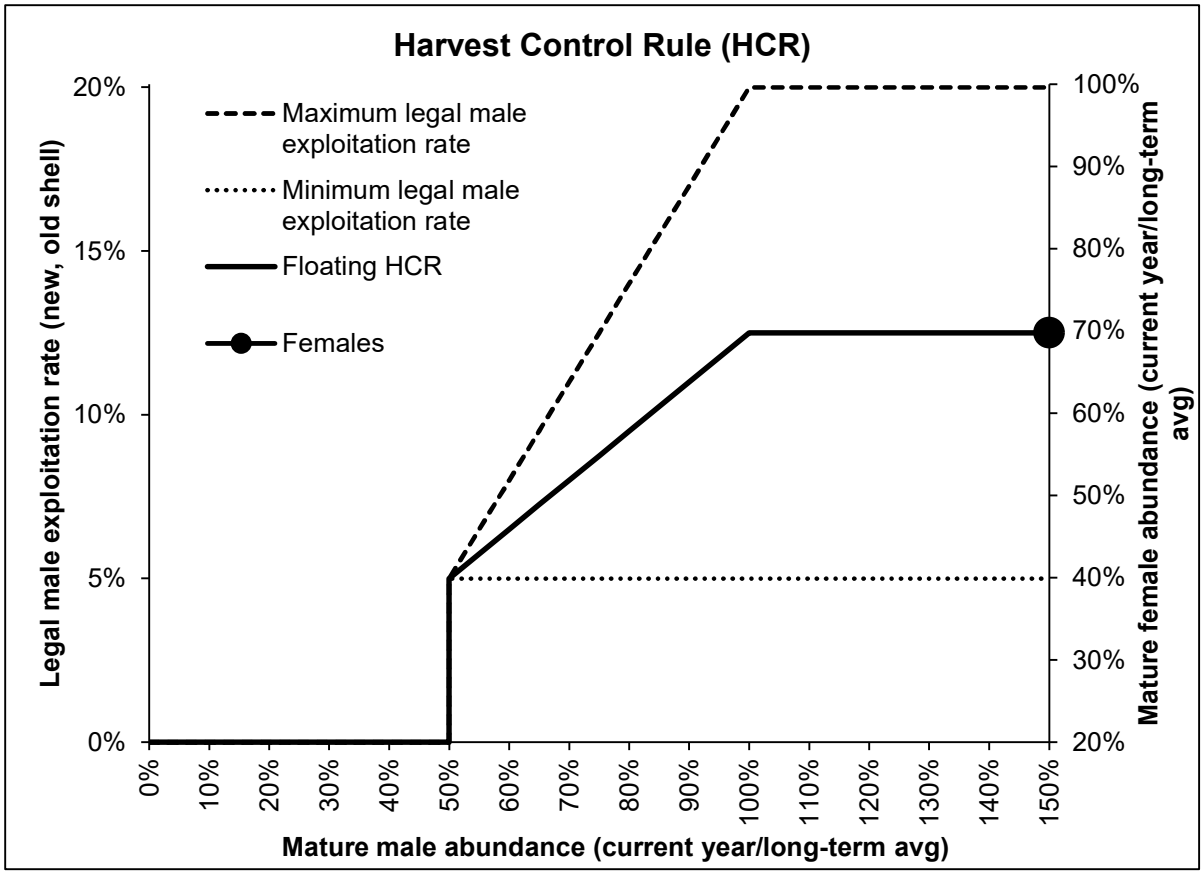


Figure 4.–Proposed exploitation rates on new and old shell legal males based on mature male and female abundance ratios (i.e., current year relative to the long-term average from 1988 to 2021).

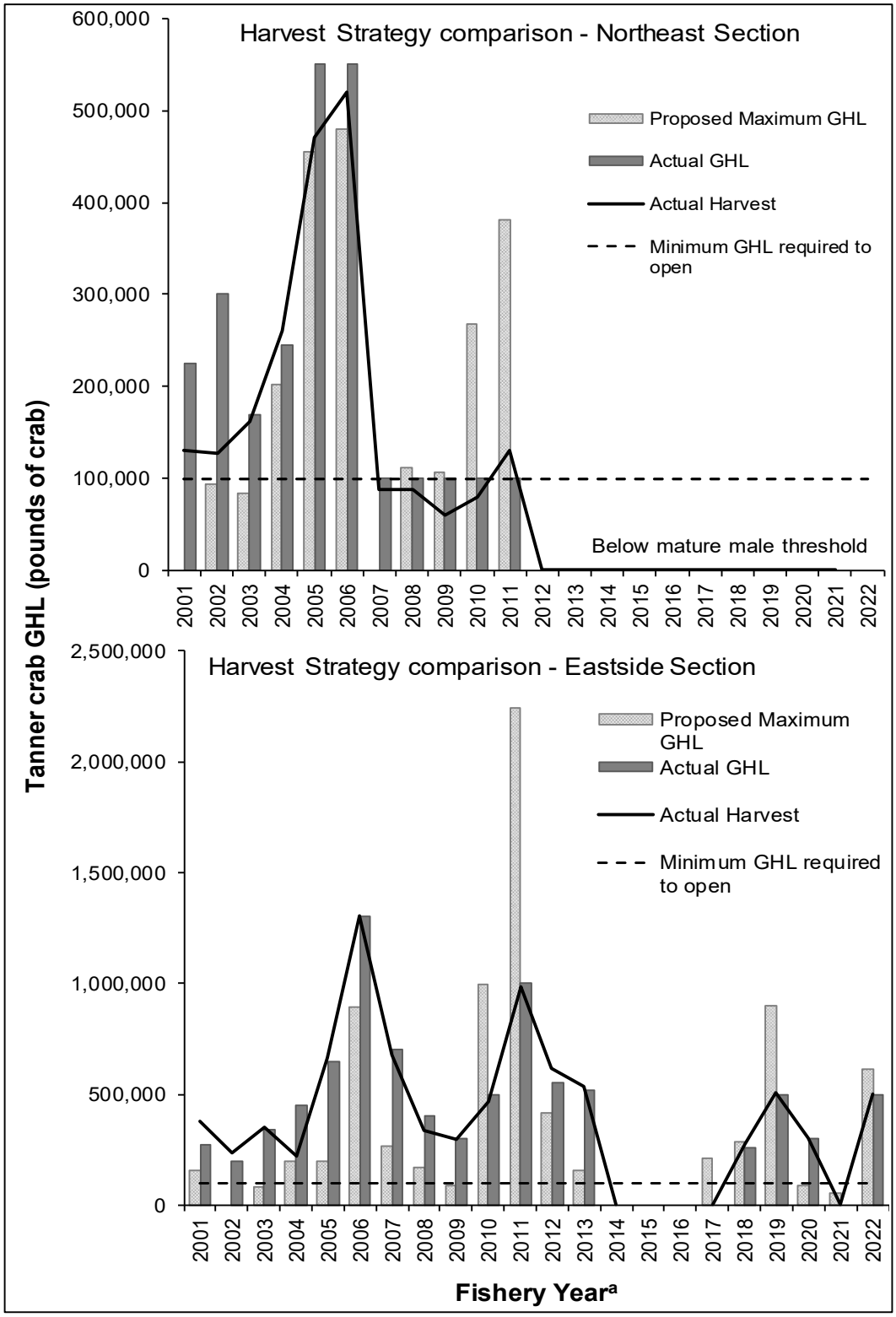


Figure 5.–Maximum GHLs based on the updated harvest strategy compared to actual GHLs and historical harvests for the Northeast and Eastside sections of the Kodiak District.

[a] 2022 harvest was estimated based on 2022 guideline harvest levels

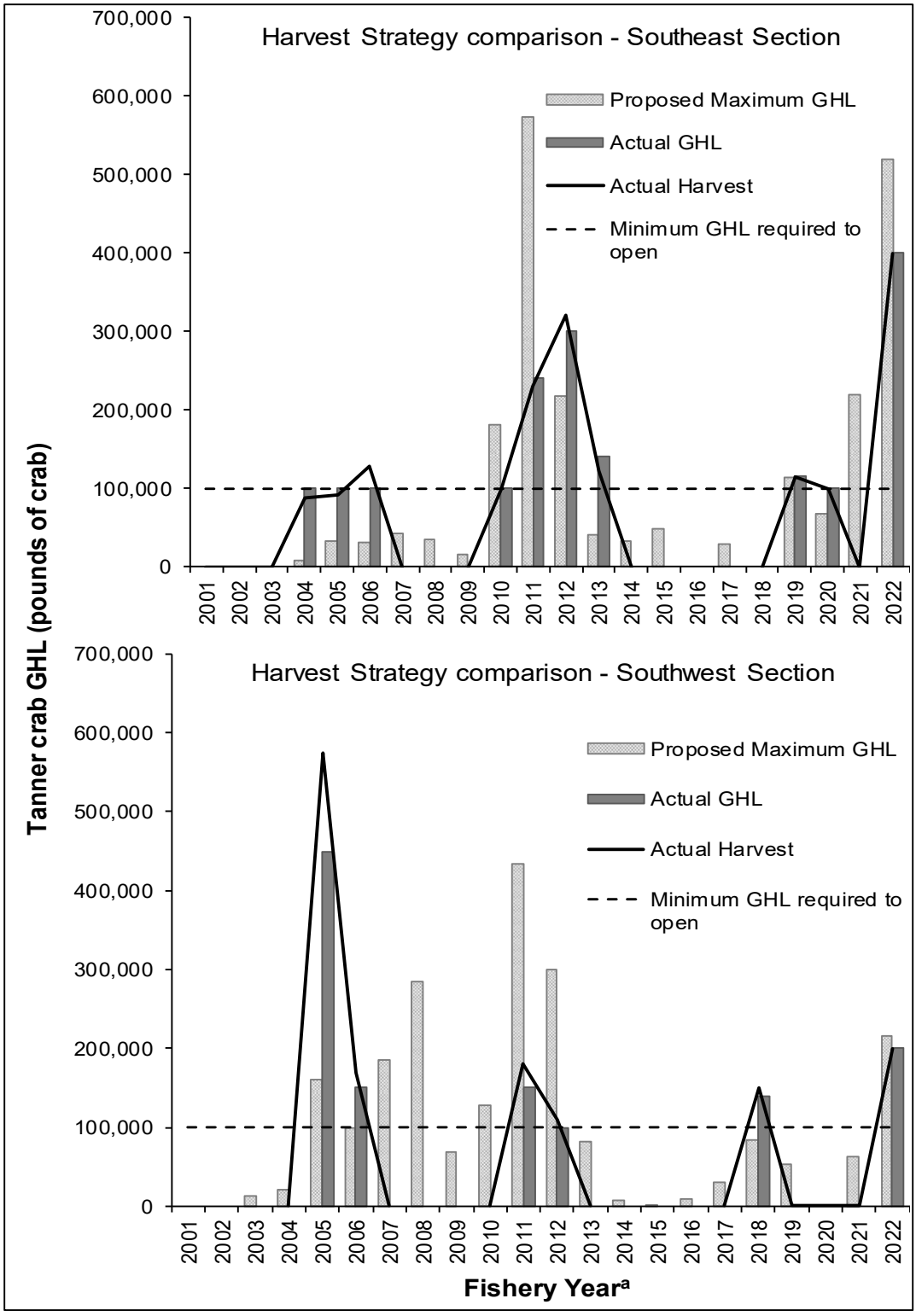


Figure 6.–Maximum GHLs based on the updated harvest strategy compared to actual GHLs and historical harvests for the Southeast and Southwest sections of the Kodiak District.

[a] 2022 harvest was estimated based on 2022 guideline harvest levels

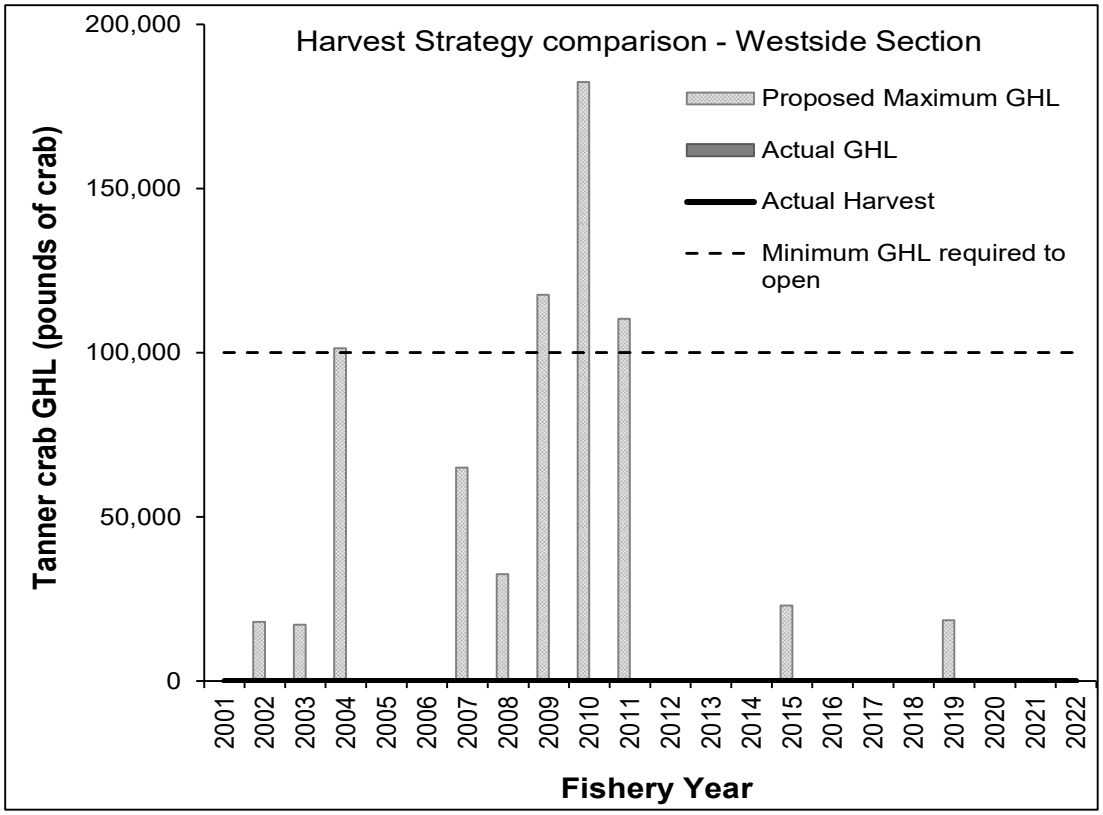


Figure 7.–Maximum GHLs based on the updated harvest strategy compared to actual GHLs and historical harvests for the Westside Section of the Kodiak District.

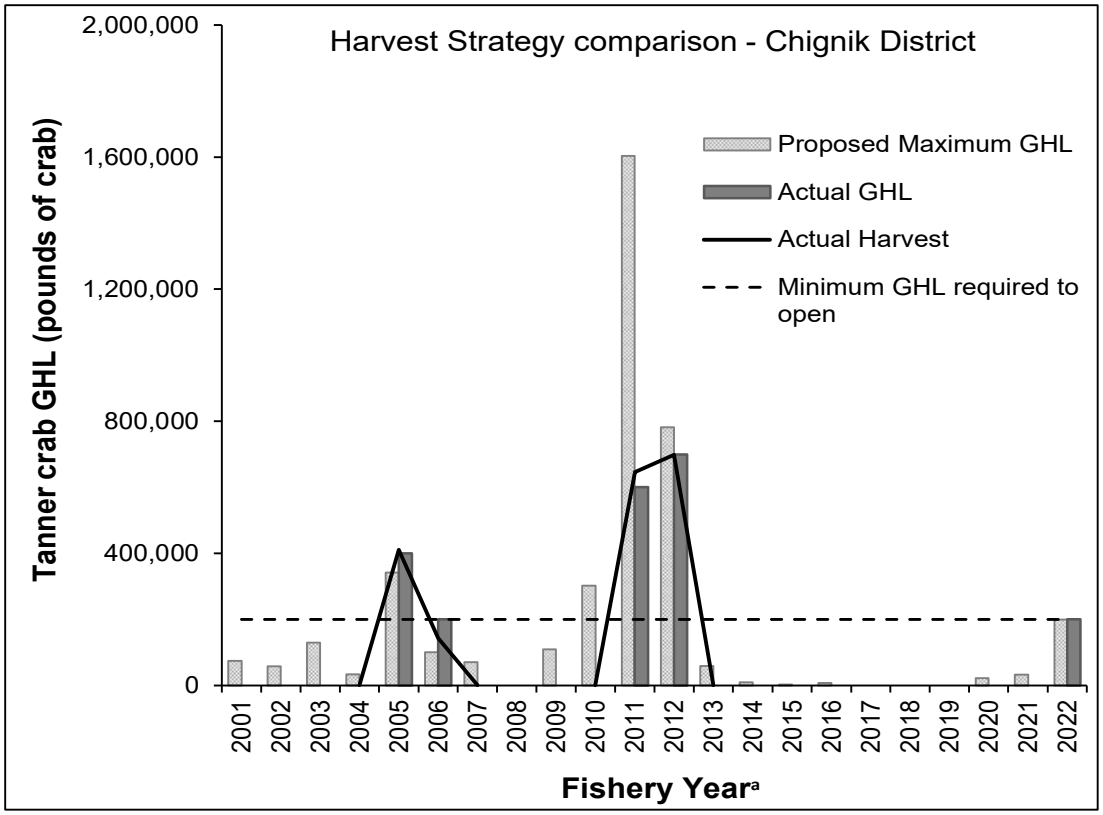


Figure 8.–Maximum GHLs based on the updated harvest strategy compared to actual GHLs and historical harvests for the Chignik District.

[a] 2022 harvest was estimated based on 2022 guideline harvest levels

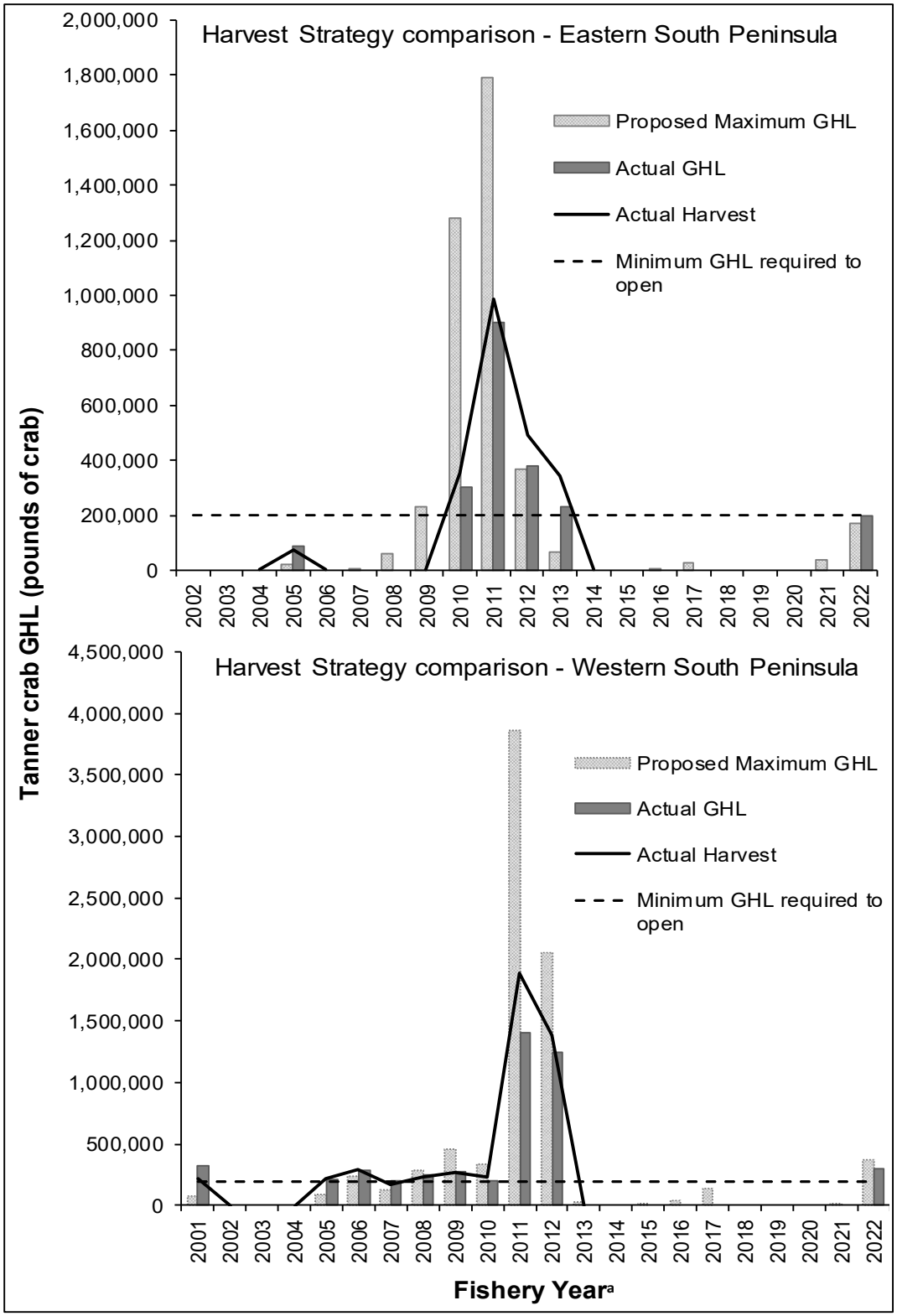


Figure 9.–Maximum GHLs based on the updated harvest strategy compared to actual GHLs and historical harvests for the Eastern and Western sections of the South Peninsula District.

[a] 2022 harvest was estimated based on 2022 guideline harvest levels

APPENDIX A. ALASKA BOARD OF FISHERIES POLICIES TO PROTECT STOCKS AND PROVIDE FOR OPTIMUM UTILIZATION

Appendix A1.–Policies set by Alaska Board of Fisheries to protect stocks and provide for optimum utilization of Tanner and king crab resources (ADF&G 1990; ADF&G 2017).

To achieve the management goal and provide the benefits available from these resources, it is necessary to set policies which will protect stocks and provide for optimum utilization of these resources. It is the policy of the Alaska Board of Fisheries to:

l) Maintain crab stocks comprised of various size and age classes of mature animals in order to maintain the long-term reproductive viability of the stock and reduce industrial dependency on annual recruitment, which is extremely variable. Benefits of this policy are most apparent when weak recruitment occurs. As population abundance and structure change with declining recruitment, harvests should be reduced.

2) Routinely monitor crab resources to provide information on abundance of females as well as prerecruit, recruit, and postrecruit males. This is necessary to detect changes in the population which may require adjustments in management to prevent irreversible damage to the reproductive potential of each stock and to better achieve the benefits listed above. Harvests must be conducted in a conservative manner in the absence of adequate information on stocks.

3) Protect king and Tanner crab stocks during biologically sensitive periods of their life cycle. Closure of the fishing season is necessary at times surrounding the annual mating, molting, and egg hatching periods in order to reduce unnecessary mortality of soft animals, disturbance during mating, and damage to egg clutches.

4) Minimize handling and unnecessary mortality of non-legal crabs and other non-target animals. Capture and handling of females, sublegal males, and animals of other species results in a loss of reproductive ability and biomass that may be detrimental to a stock.

5) Maintain an adequate brood stock to rebuild king or Tanner crab populations when they are depressed. Maintenance of an adequate brood stock takes precedence over short term economic considerations. When populations are at or below threshold, the minimum stock size that allows sufficient recruitment so that the stock can rebuild itself, fisheries must be closed and must remain closed until there is adequate brood stock.

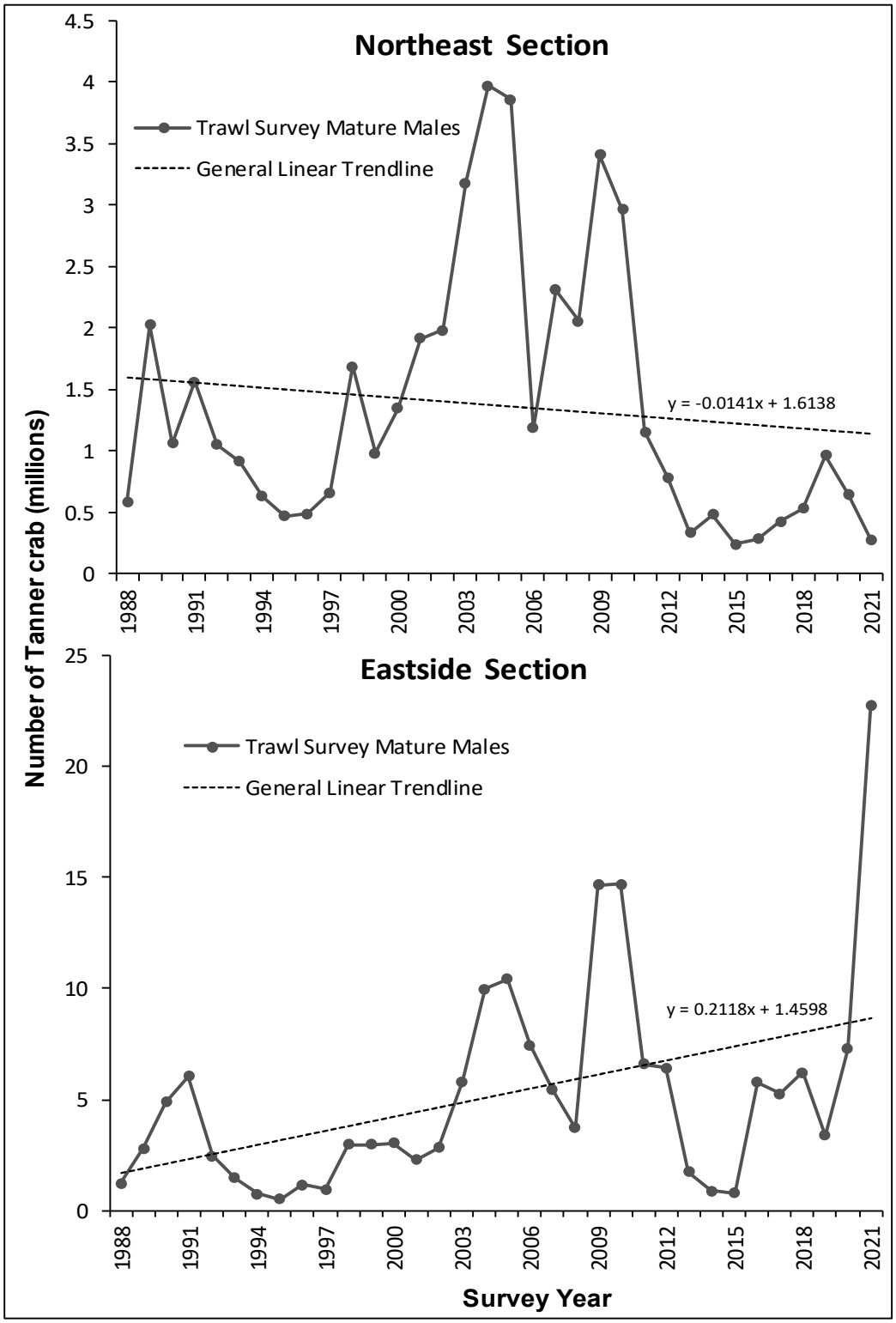
6) Establish management measures in each fishing area based on the best available information. Stock and fishery characteristics, as well as available data, vary from area to area within Alaska. Actual management practices in each area will vary accordingly.

7) Establish regulations which will help improve the socio-economic aspects of management by: harvesting crab when their meat yield is highest; providing for fair starts and closures to seasons; insuring enforceability of regulations; and other measures providing for an orderly fishery.

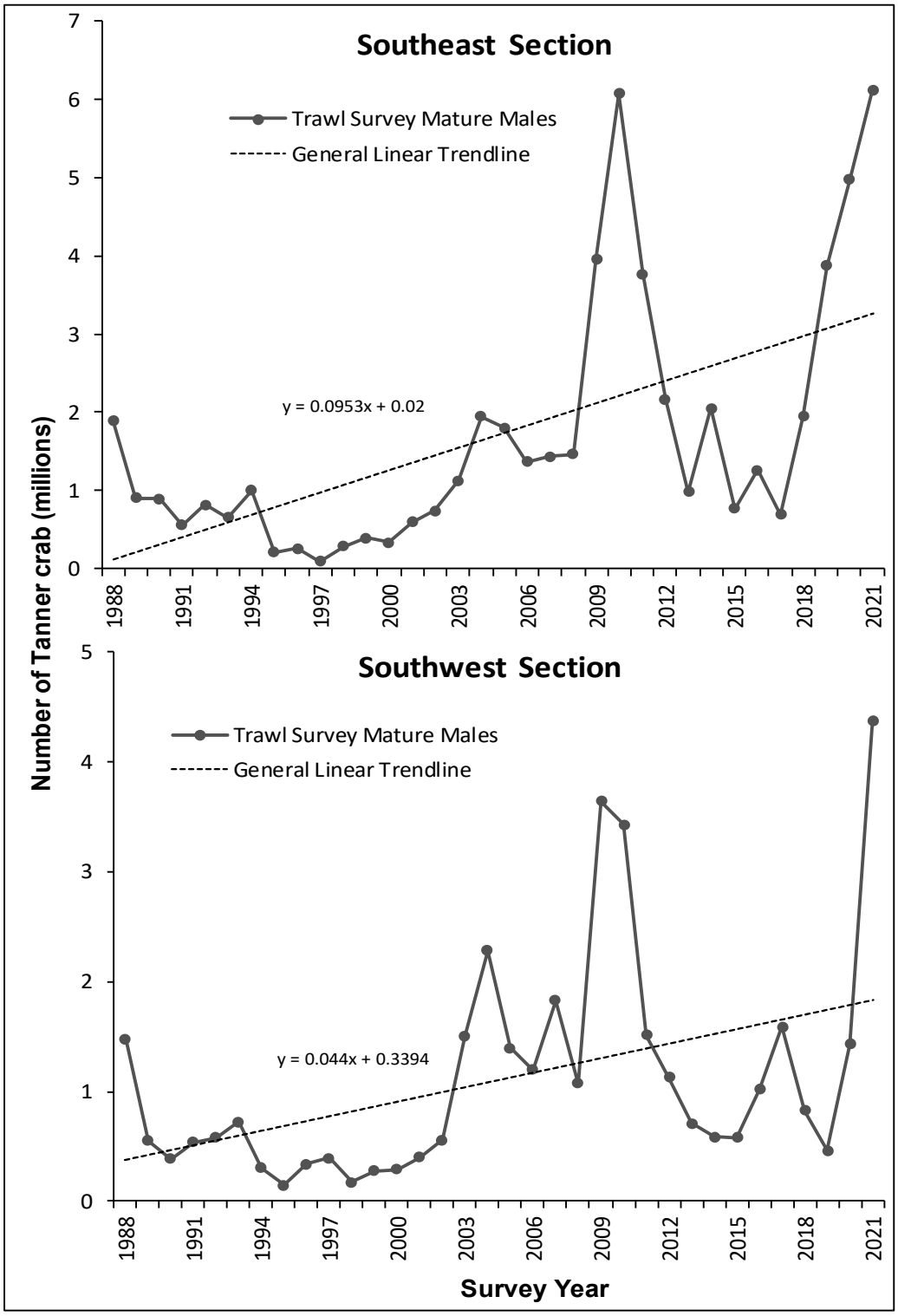
The Board recognizes these policies may not result in maximization of physical or economic yield. They will, however, provide better biological protection and help preserve the reproductive viability of king and Tanner crab stocks which inherently vary in abundance due to environmental conditions. It will also increase the stability and longevity of the king and Tanner crab fisheries beyond that provided by a recruits-only fishery.

APPENDIX B. ANNUAL MATURE MALE TANNER CRAB ABUNDANCE ESTIMATES FROM THE LARGE-MESH TRAWL SURVEY

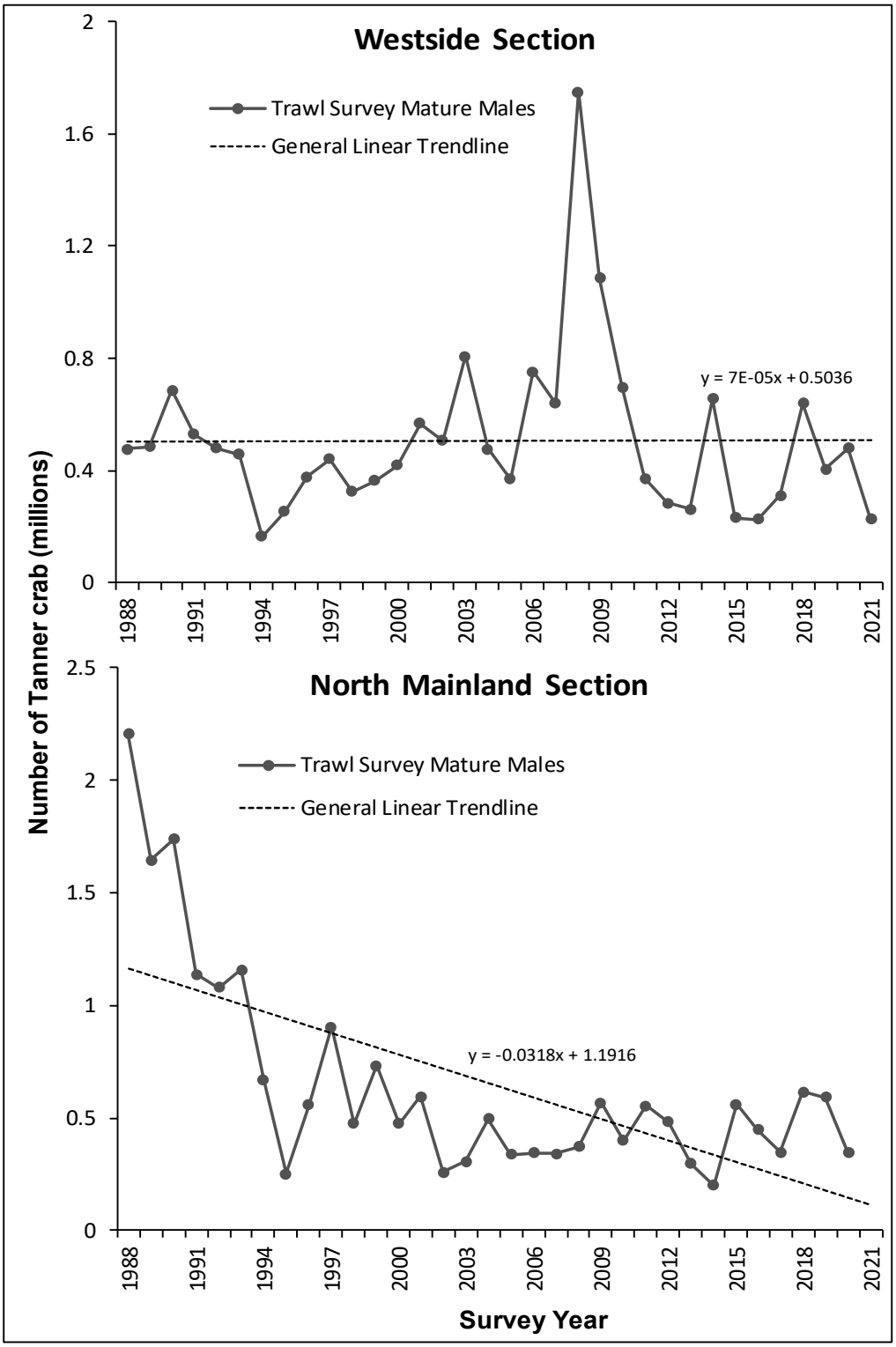
Appendix B1.–Annual Tanner crab abundance indices from the large-mesh trawl survey for the Northeast and Eastside Sections of the Kodiak District, 1988–2021.



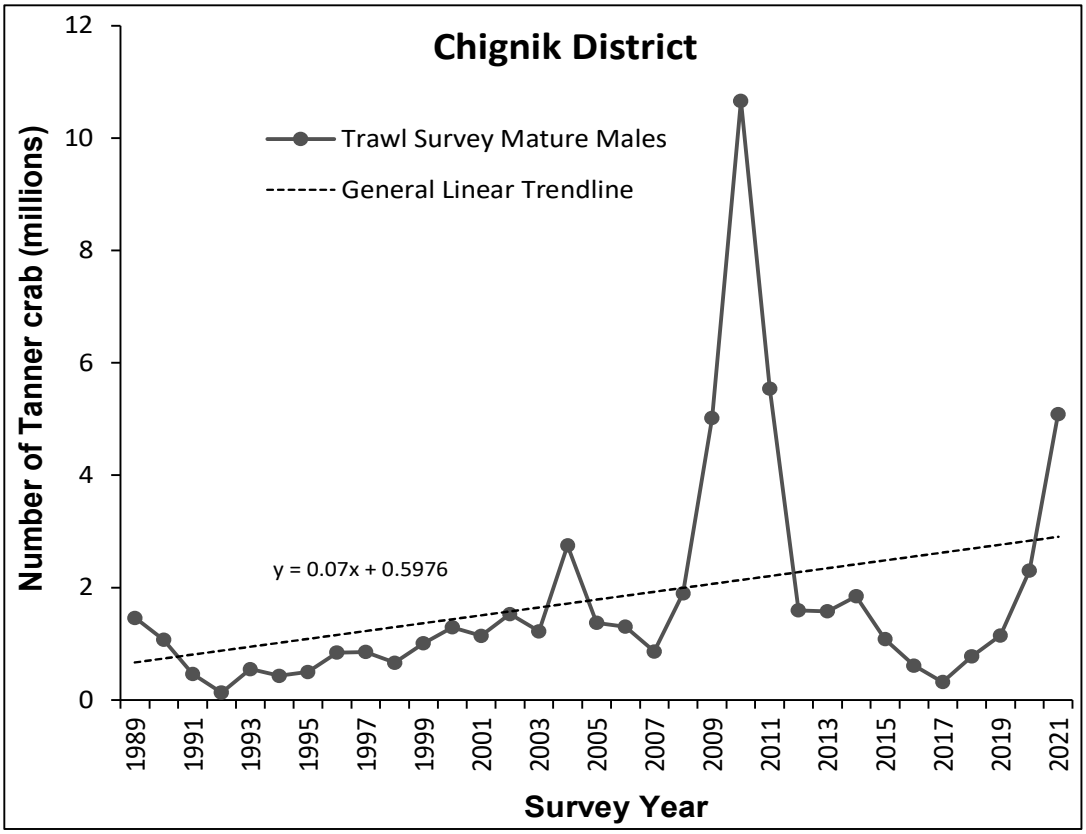
Appendix B2.–Annual Tanner crab abundance indices from the large-mesh trawl survey for the Southeast and Southwest Sections of the Kodiak District, 1988–2021.



Appendix B3.–Annual Tanner crab abundance indices from the large-mesh trawl survey for the Westside and North Mainland Sections of the Kodiak District, 1988–2021.



Appendix B4.–Annual Tanner crab abundance indices from the large-mesh trawl survey for the Chignik District, 1989–2021.



Appendix B5.–Annual Tanner crab abundance index from the large-mesh trawl survey for the Eastern and Western Sections of the South Peninsula District, 1988–2021.