Fishery Management Report No. 05-03

Reconstruction of Historic Abundances of Tanner Crabs in the Proposed Eastern and Western Sections of the South Peninsula District, Report to the Alaska Board of Fisheries

by

Dan Urban

and

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February 2005

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

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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)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

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

FISHERY MANAGEMENT REPORT NO. 05-03

RECONSTRUCTION OF HISTORIC ABUNDANCES OF TANNER CRABS IN THE PROPOSED EASTERN AND WESTERN SECTIONS OF THE SOUTH PENINSULA DISTRICT, REPORT TO THE ALASKA BOARD OF FISHERIES

by

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The Division of Sport Fish Fishery Management Reports series was established in 1989 for the publication of an overview of Division of Sport Fish management activities and goals in a specific geographic area. Since 2004, the Division of Commercial Fisheries has also used the Fishery Management Report series. Fishery Management Reports are intended for fishery and other technical professionals, as well as lay persons. Fishery Management Reports are available through the Alaska State Library and on the Internet: http://www.sf.adfg.state.ak.us/statewide/divreports/html/intersearch.cfm. This publication has undergone regional peer review.

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ABSTRACT

Tanner crab *Chionoecetes bairdi* in the South Peninsula District are managed under a harvest strategy passed by the Alaska Board of Fisheries in 1999. In that strategy, the threshold for opening the fishery and the exploitation rates are based on the long-term average abundance of mature male crabs. Analysis in 1999 reconstructed the district-wide historic population levels needed to determine that average abundance based on data from 1974-1999.

Due to differences in crab abundance and density across the district, the Alaska Department of Fish and Game proposes that it be split into two sections, with the division at 162˚ West Longitude. Pavlof Bay, the Shumagin Islands, and Stepovak Bay would be located in the proposed Eastern Section, while Belkofski Bay, Cold Bay, Morzhovoi Bay, and the Sanak Island areas would be in the Western Section.

This report presents a recalculation of the average mature male Tanner crab populations for each of the proposed sections. Commercial fishery statistics and historic stock surveys were used to reconstruct population levels of both sub-legal mature and legal-sized male Tanner crabs. A variety of established methods were used: the Leslie depletion method, trawl survey area-swept estimates, and an expansion of harvest numbers based on estimated harvest rates. While the two proposed sections showed the same broad population trends, the Eastern Section has historically produced more mature male Tanner crabs. The average population of mature male Tanner crabs from 1974-2004 in the proposed Eastern Section is estimated to be 4.03 million crabs, while the Western Section estimate is 2.50 million crabs. The combined average mature male population estimate of 6.53 million crabs is a substantial increase from the estimated average of 2.75 million crabs made in 1999.

Key words: Tanner crab harvest strategy, *Chionoecetes bairdi*, South Alaska Peninsula

INTRODUCTION

In 1999 the Alaska Board of Fisheries revised the harvest strategy for Tanner crab *Chionoecetes bairdi* fisheries in the Kodiak, Chignik, and South Peninsula Management Districts (Urban et al. 1999, 5 AAC 35.507). After being closed for nearly 10 years, Tanner crab stocks were rebuilding across these management districts and the department needed objective population criteria both for reopening the fisheries and for setting guideline harvest levels. A variable exploitation rate and minimum threshold for reopening the fishery were established based on the long-term average population of mature male crabs. When the mature population of male Tanner crabs is at one-half its long-term average, the fishery would be allowed to open at a 10% exploitation rate. When the population reached the long-term average, the exploitation rate would increase to 20%. Reconstructing the population levels of Tanner crabs was an integral part of the adoption of the new harvest strategy (Urban and Vining 1999). Several other precautionary and biological measures were also adopted with the harvest strategy.

While this strategy has generally worked well in the Kodiak District, results in the South Peninsula District have been unsatisfactory. This district is large and Tanner crab abundance is not uniformly distributed across the district. Concentrations of crabs in a small number of bays or marginally commercial quantities spread across large areas may put the abundance calculation over the threshold needed to open the entire District, while some portions of the district may not be capable of sustaining a harvest. For these reasons, the department proposes to split the district into two sections at 162^{o} West Longitude (Figure 1). This would allow the opportunity for a fishery in one portion of the district where the stocks are capable of sustaining a harvest while protecting other portions of the district where the stocks are weak and/or rebuilding. Each section would have a mature male threshold for opening and a population level at which the exploitation rate is increased. A simple apportionment of the existing average population number between the two sections was not considered appropriate because the proposed sections have distinctly

different harvest histories and amount of habitat. In addition, five additional years of survey data are now available since the long-term average abundance of mature male Tanner crabs was originally calculated in 1999. This report details the methods and results of recalculating the historic mature male Tanner crab populations in the proposed Eastern and Western Sections.

Most natural populations fluctuate between high and low levels with a tendency to return to an average value (May 1973, Dennis and Taper 1994). Ideally, a long time series of accurate surveys would provide an estimate of the normal range of fluctuations which a crab population might experience, as well as demonstrate the long-term average population level. Unfortunately, in most areas, including the South Peninsula District, reasonably accurate surveys do not cover an adequately long time period to reflect the full range of population levels. Pot surveys began in 1974, but the early pot surveys were designed to survey red king crabs *Paralithodes camtchaticus*, rather than Tanner crabs and major areas of Tanner crab harvest were outside the pot survey area. It is also difficult to generate an absolute population number from a pot survey because it is never known with certainty how large an area the pot catch represents. Partially for this reason, the Alaska Department of Fish and Game (ADF&G) began to use bottom trawl nets as a survey gear in the South Peninsula District in 1988 (Blackburn et al. 1989). Trawl surveys continue on a regular basis and have become the standard method for estimating Tanner crab populations in the South Peninsula District. The trawl survey time series, however, is still too short to capture the period of high Tanner crab abundance, which is known to have occurred in the 1970s and the early 1980s.

Catch statistics are another important source of information which can also be analyzed to provide a more complete picture of the magnitude of the population fluctuations. The commercial harvest began in 1967 (Brown 1971), quickly grew to a peak in 1978/79 of over 8 million pounds, and then declined until the fishery was closed in 1989. It remained closed until the January 2001 season when there was a 250,000-pound harvest. Another harvest is scheduled for January 2005. Harvest records before 1974 are difficult to divide into the proposed Eastern and Western Sections, but from 1974 onward the data can be reliably assigned to the proposed sections. In most years, more catch came from the eastern portion of the district.

Given the mix of catch statistics and trawl survey information, a number of different techniques were used to reconstruct the population of the mature male Tanner crabs in the proposed Eastern and Western Sections. The trawl survey area-swept method is the preferred method of assessing the Tanner crab populations, but in the absence of a trawl survey, catch statistics were utilized. The Leslie depletion method was judged the most reliable method of analyzing the catch numbers, but when a statistically significant result could not be obtained, the catch expansion technique was applied.

METHODS

AREA-SWEPT

Bottom trawl nets have long been used to determine crab and fish densities (Alverson and Pereyra 1969, Reeves 1979, Colgate and Hicks 1983). Area-swept estimates expand the density of the crabs caught in the area swept by the net to the larger area of interest. Because of the speed of sampling, the ability to generate reasonably accurate density estimates, and the ability to capture smaller size crabs, trawl nets have largely replaced pots as the preferred sampling gear for crabs.

If the dimensions of the area swept by the net across the sea bottom is known, the density of the crabs in the area swept can be determined. That density can then be expanded to the entire area of a particular trawl station or area of crab habitat. The width of the area swept is a characteristic of the trawl net configuration, whereas the length of the area swept can be determined by the vessel captain using a global positioning system (GPS). It is assumed that all crabs encountered by the net are captured. The area-swept estimates of abundance were generated from the ADF&G trawl survey database from procedures described in Alverson and Pereyra (1969).

LESLIE DEPLETION

The Leslie depletion estimator's only information requirement is commercial catch information. First used to estimate the population of rats in a closed environment, (Leslie and Davis 1939), the Leslie estimator has since been applied to American lobster *Homarus americanus* (Ennis et al. 1986), blue crab *Callinectes sapidus* (Fischler 1965), Dungeness crab *Cancer magister* (Methot and Botsford 1982), snow crab *Chionoecetes opilio* (CAFSAC 1984-1988), and red king crab *Paralithodes camtchaticus* (Otto 1986).

Leslie population estimates are based on the principle that catch rates are proportional to the population size (Leslie and Davis 1939). As the catch accumulates, catch rates should begin to fall. If the catch rate were allowed to fall to zero and every animal were caught, the accumulative catch would represent the starting population. Even before catch rates decline to zero, a total cumulative total catch can be projected using a linear relationship between catch per unit of effort and cumulative catch. Despite it's limitations, the Leslie method is a valuable tool which can be applied using common fishery statistics when reliable survey estimates are not available.

The Leslie depletion estimator is based on several assumptions (Miller and Mohn 1993, Ricker 1975, Seber 1982, Hilborn and Walters 1992). We specifically addressed the assumption that no recruitment due to molting occurs during the fishery by limiting the period of the fishing season considered from October 1 to March 31. The molting period starts in April or May and continues through the summer (Donaldson et. al 1981). In addition, Tanner crabs feed little or not at all when molting (O'Halloran and O'Dor 1988) and so typically do not enter baited pots. This factor would lower the catch rate, which in turn would falsely lower the population estimate. The Leslie depletion technique estimates the number of legal crabs at the beginning of a season. The number of mature male crabs (>114 mm carapace width) was calculated from the legal/mature crab ratio measured by the ADF&G pot surveys. The legal size in regulation is 140 mm carapace width.

Catch, date of catch, and number of potlifts were accessed from the ADF&G fish ticket database. Catch per unit effort (CPUE) was calculated by summing the total catch for a week by the total number of potlifts for the same week. A weekly tally of CPUE was used due to uncertainty in the "date of catch" data recorded on the fish tickets. Cumulative catch was also summarized weekly. Weekly data was weighted in the analyses by the number of potlifts in a week divided by the total number of potlifts for a season.

CATCH EXPANSION

Catch numbers represent a minimal estimate of the number of crabs present at the start of a fishery. These catch numbers can then be expanded to a legal population number using an estimate of the harvest rate (Rugolo et al. 1998). The catch expansion method was applied only in those years without trawl survey data and statistically non-significant Leslie estimates. When the catch expansion technique was used, the harvest of legal crabs as determined from the

ADF&G fishticket system was expand by a harvest rate from the most recent years in which the rate could be calculated. Harvest rate calculations were made using legal abundance as estimated by the Leslie depletion method and the number of crab harvested. It was assumed that for years when a harvest rate could not be calculated, the harvest rate had changed in a linear manner between the adjacent years for which an estimate of the harvest rate was available. The mature population was calculated using a mature/legal ratio determined by the pot surveys from the same year and area.

RESULTS

AREA-SWEPT

The area-swept estimates generated from the data collected on the trawl surveys were calculated for both the Eastern and Western Sections from 1988 to 2004, with the exception of 1995 when no survey was conducted (Tables 1 and 2). For both sections, the area swept estimates of mature male crabs increased after a period of low abundance during the 1990s. Estimates from the 2004 survey were the highest of the 1988-2004 area-swept time series

LESLIE DEPLETION

The Leslie depletion technique could only be calculated for 7 years for the proposed Eastern Section and for 5 years for the Western Section (Tables 1 and 2), with estimates generally being possible for the early to mid-1980s. The Leslie depletion estimates were only used when the linear regression between CPUE and cumulative catch was statistically significant at $P < 0.1$.

CATCH EXPANSION

The catch expansion technique was required for 7 years for the Eastern section and 9 years for the Western section (Tables 1 and 2), generally for the early years of the fishery in the 1970s. During the 1980s a mixture of the catch expansion and Leslie depletion technique was used. The two techniques meshed well with the Leslie depletion estimates intermediate to those provided by the catch expansion method. The catch expansion technique resulted in the highest mature male population estimates, 15.71 million crabs in the Western Section in 1974 and 20.01 million crabs 1976 in the Eastern Section.

LONG-TERM AVERAGE ABUNDANCE BY SECTION

Both the proposed Eastern and Western Sections showed the same broad trends in population abundance with high levels estimated in the late 1970s followed by a decline to low abundance levels during the decade of the 1990s. Both areas have seen a modest rebuilding of crab populations during early years of this decade (Figure 2). Historically the Eastern Section has been more productive with a long-term average mature male abundance of 4.03 million crabs, compared with the Western Section average of 2.50 million crabs. The combined average for the District of 6.53 million mature male Tanner crabs is a substantial increase from the average of 2.75 million crabs estimated in 1999. Changes in the calculations of the harvest rate and resultant catch expansion estimates as well as recent increases in Tanner crab population both contributed to the increased estimate of average mature male abundance.

DISCUSSION

The historic Tanner crab population abundances reconstructed for the proposed Eastern and Western Sections follow broad trends seen across the Central and Western Gulf of Alaska. Population levels have declined from their highs of the late 1970's with both sections showing another increase in populations around 1981-1983. Overall, these reconstructions present a picture of a resource fluctuating naturally, perhaps dramatically, in response to occasional large recruitment events.

Reconstructing historic population levels from catch statistics must be viewed with caution. Changing behavior by fishermen, as well more powerful and efficient equipment can all work to confound the analysis (Hilborn and Walters 1992). Catch expansion in particular is recognized as only a first attempt at population reconstruction in extremely data-poor situations. The estimations of historic population levels presented here should be viewed as a work in progress and refinement of these estimates may be possible with further analysis.

The recalculated mature male Tanner crab opening thresholds would be incorporated into the existing harvest strategy. The revised thresholds would require higher population levels before the fishery could open, but since the department has developed thresholds for each of the proposed sections, a single section could open independently of the other section. This could potentially allow a harvest in a portion of the district while under the existing strategy the entire district may have remained closed. Under the existing regulations, the entire district could have opened in 2001, 2004, and 2005, but with the sections and revised threshold numbers the Western Section only would have opened in two years, 2001 and 2004 (Table 3). The proposed sections and recalculated long-term average mature abundance estimates take into consideration the distinct abundances and productivity of the district's Tanner crab stocks and therefore provides better protection against over-exploitation.

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TABLES & FIGURES

Table 1.-Population estimates (millions of crabs) using trawl survey area-swept, Leslie depletion, and catch expansion for the proposed Eastern Section of the South Peninsula District, 1974-2004.

	Male Population		
Year	Mature	Legal	Technique Used
1974	7.51	2.94	Catch expansion
1975	7.88	3.08	Catch expansion
1976	20.01	7.83	Catch expansion
1977	17.65	6.90	Catch expansion
1978	12.52	5.52	Leslie depletion
1979	11.35	5.00	Catch expansion
1980	14.04	5.51	Leslie depletion
1981	3.18	1.32	Catch expansion
1982	4.75	1.67	Leslie Depletion
1983	3.56	1.16	Catch expansion
1984	2.19	0.75	Leslie Depletion
1985	1.19	0.52	Leslie Depletion
1986	2.59	1.08	Leslie Depletion
1987	2.45	1.09	Leslie Depletion
1988	0.82	0.25	Trawl survey area-swept
1989	0.96	0.23	Trawl survey area-swept
1990	0.96	0.26	Trawl survey area-swept
1991	0.67	0.15	Trawl survey area-swept
1992	0.37	0.09	Trawl survey area-swept
1993	0.44	0.08	Trawl survey area-swept
1994	0.39	0.10	Trawl survey area-swept
1995			No survey
1996	0.17	0.04	Trawl survey area-swept
1997	0.17	0.04	Trawl survey area-swept
1998	0.56	0.06	Trawl survey area-swept
1999	0.42	0.11	Trawl survey area-swept
2000	0.56	0.13	Trawl survey area-swept
2001	0.38	0.08	Trawl survey area-swept
2002	0.78	0.11	Trawl survey area-swept
2003	1.02	0.20	Trawl survey area-swept
2004	1.35	0.54	Trawl survey area-swept
AVERAGE	4.03		

Table 2.-Population estimates (millions of crabs) using trawl survey area-swept, Leslie depletion, and catch expansion for the proposed Western Section of the South Peninsula District, 1974-2004.

	Male Population		Technique used
Year	Mature	Legal	
1974	15.71	5.83	Catch expansion
1975	6.56	2.43	Catch expansion
1976	1.87	0.69	Catch expansion
1977	2.37	0.88	Catch expansion
1978	6.78	2.51	Catch expansion
1979	8.71	3.70	Leslie depletion
1980	5.36	1.65	Catch expansion
1981	1.31	0.56	Catch expansion
1982	2.53	0.94	Leslie depletion
1983	1.89	0.57	Catch expansion
1984	1.11	0.43	Leslie depletion
1985	1.17	0.47	Leslie depletion
1986	1.69	0.61	Leslie depletion
1987	0.45	0.18	Catch expansion
1988	0.75	0.20	Trawl survey area-swept
1989	0.30	0.05	Trawl survey area-swept
1990	0.92	0.22	Trawl survey area-swept
1991	0.95	0.23	Trawl survey area-swept
1992	0.62	0.14	Trawl survey area-swept
1993	0.88	0.18	Trawl survey area-swept
1994	0.50	0.09	Trawl survey area-swept
1995			No survey
1996	0.25	0.06	Trawl survey area-swept
1997	0.25	0.06	Trawl survey area-swept
1998	0.96	0.19	Trawl survey area-swept
1999	1.47	0.21	Trawl survey area-swept
2000	2.58	0.76	Trawl survey area-swept
2001	1.35	0.42	Trawl survey area-swept
2002	1.40	0.38	Trawl survey area-swept
2003	0.99	0.18	Trawl survey area-swept
2004	3.27	0.87	Trawl survey area-swept
AVERAGE	2.50		

Table 3.-Population estimates (millions of Tanner crabs) and determination whether fisheries would have been allowed under the existing strategy and with the proposed revised threshold levels and section designations, 1999-2004. The minimum harvest requirement of 200,000 pounds can sometimes prevent a fishery although the mature male threshold has been achieved.

Mature Male Population				Opening Criteria Met?		
Survey				(recalculated thresholds)		(existing threshold)
Year	Eastern	Western	District Total	Eastern (4.03)	Western (2.50)	District Total (1.375)
1999	0.42	1.47	1.89	No	No	No
2000	0.56	2.58	3.14	No	Yes	Yes
2001	0.38	1.35	1.73	No	No	No
2002	0.78	1.40	2.18	No	No	No
2003	1.02	0.99	2.01	No	No	Yes
2004	1.35	3.27	4.62	No	Yes	Yes

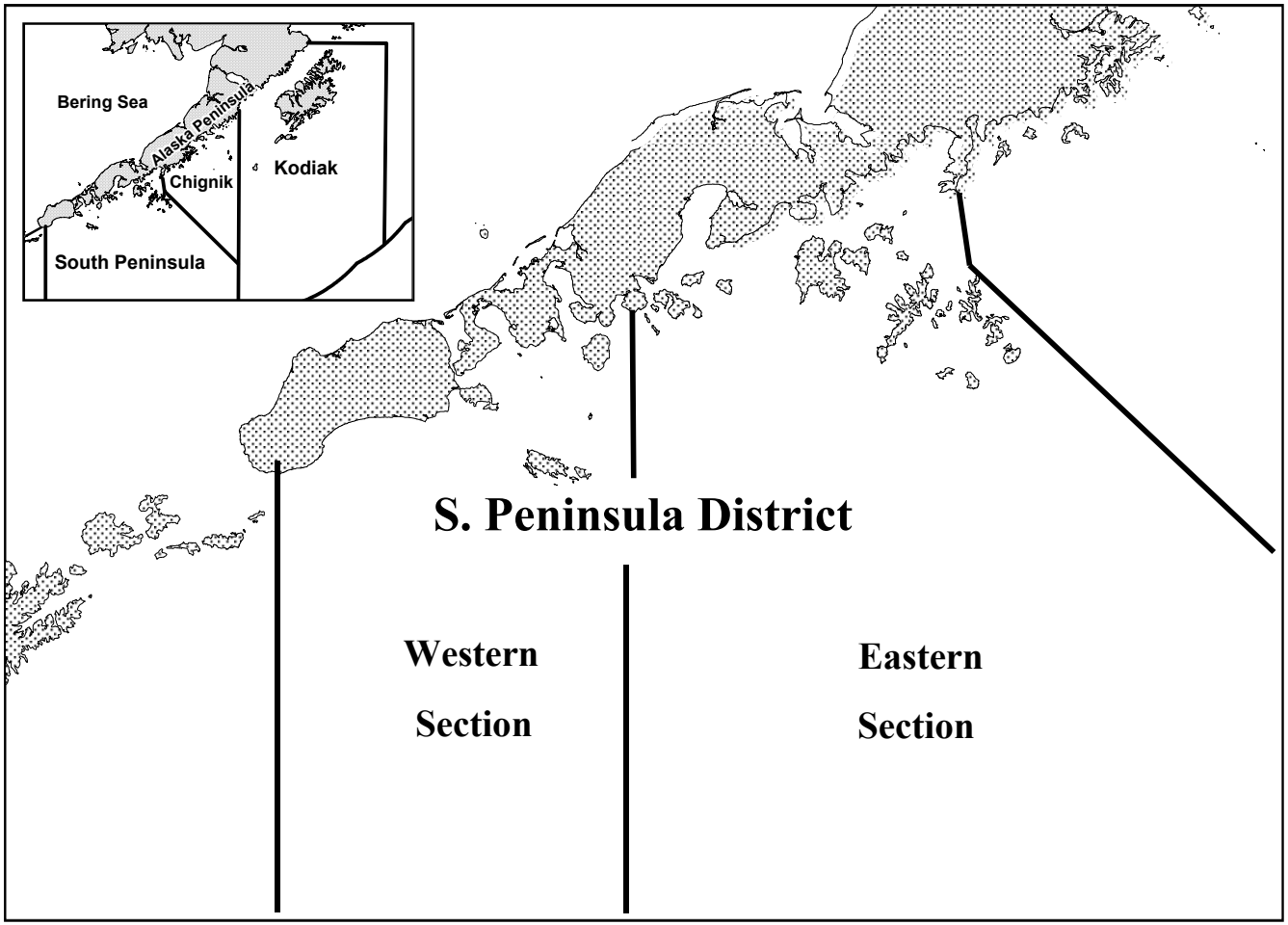

Figure 1.-Proposed sections for the South Peninsula Tanner crab District. The section boundary would be 162° West Longitude.

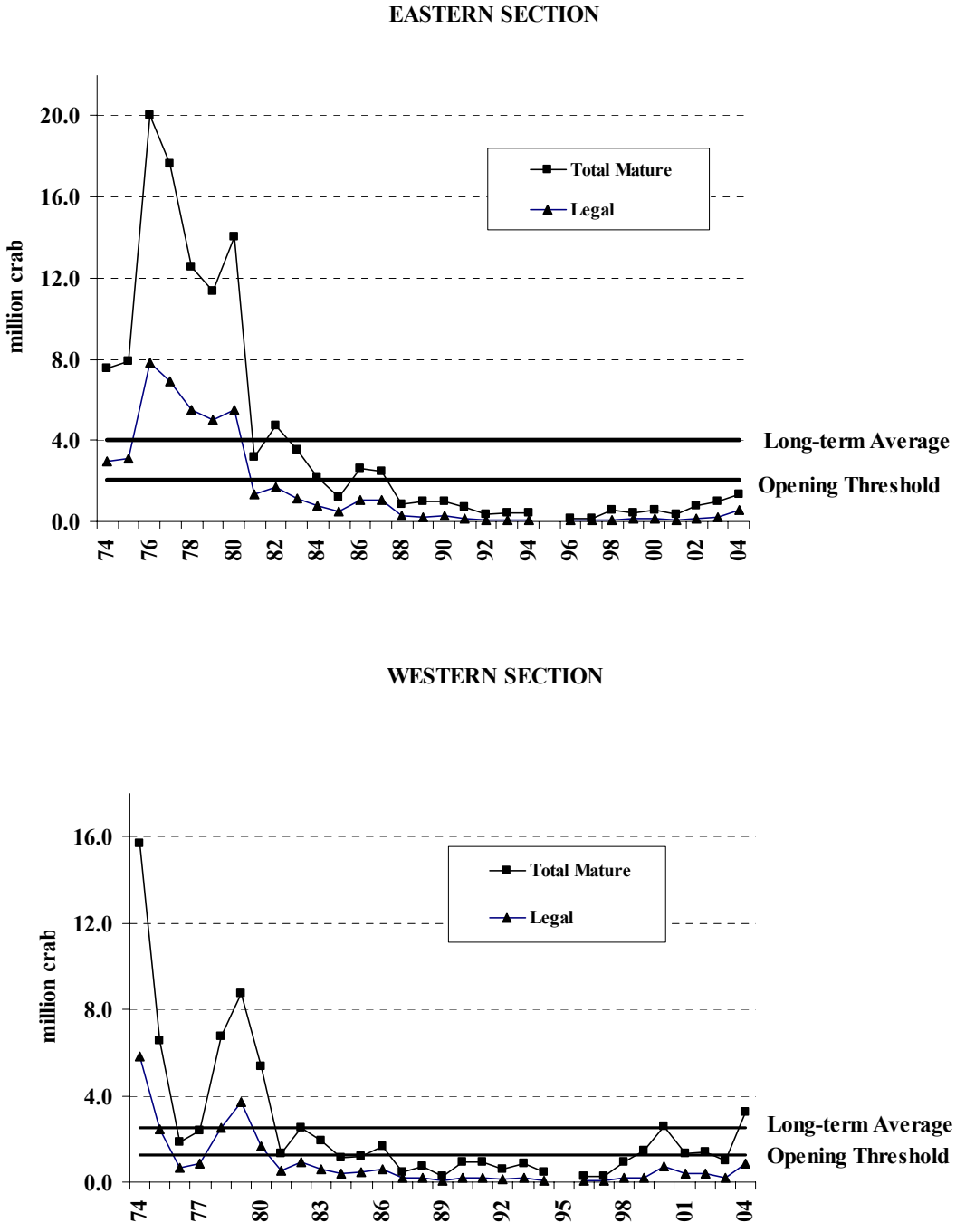

Figure 2.-Mature male and legal Tanner crab abundance estimates for the proposed Eastern and Western Sections of the South Peninsula District, 1974-2004. Opening threshold and the long-term average levels are shown for mature male abundance levels.