

RECONSTRUCTION OF HISTORIC ABUNDANCES OF KODIAK, CHIGNIK, AND SOUTH
PENINSULA TANNER CRAB,
REPORT TO THE ALASKA BOARD OF FISHERIES

By

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EXECUTIVE SUMMARY

This report presents the reconstruction of historic population levels of Tanner crab *Chionoecetes bairdi* in the Kodiak, Chignik, and South Peninsula Management Districts. This reconstruction was necessary to gain insight into the long-term productivity of these stocks which fluctuated since the commercial harvests began in the late 1960's and entered a period of decline since the high levels of the early 1980's. Commercial harvests have been closed for five or more years but some stocks have shown signs of recovery. In anticipation of an eventual recovery, an understanding of stock productivity is necessary to establish thresholds at which these fisheries can safely be reopened. Stock productivity also offers insight into sustainable fishing rates once fisheries are reopened.

Commercial fishery statistics and historic stock surveys were used to reconstruct population levels of both mature and legal male Tanner crabs. As outlined in the following report, a variety of established methods were used: the Leslie depletion estimator, catch survey analysis, area-swept estimates, and an expansion of harvest numbers based on harvest rates. While the various areas showed the same broad trends, considerable variation exists in the patterns of overall decline and in pulses of recruitment to the populations.

INTRODUCTION

This report presents the estimation methods used to reconstruct historic population levels of Tanner crab *Chionoecetes bairdi* in the Kodiak, Chignik, and South Peninsula Management Districts. In Kodiak, each of the eight sections described in regulation were considered separately since they each have been managed independently in the past: Northeast, Eastside, Southeast, Southwest, Westside, North Mainland, South Mainland, and Semidi Island Sections (Figure 1). This exercise was undertaken as a first step in developing management plans based on long-term productivity of these crab stocks.

Three main sources of information available were available and used in the estimation: commercial harvest statistics, pot surveys, and trawl surveys. None of these information sources cover the entire period from the start of the commercial harvest to the present and in addition, each of the districts and sections considered has its own particular history of harvest and surveys (Table 1).

The commercial harvest began in the late 1960's (Brown 1971). Pot surveys began in a number of areas in 1971, but were not examined for Tanner crab until 1973. The areas targeted by the early pot surveys were chosen to assess red king crab, rather than Tanner crab. Major areas of Tanner crab harvest lay outside the pot survey areas, especially in the North Mainland, Westside and Chignik areas. The Alaska Department of Fish and Game (ADF&G) began to use bottom trawl nets as a survey gear in the early 1980's (Colgate and Hicks 1983) and gradually phased out the pot surveys in all areas by 1988. By this time Tanner crab populations were in decline and only a few areas have a long overlap period of commercial harvests and trawl surveys.

Trawl surveys continue on a regular basis, even though fishing seasons have remained closed across the region for 5 years or more. They have become the standard method for estimating Tanner crab populations and would likely be the technique used to set guideline harvest levels (GHLs) in the future. The South Mainland and Semidi Island sections have had a limited commercial harvest but have no survey history. The starting year for the population reconstructions was 1973 for the sections of the Kodiak district and 1974 for the Chignik and South Peninsula districts. By these years, pot surveys had started across the region, and also the fisheries had become more fully developed with the commercial grounds being located and definite breaks occurring in the fishing seasons. Given this time period and the wide mix of information, a number of established methods were used to estimate historic Tanner crab populations.

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 Botsfor 1982), snow crab *Chionoecetes opilio* (CAFSAC 1984-1988), and red king crab *Paralithodes camtchaticus* (Otto 1986).

A number of assumptions must be met for the method to work accurately. Despite its limitations, however, the Leslie method is a valuable tool which can be applied using common fishery statistics.

Area-Swept Trawl Survey

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

Catch Survey Analysis (CSA)

This population model uses survey and commercial harvest information to provide a time series of population estimates for mature and legal crabs. Originally developed for groundfish stocks (Collie and Sissenwine 1983), this type of model has been applied to Atlantic scallops *Placopecten magellanicus* (Conser 1991), American lobster (Conser and Idoine 1992), and to king crab stocks in Alaska (Collie and Kruse 1998, Woodby 1994). This will be the first time it has been applied to Tanner crabs.

METHODS

Leslie Depletion

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, an accumulative total catch can be projected using a linear relationship between catch per unit effort and cumulative catch.

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 (Al Spalinger, personal communication, Alaska Department of Fish and Game, Kodiak, AK). In addition, Tanner crab feed little or not at all when molting (O'Halloran and O'Dor 1988) and so generally 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 crab at the beginning of a season. The number of mature male crab (>115 mm CW) was calculated from the mature:legal crab ratio measured by the survey. In years where no survey was performed, the relative proportion was

estimated as the average proportion from the previous and following year. For longer periods of Leslie estimates without survey information, an average mature:legal proportion for the year was estimated from all available surveys.

Catch, date of catch and number of potlifts were accessed from the ADF&G fish ticket database. CPUE was calculated by summing the total catch for a week by the total number of potlifts for the same week. 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.

Area-Swept

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. The area-swept estimates of abundance were generated from the ADF&G trawl survey database from procedures described in Alverson and Pereyra (1969).

Catch Survey Analysis (CSA)

The catch-survey analysis calibrates relative abundance to absolute abundance and smooths the variability in the relative abundance data. An early two-stage model considered only recruit and post-recruit crabs¹ (Collie and Kruse 1998). It has been modified into a three stage model by including pre-recruit crabs (Collie and DeLong 1998). Woodby (1994) and Collie and DeLong (1998) provide a detailed discussion of model assumptions and the sensitivity of the population estimates to various input parameters.

The pot survey relative abundance indices were accessed from the ADF&G survey database and published reports. Catch per pot was standardized to a 24 hour soak time for each pot fished (Rothschild et al. 1970) and then the average catch per pot for the section or district were computed for each of the three classes of crabs considered.

The trawl survey population estimates calculated from the ADF&G trawl survey database represent a simple total of all stations fished. Because the trawl surveys covered varying numbers of stations per year, these numbers are not strictly relative and needed to be standardized before input into the CSA model. Only those stations that were missing less than three years of survey history were used to compute the area-swept indices. A weighted average value was used to fill in missing values.

Other required inputs into the CSA model include the time between the survey and the commercial harvest, pre-recruit molt probability, average weight from the survey of pre-recruit

¹ The pre-recruit class includes those crabs which are mature and one molt away from legal size (CW 115-138 mm). Recruit crabs are those that have just entered the fishery as determined by a new shell age and a size that is within one molt increment of the minimum legal size (CW 139-164 mm). Post-recruit crabs are all other legal crabs.

and legal crab, and catchability of the survey as compared to the fishery. For a complete description of the CSA algorithm see Collie and DeLong (1998).

Pre-recruit molt probability was calculated assuming 15% of oldshell crab and 90% of newshell crab would molt. These molting probabilities for either newshell or oldshell pre-recruits may change over time, but due to lack of data, we assumed them to be constant (J.Zheng, ADF&G Juneau, personal communication). The time between the survey and the commercial harvest was calculated as the time between the mid-point of the survey and the mid-point of the commercial season. Catch numbers were accessed from the ADF&G fishticket database. An allometric equation (ADF&G unpublished data, 1978) between carapace width and weight was used to obtain an average weight of pre-recruit and legal crabs captured during the surveys.

Two assumptions of the CSA program were used. In the first form, the natural mortality of recruits and post-recruits was assumed known, while an estimate for the catchability coefficient between the fishery and survey was calculated by the model, using an initial value that we provided. The other form assumed the catchability coefficient was known and the natural mortality of recruits and post-recruits was estimated by the model, again using an initial value. Two further versions of the CSA programs were developed to perform abundance estimations when survey data was not available. The program worked with as many as 5 years of survey data missing.

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 estimate using an average harvest rate (Rugolo et al. 1998). The catch expansion method was applied only in the absence of trawl survey data and statistically non-significant Leslie estimates ($p < 0.1$).

The average harvest rate was calculated from years in which reliable population estimates overlapped with a commercial harvest. The mature population was calculated from the legal population estimate using a mature:legal ratio determined by the surveys from the same year and area. However in the North Mainland Section and Chignik District, when no survey information was available, an average mature:legal ratio from the overall Kodiak District by year was used.

RESULTS

Leslie Depletion

The Leslie depletion technique could only be calculated for certain years (Tables 2-10), with estimates generally being possible for the early to mid-80's. The Leslie depletion estimates were only used when the linear regression between CPUE and cumulative catch was statistically significant at $p < 0.1$.

Most areas had at least 5 years where the Leslie depletion regression was significant. The Southeast and Westside Section had the most with 10 years of estimates, whereas the South Mainland Section had the least with only 2.

Area-Swept

The area-swept estimates generated from the data collected on the trawl surveys have been calculated for most areas since 1987 (Tables 2-7,9-10). As discussed above in the CSA results, several areas have a longer time series of estimates, while others have had no estimates.

Catch Survey Analysis (CSA)

The CSA program provided reasonable estimates when used with trawl surveys (Tables 2-7,9-10), but when applied to pot surveys, the method consistently provided the highest population estimates, especially in the period from 1980 onward. Overestimation for this latter period may be partially explained by the fact that Tanner crab tend not to enter pots which contain king crab (Dave Jackson, ADF&G Kodiak, personal communication). When king crab stocks collapsed, CPUE of Tanner crab became artificially inflated when compared to the earlier period. The CSA pot estimates were not used due to our inability to reconcile them with the other estimates using concurrent data.

The CSA program used with trawl survey data provided estimates for most areas after 1986 through the close of the respective fisheries. In general, the CSA produced results similar to the area-swept estimates. The Eastside and North Mainland Sections had trawl surveys prior to 1986, allowing for a 10 and 13 year time series respectively. There were no estimates generated from this method for the South Peninsula District because there was an insufficient time series of overlapping fisheries and trawl surveys. The South Mainland and Semidi Island Sections also had no estimates generated from the CSA technique because there were no trawl surveys performed in these areas.

Catch Expansion

The average harvest rate used to compute the catch expansion estimate of legal Tanner crab ranged from 46% for the Eastside Section to 64% for the Southeast Section and the South Peninsula District. The number of estimates generated from the catch expansion technique varied between areas. Most of the areas had 6-8 years of abundance estimates calculated in this manner, however for the Southwest Section ten estimates were necessary.

DISCUSSION

The South Mainland and Semidi Section estimates were not included in further review, because fewer than 5 abundance estimates could be calculated (Table 8). These two areas combined

represent less than 3% of the total Tanner crab harvested in the Kodiak District. An overview of the population trends for the other areas considered is provided by Figures 2-5.

Population levels have declined from their highs of the late 1970's with all areas showing another increase in populations around 1981-1983. Since 1985 considerable variation exists in the patterns of the population declines. Pulses of recruitment to the legal and mature populations occurred in all areas since the mid 1980's, but were strongest in the Eastside and Southeast Sections (Figure 2-3). Other areas saw minor recruitment events along with slowly declining or stable populations. The Northeast and Eastside Sections and the South Peninsula District (Figures 2, 5) appear to be experiencing a recent upturn in abundance. Overall, these reconstructions present a picture of a resource fluctuating naturally, perhaps dramatically, in response to occasional large recruitment events. The recruitment events seem to have some coordination across this region, pointing out possible environmental effects.

In order to evaluate the accuracy of these population reconstruction, we need an accepted gauge to judge the methods. The area-swept method represents the technique currently employed by ADF&G to estimate populations in the region and so any overlap of the trawl survey with the other methods would provide some insight into the accuracy of the other methods. The CSA method should improve the accuracy of the trawl survey estimates by incorporating information about commercial harvest, but the period of overlap with the commercial harvest is short (Table 1). The CSA technique smoothed the greater fluctuations of the area-swept estimates, however, the CSA abundance estimates tended to be less than those calculated by the area-swept method.

There were few opportunities for comparison of the Leslie depletion estimates and the trawl survey area-swept estimates. However, in the areas where comparisons are possible, such as the Southeast and North Mainland Sections (Tables 4,7) the values estimated by the Leslie depletion method correspond quite closely to the area-swept estimates or the catch. This lends validity to the use of the Leslie estimator in periods when the trawl survey was not conducted.

As outlined in the methods, the catch expansion estimates were used only in the absence estimates generated by other techniques. Comparing catch expansion estimates calculated for years with a trawl survey would be meaningless since the trawl survey estimates would be used to generate the catch expansion numbers. It is recognized that this technique represents only a first attempt at population reconstruction in extremely data poor situations.

The different methods used in these population reconstructions produced a variety of estimates, without a distinct "best estimate", for all years and areas. It was decided that an average, by year, of the estimates from the different techniques would provide the best overall abundance estimates helping to insure the Tanner crab legal and mature male populations were not over or under estimated. 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 after further analysis.

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Table 1. History of Tanner crab harvest and surveys in the Kodiak, Chignik, and South Peninsula Districts, 1967-1998. Harvest given in millions of pounds. "P" designates pot survey, t- trawl survey, X- confidential information, less than 3 vessels.

DISTRICT SECTION	KODIAK															CHIGNIK		S. PENINSULA		
	NORTHEAST		EASTSIDE		SOUTHEAST		SOUTHWEST		WESTSIDE		N. MAINLAND		S. MAINLAND		SEMIDI IS.		harvest	survey	harvest	survey
YEAR	harvest	survey	harvest	survey	harvest	survey	harvest	survey	harvest	survey	harvest	survey	harvest	survey	harvest	survey	harvest	survey	harvest	survey
1967	< 0.1		< 0.1				< 0.1		< 0.1		< 0.1		< 0.1						>0.1	
1968	0.1		0.4				0.5		0.6		0.2		< 0.1						0.1	
1969	1.1		2.9		0.2		0.1		0.6		0.4		0.4						0.6	
1970	1.5		1.7		0.7		0.6		1.0		1.9		0.1						2.0	
1971	0.9		0.6		0.4		3.5		1.3		0.8						0.2		2.1	
1972	1.3		2.1		0.5		1.7		1.7		4.0		<0.1				0.0		3.6	
1973	5.3	p	5.9	p	1.1	p	9.4	p	2.9		6.8		0.1				0.7		5.6	
1974	4.7	p	4.3	p	1.8	p	7.4	p	1.4		5.3						4.2		9.5	p
1975	3.2	p	4.5	p	1.0	p	4.1	p	0.7		3.8		X		X		3.6		5.2	p
1976	3.6	p	2.9	p	5.5	p	3.3	p	3.9		4.3						6.9		11.2	p
1977	2.8	p	3.1	p	5.9	p	1.8	p	3.6		3.5		X				5.7		6.8	p
1978	3.9		3.9		5.0	p	8.8	p	4.6		6.8		X		0.3		4.7		7.4	
1979	6.3	p	3.1	p	2.5	p	5.1	p	4.0		7.1		0.3		0.7		2.5		8.7	p
1980	4.9	p	2.2	p	1.0	p	2.6	p	1.4		4.6		0.5		1.2		3.5		4.0	p
1981	2.4	p	1.3	p	0.5	p	2.5	p	1.4		2.1	t	0.4		1.1		3.7	t	3.3	p
1982	1.2	p	1.4	p	0.5	p	5.2	p	1.8		2.2	t	0.3		1.2		3.2	t	4.6	p
1983	2.8	p	3.1	p	2.3	p	5.6	p	1.9		2.0	t	0.2		0.9		3.5	t	2.9	p
1984	1.8	p	4.5	p/t	2.3	p	2.2	p	1.3	p	1.9	t	0.1		0.3		0.7	t	1.8	p
1985	1.1	p	5.2	p/t	1.8	p	0.8	p	0.5	p	2.3	p/t	0.1		0.2		0.4		2.6	p
1986	0.6	p	4.1	p/t	1.7	p	0.7	p	0.3	p	1.4	p/t	0.1		0.1		0.2		3.8	p
1987	0.6	t	1.8	t	0.5	t	0.5	p/t	0.4	t	1.0	t	< 0.1		< 0.1		0.2		2.4	p
1988	0.6	t	0.3	t	1.1	t	1.1	t	0.4	t	0.4	t	X		X		0.2		3.3	t
1989	0.5	t	0.6	t	1.2	t	1.7	t	0.2	t	1.0	t	X		X		0.3	t	1.1	t
1990	0.5	t	1.0	t	0.5	t	0.3	t	0.3	t	0.8	t	X		X			t		t
1991	0.5	t	0.8	t	0.4	t		t	0.1	t	0.2	t			X			t		t
1992	0.4	t	2.0	t		t		t		t		t						t		t
1993	0.2	t	0.7	t		t	0.3	t		t		t						t		t
1994	0.2	t	0.4	t		t	0.3	t		t	0.3	t						t		t
1995		t		t		t		t		t		t						t		
1996		t		t		t		t		t		t						t		
1997		t		t		t		t		t		t						t		
1998		t		t		t		t		t		t						t		
1998		t		t		t		t		t		t						t		

Table 2. Population estimates (millions of crabs) of male mature and legal Tanner crabs using Leslie-depletion, trawl survey CSA, area-swept, and catch expansion estimators for the Northeast Section of Kodiak, 1973-1998. Estimates of mature crabs were derived from estimates of legal crabs by applying an estimated mature:legal ratio. "Average of estimates" is the average of the estimates that were available. "Catch" is the commercial catch (millions of crabs) of legal crab from the commercial season following the survey estimates.

Year	Leslie Estimate		CSA Trawl Survey Estimate		Area-Swept Estimate		Catch Expansion Estimate ^a		Average of Estimates		Catch Following Year
	mature	legal	mature	legal	mature	legal	mature	legal	mature	legal	
1973							5.6	4.5	5.6	4.5	2.4
1974							2.6	1.8	2.6	1.8	1.0
1975							4.6	3.0	4.6	3.0	1.6
1976							3.5	2.0	3.5	2.0	1.1
1977							4.7	2.9	4.7	2.9	1.5
1978							7.2	4.4	7.2	4.4	2.3
1979	6.7	4.0							6.7	4.0	1.8
1980							3.8	1.7	3.8	1.7	0.9
1981	2.2	0.8							2.2	0.8	0.5
1982	4.6	2.6							4.6	2.6	1.2
1983	1.6	0.9							1.6	0.9	0.8
1984	1.1	0.6							1.1	0.6	0.4
1985	0.6	0.5							0.6	0.5	0.3
1986	0.4	0.3							0.4	0.3	0.2
1987			1.7	0.3	0.8	0.3			1.3	0.3	0.2
1988			0.9	0.3	1.1	0.4			1.0	0.4	0.2
1989			0.9	0.4	4.1	1.8			2.5	1.1	0.2
1990			0.7	0.3	1.7	0.7			1.2	0.5	0.2
1991			0.6	0.2	1.6	0.5			1.1	0.4	0.2
1992			0.6	0.2	1.0	0.2			0.8	0.2	0.1
1993	0.6	0.2	0.7	0.3	0.9	0.3			0.7	0.3	0.1
1994					0.7	0.2			0.7	0.2	
1995					0.5	0.1			0.5	0.1	
1996					0.5	0.1			0.5	0.1	
1997					0.7	0.1			0.7	0.1	
1998					2.5	0.5			2.5	0.5	

^aAverage harvest rate calculated as 53%.

Table 3. Population estimates (millions of crabs) of male mature and legal Tanner crabs using Leslie-depletion, trawl survey CSA, area-swept, and catch expansion estimators for the Eastside Section of Kodiak, 1973-1998. Estimates of mature crabs were derived from estimates of legal crabs by applying an estimated mature:legal ratio. "Average of estimates" is the average of the estimates that were available. "Catch" is the commercial catch (millions of crabs) of legal crab from the commercial season following the survey estimates.

Year	Leslie Estimate		CSA Trawl Survey Estimate		Area-Swept Estimate		Catch Expansion Estimate ^a		Average of Estimates		Catch Following Year
	mature	legal	mature	legal	mature	legal	mature	legal	mature	legal	
1973							7.7	5.0	7.7	5.0	2.3
1974							2.8	1.9	2.8	1.9	0.9
1975							5.7	4.2	5.7	4.2	2.0
1976	3.0	1.9							3.0	1.9	1.1
1977							5.1	3.1	5.1	3.1	1.4
1978	4.2	2.8							4.2	2.8	1.1
1979							3.3	2.0	3.3	2.0	0.9
1980							1.4	1.0	1.4	1.0	0.5
1981	2.2	1.5							2.2	1.5	0.5
1982	2.5	1.5							2.5	1.5	1.3
1983	4.6	2.7							4.6	2.7	1.8
1984	5.0	3.0	8.6	4.0	3.7	2.2			5.8	3.1	2.0
1985	3.7	2.7	4.6	3.0	3.4	2.1			3.9	2.6	1.6
1986			1.8	1.1	2.0	1.4			1.9	1.3	0.7
1987			2.0	0.4	1.7	0.5			1.9	0.5	0.1
1988			2.2	0.8	1.1	0.4			1.7	0.6	0.3
1989			2.5	0.9	2.4	1.1			2.4	1.0	0.4
1990			5.2	0.8	5.1	1.0			5.1	0.9	0.3
1991			4.7	2.2	6.2	3.5			5.4	2.9	0.8
1992			2.4	1.3	2.4	0.8			2.4	1.1	0.3
1993			2.2	0.7	1.5	0.5			1.8	0.6	0.2
1994					0.7	0.2			0.7	0.2	
1995					0.5	0.1			0.5	0.1	
1996					1.2	0.3			1.2	0.3	
1997					0.9	0.2			0.9	0.2	
1998					3.1	0.8			3.1	0.8	

^aAverage harvest rate calculated as 46%.

Table 4. Population estimates (millions of crabs) of male mature and legal Tanner crabs using Leslie-depletion, trawl survey CSA, area-swept, and catch expansion estimators for the Southeast Section of Kodiak, 1973-1998. Estimates of mature crabs were derived from estimates of legal crabs by applying an estimated mature:legal ratio. "Average of estimates" is the average of the estimates that were available. "Catch" is the commercial catch (millions of crabs) of legal crab from the commercial season following the survey estimates.

Year	Leslie Estimate		CSA Trawl Survey Estimate		Area-Swept Estimate		Catch Expansion Estimate ^a		Average of Estimates		Catch Following Year
	mature	legal	mature	legal	mature	legal	mature	legal	mature	legal	
	1973							1.6	1.2	1.6	
1974							0.6	0.4	0.6	0.4	0.3
1975							5.5	3.8	5.5	3.8	2.4
1976							4.8	3.6	4.8	3.6	2.2
1977							4.1	2.9	4.1	2.9	1.8
1978							2.4	1.5	2.4	1.5	0.9
1979	1.2	0.7							1.2	0.7	0.4
1980							0.5	0.3	0.5	0.3	0.2
1981	1.0	0.4							1.0	0.4	0.2
1982	2.3	1.3							2.3	1.3	1.0
1983	2.0	1.2							2.0	1.2	0.9
1984	2.0	0.9							2.0	0.9	0.7
1985	1.6	1.0							1.6	1.0	0.7
1986							0.6	0.3	0.6	0.3	0.2
1987	1.3	0.5	1.8	0.7	1.4	0.6			1.5	0.8	0.4
1988	1.5	0.9	1.5	0.6	2.1	1.0			1.7	0.8	0.5
1989	2.0	0.7	1.1	0.3	0.8	0.3			1.3	0.4	0.2
1990	0.6	0.3	1.0	0.3	1.2	0.5			0.9	0.4	0.2
1991					0.6	0.2			0.6	0.2	
1992					0.8	0.2			0.8	0.2	
1993					0.6	0.1			0.6	0.1	
1994					0.6	0.2			0.6	0.2	
1995					0.2	0.1			0.2	0.1	
1996					0.3	0.1			0.3	0.1	
1997					0.1	0.0			0.1	0.0	
1998					0.3	0.1			0.3	0.1	

^aAverage harvest rate calculated as 63%.

Table 5. Population estimates (millions of crabs) of male mature and legal Tanner crabs using Leslie-depletion, trawl survey CSA, area-swept, and catch expansion estimators for the Southwest Section of Kodiak, 1973-1998. Estimates of mature crabs were derived from estimates of legal crabs by applying an estimated mature:legal ratio. "Average of estimates" is the average of the estimates that were available. "Catch" is the commercial catch (millions of crabs) of legal crab from the commercial season following the survey estimates.

Year	Leslie Estimate		CSA Trawl Survey Estimate		Area-Swept Estimate		Catch Expansion Estimate ^a		Average of Estimates		Catch Following Year
	mature	legal	mature	legal	mature	legal	mature	legal	mature	legal	
	1973							6.8	5.4	6.8	
1974							3.9	2.7	3.9	2.7	1.4
1975							3.2	2.5	3.2	2.5	1.3
1976							1.7	1.3	1.7	1.3	0.7
1977							7.2	6.2	7.2	6.2	3.2
1978	14.7	10.3							14.7	10.3	1.9
1979							2.6	1.8	2.6	1.8	0.9
1980							3.2	1.8	3.2	1.8	0.9
1981	4.2	2.6							4.2	2.6	2.0
1982	6.4	3.7							6.4	3.7	2.2
1983	1.8	1.2							1.8	1.2	0.9
1984							1.0	0.6	1.0	0.6	0.3
1985							0.7	0.5	0.7	0.5	0.3
1986							0.8	0.4	0.8	0.4	0.2
1987	2.2	0.6	3.0	0.7	2.6	0.8			2.6	0.7	0.5
1988	1.5	1.0	1.3	1.0	2.1	1.5			1.7	1.2	0.7
1989			0.4	0.2	0.9	0.5			0.7	0.4	0.1
1990			0.4	0.1	0.8	0.1			0.6	0.1	
1991			0.6	0.1	0.7	0.1			0.7	0.1	
1992			0.7	0.3	0.6	0.4			0.6	0.3	0.1
1993			0.7	0.3	0.7	0.3			0.7	0.3	0.1
1994					0.3	0.2			0.3	0.2	
1995					0.2	0.1			0.2	0.1	
1996					0.4	0.1			0.4	0.1	
1997					0.4	0.2			0.4	0.2	
1998					0.2	0.1			0.2	0.1	

^aAverage harvest rate calculated as 52%.

Table 6. Population estimates (millions of crabs) of male mature and legal Tanner crabs using Leslie-depletion, trawl survey CSA, area-swept, and catch expansion estimators for the Westside Section of Kodiak, 1973-1998. Estimates of mature crabs were derived from estimates of legal crabs by applying an estimated mature:legal ratio. "Average of estimates" is the average of the estimates that were available. "Catch" is the commercial catch (millions of crabs) of legal crab from the commercial season following the survey estimates.

Year	Leslie Estimate		CSA Trawl Survey Estimate		Area-Swept Estimate		Catch Expansion Estimate ^a		Average of Estimates		Catch Following Year
	mature	legal	mature	legal	mature	legal	mature	legal	mature	legal	
1973							2.3	1.4	2.3	1.4	0.7
1974							0.3	0.2	0.3	0.2	0.1
1975							6.7	3.7	6.7	3.7	1.7
1976	6.8	4.0							6.8	4.0	1.4
1977							4.5	3.5	4.5	3.5	1.6
1978	4.4	2.7							4.4	2.7	1.4
1979	0.0	0.0					1.4	1.1	1.4	1.1	0.5
1980	1.9	1.1							1.9	1.1	0.5
1981	1.6	1.2							1.6	1.2	0.7
1982	3.5	2.5							3.5	2.5	0.8
1983							1.6	1.2	1.6	1.2	0.6
1984	0.3	0.2							0.3	0.2	0.2
1985	0.2	0.1							0.2	0.1	0.1
1986							0.6	0.3	0.6	0.3	0.2
1987	0.6	0.2	0.4	0.2	2.2	0.9			1.1	0.5	0.2
1988	0.3	0.1	0.4	0.1	0.9	0.3			0.5	0.2	0.1
1989	0.8	0.2	0.4	0.2	1.2	0.5			0.8	0.3	0.1
1990			0.4	0.1	1.2	0.4			0.8	0.2	0.03
1991					0.5	0.1			0.5	0.1	
1992					0.5	0.2			0.5	0.2	
1993					0.5	0.2			0.5	0.2	
1994					0.2	0.1			0.2	0.1	
1995					0.2	0.1			0.2	0.1	
1996					0.4	0.1			0.4	0.1	
1997					0.5	0.1			0.5	0.1	
1998					0.3	0.1			0.3	0.1	

^aAverage harvest rate calculated as 47%.

Table 7. Population estimates (millions of crabs) of male mature and legal Tanner crabs using Leslie-depletion, trawl survey CSA, area-swept, and catch expansion estimators for the North Mainland Section of Kodiak, 1973-1998. Estimates of mature crabs were derived from estimates of legal crabs by applying an estimated mature:legal ratio. "Average of estimates" is the average of the estimates that were available. "Catch" is the commercial catch (millions of crabs) of legal crab from the commercial season following the survey estimates.

Year	Leslie		CSA Trawl Survey		Area-Swept		Catch Expansion		Average of		Catch Following Year
	Estimate		Estimate		Estimate		Estimate ^a		Estimates		
	mature	legal	mature	legal	mature	legal	mature	legal	mature	legal	
1973							12.6	4.3	12.6	4.3	2.1
1974							8.0	2.8	8.0	2.8	1.3
1975							10.7	3.7	10.7	3.7	1.8
1976							8.0	2.8	8.0	2.8	1.3
1977							15.3	5.3	15.3	5.3	2.5
1978	19.3	6.7							19.3	6.7	2.7
1979	8.2	2.8							8.2	2.8	1.7
1980							4.7	1.6	4.7	1.6	0.8
1981	3.5	1.4	3.4	1.6	3.6	1.5			3.5	1.5	0.8
1982	5.3	1.5	3.5	1.3	8.8	2.7			5.8	1.8	0.8
1983	5.6	1.6	3.6	1.5	4.0	1.2			4.4	1.5	0.8
1984	3.1	1.2	3.0	1.7	3.8	1.9			3.3	1.6	0.9
1985	2.1	0.8	1.8	1.1	2.0	1.3			2.0	1.0	0.5
1986	2.1	0.6	1.4	0.6	2.5	0.8			2.0	0.7	0.4
1987			1.7	0.5	3.4	0.6			2.6	0.6	0.2
1988	1.5	0.7	1.4	0.8	2.3	1.0			1.7	0.8	0.4
1989			1.2	0.6	1.8	0.7			1.5	0.6	0.4
1990			0.8	0.3	1.8	0.3			1.3	0.3	0.1
1991			0.9	0.3	1.1	0.2			1.0	0.2	
1992			0.9	0.4	0.9	0.2			0.9	0.3	
1993			0.8	0.4	1.2	0.3			1.0	0.4	0.1
1994					0.7	0.3			0.7	0.3	
1995					0.3	0.1			0.3	0.1	
1996					0.6	0.2			0.6	0.2	
1997					0.9	0.2			0.9	0.2	
1998					0.4	0.1			0.4	0.1	

^aAverage harvest rate calculated as 47%.

Table 8. Population estimates (millions of crabs) using Leslie depletion with the commercial catch for the South Mainland and Semidi Island Sections of Kodiak, 1973-1993. "X" designates confidential catch, less than three vessels.

SOUTH MAINLAND SECTION				SEMIDI ISLAND SECTION			
Year	Leslie Population Estimate		Catch Following Year	Year	Leslie Population Estimate		Catch Following Year
	mature	legal			mature	legal	
1973				1973			
1974			X	1974			
1975				1975			
1976				1976			
1977				1977			0.10
1978			X	1978			0.26
1979			X	1979			0.45
1980	0.33	0.10	0.15	1980			0.42
1981	0.30	0.12	0.11	1981	1.45	0.62	0.50
1982			0.07	1982	0.90	0.54	0.37
1983			0.03	1983	0.86	0.45	0.12
1984			0.02	1984	0.23	0.10	0.07
1985			0.03	1985			0.03
1986			0.01	1986			0.02
1987			X	1987			X
1988				1988			X
1989				1989			
1990				1990			
1991				1991			
1992				1992			
1993				1993			

Table 9. Population estimates (millions of crabs) of male mature and legal Tanner crabs using Leslie-depletion, trawl survey CSA, area-swept, and catch expansion estimators for the Chignik District, 1974-1998. Estimates of mature crabs were derived from estimates of legal crabs by applying an estimated mature:legal ratio. "Average of estimates" is the average of the estimates that were available. "Catch" is the commercial catch (millions of crabs) of legal crab from the commercial season following the survey estimates.

Year	Leslie Estimate		CSA Trawl Survey Estimate		Area-Swept Estimate		Catch Expansion Estimate ^a		Average of Estimates		Catch Following Year
	mature	legal	mature	legal	mature	legal	mature	legal	mature	legal	
	1974							5.3	2.3	5.3	
1975							16.6	7.0	16.6	7.0	4.4
1976							7.9	3.3	7.9	3.3	2.1
1977							6.5	2.7	6.5	2.7	1.7
1978							3.5	1.5	3.5	1.5	0.9
1979	3.4	1.4							3.4	1.4	1.4
1980							5.8	2.4	5.8	2.4	1.5
1981			5.5	2.1	5.3	2.1			5.4	2.1	1.3
1982			2.8	1.9	4.9	2.9			3.9	2.4	1.4
1983			0.9	0.5	1.1	0.6			1.0	0.5	0.3
1984			0.6	0.3	1.0	0.3			0.8	0.3	0.1
1985							0.2	0.1	0.2	0.1	0.04
1986	0.2	0.1							0.2	0.1	0.1
1987	0.2	0.1							0.2	0.1	0.1
1988	0.5	0.2							0.5	0.2	0.1
1989					1.7	0.5			1.7	0.5	
1990					1.3	0.4			1.3	0.4	
1991					0.5	0.2			0.5	0.2	
1992					0.1	0.1			0.1	0.1	
1993					0.3	0.1			0.3	0.1	
1994					0.2	0.1			0.2	0.1	
1995					0.3	0.1			0.3	0.1	
1996					0.6	0.3			0.6	0.3	
1997					0.6	0.3			0.6	0.3	
1998					0.5	0.2			0.5	0.2	

^aAverage harvest rate calculated as 63%.

Table 10. Population estimates (millions of crabs) of male mature and legal Tanner crabs using Leslie-depletion, trawl survey CSA, area-swept, and catch expansion estimators for the South Peninsula District, 1974-1998. Estimates of mature crabs were derived from estimates of legal crabs by applying an estimated mature:legal ratio. "Average of estimates" is the average of the estimates that were available. "Catch" is the commercial catch (millions of crabs) of legal crab from the commercial season following the survey estimates.

Year	Leslie Estimate		Area-Swept Estimate		Catch Expansion Estimate ^a		Average of Estimates		Catch Following Year
	mature	legal	mature	legal	mature	legal	mature	legal	
	1974					4.4	3.2	4.4	
1975					5.7	4.3	5.7	4.3	2.7
1976					6.0	3.9	6.0	3.9	2.5
1977					6.1	4.4	6.1	4.4	2.8
1978					6.8	5.1	6.8	5.1	3.2
1979					5.4	4.1	5.4	4.1	2.6
1980					3.1	1.6	3.1	1.6	1.0
1981	3.6	2.6					3.6	2.6	1.8
1982					3.4	1.8	3.4	1.8	1.2
1983	2.6	1.1					2.6	1.1	0.8
1984	1.5	0.9					1.5	0.9	0.8
1985	2.6	1.9					2.6	1.9	1.2
1986	2.2	1.5					2.2	1.5	0.8
1987	3.1	2.4					3.1	2.4	1.2
1988			1.6	0.7			1.6	0.7	0.4
1989			1.0	0.3			1.0	0.3	
1990			1.3	0.4			1.3	0.4	
1991			1.1	0.4			1.1	0.4	
1992			0.9	0.3			0.9	0.3	
1993			1.1	0.3			1.1	0.3	
1994			0.7	0.2			0.7	0.2	
1995							0.0		
1996			0.3	0.1			0.3	0.1	
1997			0.3	0.1			0.3	0.1	
1998			1.3	0.3			1.3	0.3	

^a Average harvest rate calculated as 64%.

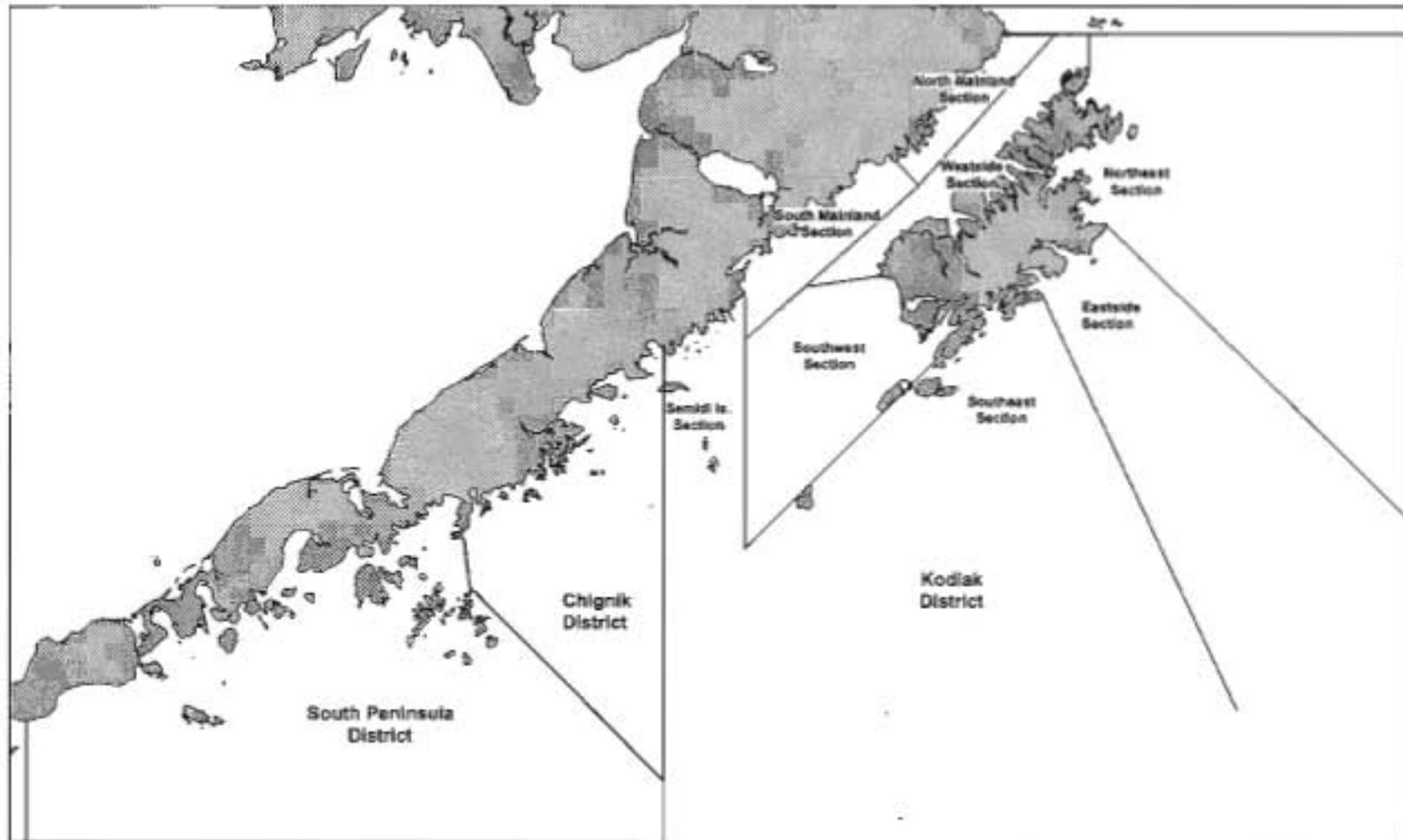


Figure 1. Tanner crab management Districts and Sections.

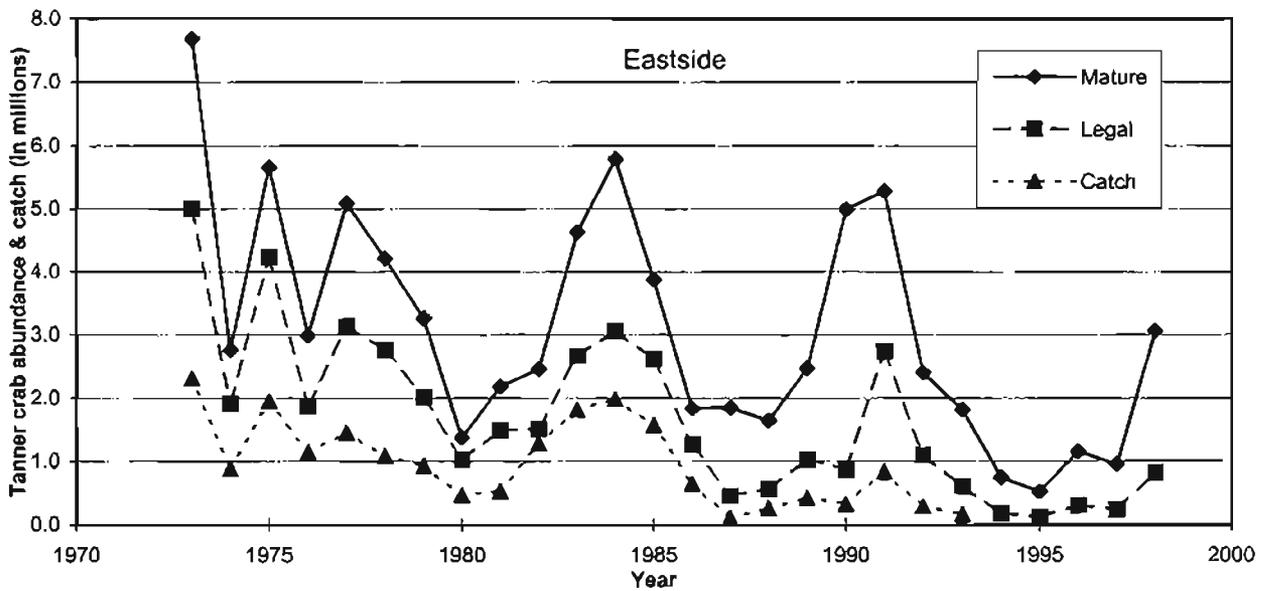
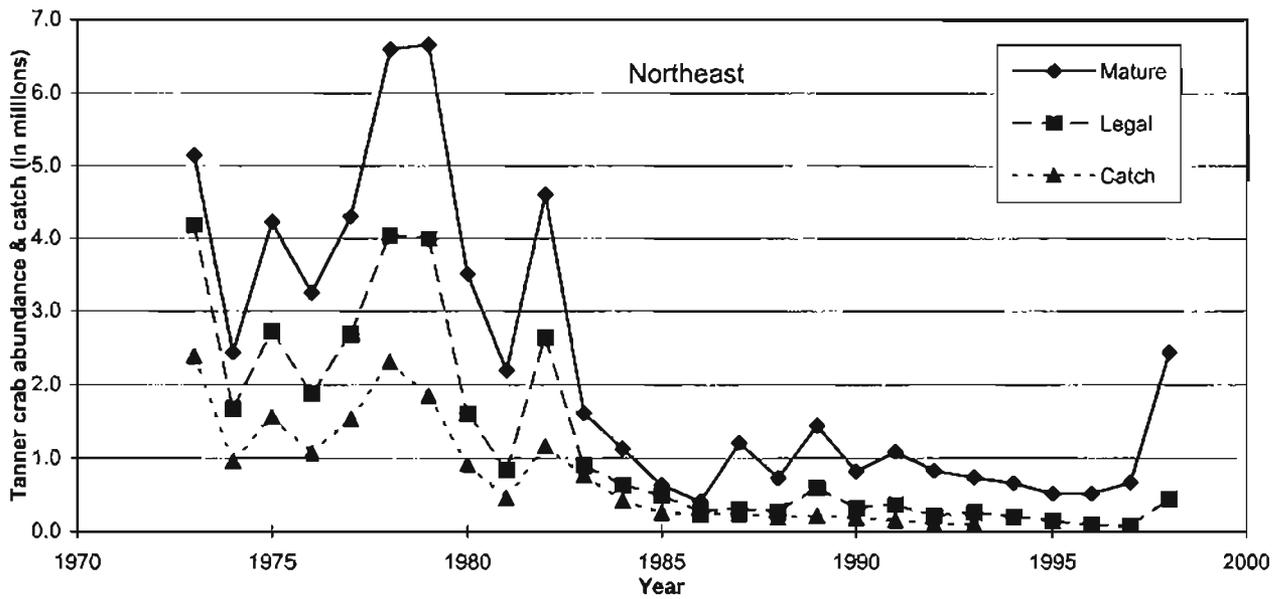


Figure 2. Mature male and legal Tanner crab abundance estimates, and catch for the Northeast and Eastside Sections of the Kodiak District, 1973-1998.

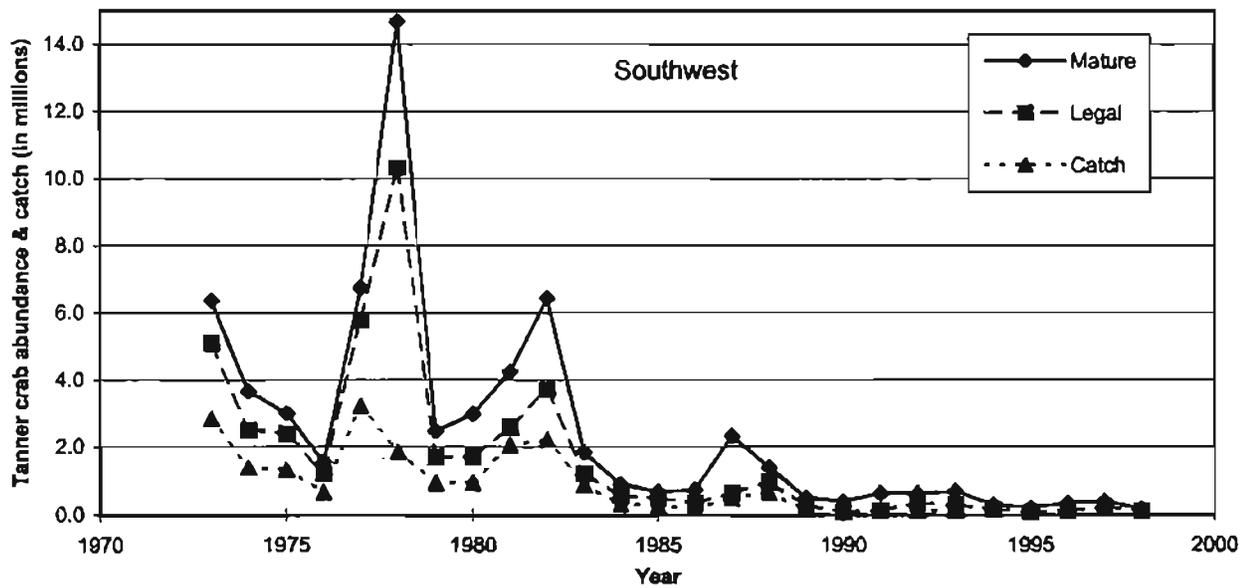
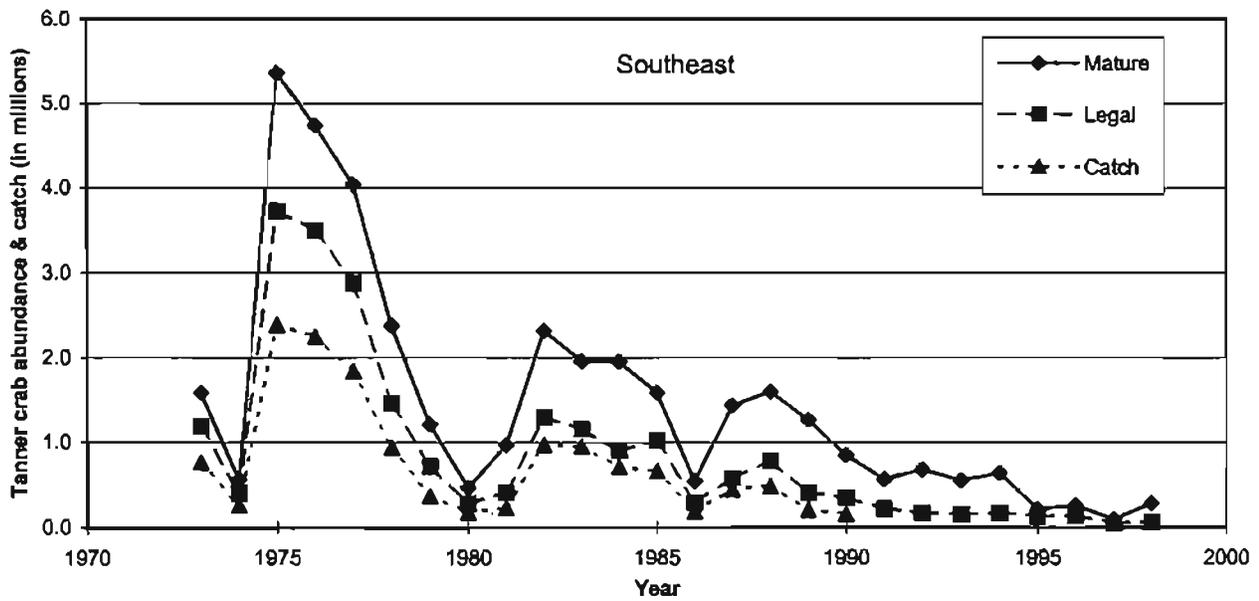


Figure 3. Mature male and legal Tanner crab abundance estimates, and catch for the Southeast and Southwest Sections of the Kodiak District, 1973-1998.

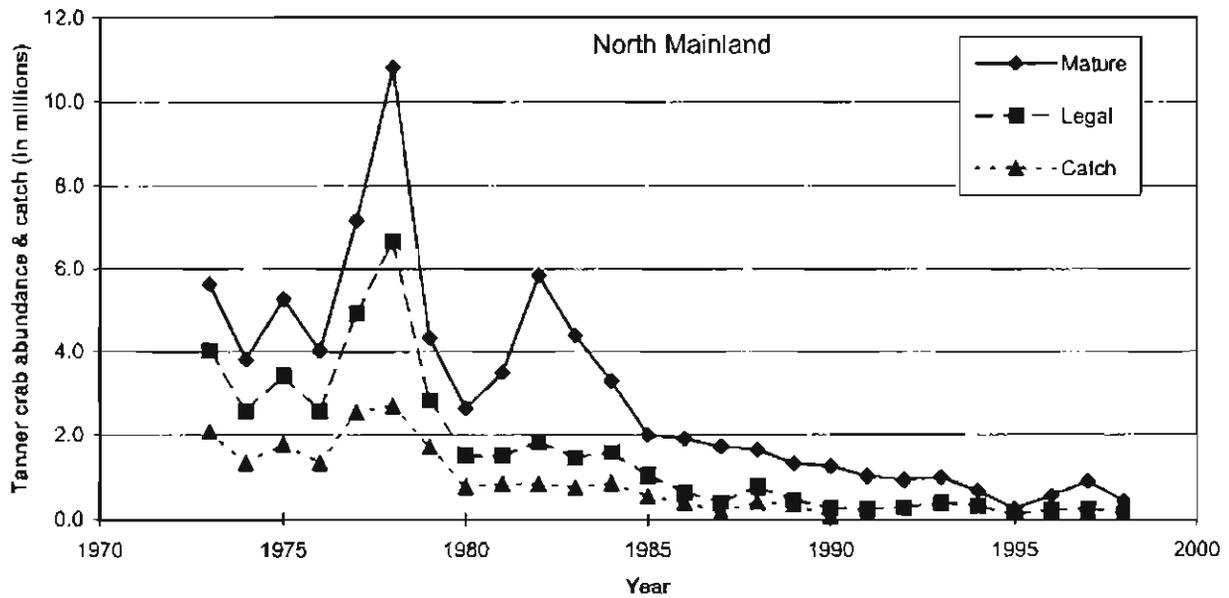
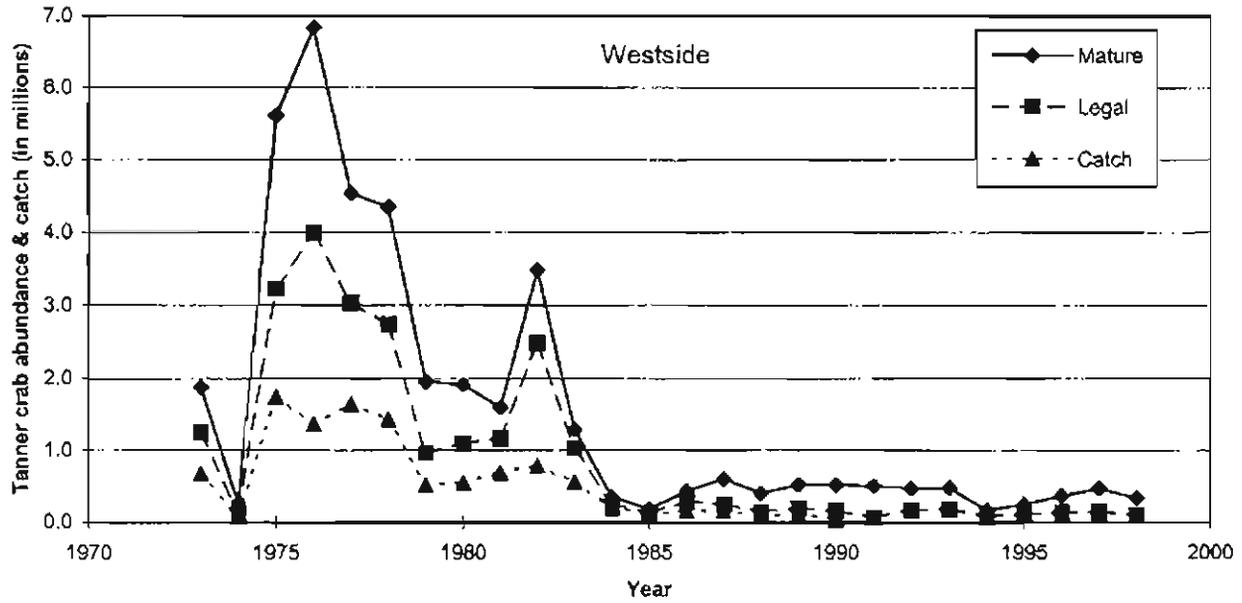


Figure 4. Mature male and legal Tanner crab abundance estimates, and catch for the Westside and North Mainland Sections of the Kodiak District, 1973-1998.

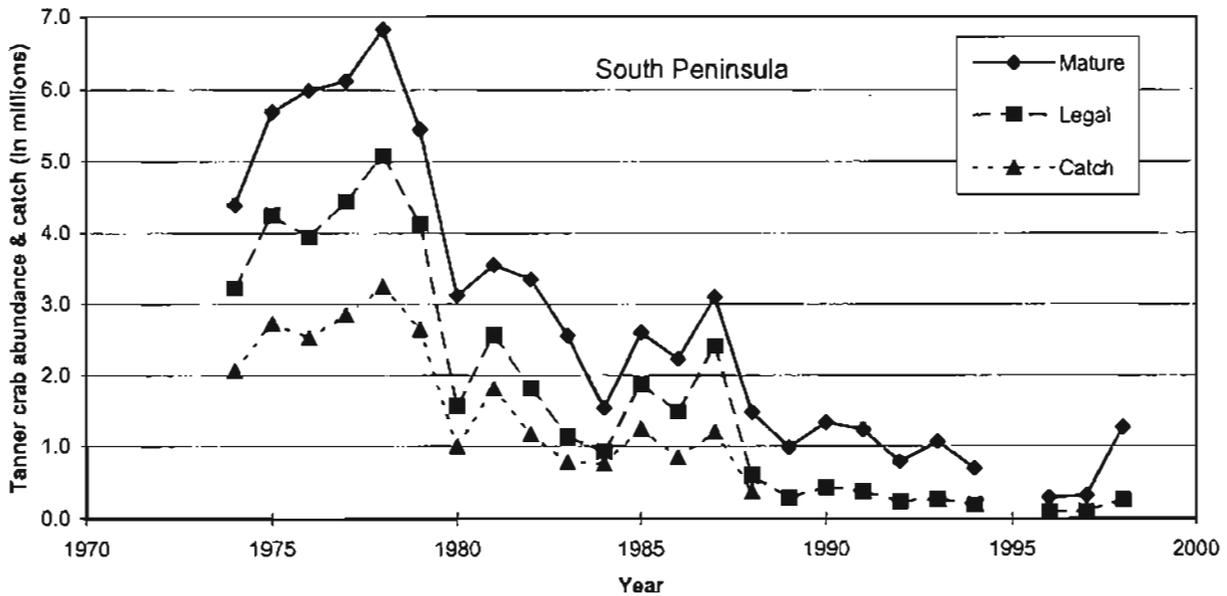
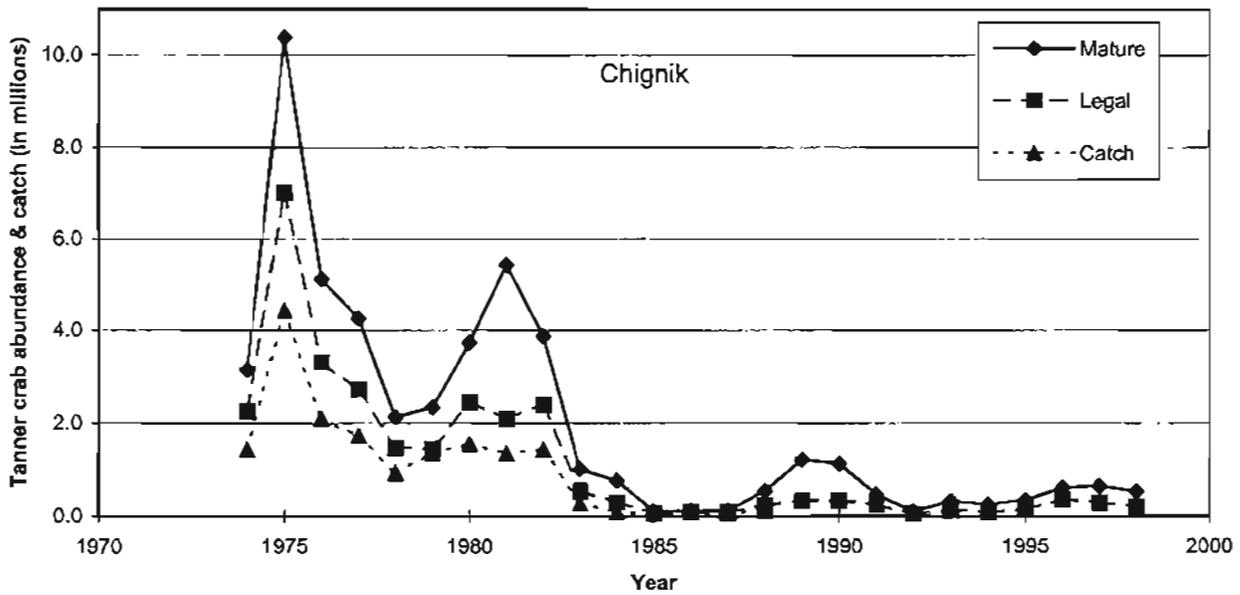


Figure 5. Mature male and legal Tanner crab abundance estimates, and catch for the Chignik and South Peninsula Districts, 1974-1998.

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