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Addendum to SP21-11: Tanner Crab Commercial Fishery Harvest Strategy in Prince William Sound, 2022

by

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and

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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)

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

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ADDENDUM TO SP21-11: TANNER CRAB COMMERCIAL FISHERY HARVEST STRATEGY IN PRINCE WILLIAM SOUND, 2022

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ABSTRACT

This report summarizes the previous, proposed, and amended Prince William Sound Tanner crab *Chionoecetes bairdi* harvest strategies, defines how minimum abundance thresholds were calculated for new management districts, and describes the bottom trawl surveys that will be used to inform the harvest strategy. The Alaska Department of Fish and Game (ADF&G) submitted a proposal to redefine and rename 5 Tanner crab commercial fishery districts in the Prince William Sound Area (PWSA; Registration Area E) that was adopted into regulation at the November/December 2021 Alaska Board of Fisheries (BOF) meeting. ADF&G also submitted a proposal for a new Tanner crab harvest strategy for 3 of the new districts in PWSA following staff recommendations that were published prior to the 2021 BOF meeting (Rhea-Fournier et al. 2021). The proposed harvest strategy was amended during the meeting after discussions among ADF&G staff, BOF members, and fishery stakeholders before being adopted into regulation. The amended harvest strategy includes minimum abundance thresholds to open a fishery in 3 of the 5 new Tanner crab commercial fishery districts and follows the approach in the original Registration Area E Tanner crab harvest strategy adopted at the 2017 BOF meeting that utilizes commercial harvest and ADF&G bottom trawl survey information. Three significant modifications were made to the original ADF&G harvest strategy proposal, including shortening the time series of annual abundance used to develop a proxy for maximum sustainable yield from 1977–2015 to 1982–2015. The size class of crab for the time series of annual abundance was reduced from the historical legal size to the mature size of male Tanner crab. Finally, the stepwise harvest rates were adjusted to mature-size male crab considering the new approach and a maximum harvest rate on legal-size crab was established for 3 of the 5 new Tanner crab commercial fishery districts.

Keywords: Tanner crab, *Chionoecetes bairdi*, trawl survey, Prince William Sound, harvest strategy

INTRODUCTION

This report will provide background information on historical and current Tanner crab *Chionoecetes bairdi* commercial fisheries in the Prince William Sound Area (PWSA; Registration Area E) and the associated harvest strategies and assessment surveys. The Alaska Department of Fish and Game (ADF&G) Division of Commercial Fisheries (DCF) has the responsibility to sustainably manage Tanner crab in the PWSA, which encompasses both the waters of Prince William Sound and waters in the Gulf of Alaska (Figure 1). The first commercial harvest of Tanner crab in PWSA occurred in 1966 and the fishery rapidly developed in the first few years (Pirtle et al. 1969). Over the next 5 decades, ADF&G DCF established a series of Tanner crab management measures based upon assessment surveys as the fishery sustained large harvests through the 1970s, declined in the 1980s, closed in 1989, and reopened in 2018.

COMMERCIAL FISHERIES

In the first years of the Tanner crab fishery in PWSA, there were no restrictions on size or sex of crab harvested (Pirtle et al. 1969). At the beginning of the fishery, the commercial fleet was based out of Cordova and through 1971, most of the harvest was within the inside waters of PWSA (within Prince William Sound) with a mean of less than 1 million lb of harvest annually (Pirtle et al. 1972). In 1972, the harvest increased to 8.5 million lb as the fleet began to move into the outside waters of PWSA into the Gulf of Alaska (GOA). Subsequently, Tanner crab fishing areas and harvest quotas for PWSA were promulgated by the Alaska Board of Fish and Game in 1972. The Inside area, which consisted of the waters of Prince William Sound, had a quota of 3.5 million lb of Tanner crab; the Outside area, made of the waters of GOA between Cape Suckling and Cape Fairfield (Figure 1), had a quota of 12 million lb (Pirtle and Fridgen 1974). The harvest for the 1972–1973 season (October 15–June 22) remains the largest harvest on record for PWSA Tanner crab at 14 million lb, of which 11.7 million lb was from the Outside area. Although the 1973–1974 season had the second-highest harvest on record at 10 million lb (8.5 million lb from Outside area), the following 3 years had a substantial decrease in harvest (Pirtle 1978a). During 1972–1976, the

Tanner crab harvest in the Outside area of PWSA occurred south of Montague Island, south of Hinchinbrook Entrance, and south of the Copper River Delta. Concurrent efforts in the Inside area targeted the Hinchinbrook Entrance, Orca Bay, Port Fidalgo, and just outside Port Valdez.

In 1976, the Alaska Board of Fisheries (BOF) adopted harvest regulations to limit PWSA harvest of Tanner crab to males of at least 5.3 in carapace width (CW) including spines, with a guideline harvest level (GHL) of 3–7 million lb (Pirtle 1978b). For this report, "legal-size crab" will refer to legal-size male Tanner crab. Following the adoption of harvest regulations in 1976, the fleet expanded again looking for larger male Tanner crab and began fishing the entire expanse of PWSA Outside area from Cape Suckling to Cape Fairfield and began fishing the Inside area in Montague Strait. Starting in 1977, Tanner crab harvest in PWSA was reported and managed by 4 new districts (Figure 1). The Northern and Hinchinbrook districts were in Prince William Sound, the Eastern District was in the GOA, and the Western District included waters in both Prince William Sound and the GOA. After 1977, most of the harvest occurred in the Eastern and Western Districts until harvest began to decline in the early 1980s. District closures occurred during 1984 and 1985 along with limited effort. The final 3 years of the fishery, 1986–1988, yielded smaller harvests of approximately 0.5 million lb (Rumble et al. 2020). In 1989, the PWSA commercial Tanner crab fishery was closed and remained closed until the 2017 BOF meeting when a proposal to allow a commissioner's permit fishery for Tanner crab in Registration Area E was adopted into regulation (5 AAC 35.311). This regulation allowed commissioner's permits to be issued in PWSA starting in 2018 for the harvest of Tanner crab in the Western and Eastern Districts. Although this fishery did not have an associated harvest strategy or GHL, provisions under the commissioner's permit included a limit of 50 pots per vessel and allowed ADF&G to specify season dates and areas of fishing operation. This new fishery was conducted from 2018 to 2021 with the majority of effort and harvest occurring in the Western District (Rumble et al. 2021). The commissioner's permit fishery had similar trends in effort and harvest as the historical fishery in the 1970s. Both fisheries began with high effort and harvest in the inside waters of PWSA and then expanded into the outside waters of the Gulf of Alaska.

LEGAL SIZE AND SIZE AT MATURITY

At the 1976 BOF meeting, statewide Tanner crab commercial harvest regulations were adopted to limit harvest of Tanner crab to males of at least 5.5 in (140 mm) CW, except for in PWSA where the legal size was set at 5.3 in (135 mm) CW. The CW legal size for Tanner crab commercial harvest, as defined by ADF&G, includes the spines as part of the measurement. At the 1976 BOF meeting, ADF&G biologists stated that male Alaska Tanner crab were believed to be sexually mature at 110–115 mm CW, except for in PWSA where the mean size at maturity was 4.3 in or 109 mm (Donaldson and Donaldson 1992). ADF&G biologists at the 1976 BOF meeting suggested that crabs 110–139 mm would be sexually mature at least 1 year and up to 2 years before being available to the commercial fishery (Donaldson and Donaldson 1992).

Growing via a succession of molts through maturity is an indeterminate growth life history strategy that has been identified in other commercially important crab species such as Dungeness crab *Cancer magister* (Wainwright and Armstrong 1993) and red king crab *Paralithodes camtschaticus* (Zhou et al. 1998). Since the 1976 BOF meeting, research has indicated that male Tanner crab exhibit a determinate growth life history strategy, in which crab cease to molt after morphological maturity, a stage that is referred to as the terminal molt in *Chionoecetes* species (Conan and Comeau, 1986; Hartnoll et al. 1993). Male morphological maturity in members of the genus

Chionoecetes refers to crab in the large-clawed morphotype as the relative size of the chela height (CH) becomes larger at the terminal molt (Somerton 1980; Conan and Comeau 1986). The occurrence of a terminal molt at morphological maturity in the genus *Chionoecetes* has been introduced and observed in laboratory studies (Conan and Comeau 1986), refuted in laboratory and field observations (Donaldson and Johnson 1988; Dawe et al. 1991; Paul and Paul 1995), and further debated (Conan et al. 1988). Evidence of a terminal molt at morphological maturity has been found in other *Chionoecetes* species, the Bering Sea snow crab (*Chionoecetes opilio*), as indicated by low levels of circulating molting hormones (Tamone et al. 2005) and from premolt indicators and molt stage analysis via setagenesis (Rugolo et al. 2005). The concept of a male Tanner crab terminal molt was controversial until more recent data on Tanner crab hormone levels in Southeast Alaska confirmed previous analysis (Tamone et al. 2007) and it became more widely accepted (Zheng et al. 2011) and is now considered in ADF&G annual management reports (Rumble et al. 2020; Rebert et al. 2021), maturity research (Siddon and Bednarski 2010), and harvest strategy recommendations (Daly et al. 2020).

Size at morphological maturity has been assessed within each region of Alaska since the 1976 BOF meeting with the acceptance of determinate growth and a terminal molt in all Tanner crab stocks. Size estimates for morphologically mature male Tanner crab are similar across Alaska, except for in the western Bering Sea. The CW at which approximately 50% of male Tanner crab have reached morphological maturity (CW_{50}) for PWSA Tanner crab collected during the 2007–2014 ADF&G trawl surveys was estimated at 113 mm (Goldman et al. 2018). Male Tanner crab caught in the ADF&G Kachemak Bay trawl survey had a CW_{50} estimate of 112 mm[1]. In Southeast Alaska, CW_{50} averaged 117 mm and ranged from 108–135 mm throughout the region (Siddon and Bednarski 2010). In the Kodiak, Chignik, South Peninsula, and Eastern Aleutian Districts, ADF&G defines "mature male abundance" as those crab that are 114 mm CW or greater (Richardson et al. 2020). Tanner crab in the Bering Sea are managed across 2 management areas with males in the western portion having an estimated size at maturity of 103 mm, whereas those in the eastern portion have an estimated size at maturity of 113 mm (Zacher et al. 2020).

In 2017, the BOF adopted an ADF&G proposal to decrease the legal minimum size of PWSA Tanner crab to 5 in (127 mm) from the historical legal size of 5.3 in (135 mm) CW. This was the first change to the legal size of crab in an active commercial Tanner crab fishery in the GOA since regulations were adopted at the 1976 BOF meeting. The proposed decrease in the legal size by ADF&G in PWSA was supported by an analysis of PWSA Tanner crab fishery and survey data suggesting that due to a terminal molt, a majority of males would not reach legal size and not be available for harvest (ADF&G 2017; Goldman et al. 2018). Tanner crab legal size was reduced in the eastern Bering Sea prior to this change in PWSA with the anticipated benefit of reducing bycatch of undersized crab, achieving higher long-term yield, and lowering harvest rates of faster growing larger males (Zheng and Pengilly 2011).

REGISTRATION AREA E TANNER CRAB HARVEST STRATEGY

In 2017, the BOF adopted an ADF&G proposal for the Registration Area E Tanner crab harvest strategy (5 AAC 35.308). This harvest strategy followed the traditional approach for Tanner crab stocks in the GOA that have a minimum abundance threshold to open a commercial fishery set at

[1] Correspondence from Jie Zheng, ADF&G Fisheries Scientist, to Ken Goldman, ADF&G Fisheries Biologist, dated November 17, 2016, unpublished (Analysis of Harvest Strategy and Legal Size for Cook Inlet Tanner Crab). Unpublished document obtained from Ken Goldman, ADF&G Fisheries Biologist, Homer.

50% of the mean annual abundance of crab over a defined time period (Bishop et al. 2011). The mean annual abundance estimate serves as a proxy of maximum sustainable yield (MSY_{proxy}). In the absence of model-based estimates of MSY for PWSA Tanner crab, the Registration Area E Tanner crab harvest strategy also followed this traditional approach (Goldman et al. 2018). The Registration Area E Tanner crab harvest strategy followed the management policies in the Bering Sea that reduced the legal size of male Tanner crab for commercial fishery harvest (Zheng and Pengilly 2011). The Registration Area E Tanner crab harvest strategy used the abundance estimates of larger size crab (historical legal size) to set the minimum abundance threshold to open a commercial fishery on a smaller size crab (Goldman et al. 2018).

Annual abundance estimates of historical legal-size (135 mm) Tanner crab were generated for PWSA from 1977–2015 (Figure 2) with the mean serving as the MSY_{proxy} and 50% of the mean defined as the minimum abundance threshold to open a commercial fishery (Goldman et al. 2018). The harvest strategy included a mechanism to open the entire registration area to the harvest of legal-size (CW ≥ 5.0 in or 127 mm) crab if the estimated abundance of historical legal-size (CW ≥ 5.3 in or 135 mm) crab in PWSA met or exceeded the threshold. The time series (1977–2015) to generate abundance estimates was based on multiple data sources and methods. For the years 1977–1988, the abundance of historical legal-size crab in the Northern and Hinchinbrook Districts was estimated using a combination of the commercial harvest, an estimate of exploitation rate from mark–recapture data, and mean weights in the fishery. Abundance estimates of historical legal-size crab from the PWSA trawl survey were used for the years 1990–2015 to complete the time series.

The time series of abundance estimates was over a period of highly variable relative abundance and harvest. During 1977–1988, harvest varied and was assumed to exceed MSY and the relative abundance decreased as the stock eventually declined to the point that Registration Area E was closed. During 1990–2015, trends in the historical legal-size Tanner crab relative abundance (from trawl survey abundance estimates) varied from an initial high, a depressed state in the late 1990s, a second peak in 2013, and a decreasing trend through 2019 (Rhea-Fournier et al. *In prep* a), all during a period of commercial fishery closure.

The annual combined abundance estimates for historical legal-size crab from 1977–2015 had a mean of 400,000 crab, which became the MSY_{proxy}. The minimum abundance threshold to open the fishery was defined as 50% MSY_{proxy} or 200,000 historical legal-size crab, as recommended in Goldman et al. 2018. The GHL was set using a step approach with harvest rates at each step scaled to the most recent abundance estimate relative to MSY_{proxy}. The resulting regulation provided a stepwise harvest rate and GHLs starting at 30,000 legal-size crab (15% of the abundance estimate) for PWSA if the minimum abundance threshold was achieved (Table 1).

HISTORICAL ASSESSMENT SURVEYS

From 1977–1991, ADF&G conducted a pot survey in PWSA for Tanner crab. The CPUE (number of crab per pot) of legal-size crab from this survey declined in a manner similar to that observed in the commercial fishery (Goldman et al. 2018). The pot survey was distributed both within Prince William Sound and in the outside waters of PWSA that had the highest effort and harvest before the fishery declined in the early 1980s. The pot survey covered the inside waters of Hinchinbrook Entrance, Orca Bay, and Port Fidalgo and extended from Montague Strait into the outside waters south of Montague Island. The pot survey also covered the outside waters south of Hinchinbrook Entrance, south of the Copper River Delta, and west of Kayak Island. These surveys produced

indices of crab abundance to compare to ensuing commercial harvests (Kimker and Trowbridge 1992).

In 1990, ADF&G replaced the inside waters pot survey with a trawl survey to produce an area-swept abundance estimate, whereas the outside waters pot survey was terminated and not replaced with a trawl survey. The trawl survey area included the eastern portion of the Northern District, the northern portion of the Hinchinbrook District, and the northeastern portion of the Western District (Figure 1). Selection of the survey areas was based on the historical pot survey area, commercial catch information, and Tanner crab habitat, which was composed of waters between 50 and 155 fathoms (Kimker and Trowbridge 1992). The survey was conducted annually until 1995, biennially until 2013, and annually through 2019. The survey area was divided up into a grid composed of stations that were towed every year and were used to calculate an abundance estimate for the surveyed area. The mean CPUE (number of crab per nmi^2) from each surveyed station was expanded to the total survey area to generate an abundance estimate for the surveyed area. The historical PWSA trawl survey did not estimate or project an abundance estimate of Tanner crab for the entire PWSA.

The historical PWSA trawl survey grid consists of 43 stations encompassing 249.6 nmi^2 of survey area resulting in one bottom trawl tow per 5.8 nmi^2 of survey area. ADF&G has relied on the historical bottom trawl survey to assess the PWSA Tanner crab population and has provided a reliable index of stock status for informing management and a means to open and close the fishery. The historical survey results are difficult to interpret relative to the harvest strategy adopted in 2017 because it does not provide a total abundance estimate for the entirety of Registration Area E. The historical survey design does not assess areas with historical high harvest in the outside waters of PWSA or areas with recent commissioner's permit fishery harvest. Areas outside the trawl survey area would open by regulation if minimal thresholds were met, but population status in those areas would not inform the harvest strategy. Furthermore, the abundance estimate time series of historical legal-size crab for the historical trawl survey area does not match the spatial extent of the abundance estimate produced from historical harvest for the Registration Area E harvest strategy. The historical legal-size crab abundance estimates generated from commercial harvest (1977–1988) are from the entire Hinchinbrook and Northern Districts, whereas the abundance estimates from the historical trawl survey (1990–2015) are for the Hinchinbrook District, part of the Northern District, and a small portion of the Western District (Figure 1). A relatively small portion of the historical survey area is in the Western District, which was open for the commissioner's permit fishery, and thus the historical survey design covers waters that have recently been open to harvest, waters that could potentially be open to harvest, waters where the historical commercial harvest occurred, and waters that are permanently closed to harvest (Figure 1).

PROPOSED DISTRICTS AND HARVEST STRATEGY

At the 2021 BOF, ADF&G submitted a proposal to redefine and rename Tanner crab commercial fishery districts in PWSA (Figure 3) that was adopted into regulation in 5 AAC 35.305 (ADF&G 2021). The 5 new commercial fishery districts adopted included 3 districts for which a new harvest strategy was developed. The Northeastern, Central, and Southwestern Districts were aligned with historical statistical areas to develop a more accurate time series of statistical area-specific historical harvest (Figure 4) and closely aligned to current statistical areas for management purposes (Figure 5). These 3 districts contain a considerable amount of trawlable Tanner crab

habitat and thus allow ADF&G to continue using bottom trawl surveys as the primary Tanner crab assessment method (Rhea-Fournier et al. 2021). The Northwestern District did not have sufficient trawlable habitat to develop an assessment and thus a management strategy based upon trawl assessments could not be developed. The Southeastern District did not have any substantial harvest during recent commissioner's permit and test fisheries and its large size did not make it feasible to develop a management strategy based upon trawl survey assessments.

At the 2021 BOF meeting, ADF&G submitted a proposal to replace the existing Tanner crab harvest strategy in the Prince William Sound Area (Registration Area E) with a new harvest strategy in 5 AAC 35.308 for 3 of the 5 new proposed Tanner crab commercial fishery districts (ADF&G 2021). The proposed harvest strategy and associated bottom trawl assessment surveys were published prior to the BOF meeting as recommendations (Rhea-Fournier et al. 2021).

The proposed harvest strategy followed the approach in the original Registration Area E harvest strategy that used the abundance estimates of historical legal-size crab to develop minimum abundance thresholds to open a commercial fishery on current legal-size crab (Goldman et al. 2018). Since the 2017 BOF meeting and drafting of original Registration Area E Tanner crab harvest strategy, the historical Tanner crab harvest in the ADF&G OceanAK fish ticket database has been updated to include statistical area-specific harvest. Prior to the creation of the original Registration Area E Tanner crab harvest strategy, only district-level Tanner crab historical harvest information was available. The smaller spatial resolution of the historical harvest data allowed for the development of new Tanner crab commercial fishing districts with district-specific historical abundance estimates and associated abundance thresholds to open a commercial fishery.

A MSY_{proxy} was defined for 3 districts as the mean annual abundance estimate from 1977–2015 (same time series as the original Registration Area E harvest strategy) of historical legal-size crab, and the minimum abundance thresholds were 50% of MSY_{proxy}. Abundance for the first part of the time series was estimated from statistical area-specific harvest using a harvest rate conversion (Goldman et al. 2018). The second part of the time series was derived from historical trawl survey information. The density of historical legal-size crab (number of crab per nmi^2) was assumed to be similar between the new commercial fishery districts and historical survey area. The annual CPUE (number of crab per nmi^2) or density of historical legal-size crab from the trawl survey was applied to the Tanner crab habitat in each proposed fishing area (to later be defined as commercial Tanner crab fishing districts) to estimate annual abundance. The 2 data sets were combined to provide a time series of estimated abundance to calculate district-specific MSY_{proxys} and minimum abundance thresholds. This harvest strategy provided stepwise harvest rates to set GHLs for 3 of the 5 new commercial fishing districts in PWSA.

Also, since the 2017 BOF meeting and drafting of original Registration Area E Tanner crab harvest strategy, ADF&G's bottom trawl assessment surveys have expanded beyond the historical survey area into areas with recent commercial harvest. Bottom trawl assessment surveys were designed for the 3 districts within the proposed harvest strategy to estimate abundance following the approach of the historical PWSA bottom trawl survey (Rhea-Fournier et al. 2021a–b, Rhea-Fournier et al. 2022).

AMENDED HARVEST STRATEGY PROPOSAL

After the Registration Area E Tanner crab harvest strategy proposal was presented at the 2021 BOF, discussions took place among ADF&G staff, BOF members, and stakeholders to amend it with substitute language (Record Copy 109). Changes that were discussed and implemented at the

2021 BOF included changing the length of the time series and the size of crab used to develop a MSY_{proxy} and the resulting minimum abundance thresholds to open a commercial fishery in 3 new Tanner crab districts. This amended approach required changes to the stepwise harvest rates resulting in new district-specific GHLs. Finally, a maximum harvest rate was established for the 3 districts. This report describes the methods and results for these changes that resulted in the new Registration Area E Tanner crab harvest strategy that was adopted at the 2021 BOF.

NEW TRAWL SURVEY ASSESSMENT

This report describes the bottom trawl assessment survey that will be used to estimate crab abundance in each of the 3 districts. These abundance estimates will determine if the minimum abundance thresholds have been met. A correction to the source data table of PWSA Tanner crab observations by depth (habitat) is included. A correction in this report modified the previously reported total survey area in the Northeastern, Central, and Southwestern districts (Rhea-Fournier et al. 2021) and stations were added to the Southwestern District.

OBJECTIVES

1. Document the amendments to the proposed Registration Area E (PWSA) Tanner crab harvest strategy.
2. Describe the new bottom trawl survey area and designate survey stations in 3 new PWSA Tanner crab commercial fishery districts.

METHODS

AMENDED HARVEST STRATEGY PROPOSAL

Amendments to the proposed Tanner crab harvest strategy included reducing the length of the time series and the size of male crab used to calculate an MSY_{proxy}. Amendments were also made to the stepwise harvest rates, and a maximum harvest rate for the new Northwestern, Central, and Southwestern districts in PWSA was established.

Minimum Abundance Thresholds

The first amendment to the proposed harvest strategy at the 2021 BOF was to shorten the time series of annual abundance to develop the MSY_{proxy} from 1977–2015 to 1983–2015. This was done to be more representative of current stock status by removing abundance estimates prior to the North Pacific Regime Shift (Wooster and Zhang 2004).

Another amendment to the proposed harvest strategy was to change the size of male Tanner crab for which the time series of annual abundance is based upon from the historical legal size (≥135mm) to mature size (≥113mm). Using the mean from a time series of mature-size male crab abundance to set and assess minimum abundance thresholds is part of commercial fishery management policies in the Kodiak, Chignik, South Peninsula, and Eastern Aleutian Districts and in the Southeast Alaska Region. Further reasoning for changing the size of crab to set minimum abundance thresholds is that smaller crab are present at relatively higher abundance than larger crab and thus are more likely to be caught in assessment surveys. Recent ADF&G trawl assessment surveys caught very few historical legal-size crab and at a low frequency relative to mature-size crab in the Central and Southwestern districts (Rhea-Fournier et al. 2022, *In prep* b). Utilizing a smaller size class of crab that are caught more frequently and in relatively high numbers in the

trawl survey reduces CPUE variance and provides more confidence in abundance estimates for assessment and management purposes.

The development of minimum abundance thresholds for 3 commercial fishery districts follows methods in Goldman et al. (2018) that led to the original Registration Area E Tanner crab harvest strategy, which relies on a time series of abundance estimates of Tanner crab to generate a proxy for MSY. The first part of the time series (1983–1988) estimates abundance from commercial harvest, and the second part of the time series (1990–2015) estimates abundance using information from the historical ADF&G bottom trawl survey. The MSY_{proxy} for the amended harvest strategy proposal is the mean of annual abundance estimates from 1983–2015, and the minimum abundance threshold to open a commercial fishery is 50% of the MSY_{proxy}. An MSY_{proxy} and associated minimum abundance threshold was calculated specifically for the Northeastern, Central, and Southwestern Tanner crab commercial fishery districts in PWSA.

The annual abundance estimates of mature-size male Tanner crab from 1983–1988 were calculated through 3 steps. First, annual harvest (lb) of historical legal-size crab from the historical statistical areas in each of the 3 districts was summed for each year from fish ticket information. Second, abundance of historical-size crab was estimated from the harvest following the methods in Goldman et al. (2018) first developed by Bechtol et al. (2002). Harvest by weight (W_t) was converted to harvest in numbers of crab (N_t) for each year (t):

$$N_t = \frac{W_t}{\overline{w}_t} \tag{1}$$

where $\overline{w}_t$ is the mean weight (2.1 lb) of historical legal-size Tanner crab.

The results of a Tanner crab tagging study conducted over the 1977/78–1981/1982 fishing seasons indicated a mean return rate of 46.5% for historical legal-size crab (Donaldson 1986) and was assumed to be an estimate for a harvest rate (Goldman et al. 2018). Harvest (N_t) was converted to total abundance of historical legal-size crab (L_t) by dividing the mean harvest rate (h) of 0.465 for each year (t):

$$L_t = \frac{N_t}{h} \tag{2}$$

Finally, the annual total abundance of mature-size crab from 1983–1988 was estimated from the annual total abundance of historical legal-size crab by applying the ratio of mature-size to historical legal-size crab caught in the ADF&G bottom trawl survey following previous recommendations (Goldman et al. 2018). The mean annual ratio was calculated from the years 1990–1994 and 2007–2019, which excludes those years of lowest abundance estimates from the trawl survey (Goldman et al. 2018). The ratio (r) was multiplied by the total abundance of historical legal-size crab (L_t) to estimate the total abundance of mature-size crab (M_t):

$$M_t = rL_t \tag{3}$$

The annual abundance estimates of mature-size male Tanner crab from 1990–2015 for the 3 districts were reconstructed using the annual mean CPUE (crab per nmi^2) or density of mature-size crab from the historical trawl survey. The annual mean CPUE of mature-size crab was applied to the nmi^2 of Tanner crab habitat within each of 3 districts using methods from Rhea-Fournier et al. (2020). The commercial Tanner crab fishery was closed during this time series (1990–2015), and thus it was assumed that Tanner crab shared similar population dynamics within PWSA. The density of crab within the traditional trawl survey area was assumed to be similar to the density of

crab in the 3 new districts during this time period. Once test fisheries and commissioner's permit fisheries began in waters mostly outside of the historical trawl survey area, it was no longer appropriate to apply the unfished Tanner crab CPUE from the trawl survey to the new districts where harvest had occurred. The CPUE is calculated using area-swept calculations (Gunderson 1993). The annual mean CPUE was then multiplied by the amount of crab habitat (nmi^2) in each of the 3 new districts (Table 2). $CPUE_i$ for each station (i) within the traditional trawl survey area is calculated by:

$$CPUE_i = \frac{c_i}{d_i p}. \quad (4)$$

Where:

c_i = the number of crab for station i;

d_i = the distance towed (nmi) for station i; and

p = the effective trawl path width (nmi).

Distance towed (d_i) is calculated as the straight-line distance from the start to the end of the tow while the net was on bottom. The effective trawl path width (p) is equal to the designed net width opening of 40 ft converted to nmi.

Mean $CPUE_{jt}$ for each area/district j and each survey year t is calculated as:

$$\overline{CPUE_{jt}} = \frac{\sum_{i=1}^{n_j} CPUE_i}{n_j}, \quad (5)$$

and using the $\overline{CPUE_{jt}}$ above, the annual abundance estimate $\widehat{N}_{jt}$ is reconstructed for each area/district j and each survey year t as:

$$\widehat{N}_{jt} = \overline{CPUE_{jt}} \times A_j . \quad (6)$$

Where:

n_j = the number of stations successfully completed in the area/district j, and

A_j = the survey area (nmi^2) within each district or historical survey station grid j.

Harvest Rates

The final amendment to the proposed harvest strategy was to adjust the harvest rates considering the change in size of male crab used to assess minimum abundance thresholds. For each of the 3 districts, legal harvest rates follow a stepwise approach (Figure 6):

1. 10% if the estimated abundance of mature-size male crab (≥113mm) males is equal to or greater than the threshold (50% MSY_{proxy}) and less than 75% MSY_{proxy},
2. 15% if the estimated abundance of mature-size male crab (≥113mm) males is equal to or greater than the 75% MSY_{proxy} and less than the MSY_{proxy}, and
3. 20% if the estimated abundance of mature-size male crab (≥113mm) males is equal to or greater than the MSY_{proxy}.

MSY_{proxy}, minimum abundance thresholds, and harvest rates were all calculated and then rounded to the hundreds for ease of management applications.

NEW TRAWL SURVEY ASSESSMENT

Abundance is estimated for the survey area in each of the 3 districts to assess if the minimum abundance threshold has been met to open a fishery. The survey area is based upon Tanner crab habitat, which is defined from observations of Tanner crab catches from multiple sources within each of the 3 districts (Table 3). Catch and depth information from ADF&G surveys along with commissioner's permit and test fisheries (with logbooks requiring location and depth of pot lifts) were compiled to summarize catch by depth. Within each of the 3 districts, over 98% of the legal-size Tanner crab were caught between 50 and 155 fathoms (Figure 7).

RESULTS

AMENDED HARVEST STRATEGY

The amended harvest strategy in this report was submitted by ADF&G as Record Copy 109 and adopted into regulations at the December 2021 BOF as substitute language for Proposal 75, ADF&G's previously submitted harvest strategy recommendation (Rhea-Fournier et al. 2021).

Minimum Abundance Thresholds and Harvest Rates

A time series of annual abundance estimates of historical legal-size Tanner crab (135 mm) was generated for each of 3 districts beginning in the 1982/1983 commercial fishing season and ending with the 2015 historical PWSA bottom trawl survey. For the first part of the time series, abundance estimates are derived from historical commercial harvest information. Commercial harvest (lb) from each historical statistical area in each of the 3 districts was summed for each commercial season (Table 4). The weight of the seasonal harvest was converted to numbers of crab using a mean Tanner crab weight (Equation 1), and the harvested number of crab was converted to an abundance estimate by dividing by the estimated harvest rate (Equation 2) to produce a time series of annual abundance estimates for historical legal-size crab from the 1982/1983 season through the 1987/1988 season (Table 5). The annual abundance estimates for historical legal-size crab were converted to abundance estimates of mature-size crab by multiplying the mean ratio (r) of mature-size crab to historical legal-size crab abundance estimates (r = 4.107) from the historical trawl survey (1991 to 1994 and 2007 to 2015) in Equation 3 for the time series (Table 6). Surveys occurring from 1995 to 2006 were not included due to very low abundance.

For the second part of the time series, abundance estimates are derived from historical trawl survey information. The annual mean CPUE (crab per nmi^2) of mature-size crab calculated from Equations 3 and 4 from the historical PWSA bottom trawl survey was multiplied by the nmi^2 of Tanner crab habitat in each of the 3 districts (Equation 5, Table 1) to construct a time series of estimated abundance of mature-size crab from 1990 to 2015 (Table 7).

The mean annual abundance estimate serves as a MSY_{proxy} and the minimum abundance threshold is 50% of the MSY_{proxy} (Goldman et al. 2018) for each of the 3 districts (Table 8). The harvest rates (in numbers of crab) of 10, 15, and 20% for the assessed population are applied to each of the 3 new districts respectively.

The completed time series of annual abundance produced a mean estimate (MSY_{proxy}) for the Northeastern District of 435,700 mature-size crab and a minimum abundance threshold (50% of MSY_{proxy}) of 217,800 mature-size crab (Figure 8). If the minimum abundance threshold is met, the minimum harvest would be 10% of the mature-size crab abundance estimate; 21,800 legal-size crab (Table 9).

The completed time series of annual abundance produced a mean estimate (MSY_{proxy}) for Central District of 493,500 mature-size crab and a minimum abundance threshold (50% of MSY_{proxy}) of 246,700 mature-size crab (Figure 9). If the minimum abundance threshold is met, the minimum harvest would be 10% of the mature-size crab abundance estimate, or 24,700 legal-size crab (Table 10).

The completed time series of annual abundance produced a mean estimate (MSY_{proxy}) for Southwestern District of 653,900 mature-size crab and a minimum abundance threshold (50% of MSY_{proxy}) of 327,000 mature-size crab (Figure 10). If the minimum abundance threshold is met, the minimum harvest would be 10% of the mature-size crab abundance estimate; 32,700 legal-size crab (Table 11).

Finally, a maximum harvest rate of 20% legal Tanner crab was defined for all 3 of the districts.

NEW TRAWL SURVEY ASSESSMENT

The survey area (Tanner crab habitat) in each of the 3 districts was modified slightly from the previous publication (Rhea-Fournier et al.) and stations were added to the Southwestern District (Table 12).

Survey areas were defined for the Northeastern, Central, and Southwestern Districts and a fixed station bottom trawl survey grid was established (Figure 11) following the methods for the ADF&G historical bottom trawl survey (Goldman et al. 2017). The district boundaries and station definitions in the Northeastern and Central Districts remain the same as previously described (Rhea-Fournier et al. 2021) with the survey area defined as all waters considered Tanner crab habitat (50 to 155 fathoms in depth). Station size was based on 6.25 nmi^2 grid stations and then modified to account for depth, slope, and ability to trawl. The 46 stations in the Northeastern District and the 42 stations in the Central District resulted in one trawl tow per 6.9 nmi^2 of Tanner crab habitat.

The mean station size in the Southwestern District is larger than in the Northeastern and Central districts due to the larger area and the need to accommodate limited vessel time, funding, and vessel capacity. The Southwestern District is offshore and thus weather and sea state can be much more turbulent than in the inside waters of PWSA. There are no safe harbors to anchor so each survey day requires additional travel that is not necessary for surveys in the inside waters. In addition, the southern boundary of the newly created Southwestern District now ends at the northern margin of the United States exclusive economic zone (EEZ) boundary, which is 200 nmi from the territorial sea baseline. At 2,325 nmi^2, the Southwestern District is relatively large comparatively and thus it is not feasible to survey all waters considered to be potential Tanner crab habitat. Therefore, the survey area in the Southwestern District (for which Tanner crab abundance estimates are generated) is limited to waters north of 59° 30′ N latitude, excluding the Junken Bank (Figure 11). The Junken Bank, located in the southwest corner of the Southwestern District, has very rough (rugose), hard substrate that is not considered appropriate Tanner crab habitat and thus waters less than 80 fathoms in depth are excluded from the survey area. The new Southwestern District boundary was extended east to 147° 54′ W longitude at Cape Cleare, located at the southwestern tip of Montague Island. Because this survey area was increased, there was a need to add 2 new stations, which is an update to the total number of stations in the previously published assessment survey plan in Rhea-Fournier et al. 2021. There are 56 stations in the Southwestern District survey area resulting in 1 trawl tow per 9.9 nmi^2.

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TABLES AND FIGURES

Table 1.–Registration Area E (Prince William Sound Area) harvest strategy, harvest rates, and guideline harvest levels (GHL) adopted at the 2017 Alaska Board of Fisheries.

Abundance estimate[a]	% MSY_{proxy}	Harvest rate	GHL[b]
200,000 to <300,000	50% to <75%	15%	30,000 to 45,000
300,000 to <400,000	75% to <100%	20%	60,000 to 80,000
≥400,000	100%+	25%	100,000+

[a] Number of historical legal-size (≥135 mm) crab.

[b] Number of legal-size (≥127 mm) crab.

Table 2.–Tanner crab habitat within 3 new Tanner crab commercial fishery districts in the Prince William Sound Area used to generate time series of annual abundance from historical trawl survey catch-per-unit-effort.

District	nmi^2
Northeastern	319.66
Central	288.84
Southwestern	537.27

Table 3.–Number of legal-size male (carapace width ≥127 mm) Tanner crab caught, by depth range, in 3 new Tanner crab commercial fishery districts in the Prince William Sound Area.

Data Source	Years	Districts	Depth (fathoms) <50	Depth (fathoms) 50–155	Depth (fathoms) >155	Total observations	Percentage (50–155 fathoms)
Historical pot survey	1977–1991	Northeastern	1,242	63,440	0	64,682	98.08%
Historical pot survey	1977–1991	Central	0	52,481	528	53,009	99.00%
Historical pot survey	1977–1991	Southwestern	6	3,160	0	3,166	99.81%
Trawl survey	1990–2020	Northeastern	0	2,267	0	2,267	100.00%
Trawl survey	1990–2020	Central	0	610	0	610	100.00%
Trawl survey	1990–2020	Southwestern	0	10	0	10	100.00%
Pot survey	2018–2019	Northeastern	0	20	0	20	100.00%
Pot survey	2018–2019	Central	0	291	0	291	100.00%
Pot survey	2018–2019	Southwestern	0	26	0	26	100.00%
Commissioner's Permit Fishery	2018–2020	Northeastern	0	3,782	0	3,782	100.00%
Commissioner's Permit Fishery	2018–2020	Central	54	28,126	240	28,420	98.97%
Commissioner's Permit Fishery	2018–2020	Southwestern	105	115,692	0	115,797	99.91%
Test fishery	2016 and 2020	Northeastern	0	7,645	0	7,645	100.00%
Test fishery	2016 and 2020	Central	0	566	0	566	100.00%
Test fishery	2016 and 2020	Southwestern	0	0	0	0	0.00%

Table 4.–Historical harvest (lb) of Tanner crab from OceanAK historical fish tickets query for 3 new Tanner crab commercial fishery districts in the Prince William Sound Area.

	Northeastern District								Central District			Southwestern District		
	Statistical areas								Statistical areas			Statistical areas		
Season	20305	20306	20307	20308	20309	20310	20311	Total	20101	20400	Total	20102	20105	Total
1976/77		134,770	98,455	102,853	61,842	169,878	127,603	695,401	80,410	424,490	504,900	78,288	191,930	270,218
1977/78		168,634	91,000	162,341	50,292	337,804	143,745	953,816	25,215	688,331	713,546	86,544	296,148	382,692
1978/79		99,045	96,893	68,938	22,527	66,143	156,905	510,451	23,295	535,440	558,735	146,692	397,019	543,711
1979/80		20,851	7,297	20,473	205	30,828	20,019	99,673	20,754	151,425	172,179	35,322	128,590	163,912
1980/81	8,890	17,770	33,552			39,946	16,447	116,605	57,625	500,603	558,228	182,233	369,974	552,207
1981/82	54,848	42,526	57,128			91,403	15,955	261,860	138,585	335,967	474,552	73,146	404,870	478,016
1982/83	199,604	126,310	26,038					351,952	162,630	31,447	194,077	27,211	331,430	358,641
1985/86	10,581	47,006	9,464			38,921		105,972	102,754	235,127	337,881	29,297	29,042	58,339
1986/87	75,021	25,491	1,360			13,039		114,911	67,388	204,917	272,305	59,228	28,459	87,687
1987/88	18,804	948	1,853			18,465		40,070	35,395	212,600	247,995	100,566	33,863	134,429

Note: Blank cells indicate that no harvest occurred.

Table 5.–Estimated abundance of historical legal-size Tanner crab (≥135 mm) from commercial fishery harvest for 3 new Tanner crab commercial fishery districts in the Prince William Sound Area.

	Northeastern District			Central District			Southwestern District		
Season	Harvest (*W*)	Harvest (*N*)	Abundance	Harvest (*W*)	Harvest (*N*)	Abundance	Harvest (*W*)	Harvest (*N*)	Abundance
1976/77	695,401	331,143	712,136	504,900	240,429	517,051	270,218	128,675	276,721
1977/78	953,816	454,198	976,770	713,546	339,784	730,718	382,692	182,234	391,902
1978/79	510,451	243,072	522,735	558,735	266,064	572,181	543,711	258,910	556,796
1979/80	99,673	47,463	102,072	172,179	81,990	176,323	163,912	78,053	167,857
1980/81	116,605	55,526	119,411	558,228	265,823	571,662	552,207	262,956	565,496
1981/82	261,860	124,695	268,162	474,552	225,977	485,972	478,016	227,627	489,520
1982/83	351,952	167,596	360,422	194,077	92,418	198,748	358,641	170,781	367,272
1985/86	105,972	50,463	108,522	337,881	160,896	346,012	58,339	27,780	59,743
1986/87	114,911	54,720	117,676	272,305	129,669	278,858	87,687	41,756	89,797
1987/88	40,070	19,081	41,034	247,995	118,093	253,963	134,429	64,014	137,664

Note: W = weight of crab (lb), *N* = number of crab.

Table 6.–Estimated abundance of mature-size Tanner crab (≥113 mm) for 3 new Tanner crab commercial fishery districts estimated from historical harvest.

	Abundance by district		
Year	Northeastern	Central	Southwestern
1976/77	2,924,602	2,123,425	1,136,438
1977/78	4,011,401	3,000,913	1,609,463
1978/79	2,146,770	2,349,835	2,286,650
1979/80	419,188	724,122	689,354
1980/81	490,398	2,347,703	2,322,381
1981/82	1,101,287	1,995,792	2,010,360
1982/83	1,480,181	816,217	1,508,313
1985/86	445,679	1,421,004	245,352
1986/87	483,274	1,145,215	368,779
1987/88	168,520	1,042,976	565,359

Table 7.–Estimated abundance of mature-size Tanner crab (≥113 mm) for 3 new Tanner crab commercial fishery districts estimated from bottom trawl survey mean CPUE ($\overline{\text{CPUE}}$).

		Abundance by district		
Year	$\overline{\text{CPUE}}$	Northeastern	Central	Southwestern
1990	1,738.5	555,727	502,142	934,041
1991	1,643.9	525,492	474,822	883,224
1992	1,547.0	494,515	446,832	831,159
1993	1,559.3	498,441	450,379	837,758
1994	954.1	304,984	275,576	512,603
1995	503.2	160,863	145,352	270,372
1997	182.8	58,424	52,791	98,197
1999	82.0	26,215	23,687	44,061
2001	263.5	84,231	76,109	141,571
2003	424.4	135,663	122,582	228,016
2005	586.5	187,482	169,404	315,111
2007	976.6	312,187	282,085	524,711
2009	1,525.3	487,574	440,561	819,494
2011	3,054.1	976,276	882,140	1,640,882
2013	2,032.3	649,643	587,002	1,091,891
2014	1,860.4	594,712	537,368	999,567
2015	1,622.8	518,733	468,715	871,864

Note: CPUE = number of crab per nmi^2.

Table 8.–Maximum Sustainable Yield proxy (MSY_{proxy}) and minimum abundance threshold (50% MSY_{proxy}) to open commercial fisheries in 3 new Tanner crab commercial fishery districts in the Prince William Sound Area.

District	MSY_{proxy}[a]	Threshold[a]
Northwestern	435,700	217,800
Central	493,500	246,700
Southwestern	653,900	327,000

Note: MSY_{proxy} is mean annual abundance estimate.

[a] Number of mature-size (≥113 mm) crab.

Table 9.–Northwestern District recommended harvest rate and guideline harvest level (GHL).

Abundance estimate[a]	% MSY_{proxy}	Harvest rate	GHL[b]
217,800 to <326,700	50% to <75%	10%	21,800 to 32,700
326,700 to <435,700	75% to <100%	15%	49,000 to 65,400
≥435,700	100%+	20%	87,100+

Note: MSY_{proxy} is Maximum Sustainable Yield proxy (mean annual abundance estimate).

[a] Number of mature-size (≥113 mm) crab.

[b] Number of legal-size (≥127 mm) crab.

Table 10.–Central District recommended harvest rate and guideline harvest level (GHL).

Abundance estimate[a]	% MSY_{proxy}	Harvest rate	GHL[b]
246,700 to <370,100	50% to <75%	10%	24,700 to 37,000
370,100 to <493,500	75% to <100%	15%	55,500 to 74,000
≥493,500	100%+	20%	98,700+

Note: MSY_{proxy} is Maximum Sustainable Yield proxy (mean annual abundance estimate).

[a] Number of mature -size (≥113 mm) crab.

[b] Number of legal-size (≥127 mm) crab.

Table 11.–Southwestern District recommended harvest rate and guideline harvest level (GHL).

Abundance estimate[a]	% MSY_{proxy}	Harvest rate	GHL[b]
327,000 to <490,400	50% to <75%	10%	32,700 to 49,000
490,400 to <653,900	75% to <100%	15%	73,600 to 98,100
≥653,900	100%+	20%	130,800+

Note: MSY_{proxy} is Maximum Sustainable Yield proxy (mean annual abundance estimate).

[a] Number of mature -size (≥113 mm) crab.

[b] Number of legal-size (≥127 mm) crab.

Table 12.–Tanner crab district and station size following post-2021 survey and BOF action.

District	Survey area (nmi^2)	Stations	Avg. station size (nmi^2)
Central	291.07	42	6.9
Northeastern	318.85	46	6.9
Southwestern	559.31	56	9.9

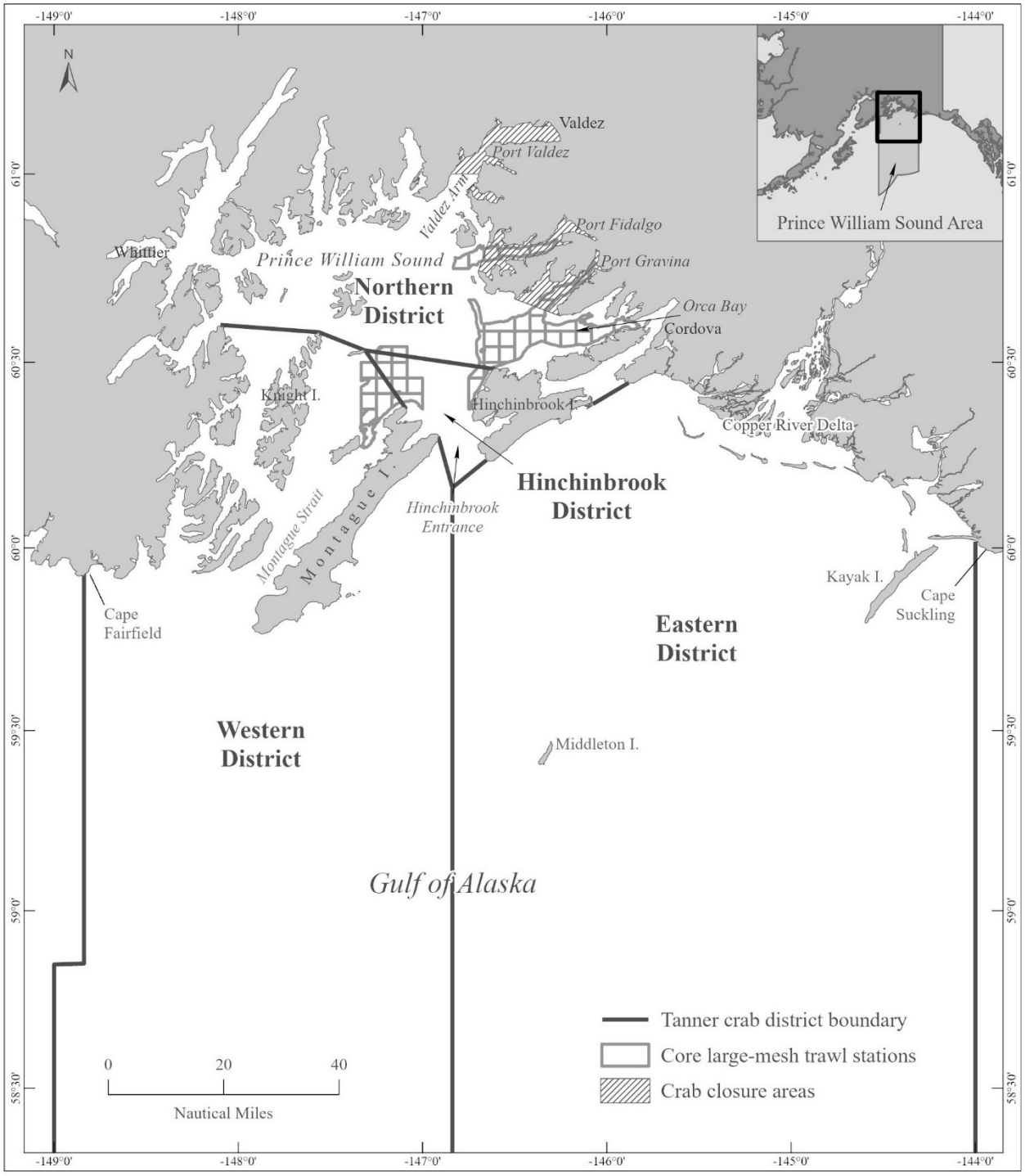

Figure 1.–Prince William Sound Area (Registration Area E) Tanner crab commercial fishery districts (prior to 2021) and location of historical trawl survey stations.

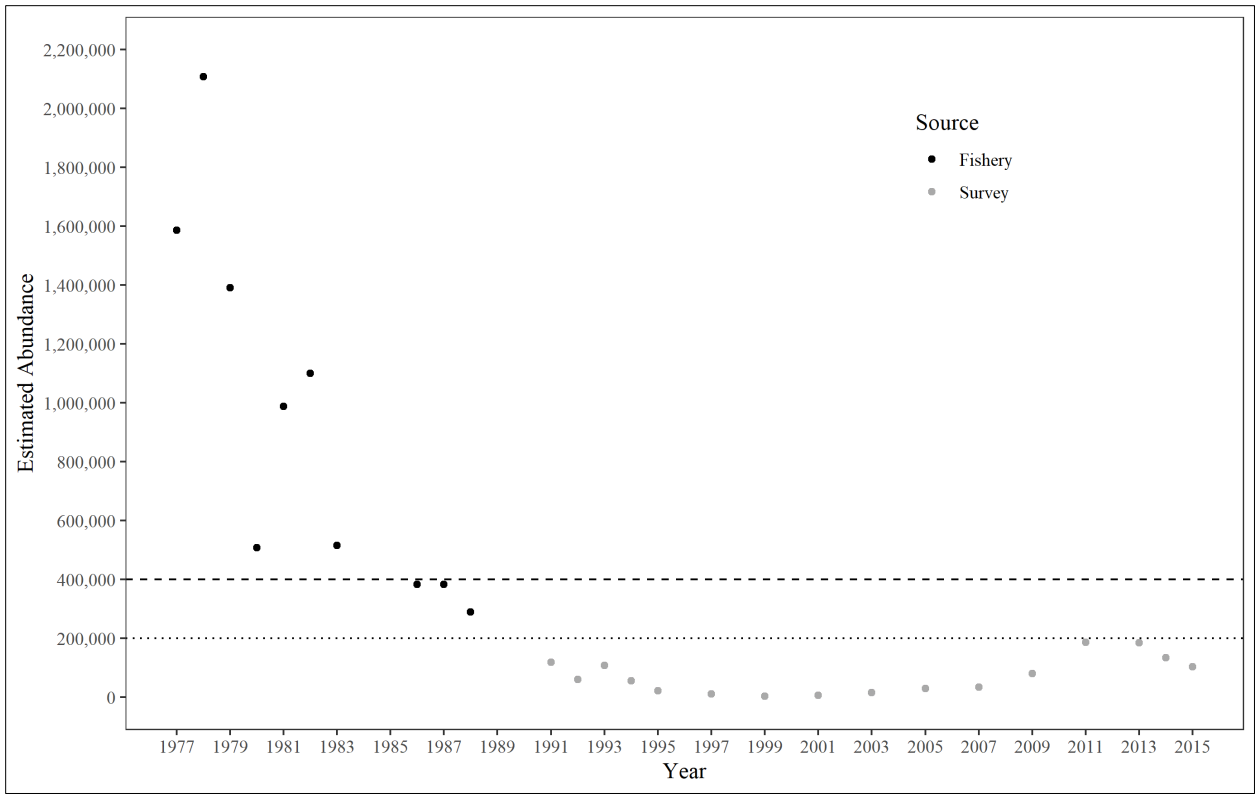

Figure 2.–Annual abundance estimates of historical legal-size (≥135 mm) Tanner crab for the Registration Area E (Prince William Sound Area) harvest strategy adopted at the 2017 Alaska Board of Fisheries.

Note: Dashed line is MSY_{proxy} (mean annual abundance estimate); dotted line is minimum abundance threshold (50% MSY_{proxy}).

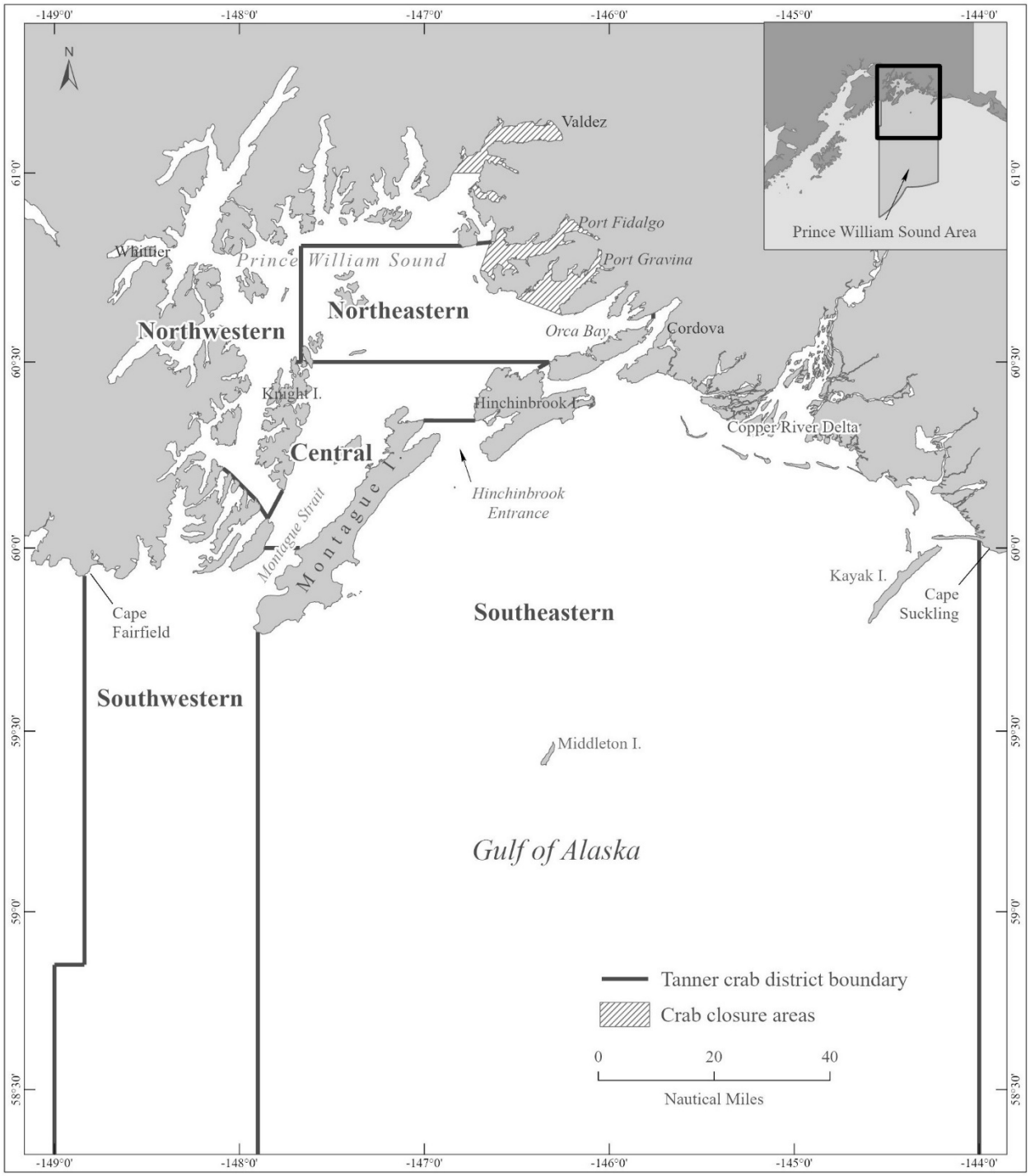

Figure 3.–New Tanner crab commercial fishery districts in the Prince William Sound Area.

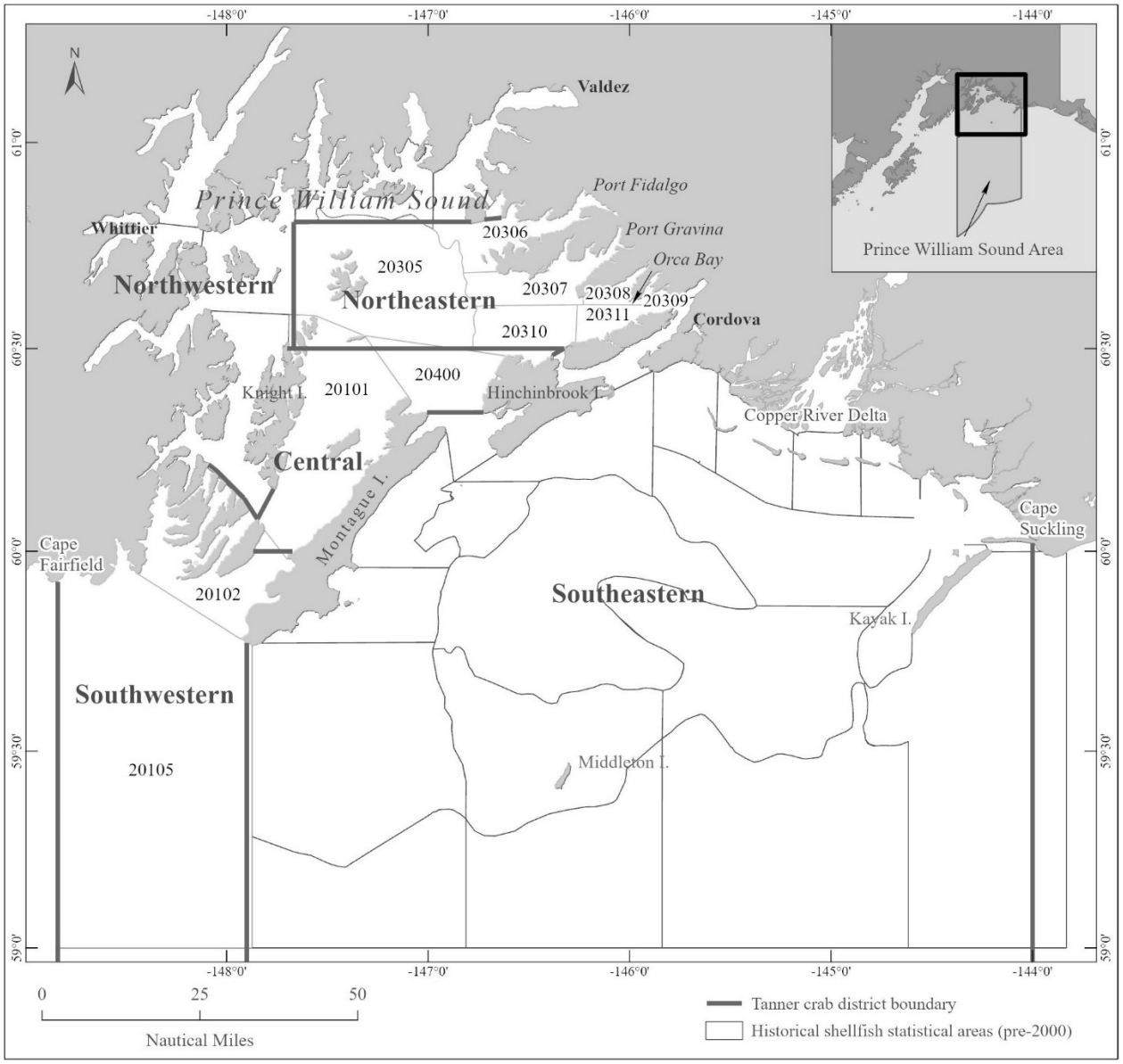

Figure 4.–New Tanner crab commercial fishery districts and historical shellfish statistical reporting areas in the Prince William Sound Area.

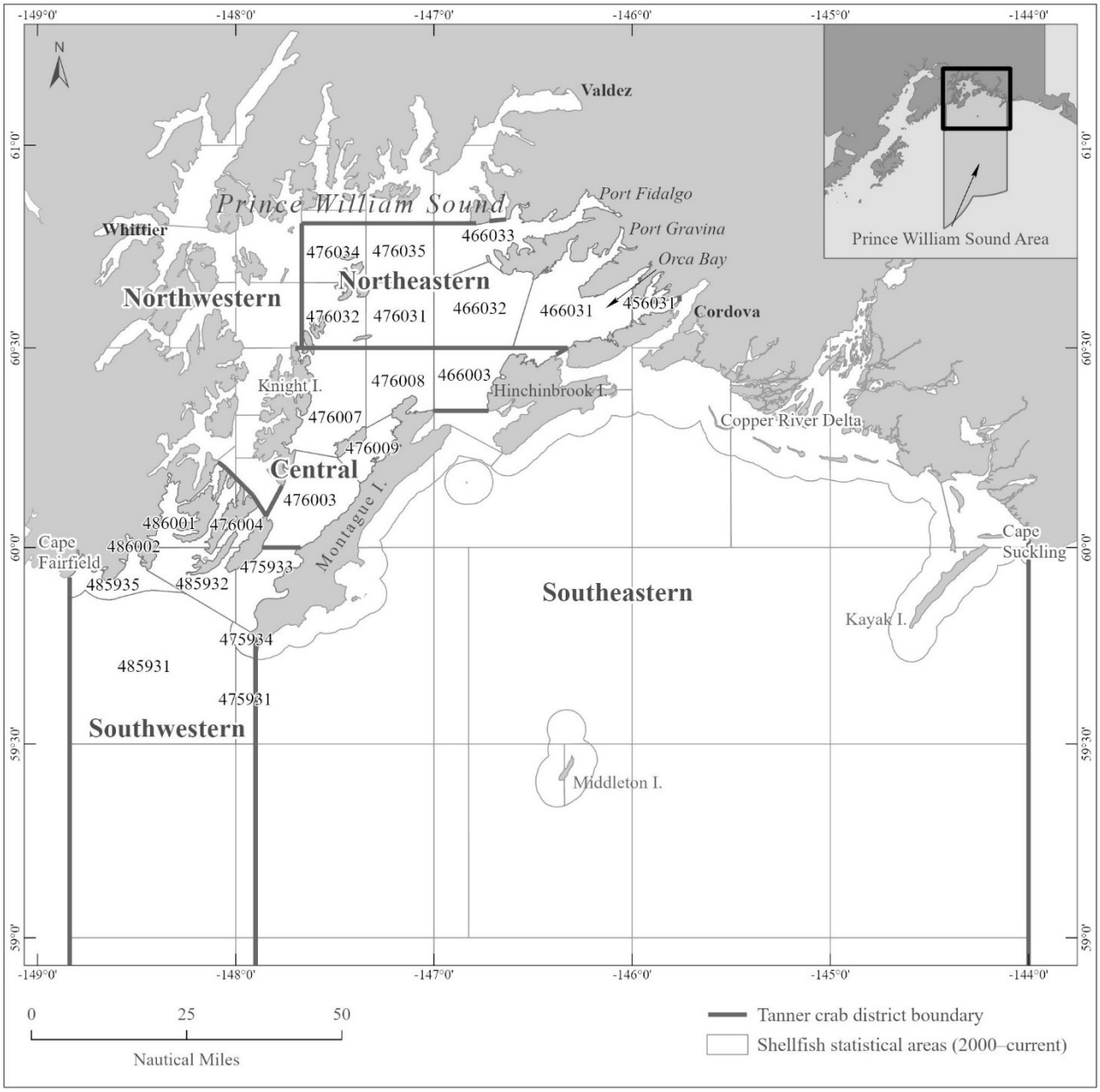

Figure 5.–New Tanner crab commercial fishery districts and current groundfish/shellfish statistical reporting areas in the Prince William Sound Area.

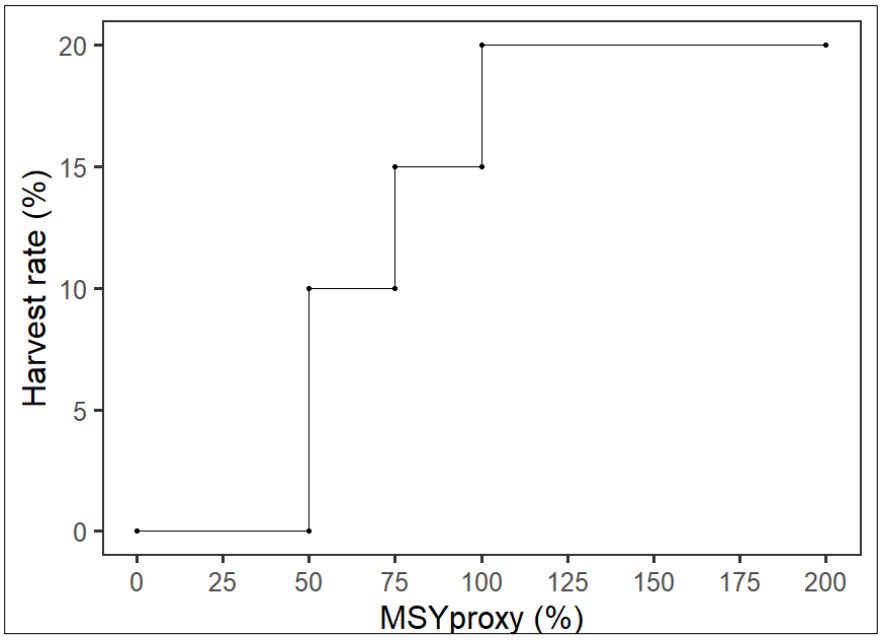

Figure 6.–Harvest control rule for Prince William Sound Area Tanner crab commercial fishery.

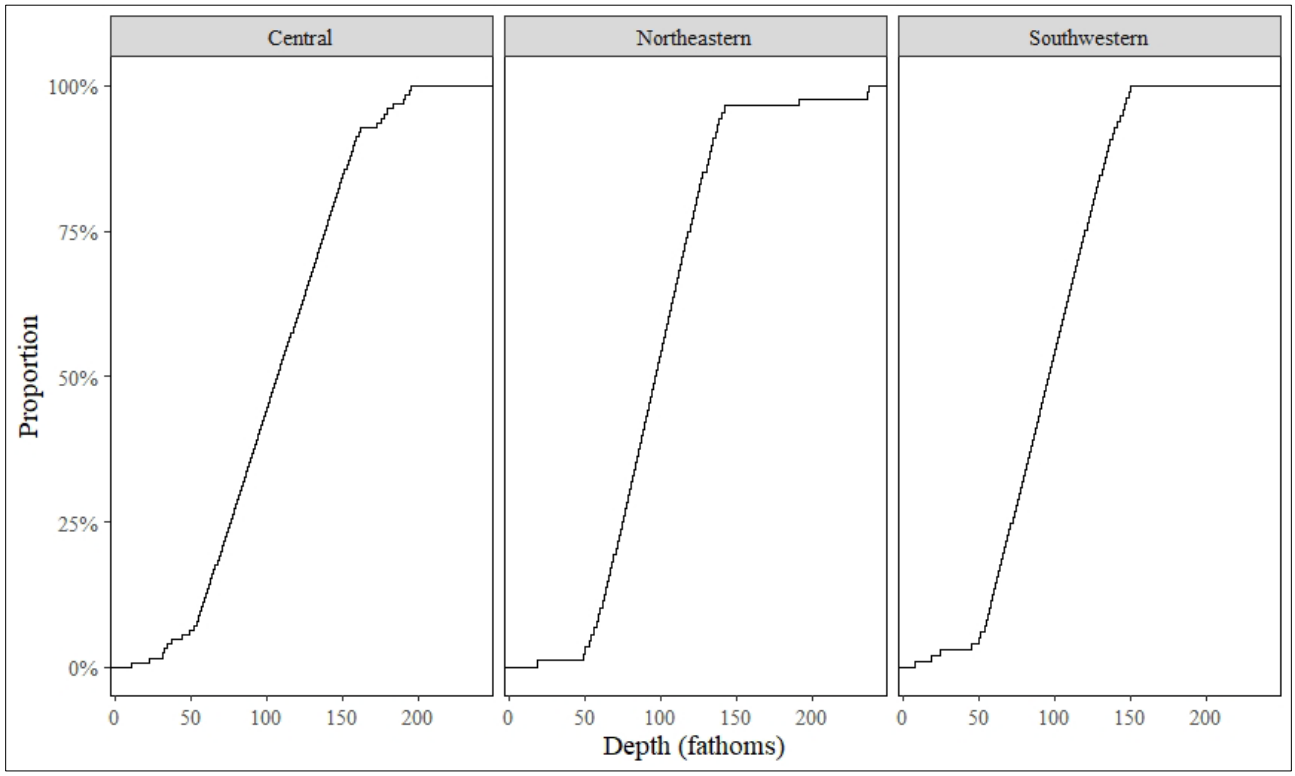

Figure 7.–Legal-size male Tanner crab (≥127 mm) catches by depth for 3 new Tanner crab commercial fishery districts in the Prince William Sound Area.

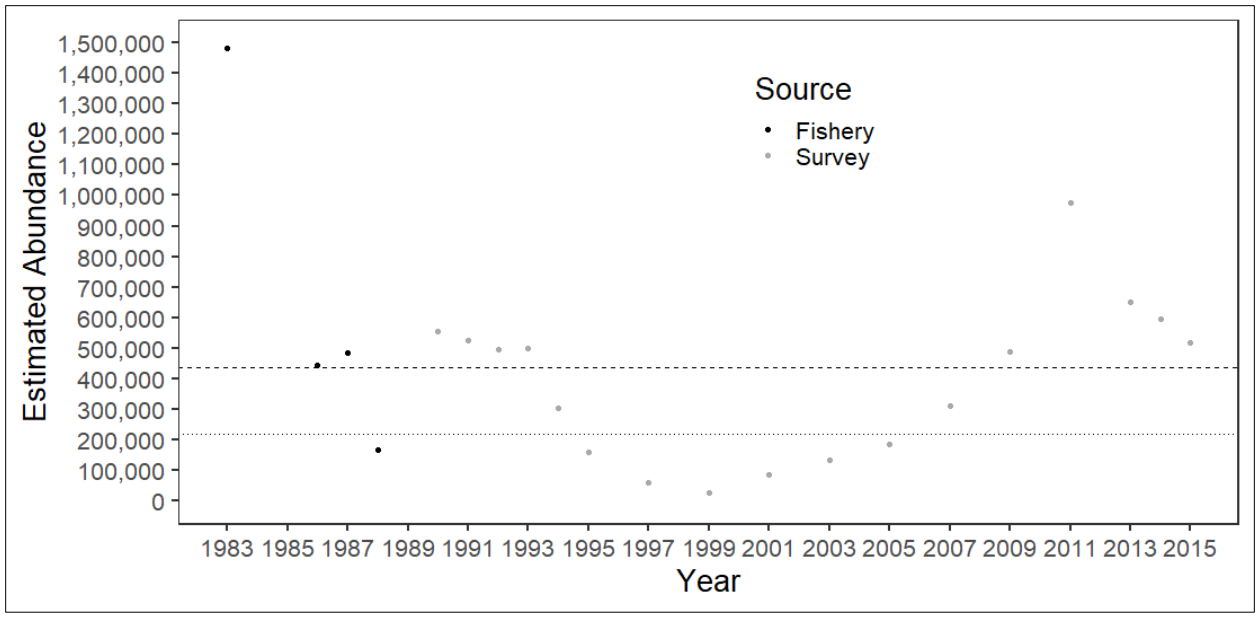

Figure 8.–Northeastern District annual abundance estimates of mature-size (≥113 mm) Tanner crab.

Note: Dashed line is MSY_{proxy} (mean annual abundance estimate); dotted line is minimum abundance threshold (50% MSY_{proxy}).

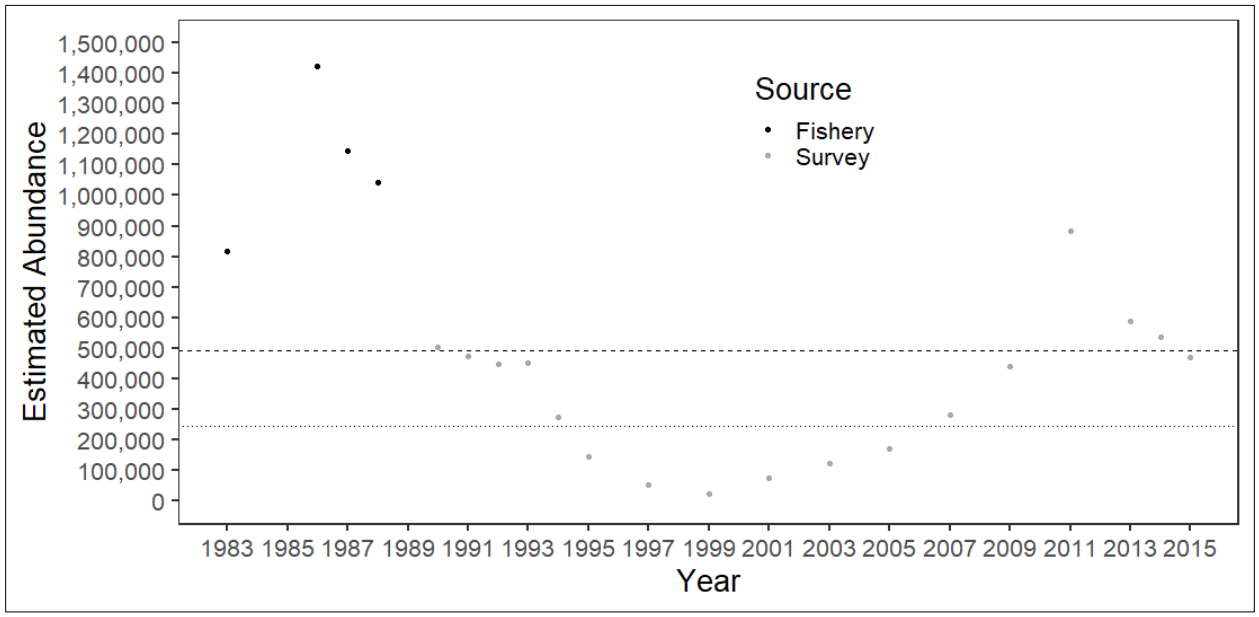

Figure 9.–Central District annual abundance estimates of mature-size (≥113 mm) Tanner crab.

Note: Dashed line is MSY_{proxy} (mean annual abundance estimate); dotted line is minimum abundance threshold (50% MSY_{proxy}).

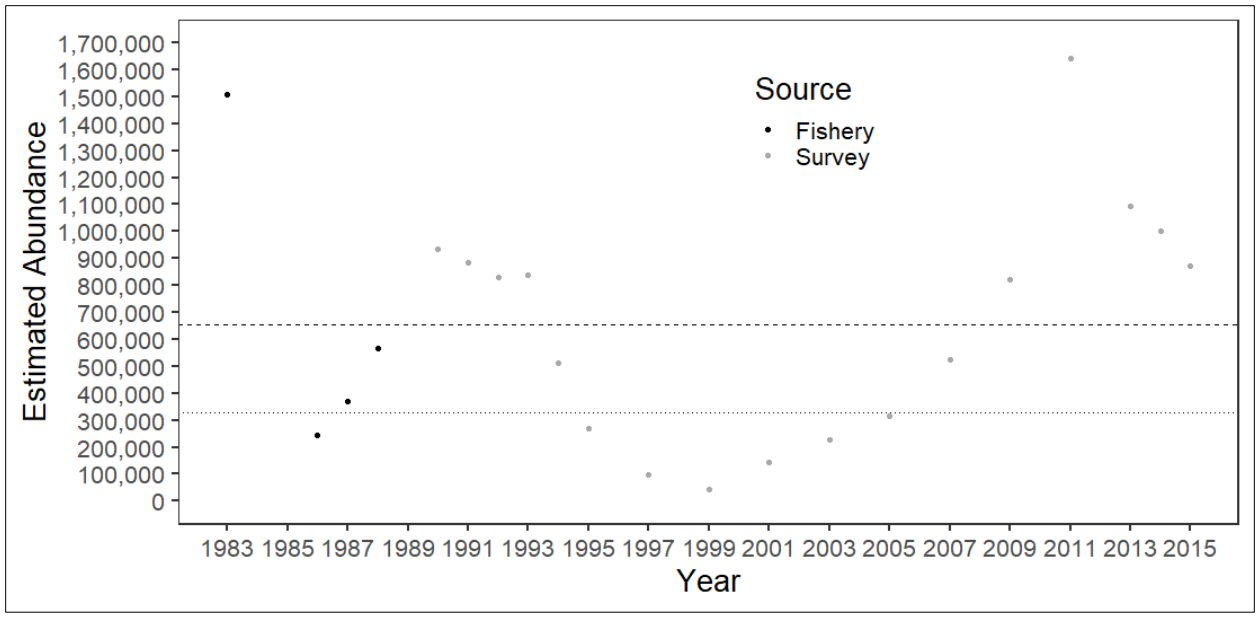

Figure 10.–Southwestern District annual abundance estimates of mature-size (≥113 mm) Tanner crab.

Note: Dashed line is MSY_{proxy} (mean annual abundance estimate); dotted line is minimum abundance threshold (50% MSY_{proxy}).

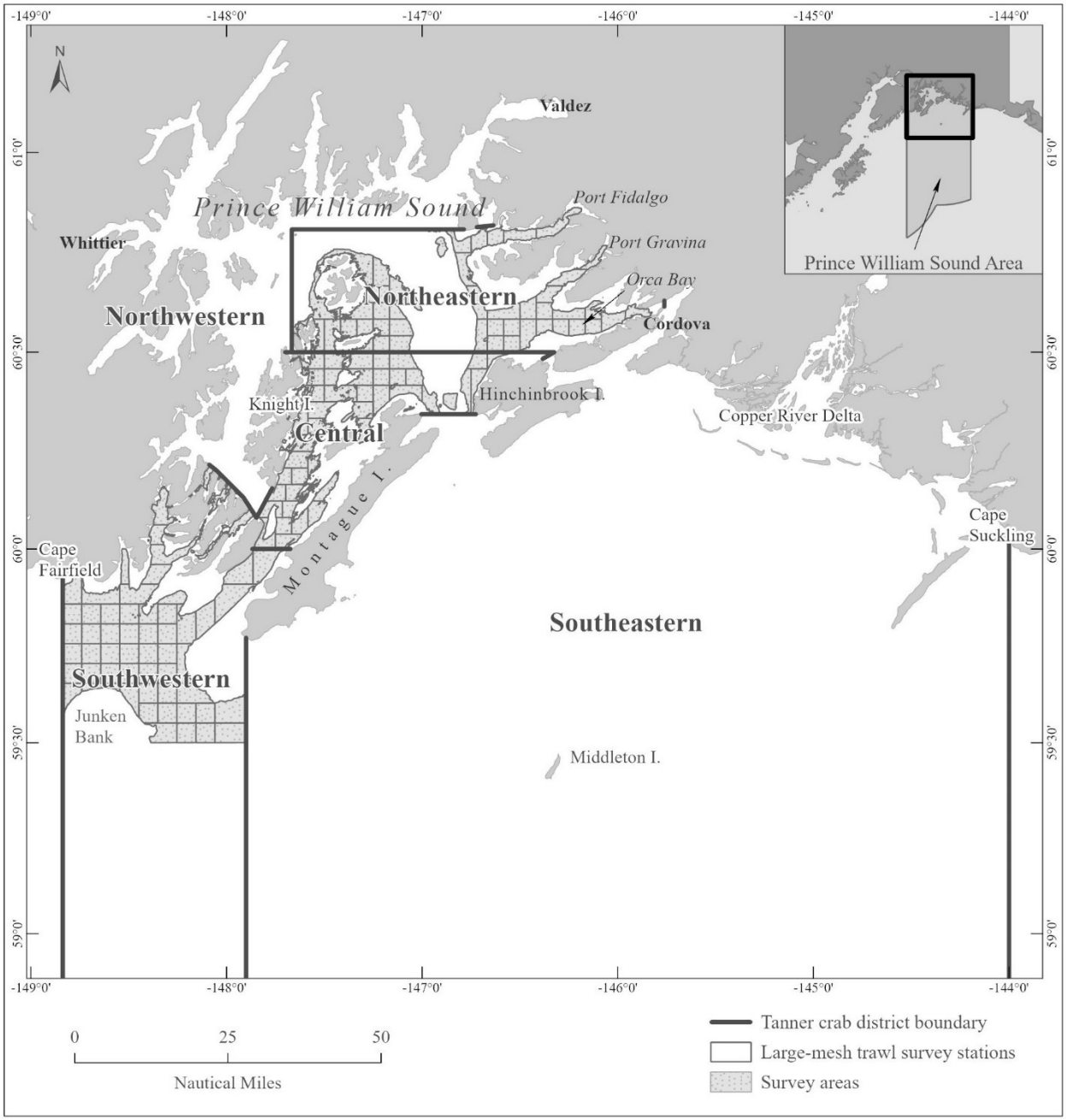

Figure 11.–Bottom trawl survey assessment stations in 3 new Tanner crab commercial fishery districts in the Prince William Sound Area.