Special Publication No. 21-11

Prince William Sound Tanner Crab Commercial Fishery Harvest Strategy Recommendations and Proposed Assessment, 2022

by

Wyatt Rhea-Fournier

Chris Russ

and

Mike Byerly

November 2021

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

Symbols and Abbreviations

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

Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Mathematics, statistics

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

SPECIAL PUBLICATION NO. 21-11

PRINCE WILLIAM SOUND TANNER CRAB COMMERCIAL FISHERY HARVEST STRATEGY RECOMMENDATIONS AND PROPOSED ASSESSMENT, 2022

by
Wyatt Rhea-Fournier, Chris Russ, and Mike Byerly
Alaska Department of Fish and Game, Division of Commercial Fisheries, Homer

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1565

November 2021

The Special Publication series was established by the Division of Sport Fish in 1991 for the publication of techniques and procedures manuals, informational pamphlets, special subject reports to decision-making bodies, symposia and workshop proceedings, application software documentation, in-house lectures, and became a joint divisional series in 2004 with the Division of Commercial Fisheries. Special Publications are intended for fishery and other technical professionals. Special Publications are available through the Alaska State Library, Alaska Resources Library and Information Services (ARLIS) and on the Internet: http://www.adfg.alaska.gov/sf/publications/. This publication has undergone editorial and peer review.

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

Wyatt Rhea-Fournier, Chris Russ, and Mike Byerly,
Alaska Department of Fish and Game, Division of Commercial Fisheries,
3298 Douglas Place, Homer, AK 99603, USA

This document should be cited as follows:
Rhea-Fournier, W. M. Byerly, and C. Russ. 2021. Prince William Sound Tanner crab commercial fishery harvest strategy recommendations and proposed assessment, 2022. Alaska Department of Fish and Game, Special Publication No. 21-11, Anchorage.

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

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

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

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

TABLE OF CONTENTS

Page

LIST OF TABLES ii

LIST OF FIGURES ii

ABSTRACT 1

INTRODUCTION 1

Commercial Fisheries 1

Size at Maturity and Terminal Molt 2

Current Regulations and Harvest Strategy 3

Historical Assessment Surveys 4

Alternative Harvest Strategy 5

OBJECTIVES 6

METHODS 6

Areas 6

Alternative Harvest Strategy 7

Minimum Abundance Thresholds 7

Harvest Rates 8

Proposed Assessment Surveys 9

RESULTS 9

Areas 9

Alternative Harvest Strategy 10

Minimum Abundance Thresholds and Harvest Rates 10

Proposed Assessment Surveys 11

RECOMMENDATIONS 11

ACKNOWLEDGEMENTS 12

REFERENCES CITED 12

TABLES AND FIGURES 15

LIST OF TABLES

Table **Page**

1. Current Registration Area E (Prince William Sound Area) harvest strategy, harvest rate, and guideline harvest level 16
2. Number of legal-size male Tanner crab caught by depth range in the Prince William Sound Area. 16
3. Historical harvest of Tanner crab from OceanAK historical fish tickets query for 3 areas in the Prince William Sound Area. 17
4. Estimated abundance of historical legal-size Tanner crab from commercial fishery harvest for 3 areas in the Prince William Sound Area. 17
5. Tanner crab habitat within 3 areas in the Prince William Sound Area. 18
6. Estimated abundance of historical legal-size Tanner crab for 3 areas based on bottom trawl survey mean CPUE 18
7. Maximum Sustainable Yield proxy and minimum abundance threshold to open commercial fisheries for 3 areas in the Prince William Sound Area. 19
8. Area 1 recommended harvest rate and guideline harvest level 19
9. Area 2 recommended harvest rate and guideline harvest level 19
10. Area 3 recommended harvest rate and guideline harvest level 19

LIST OF FIGURES

Figure **Page**

1. Prince William Sound Area commercial Tanner crab fishery districts and location of historical trawl survey stations. 20
2. Annual abundance estimates of historical legal-size Tanner crab for Registration Area E harvest strategy. 21
3. Tanner crab habitat within 3 proposed areas in the Prince William Sound Area. 22
4. Legal-size male Tanner crab catches by depth for 3 proposed areas in the Prince William Sound Area. 23
5. Proposed areas and historical shellfish statistical reporting areas in the Prince William Sound Area. 24
6. Proposed areas and current shellfish statistical reporting areas in the Prince William Sound Area. 25
7. Area 1 annual abundance estimates of historical legal-size Tanner crab. 26
8. Area 2 annual abundance estimates of historical legal-size Tanner crab. 26
9. Area 3 annual abundance estimates of historical legal-size Tanner crab. 27
10. Area 1 proposed trawl survey assessment stations in the Prince William Sound Area. 28
11. Area 2 proposed trawl survey assessment stations in the Prince William Sound Area. 29
12. Area 3 proposed trawl survey assessment stations in the Prince William Sound Area. 30

ABSTRACT

The Alaska Department of Fish and Game (ADF&G) has developed a Tanner crab *Chionoecetes bairdi* commercial fishery harvest strategy recommendation with an associated trawl survey assessment for the Prince William Sound Area (PWSA). Methods for developing this harvest strategy follow the approach in the Registration Area E Tanner crab harvest strategy, and methods for developing the survey assessment follow the approach for the historical ADF&G PWSA large-mesh bottom trawl survey. New areas have been proposed and defined within the PWSA with minimum abundance thresholds to open a commercial fishery and harvest rates specific to each area. A bottom trawl survey has been designed for each of the areas to estimate the abundance of Tanner crab and assess if the minimum abundance threshold has been met. Trawl surveys have been completed in 2 of the areas occurring in 2020 and 2021 with results indicating that the abundance estimate does not meet the minimum abundance threshold to open a commercial fishery for Tanner crab in those 2 areas. These recommendations will provide the basis for ADF&G proposals to be submitted at the November 2021 Alaska Board of Fisheries meeting and will inform commercial fishery management decisions in 2022.

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

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) is responsible for the sustainable management of Tanner crab *Chionoecetes bairdi* fisheries in the Prince William Sound Area (PWSA; Registration Area E). Commercial fishing of Tanner crab in PWSA began in 1966 and the fishery rapidly developed in the first few years (Pirtle et al. 1969). Over the next 5 decades, ADF&G established a series of Tanner crab management measures and assessment surveys as the fishery sustained large harvests through the 1970s, declined in the 1980s, closed in 1989, and recently reopened in 2018.

COMMERCIAL FISHERIES

In the first years of the PWSA Tanner crab fishery there were no restrictions on size or sex of crab harvested (Pirtle et al. 1969). PWSA encompasses both the waters of Prince William Sound and the Gulf of Alaska (GOA; Figure 1). At the beginning of the fishery, the commercial fleet was based out of Cordova and through 1971, most of the harvest was in the inside waters of PWSA (within Prince William Sound) with a mean of less than 1 million lb 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 GOA; subsequently, Tanner crab fishing areas and harvest quotas were promulgated by the Alaska Board of Fish and Game for PWSA in 1972. The "Inside" Area, which comprised the waters of Prince William Sound, had a quota of 3.5 million lb of Tanner crab; the "Outside" Area, the waters of the GOA between Cape Suckling and Cape Fairfield, 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 the Outside Area), the following 3 years had a substantial decrease in harvest (Pirtle 1978a). From 1972 to 1976, the majority of Tanner crab harvest from the Outside Area of PWSA occurred south of Montague Island, south of Hinchinbrook Entrance, and south of the Copper River Delta. Concurrent substantial efforts in the inside waters targeted Hinchinbrook Entrance, Orca Bay, Port Fidalgo, and waters just south of 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 inches carapace width (CW) including spines, with a guideline harvest of 3–7 million lb (Pirtle 1978b). Following the adoption of these 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 within Montague Strait in the Inside Area. Starting in 1977, Tanner crab harvest in PWSA was reported and managed by 4 new Tanner crab commercial fishery districts (Figure 1). The Northern and Hinchinbrook Districts are in Prince William Sound, the Eastern District is in the GOA, and the Western District includes 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 PWSA was adopted into regulation (5 AAC 35.311). This regulation allowed commissioner's permits to be issued starting in 2018 for the harvest of Tanner crab in the Western and Eastern Districts. Although this fishery does 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 statistical 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. The current commissioner's permit fishery has similar trends in effort and harvest as the historical fishery in the 1970s. Both the current and historical fishery began with high effort and harvest in the inside waters of PWSA and then expanded into the outside waters.

SIZE AT MATURITY AND TERMINAL MOLT

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 minimum legal size was set at 5.3 in (135 mm) CW. At the 1976 BOF meeting, ADF&G biologists testified that male Tanner crab were believed to be sexually mature at 110–115 mm CW, except for in PWSA where the mean size at maturity was 109 mm (Donaldson and Donaldson 1992). ADF&G biologists at the 1976 BOF meeting suggested that male Alaska Tanner crabs 110–139 mm would be sexually mature at least 1 year and up to 2 years before being of legal size for harvest in 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 where 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 because the relative increase in size of the chela height (CH) enables copulation through grasping of the females (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 Bering Sea snow crab *Chionoecetes* species, as indicated by low levels of circulating molting hormones (Tamone et al. 2005) and findings 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 similar results for each region. The CW size 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} had a mean of 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). There are 2 main stocks of Tanner crab in the Bering Sea; male crab in the western portion are estimated to mature at 103 mm, and male crab in the eastern portion are estimated to mature at 113 mm (Zacher et al. 2020).

CURRENT REGULATIONS AND HARVEST STRATEGY

In 2017, the BOF adopted an ADF&G proposal to decrease the minimum legal size of PWSA Tanner crab to 5 in (127 mm) from the historical minimum legal size of 5.3 in (135 mm) CW. This was the first change to the legal size of an active commercial Tanner crab fishery in the GOA since regulations were adopted at the 1976 BOF meeting. GOA Tanner crab stocks all exhibit determinate growth, a terminal molt, and similar size at maturity, but PWSA is the only active commercial fishery in the GOA that has a reduced legal size, although the legal size of the active fishery in the Bering Sea has also been reduced (Zheng and Pengilly 2011). All other ongoing commercial Tanner crab fisheries in the GOA have kept the minimum legal size of 5.5 in (140 mm) established at the 1976 BOF meeting. The decrease in 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). For terminal molt stocks, the desired results of reducing the legal size are lower bycatches and thus a higher yield over a long term, and lower harvest rates for the faster growing, larger males (Goldman et al. 2018).

In 2017, the BOF also adopted an ADF&G proposal for the Registration Area E Tanner crab harvest strategy (5 AAC 35.308). Tanner crab stocks in the GOA traditionally have a minimum abundance threshold to open a commercial fishery set at 50% of the mean annual abundance of crab over a defined time period (Bishop et al. 2011). The mean annual abundance serves as a proxy of MSY (maximum sustainable yield). In the absence of model-based estimates of MSY for the PWSA Tanner crab stock, the Registration Area E Tanner crab harvest strategy followed this traditional approach (Goldman et al. 2018). Harvest strategies that include a reduced legal size, as

[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.

in the PWSA and the Bering Sea Tanner crab fishery, are recommended to use a larger size class of crab to set harvest levels (Zheng and Pengilly 2011). The abundance estimates for the larger-size crab are used for calculating thresholds to open the fishery and to set total allowable catch of the smaller legal-size crab (Goldman et al. 2018).

A mean annual abundance of historical legal-size (≥135 mm) crab from 1977 to 2015 (a MSY_{proxy}) was generated for PWSA Tanner crab, and 50% of the mean became the minimum abundance threshold in the Registration Area E Tanner crab harvest strategy. The harvest strategy specifies that the department shall estimate the abundance of historical legal-size (≥135 mm) Tanner crab in PWSA and that the commercial fishery will open the entire registration area if the current estimated abundance meets the threshold. The time series (1977–2015) to generate abundance estimates was based on multiple sources over a period of widely ranging stock levels. For the years 1977–1988, abundances for the Northern and Hinchinbrook Districts were estimated using a combination of the commercial harvest, an estimate of exploitation rate from mark–recapture data, and mean weights in the fishery. During 1977–1988, harvest varied and was assumed to exceed MSY and the relative abundance decreased as the stock eventually declined to the point of PWSA closure. Abundance estimates from PWSA trawl surveys were used for the years 1990–2015 to complete the time series. During 1990–2015, trends in abundance estimates from PWSA trawl surveys varied from an initial high, a depressed state in the late 1990s, a second peak in 2013, and a decreasing trend through 2015 (Rhea-Fournier et al. *In prep* a), all during a period of commercial fishery closure. The ADF&G trawl survey area includes the eastern portion of the Northern District, the Hinchinbrook District, and a small portion of the Western District (Figure 1). The abundance estimates from the trawl survey do not match the spatial extent of the abundance estimates generated from commercial harvest. The annual combined abundance estimates for historical legal-size crab from 1977–2015 (Figure 2) 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 subsequent guideline harvest level (GHL) was established using a stepwise 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 crab (15%) for all of PWSA if the minimum abundance threshold was achieved (Table 1).

HISTORICAL ASSESSMENT SURVEYS

The Tanner crab population in PWSA has been assessed through 2 survey methods over the past 5 decades. A pot survey began in 1977 and was conducted until 1991, with the CPUE (number of legal-size crab per pot) showing a decreasing trend that generally paralleled the number of crab harvested in the commercial fishery (Goldman et al. 2018). The pot survey was distributed across the inside and outside waters of PWSA that were fished once the fishery expanded. This survey produced an index of crab abundance (CPUE) 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, as described in the previous section in this report, 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 area was based on the historical pot survey, commercial catch information, and

Tanner crab habitat (Kimker and Trowbridge 1992) and was composed of select waters between 50 and 155 fathoms. The survey was conducted annually until 1995, biennially until 2013, and annually through 2019 (Goldman et al. 2018; Rhea-Fournier et al. *In prep* a). The survey area was divided into a grid composed of fixed core stations that were towed every year and were used to calculate an abundance estimate for the survey area. The mean CPUE (number of crab per nmi^2) from the fixed core stations was expanded to the total survey area to generate an abundance estimate for only the survey area. The historical ADF&G bottom trawl survey did not estimate an abundance of historical legal-size Tanner crab for the entire PWSA. The historical PWSA trawl survey consists of 43 fixed core stations distributed across 249.6 nmi^2 of Tanner crab habitat resulting in a mean of 1 tow per 5.8 nmi^2 of habitat. ADF&G has relied on the historical bottom trawl survey to assess PWSA Tanner crab population and although it did provide a reliable index of stock status for informing management and provided a means to open and close the fishery, it was not directly applicable to the harvest strategy adopted in 2017 because it did not provide a total abundance estimate for the entirety of Registration Area E. The historical survey design also did not directly assess portions of PWSA where harvest occurred during the recent commissioner's permit fishery.

The ADF&G trawl survey provides the only fishery-independent information to monitor Tanner crab stock status in PWSA. In the event of the threshold being achieved in the current harvest strategy, the entire PWSA would be open to commercial fishing and only fishery-dependent data would be available to monitor and manage the fisheries outside of the historical trawl survey area. The Western and Eastern District commissioner's permit fishery, which was opened by the BOF in 2017, has occurred from 2018 to 2021 and is predominantly in portions of the PWSA that are not assessed with the bottom trawl survey. Because there is currently no fishery-independent survey to monitor stock status in the waters of the Eastern and Western Districts, fishery managers have had to rely upon inseason fishery data to monitor and control harvest. The harvest rates and minimum abundance thresholds in regulations apply to the entire PWSA, and thus there are no management strategies for these smaller areas that were fished. Without area-specific strategies, managers must instead use fishery performance, measured by CPUE, to determine when Tanner crab within an area are at risk of becoming depleted.

ALTERNATIVE HARVEST STRATEGY

An alternative to the current Registration Area E Tanner crab harvest strategy would be to have thresholds developed for several smaller areas with new specific trawl survey assessments for each proposed area. The sum of these proposed areas would include the historical bottom trawl survey area, waters commercially fished historically, and waters fished in the recent PWSA Commissioner's Permit fishery. The proposed areas could have a MSY_{proxy} (mean abundance estimate from 1977 to 2015) and resulting minimum abundance thresholds and harvest rates developed following the approach in the Registration Area E Tanner crab harvest strategy. Since the 2017 BOF meeting and drafting of 5 AAC 35.308 Registration Area E Tanner crab harvest strategy development, the historical Tanner crab harvest, as documented in the ADF&G fish ticket database (OceanAK), has been updated to include statistical area-specific harvest. Prior to the creation of 5 AAC 35.308, only district-level Tanner crab historical harvest information was available. The smaller spatial resolution of the historical harvest data should result in a more accurate spatial match when developing the time series of abundance estimates for a MSY_{proxy}. The Registration Area E Tanner crab harvest strategy utilized harvest data from the entirety of the Hinchinbrook and Northern Districts for the first half of the time series and the abundance

estimates from the historical trawl survey for the second half of the time series. These 2 data sources do not have the same spatial extent because the historical trawl survey did not assess all the Tanner crab habitat in these 2 districts.

Proposed areas can be aligned with historical statistical areas to develop a more accurate time series of statistical area-specific historical harvest. Abundance for these proposed areas would be estimated using the same methods used in the current harvest strategy, only with more accurate harvest data. Assuming the density of crab is similar among these proposed areas, mean annual CPUE (number of crab per square nmi) from the historical trawl survey can be applied to the Tanner crab habitat in the proposed areas to complete the time series to calculate MSY_{proxy}. This strategy could provide minimum abundance thresholds and harvest rates specific to each proposed area that would be on a smaller spatial scale than the current Registration Area E Tanner crab harvest strategy. Much of the waters fished in the commissioner's permit fishery is suitable for trawling and thus could be assessed with an expanded bottom-trawl survey to monitor stock status relative to harvest thresholds and the GHLs.

This report proposes 3 area delineations that ADF&G has included in a submitted proposal (Proposal 74) for the 2021 BOF meeting to be considered for boundaries of newly defined Tanner crab commercial fishery districts within PWSA. This report recommends a PWSA Tanner crab commercial fishery harvest strategy with associated trawl survey stock assessments for the 3 proposed areas. An ADF&G proposal (Proposal 75) has been submitted for the 2021 BOF meeting following these recommendations, and if adopted the proposed harvest strategy would supplant the current Registration Area E Tanner crab harvest strategy.

OBJECTIVES

1. Develop a harvest strategy for 3 proposed areas in the PWSA, with each area having a specific MSY_{proxy}, minimum abundance threshold, and harvest rate.
2. Design assessment surveys for 3 proposed areas in the PWSA to generate abundance estimates to inform the harvest strategy.

METHODS

AREAS

Areas have been proposed within PWSA that have historical or recent commercial harvest (or both) and considerable trawlable benthic terrain (slope less than 5 degrees). The 3 proposed areas have substantial Tanner crab habitat, defined as 50 to 155 fathoms (Figure 3). Fishery-dependent and independent data for Tanner crab harvest and collections indicate over 98% of legal-size Tanner crab (≥127 mm) caught occur between 50 and 155 fathoms (Table 2) in each of these 3 areas (Figure 4). The historical PWSA trawl survey area was also limited to a depth of 155 fathoms with respect to geographic areas that had very limited probability of Tanner crab catch or were too deep to trawl (Trowbridge 1992). Depths shallower than 50 fathoms were also excluded from the historical PWSA trawl survey to reduce gear damage and to better represent Tanner crab habitat (Bechtol 1999). Information used to define Tanner crab habitat for this report consists of all data available to ADF&G at the time of this report. Additional information from future fisheries will be analyzed to determine if this definition of Tanner crab habitat is appropriate for the 3 areas. Bathymetry data used to delineate the Tanner crab habitat depth boundaries in each of the 3 areas were obtained from 2 previously compiled digital elevation model (DEM) mosaics. Most of the

PWSA of interest was covered by a DEM created by the National Geophysical Data Center for tsunami modeling (Caldwell et al. 2009). This DEM used an 8/3 arc-second grid at an ~60 m resolution and spanned all the PWSA of interest north of 59° 39′N lat and east of 146° 46′W long. Bathymetry for the southernmost portion of interest in PWSA was obtained from a 100 m raster compiled central GOA by the Alaska Fisheries Science Center (Zimmermann and Prescott 2015). Both DEMs were projected to the same coordinate system (UTM 6N, NAD83). The central GOA raster was resampled with an output cell size the same as the 8/3 arc-second grid, and the 2 rasters were then mosaiced to a single DEM. Raster cell values 91.44 to 283.46 m (50 to 155 fathoms) were reclassed to a single value to create a layer representing available Tanner crab habitat.

The 3 area boundaries were designed to generally align with current statistical area boundaries to facilitate effective management. However, alignment with historical statistical area boundaries was also a goal so historical harvests could be used to generate historical abundance estimates following Goldman et al. (2018).

ALTERNATIVE HARVEST STRATEGY

The years included in the time series to develop the alternative harvest strategy are the same as the years in the time series for the current Registration Area E Tanner crab harvest strategy (1977–2015). The years for both the current and alternative harvest strategy were selected for consistency and accuracy. Prior to 1977, there were no sex or size restrictions on the commercial fishery and thus the harvest information used to estimate abundance may not represent historical legal-size males. The time series for the abundance estimates ended in 2015 due to the absence of an ADF&G trawl survey in PWSA in 2016.

Minimum Abundance Thresholds

The development of minimum abundance thresholds for the 3 areas follows methods in Goldman et al. (2018) that led to the 5 AAC 35.308 Registration Area E Tanner crab harvest strategy, which relies on abundance estimates of historical legal-size (≥135 mm) Tanner crab to generate a proxy for MSY. The MSY_{proxy} is the mean of annual abundance estimates from 1977–2015, and the minimum abundance threshold is 50% MSY_{proxy}.

The 1977–1988 abundance estimates of historical legal-size (≥135 mm) Tanner crab for each of the 3 areas is based on statistical area-specific harvest. The harvest from the historical statistical areas in each of the 3 areas was summed for each year. The harvest was converted to abundance 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):

$$N_t = W_t / mean\ wt. \quad (1)$$

Where *mean wt* 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 (≥135 mm) 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 (A_t) by dividing the mean harvest rate (h) of 0.465 for each year (t):

$$A_t = N_t / h. \quad (2)$$

To complete the time series, abundance estimates of historical legal-size (≥135 mm) Tanner crab from 1990–2015 for the 3 areas were reconstructed using the annual mean CPUE or density of

crab (crab per nmi^2) from the historical trawl survey. The annual mean CPUE was applied to the nmi^2 of Tanner crab habitat within each of the 3 areas. The commercial Tanner crab fishery was closed from 1990–2015 in PWSA, and thus it was assumed that Tanner crab shared similar population dynamics and had a similar density of crab within the traditional trawl survey area and the 3 proposed areas. 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 3 proposed areas where harvest had occurred. The CPUE is calculated using area-swept calculations (Gunderson 1993). The annual mean CPUE was applied to the defined Tanner crab habitat (50 to 155 fathoms) in each of the 3 areas. $CPUE_i$ for each station (i) is calculated by:

$$CPUE_i = \frac{c_i}{d_i p}. \tag{3}$$

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 $CPUE_t$ ($\overline{CPUE}$) for each survey year is calculated for all stations by:

$$\overline{CPUE} = \frac{\sum_{i=1}^{n} CPUE_i}{n}, \tag{4}$$

and the annual abundance estimate for each area j ($\widehat{N}_{j,t}$) is reconstructed using the $\overline{CPUE}_t$ for each year (t) by:

$$\widehat{N}_{j,t} = \overline{CPUE_t}\, A_j\ . \tag{5}$$

Where:

n = the number of stations successfully completed, and

A_j = the standardized area (nmi^2) of Tanner crab habitat within area j.

Harvest Rates

The legal-size (≥127 mm) Tanner crab harvest rates for each of the 3 new areas follow the recommendation provided in Goldman et al. (2018):

1. 15% if the estimated abundance of historical legal-size (≥135 mm) males is equal to or greater than the threshold, but less than 0.75 MSY_{proxy},
2. 20% if the estimated abundance of historical legal-size (≥135 mm) males is equal to or greater than the 0.75 MSY_{proxy} but less than the MSY_{proxy}, and
3. 25% if the estimated abundance of historical legal-size (≥135 mm) 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.

PROPOSED ASSESSMENT SURVEYS

In order to inform the harvest strategy, new trawl survey assessments will be designed for each of the 3 areas using the same trawl survey design and methodology as the historical PWSA Tanner crab large-mesh bottom trawl survey (Goldman at al. 2018). Using a fixed station design, new stations were distributed across Tanner crab habitat in each of the 3 areas with a similar station density (number of stations per nmi^2 of Tanner crab habitat) as the historical PWSA trawl survey.

One trawl tow is conducted at each station and the mean CPUE (number of crab per nmi^2) of all successfully towed stations is applied to the total nmi^2 of Tanner crab habitat within each of the 3 areas to generate an area-specific abundance estimate. The size of each station is not relevant to the survey CPUE calculation. The stations serve as a mechanism to spatially distribute the trawl tows (samples) across the Tanner crab habitat. All stations will be developed, identified, and then assessed during the survey with input from the vessel captain. The vessel captain will determine if a trawl tow is feasible and pick a tow path considering bathymetry, current, and vessel capabilities.

RESULTS

AREAS

The 3 areas that were identified had considerable trawlable bathymetry within the delineated Tanner crab habitat and were aligned with historical (Figure 5) and current statistical reporting areas (Figure 6). The historical statistical areas were partially based on bathymetry contours, whereas the current statistical areas align predominately with latitudinal and longitudinal lines, and thus there are boundaries for the 3 areas that do not completely follow current statistical area delineations.

Area 1 is almost entirely within the Northern District and thus was not fished during the commissioner's permit fishery. Area 1 was consistently fished in earlier fisheries and produced high harvest of crab. Areas 2 and 3 are within the commissioner's permit fishery in the Western District and contain the areas of high harvest and effort in Montague Straight (Area 2) and in the southwest outside PWSA waters (Area 3).

Located in the northeastern inside waters of PWSA, Area 1 includes Orca Bay, Port Fidalgo, Port Gravina, and waters surrounding Naked Island. Area 1 contains the historical statistical areas 20305, 20306, 20307, 20308, 20309, 20310, and 20311 (Figure 5) and the current statistical areas 456031, 466031, 466032, 466033, 476031, 476032, 476034, and 476035 (Figure 6). Area 1 includes those waters east of 147° 40.0′ W long, south of 60° 48.50′ N lat and west to Bligh Island, south of a line from the southeastern point of Bligh Island to Bidarka Point, north of 60° 30.0′ N lat and west to Hawkins Island, and waters west of Salmo Point at 145° 45.86′ W long.

Area 2 is in the central inside waters of PWSA in Montague Straight, Hinchinbrook Entrance, and waters east of Knight Island and was initially developed for the 2020 PWSA trawl survey (Rhea-Fournier et al. 2020). Area 2 contains the historical statistical areas 20101, 20102, and 20400 (Figure 5) and the current statistical areas 466003, 476003, 476007, 476008, and 476009 (Figure 6). Fishery Area 2 encompasses those waters north of a line between Montague Island and Latouche Island at 60° N lat, east of a line from Point Grace to Point Helen, south of 60° 30.0′ N lat from Knight Island to Hawkins Island, west of a line from Hawkins Island to Hinchinbrook

Island (60° 30.0 N lat and 146° 19.45 W long to 60° 28.87′ N lat and 146° 23.13′ W long), and north of a line from Bear Cape to Middle Point at 60° 20.60′ N lat.

Area 3 is in the southwest outside waters of PWSA and was initially developed for the 2021 PWSA trawl survey (Rhea-Fournier et al. 2021). Area 3 contains the historical statistical areas 20102 and 20105 (Figure 5) and the current statistical areas 475933, 476004, 485931, 485935, 485932, 486001, and 486002 (Figure 6). Fishery Area 3 includes those waters east from Cape Fairfield at 148° 50.25′ W long and north of 59° 30′ N and west of 148°, west of point at 59° 44.92′ N lat and 148° W long, then west of Cape Cleare following the state and federal waters 3 nmi boundary north to a point at 59° 48.73′ N lat and 148 0.8′ W long then southeast to Montague Island at 59° 47.11′ N lat and 147° 55.47′ W long, south of line at 60° N lat between Montague Island and Latouche Island, and those waters southwest of a line running from Point Countess to Bainbridge Point to Evans Point and then to Point Grace.

ALTERNATIVE HARVEST STRATEGY

The ADF&G's alternative harvest strategy recommended in this report may be implemented for the 2022 commercial fishery season in PWSA if it is approved by BOF and regulations are amended. For management purposes, the 3 new area delineations in this report will be used to develop new Tanner crab commercial fishery districts to be proposed by ADF&G at the November 2021 BOF meeting. The alternative harvest strategy in this report includes minimum abundance thresholds for each of the 3 areas (proposed districts) that would need to be achieved to open area (district) specific fisheries.

Minimum Abundance Thresholds and Harvest Rates

A time series of annual estimated abundance for historical legal-size Tanner crab (135 mm) was generated for each of the 3 areas beginning in the 1976/1977 commercial fishing season and ending with the 2015 historical PWSA bottom trawl survey. Commercial harvest (lb) from each historical statistical area in each of the 3 areas was summed for each commercial season (Table 3). 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 estimated abundance from the 1976/1977 season through the 1987/1988 season (Table 4). The annual mean CPUE (crab per nmi^2) 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 areas (Equation 5, Table 5) to reconstruct a time series of estimated abundance from 1990 to 2015 (Table 6).

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 areas (Table 7). The recommended harvest rates (in numbers of crab) from Goldman et al. (2018) of 15–25% for the assessed population were applied to each of the 3 areas.

The mean annual abundance estimate (MSY_{proxy}) for Area 1 was 186,600 historical legal-size crab and thus the minimum abundance threshold (50% of MSY_{proxy}) was 93,300 historical legal-size crab (Table 7, Figure 7). If the minimum abundance threshold is met, the minimum harvest would be 15% of the historical legal-size crab abundance estimate or 14,000 legal-size crab (Table 8).

The mean annual abundance estimate (MSY_{proxy}) for Area 2 was 210,000 historical legal-size crab, and the minimum abundance threshold was 105,000 historical legal-size crab (Table 7, Figure 8).

If the minimum abundance threshold is met, the minimum harvest would be 15% of the historical legal-size crab abundance estimate or 15,800 legal-size crab (Table 9).

The mean annual abundance estimate (MSY_{proxy}) for Area 3 was 221,000 historical legal-size crab and the minimum abundance threshold was 110,500 historical legal-size crab (Table 7, Figure 9). If the minimum abundance threshold is met, the minimum harvest would be 15% of the historical legal-size crab abundance estimate or 16,600 legal-size crab (Table 10).

PROPOSED ASSESSMENT SURVEYS

Station size was initially based on 6.25 nmi^2 grid stations in Areas 1 and 2 and then modified to account for depth and slope. The station size in Area 3 is largest and based on a 9 nmi^2 grid due to the larger size and the need to develop an area that can be efficiently trawled considering limited vessel time, funding, and vessel capacity. Area 3 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 for the night in this offshore area, so each survey day requires additional travel that is not necessary for surveys in the inside waters.

The survey stations in Area 1 cover 320.3 nmi^2 of Tanner crab habitat. The historical fixed core survey stations in Port Fidalgo, Port Gravina, and Orca Bay remained the same. New stations were developed in the waters surrounding Naked Island. A total of 46 stations were identified in Area 1 (Figure 10), resulting in 1 trawl tow per 6.9 nmi^2 of Tanner crab habitat.

The survey stations in Area 2 encompass 288.6 nmi^2 of Tanner crab habitat. New trawl stations were developed adjacent to historical core survey stations, which remained the same, between Hinchinbrook and Montague islands. New stations were also developed in the waters east of Knight Island, north of Montague Island, and in Montague Straight. A total of 42 stations were identified in Area 2 (Figure 11) resulting in 1 trawl tow per 6.9 nmi^2 of Tanner crab habitat.

The survey stations in Area 3 make up 537.3 nmi^2 of Tanner crab habitat. All the stations developed in Area 3 were new and located in the southern end of Montague Strait and in the western outside waters of PWSA. Junken Bank in the southwest corner of Area 3 is excluded from the assessment. Junken Bank has very rough (rugose), hard substrate that is not considered as Tanner crab habitat. This habitat predominantly occurs in waters shallower than 80 fathoms, so depths shallower than this were not included because Tanner crab live on the bank. A total of 55 stations were identified in Area 3 (Figure 12), resulting in 1 trawl tow per 9.8 nmi^2 of Tanner crab habitat.

RECOMMENDATIONS

The alternate harvest strategy and proposed assessment surveys presented here form the recommended Tanner crab commercial fishery management policy for PWSA by ADF&G. Assessment surveys were completed in Area 2 in 2020 (Rhea-Fournier et al. *In prep* b) and in Area 3 in 2021 (Rhea-Fournier et al. *In prep* c). Historical legal-size Tanner male crab abundance estimates generated from both surveys were well below the minimum abundance thresholds for Areas 2 and 3 to open a fishery following the alternate harvest strategy presented in this report. If the BOF adopts the alternate harvest strategy, ADF&G would recommend that Areas 2 and 3 be closed to commercial harvest in 2022. Area 1 has not been assessed by an ADF&G trawl survey and thus it is not known if the Tanner crab abundance in Area 1 meets the minimum abundance threshold to open a commercial fishery in accordance with the alternate harvest strategy. The

recommendation from ADF&G would be to keep Area 1 closed to Tanner crab harvest until an assessment is completed. The PWSA bottom trawl survey is scheduled to assess Area 1 in 2022.

ACKNOWLEDGEMENTS

The authors would like to thank David Anderson, Justin Nuzzi, and Chatham Warga of the *R/V Solstice* for exploring new survey areas, being proficient and diligent in trawl gear setting, and rendering assistance while sorting the catch.

REFERENCES CITED

ADF&G (Alaska Department of Fish and Game). 2017. Staff comments on statewide (except Southeast and Yakutat) king and Tanner crab and supplemental issues. Alaska Department of Fish and Game, Regional Information Report 4K17-01, Kodiak.

Bechtol, W. R. 1999. A bottom trawl survey for crabs and groundfish in the Prince William Sound management area, 16-26 August 1997. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A99-24, Anchorage.

Bechtol, W. R., C. E. Trowbridge, and N. Szarzi. 2002. Tanner and king crabs in the Cook Inlet Management Area: stock status and harvest strategies. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A02-07, Anchorage.

Bishop, G., J. Zheng, L. M. Slater, K. Spalinger, and R. Gustafson. 2011. The current status of the fisheries for Chionoecetes spp. (Decapoda, Oregoniidae) in Alaska waters. Pages 109–126 *[In*] New Frontiers in Crustacean Biology. Koninklijke Brill NV, Leiden.

Caldwell, R. J., B. W. Eakins, and E. Lim. 2011. Digital elevation models of Prince William Sound, Alaska—Procedures, data sources and analysis. National Geophysical Data Center, NOAA technical memorandum NESDIS-NGDC-40. https://repository.library.noaa.gov/view/noaa/1178/

Conan, G. Y., and M. Comeau. 1986. Functional maturity and terminal molt of male snow crab, *Chionoecetes opilio*. Canadian Journal of Fisheries and Aquatic Sciences 43(9): 1710–1719.

Conan, G. Y., M. Comeau, M. Moriyasu, and R. Cormier. 1988. Reply to Donaldson and Johnson. Canadian Journal of Fisheries and Aquatic Sciences 45(8): 1501–1503.

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

Dawe, E. G., D. M. Taylor, J. M. Hoenig, W. G. Warren, G. P. Ennis, R. G. Hooper, W. E. Donaldson, A. J. Paul, and J. M. Paul. 1991. A critical look at the idea of terminal molt in male snow crab (*Chionoecetes opilio*). Canadian Journal of Fisheries and Aquatic Sciences 48(11): 2266–2275.

Donaldson, W. E., and B. A. Johnson. 1988. Some remarks on "Functional maturity and terminal molt of male snow crab, *Chionoecetes opilio*." Canadian Journal of Fisheries and Aquatic Sciences 45(8): 1499–1501.

Donaldson, W. E., and W. K. Donaldson. 1992. A review of the history and justification for size limits in Alaskan king, Tanner, and snow crab fisheries. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fishery Research Bulletin 92-02, Juneau.

Goldman, K. J., M. Byerly, J. Mumm, J. Rumble, and J. Zheng. 2018. Bottom trawl surveys for Tanner crab in Lower Cook Inlet and Prince William Sound 1990–2015, with harvest strategy for Prince William Sound. Alaska Department of Fish and Game, Fishery Manuscript No. 18-02, Anchorage.

Gunderson, D. R. 1993. Surveys of fisheries resources. John Wiley & Sons, Inc., London.

Hartnoll, R. G., A. D. Bryant, and P. Gould. 1993. Size distribution in spider crab populations–spatial and temporal variation. Journal of Crustacean Biology 13(4): 647–655.

REFERENCES CITED (Continued)

Kimker, A., and C. Trowbridge. 1992. A bottom trawl survey for crabs in the Prince William Sound management area, August 20-30, 1991. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A92-14, Anchorage.

Paul, A. J., and J. M. Paul. 1995. Molting of functionally mature male *Chionoecetes bairdi* Rathbun (Decapoda: Majidae) and changes in carapace and chela measurements. Journal of Crustacean Biology 15(4): 686–692.

Pirtle, R. B., P. J. Fridgen and J. C. Bailey. 1969. Annual statistical report, Cordova area, 1968. Alaska Department of Fish and Game, Division of Commercial Fisheries, Annual Management Report, Anchorage.

Pirtle, R. B., P. J. Fridgen and J. R. Bailey. 1972. Annual management report, Prince William Sound area, 1971. Alaska Department of Fish and Game, Division of Commercial Fisheries, Annual Management Report, Anchorage.

Pirtle, R. B., and P. J. Fridgen. 1974. Annual management report, Prince William Sound area, 1972 - 1973. Alaska Department of Fish and Game, Annual Management Report, Anchorage.

Pirtle, R. B. 1978a. Annual management report, Prince William Sound area, Region II, 1976. Alaska Department of Fish and Game, Annual Management Report, Anchorage.

Pirtle, R. B. 1978b. Annual management report, Prince William Sound area, Region II, 1977. Alaska Department of Fish and Game, Annual Management Report, Anchorage.

Rebert, A., J. Stratman, K. Palof, A. Messmer, and A. Olson. 2021. Management report for the Southeast Alaska and Yakutat Tanner crab fisheries, 2017/18–2019/20. Alaska Department of Fish and Game, Fishery Management Report No. 21-15, Anchorage.

Rhea-Fournier, W. J., M. Byerly, and C. Russ. 2020. Bottom trawl survey for Tanner crab in Prince William Sound, 2020. Alaska Department of Fish and Game, Regional Operational Plan ROP.CF.2A.2020.06, Homer.

Rhea-Fournier, W. J., M. Byerly, and C. Russ. 2021. Bottom trawl survey for Tanner crab in Prince William Sound, 2021. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Operational Plan No. ROP.CF.2A.2021.03, Homer.

Rhea-Fournier, W. J., M. Byerly, and C. Russ. *In prep* a. Bottom trawl survey for Tanner crab in Prince William Sound, 2017 to 2019. Alaska Department of Fish and Game, Division of Commercial Fisheries, Fisheries Data Series, Anchorage.

Rhea-Fournier, W. J., M. Byerly, and C. Russ. *In prep* b. Bottom trawl survey for Tanner crab in Prince William Sound, 2020. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Rhea-Fournier, W. J., M. Byerly, and C. Russ *In prep* c. Bottom trawl survey for Tanner crab in Prince William Sound, 2021. Alaska Department of Fish and Game, Fishery Data Series, Anchorage.

Richardson, N., K. Bevaart, and K. Phillips. 2020. Annual management report for shellfish fisheries in the Kodiak, Chignik, and South Peninsula Districts, 2019. Alaska Department of Fish and Game, Fishery Management Report No. 20-22, Anchorage.

Rugolo, L. J., D. Pengilly, R. MacIntosh and K. Gravel. 2005. Reproductive dynamics and life-history of snow crab (*Chionoecetes opilio*) in the eastern Bering Sea. Final Completion Report to the NOAA, Award NA17FW1274, Bering Sea Snow Crab Fishery Restoration Research.

Rumble, J., E. Russ, M. Byerly and C. Russ. 2020. Cook Inlet and Prince William Sound area management report for Tanner and king crab fisheries through 2019. Alaska Department of Fish and Game, Fishery Management Report No. 20-10, Anchorage.

Siddon, C. E., and J. A. Bednarski. 2010. Variation in size at maturity of Tanner crab in Southeastern Alaska, U.S.A. Pages 283-294 [*In*] G. H. Kruse, G. L. Eckert, R. J. Foy, R. N. Lipcius, B. Sainte-Marie, D. L. Stram, and D. Woodby, editors. Biology and management of exploited crab populations under climate change. Alaska Sea Grant, University of Alaska Fairbanks.

REFERENCES CITED (Continued)

Somerton, D. A. 1980. A computer technique for estimating the size of sexual maturity in crab. Canadian Journal of Fisheries and Aquatic Sciences 37(10): 1488–1494.

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

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

Trowbridge, C. 1992. A bottom trawl survey for crabs in the Prince William Sound management area, August 3–13, 1992. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 2A92-31, Anchorage.

Wainwright, T. C., and D. A. Armstrong. 1993. Growth patterns in the Dungeness crab (*Cancer magister* Dana): synthesis of data and comparison of models. Journal of Crustacean Biology 13(1): 36–50.

Zacher, L. S., J. I. Richar, and R. J. Foy. 2020. The 2019 eastern and northern Bering Sea continental shelf bottom trawl surveys: Results for commercial crab species. U.S. Department of Commerce, NOAA Technical Memo NMFS-AFSC-400.

Zheng, J., and D. Pengilly. 2011. Overview of proposed harvest strategy and minimum size limits for Bering Sea district Tanner crab. Alaska Department of Fish and Game, Special Publication No. 11-02, Anchorage.

Zimmermann, M., and M. M. Prescott. 2015. Smooth sheet bathymetry of the Central Gulf of Alaska. Alaska Fisheries Science Center, NOAA technical memorandum NMFS-AFSC-287. http://doi.org/10.7289/V5GT5K4F

Zhou, S., T. C Shirley, and G. H Kruse. 1998. Feeding and growth of the red king crab *Paralithodes camtschaticus* under laboratory conditions. Journal of Crustacean Biology 18(2): 337–345.

TABLES AND FIGURES

Table 1.–Current Registration Area E (Prince William Sound Area) harvest strategy, harvest rate, and guideline harvest level (GHL).

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

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

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

	Area 1								Area 2			Area 3		
	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 4.–Estimated abundance of historical legal-size Tanner crab (≥135 mm) from commercial fishery harvest for 3 areas in the Prince William Sound Area.

	Area 1			Area 2			Area 3		
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 5.–Tanner crab habitat (50–155 fathoms) within 3 areas in the Prince William Sound Area.

Area	Habitat[a]
1	320.3
2	288.6
3	537.3

[a] Square nmi.

Table 6.–Estimated abundance of historical legal-size Tanner crab (≥135 mm) for 3 areas based on bottom trawl survey mean CPUE ($\overline{CPUE}$).

		Abundance		
Year	$\overline{CPUE}$	Area 1	Area 2	Area 3
1990	670.8	214,854	193,576	360,390
1991	540.1	173,011	155,876	290,203
1992	272.9	87,416	78,758	146,629
1993	407.6	130,568	117,637	219,011
1994	222.5	71,278	64,219	119,559
1995	68.4	21,914	19,744	36,758
1997	45.4	14,547	13,107	24,401
1999	14.7	4,719	4,252	7,916
2001	26.5	8,503	7,661	14,263
2003	59.9	19,200	17,298	32,205
2005	115.9	37,138	33,460	62,294
2007	147.0	47,089	42,425	78,986
2009	316.9	101,501	91,448	170,254
2011	731.0	234,131	210,943	392,724
2013	741.2	237,396	213,885	398,201
2014	540.6	173,150	156,002	290,437
2015	411.8	131,907	118,843	221,256

Note: CPUE = number of crab per square nmi.

Table 7.–Maximum Sustainable Yield proxy (MSY_{proxy}) and minimum abundance threshold (50% MSY_{proxy}) to open commercial fisheries for 3 areas in the Prince William Sound Area.

Area	MSY_{proxy}[a]	Threshold[a]
1	186,600	93,300
2	210,000	105,000
3	221,000	110,500

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

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

Table 8.–Area 1 recommended harvest rate and guideline harvest level (GHL).

Abundance estimate[a]	% MSY_{proxy}	Harvest rate	GHL[b]
93,300 to <139,900	50% to <75%	15%	14,000 to 21,000
139,900 to <186,600	75% to <100%	20%	28,000 to 37,300
≥186,600	100%+	25%	46,700+

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

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

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

Table 9.–Area 2 recommended harvest rate and guideline harvest level (GHL).

Abundance estimate[a]	% MSY_{proxy}	Harvest rate	GHL[b]
105,000 to <157,500	50% to <75%	15%	15,800 to 23,600
157,500 to <210,000	75% to <100%	20%	31,500 to 42,000
≥210,000	100%+	25%	52,500+

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

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

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

Table 10.–Area 3 recommended harvest rate and guideline harvest level (GHL).

Abundance estimate[a]	% MSY_{proxy}	Harvest rate	GHL[b]
110,500 to <165,800	50% to <75%	15%	16,600 to 24,900
165,800 to <221,000	75% to <100%	20%	33,200 to 44,200
≥221,000	100%+	25%	55,300+

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

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

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

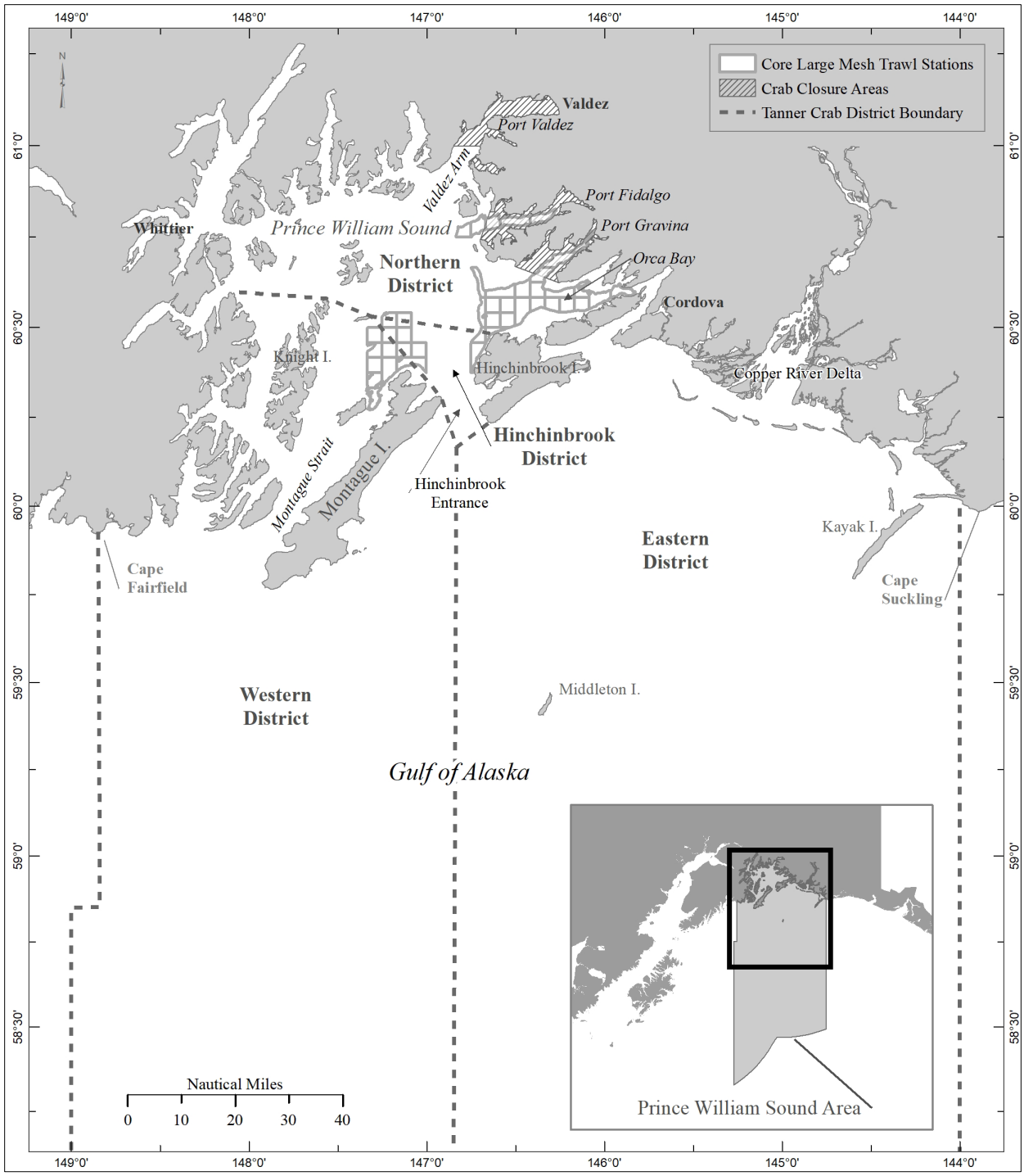

Figure 1.–Prince William Sound Area (Registration Area E) commercial Tanner crab fishery districts and location of historical trawl survey stations.

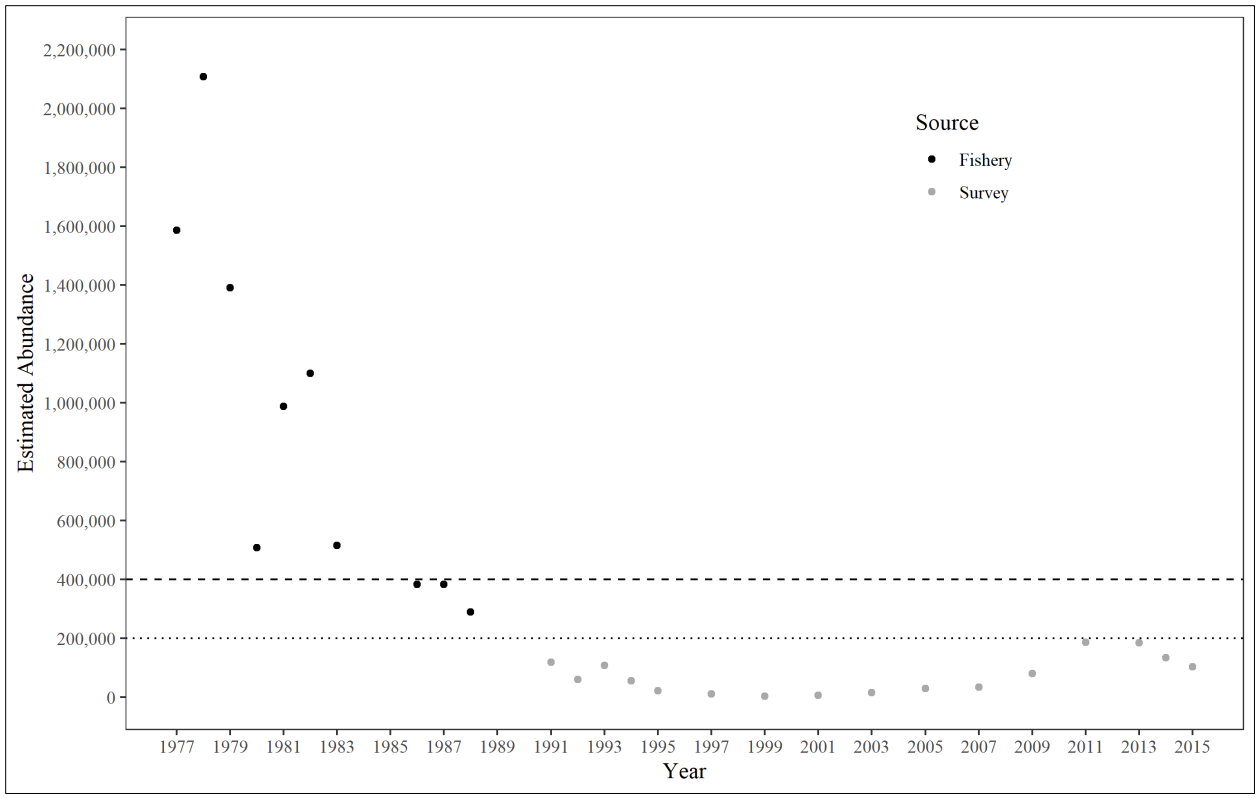

Figure 2.–Annual abundance estimates of historical legal-size (≥135 mm) Tanner crab for Registration Area E (Prince William Sound Area) harvest strategy.

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

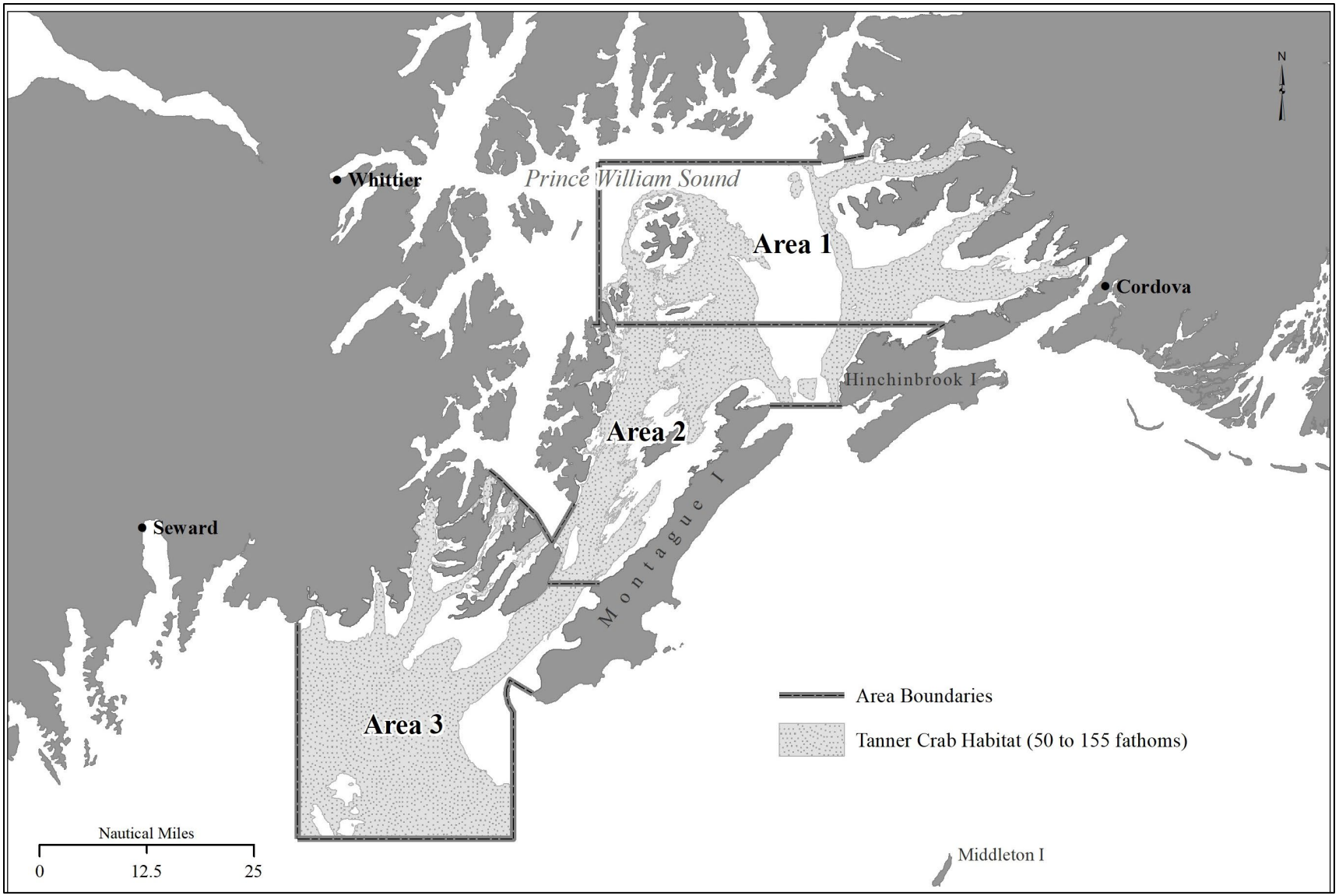

Figure 3.–Tanner crab habitat within 3 proposed areas in the Prince William Sound Area.

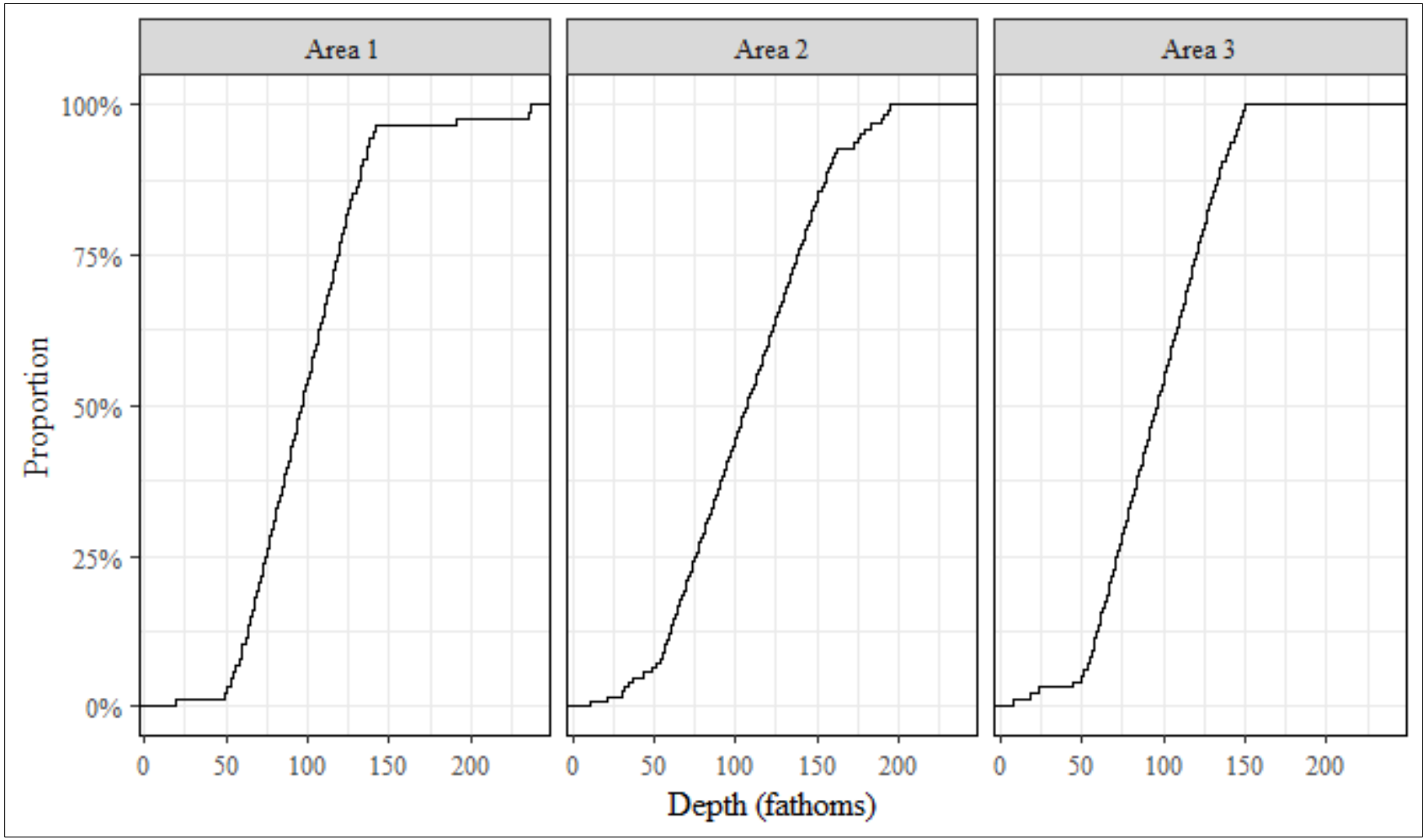

Figure 4.–Legal-size male Tanner crab (≥127 mm) catches by depth for 3 proposed areas in the Prince William Sound Area.

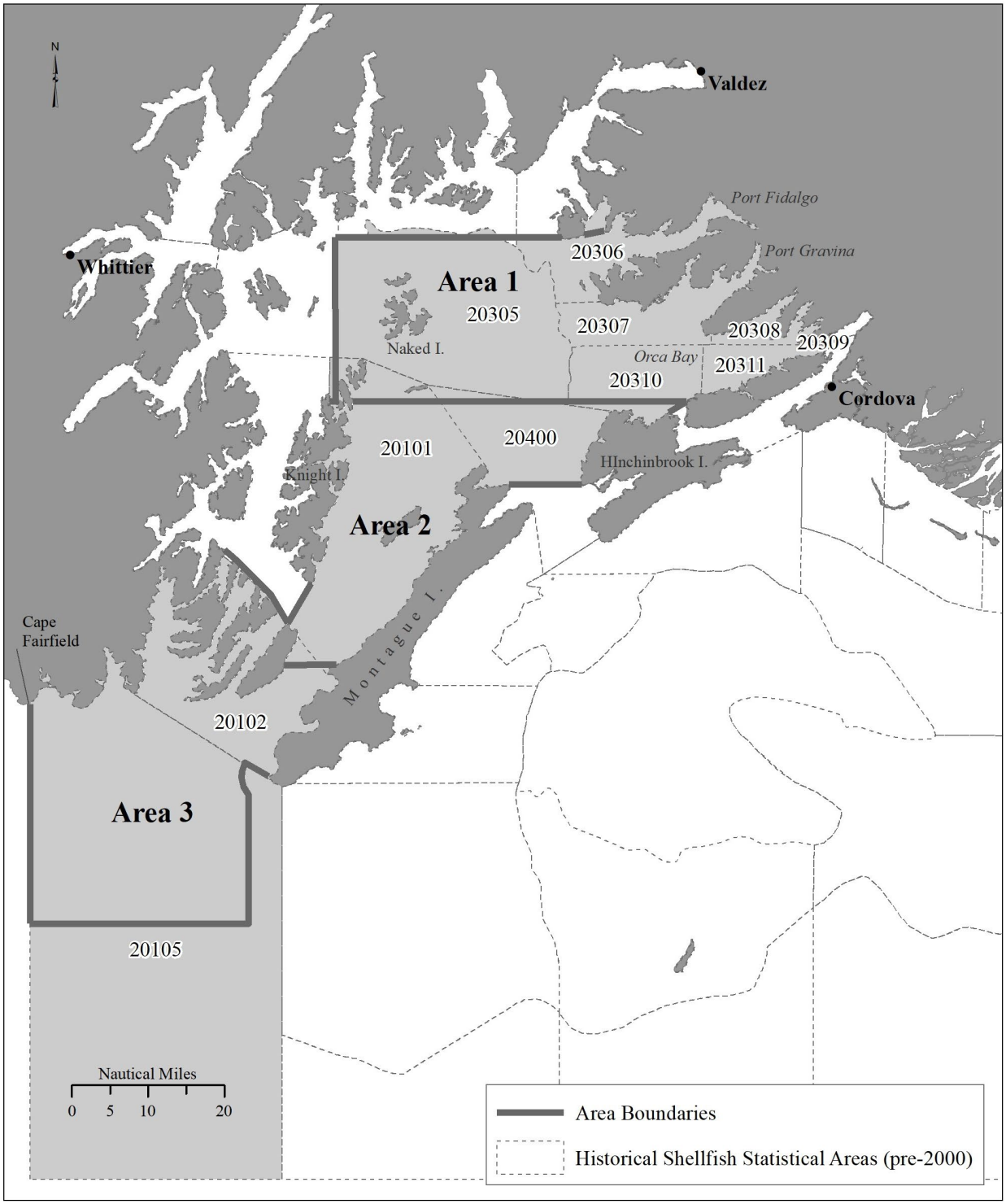

Figure 5.–Proposed areas and historical shellfish statistical reporting areas in the Prince William Sound Area.

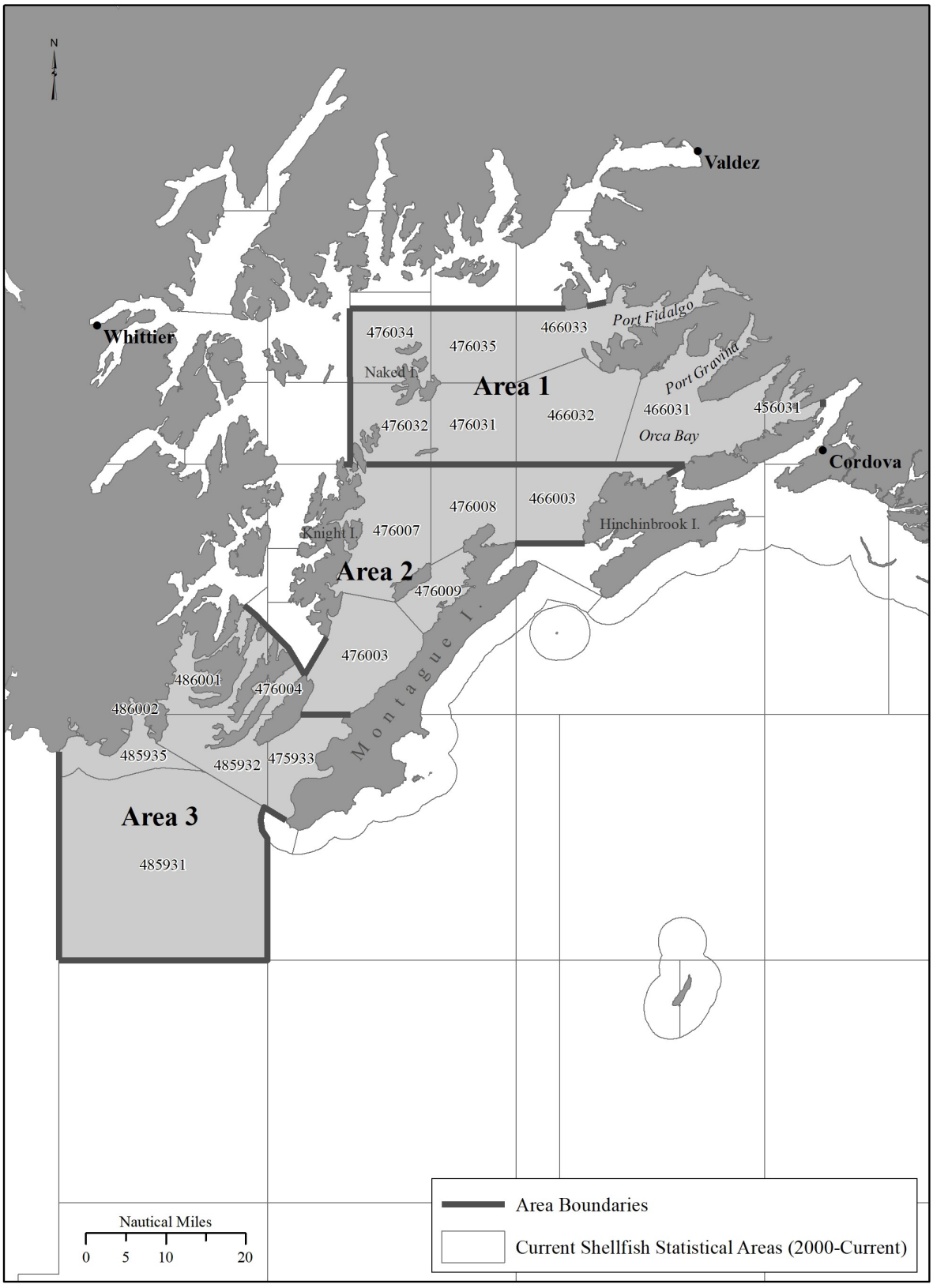

Figure 6.–Proposed areas and current shellfish statistical reporting areas in the Prince William Sound Area.

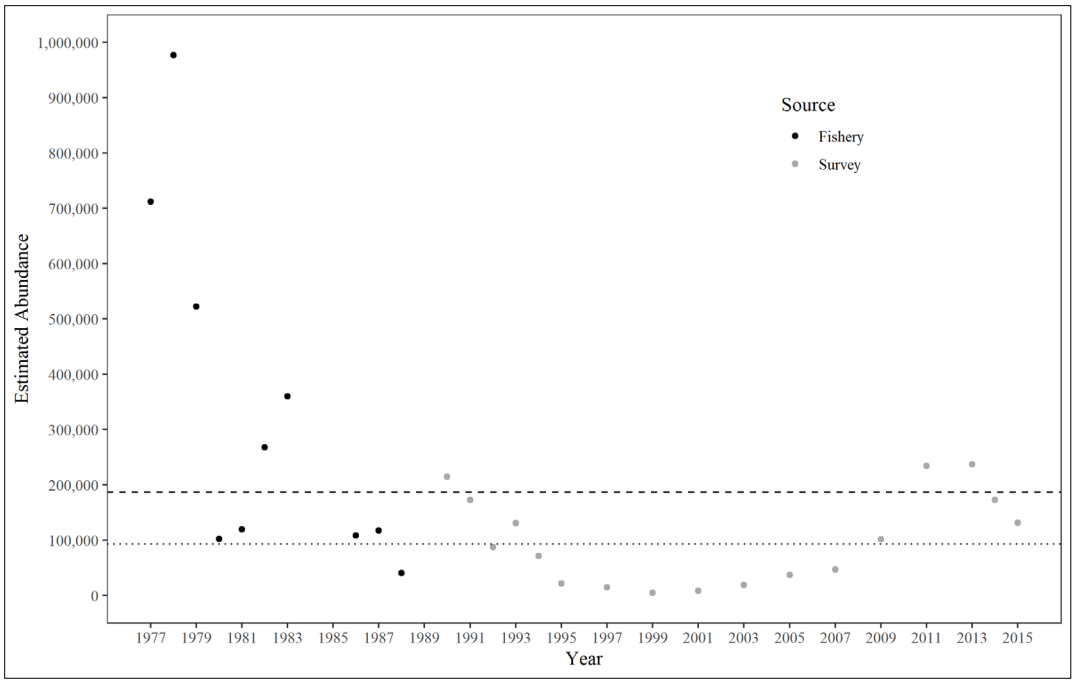

Figure 7.–Area 1 annual abundance estimates of historical legal-size (≥135 mm) Tanner crab.

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

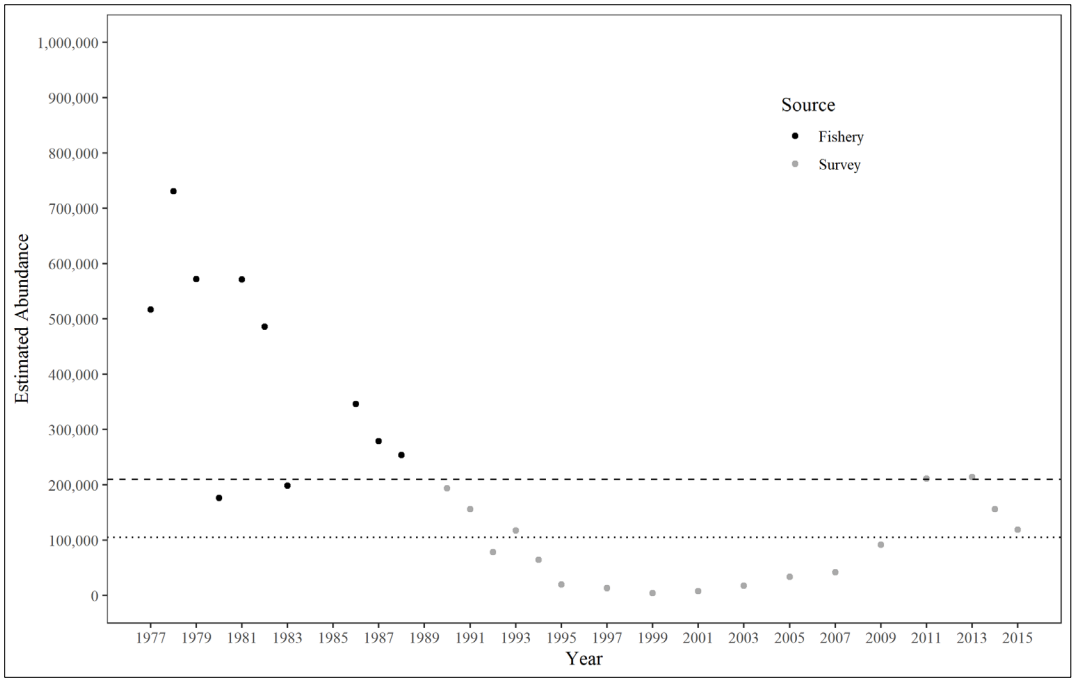

Figure 8.–Area 2 annual abundance estimates of historical legal-size (≥135 mm) Tanner crab.

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

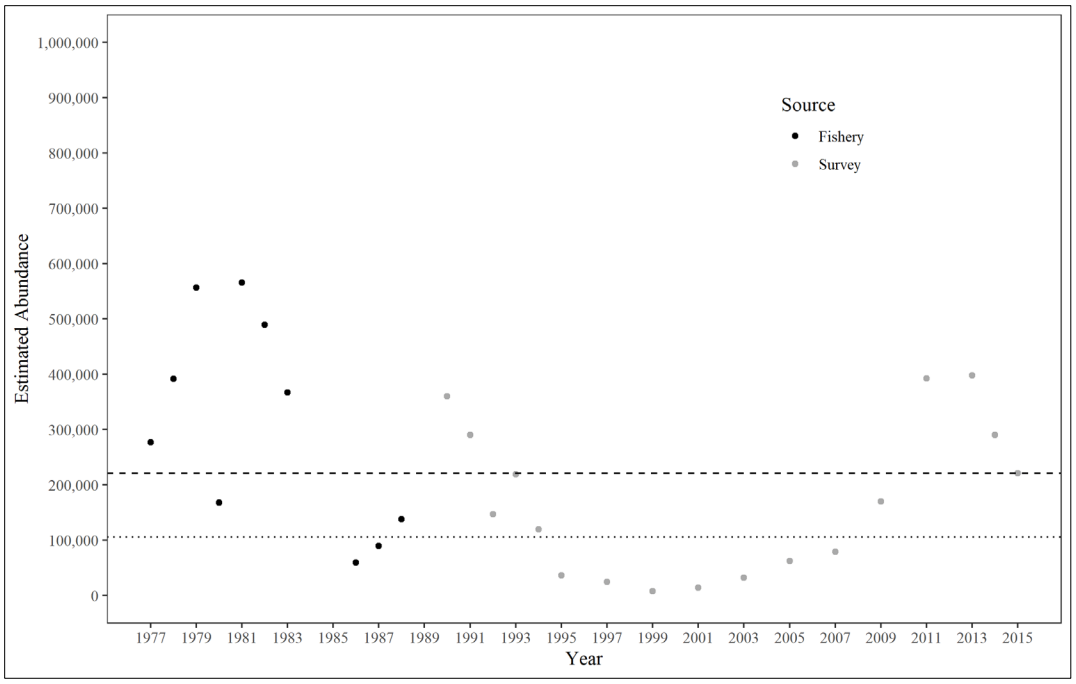

Figure 9.–Area 3 annual abundance estimates of historical legal-size (≥135 mm) Tanner crab.

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

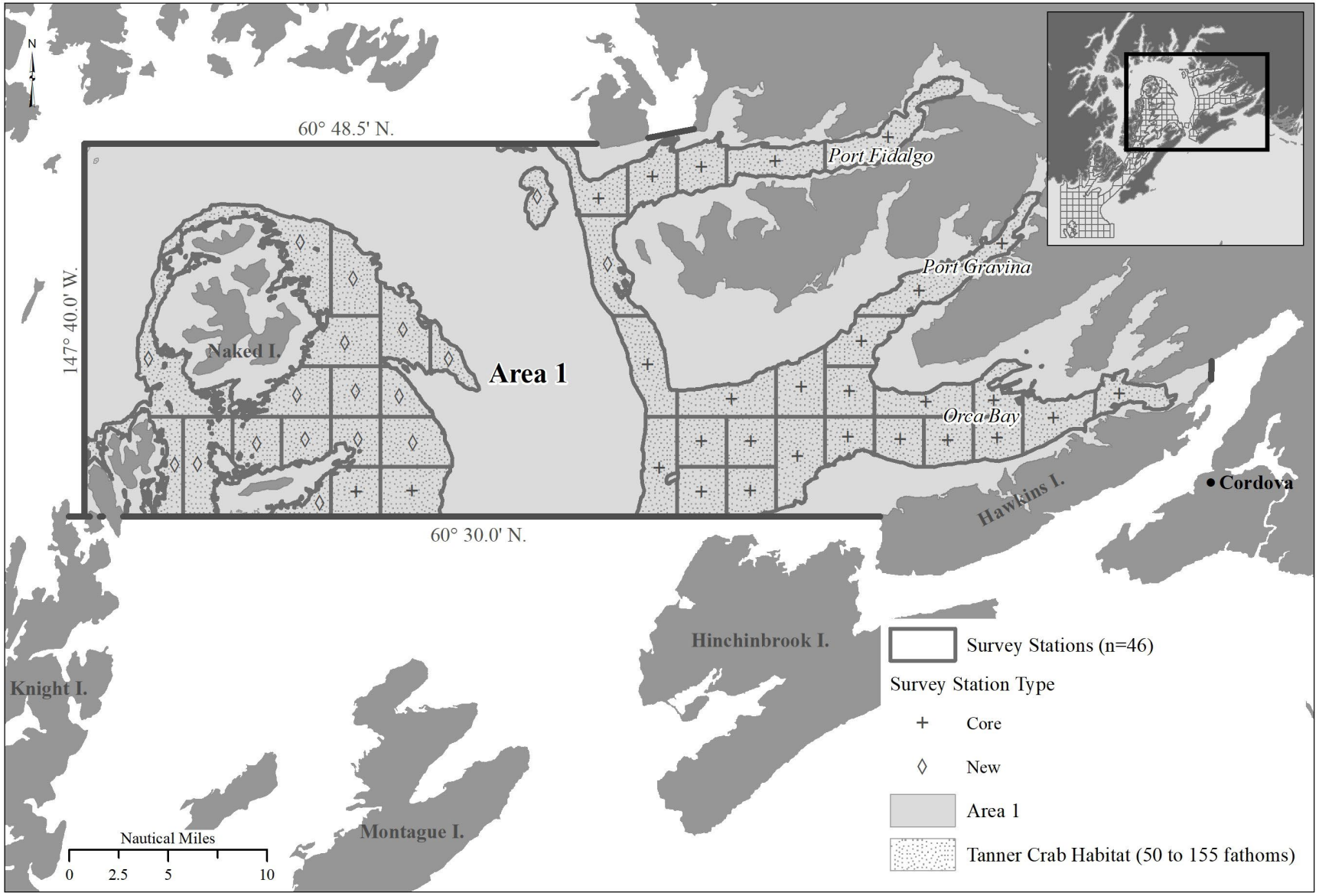

Figure 10.–Area 1 proposed trawl survey assessment stations in the Prince William Sound Area.

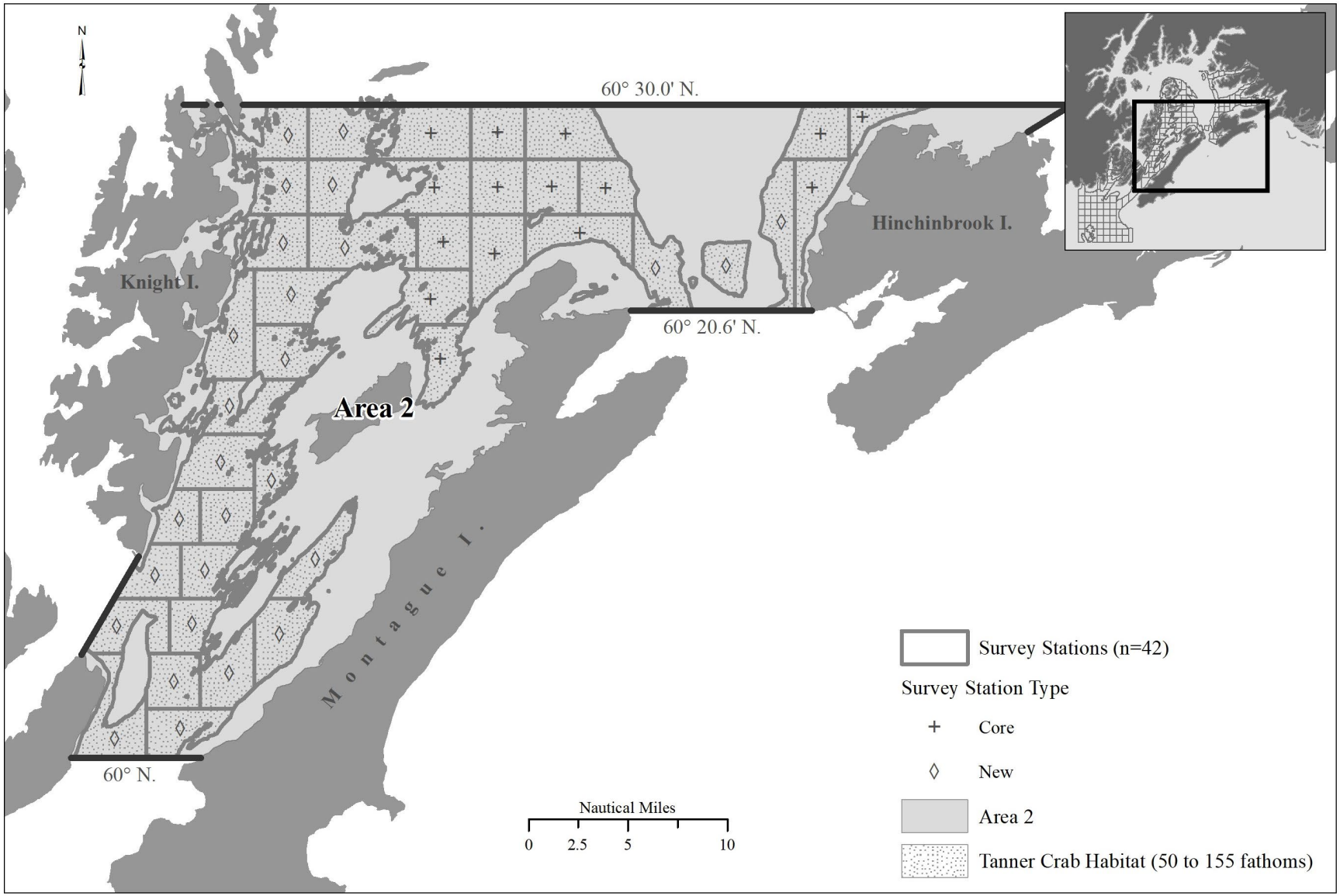

Figure 11.–Area 2 proposed trawl survey assessment stations in the Prince William Sound Area.

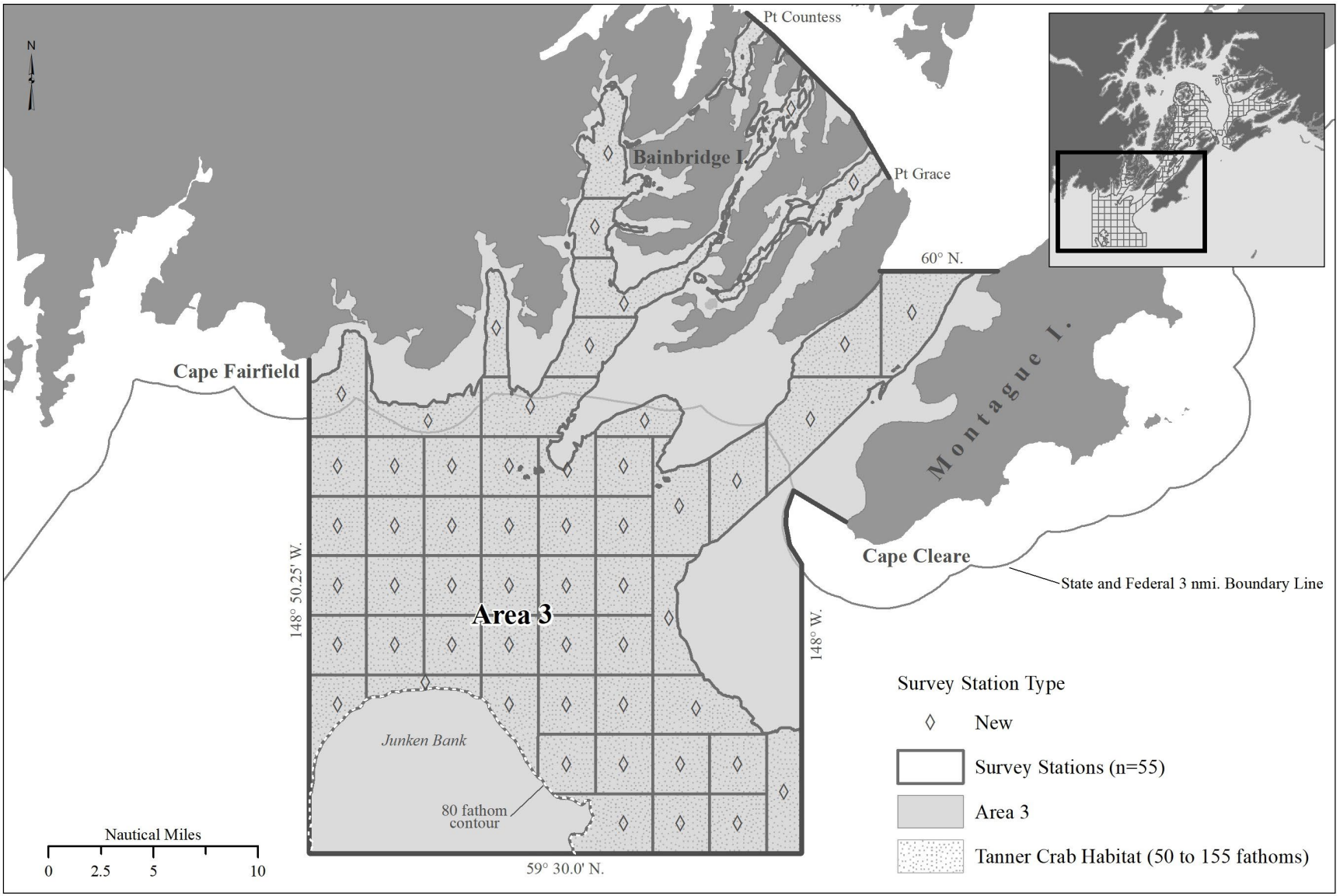

Figure 12.–Area 3 proposed trawl survey assessment stations in the Prince William Sound Area.