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Norton Sound Red King Crab Harvest Strategy

by

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and

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

Symbols and Abbreviations

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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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ABSTRACT

Red king crab (*Paralithodes camtschaticus*, RKC) are harvested throughout the Bering Sea, and Norton Sound harbors one of the northernmost commercially harvestable stocks. Annual crab harvest levels are determined preseason using models that predict biomass of legal male RKC. This report provides an overview of crab prediction models for determining guideline harvest levels (GHL), changes to those prediction models, realized exploitation rates, and proposed changes to GHL regulations for Norton Sound RKC. When historical abundances are reconstructed, it is evident that previous models overestimated abundance. Nonetheless, Norton Sound RKC biomass has been increasing, suggesting (1) that recent harvests have been sustainable despite population overestimates, and (2) that current harvest rate thresholds set in regulation would be too conservative if applied under the revised prediction models. Applying current harvest rates to the revised population estimates would result in substantial reductions to commercial harvests. Multiple scenarios are presented, including status quo, proposed regulation changes, and an alternative regulation change option, as well as the potential benefits and detriments to the stock and fishery under each scenario.

Key words: red king crab, *Paralithodes camtschaticus*, Norton Sound, abundance, biomass estimate, population estimate, Alaska Board of Fisheries

INTRODUCTION

Norton Sound red king crab (*Paralithodes camtschaticus*, RKC) is one of the northernmost, commercially harvestable king crab stocks (Powell et al. 1983). Norton Sound Section (Q3) consists of all waters in Registration Area Q north of the latitude of Cape Romanzof (61 degrees 49 minutes N. latitude), east of the International Dateline, and south of 66 degrees N. latitude (Figure 1).

Red king crab in Norton Sound are found in areas with a mean depth range of 19 ± 6 (SD) m and bottom temperatures of 7.4 ± 2.5 (SD) °C during the summer (NPFMC 2011). Norton Sound RKC sublegal males and females tend to occur near shore during the summer, and this is also where subsistence harvest tends to occur; hence, the coastal area is closed for the summer commercial crab fishery (Figure 2). Red king crab migrate between deeper offshore waters during molting/feeding and inshore shallow waters during the mating period (NPFMC 2011). Timing of the inshore mating migration is unknown: they are assumed to mate during March–June. Offshore migration is considered to begin in May–July. Trawl surveys within Norton Sound, occurring every 3–5 years since 1976, show that crab distribution is dynamic (Soong 2008).

Norton Sound RKC mature smaller and do not attain as large of maximum size as is found in more southerly stocks. Size at which 50% of females are mature is 71 mm for Norton Sound stocks (Otto et al. 1990), compared to 89 mm for Aleutian Islands and Bristol Bay, and 102 for Pribilof District stocks (Blau 1990; Somerton 1980; Otto et al. 1990). Known differences in life history characteristics of Norton Sound RKC compared to other RKC stocks may be a result of the stock's location, near the northern extreme of the species distribution. It is unknown how other life history parameters differ between Norton Sound and other RKC stocks.

Because of the northerliness of the stock, basic research is challenging and data is limited for understanding population dynamics. Ice cover limits research in much of the year, and the remoteness and geographic expanse of the Sound makes surveys costly. Life history characteristics, such as mortality rates, are not yet defined for this stock. Abundance or biomass estimates are difficult and expensive to obtain, and methodologies have not been consistent over time.

COMMERCIAL FISHERY OVERVIEW

The federal *Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs* (FMP) establishes a cooperative structure deferring management of Bering Sea and Aleutian Islands (BSAI) king and Tanner crab fisheries to the State of Alaska, with federal oversight. The Norton Sound RKC commercial fishery has two seasons: the summer season (June 15–September 3) (Figure 3) constitutes the bulk of the commercial harvest, while the winter season (November 15–May15) harvest is nominal and averages approximately 2,500 crab (Menard et al. 2011).

A large-vessel summer commercial crab fishery existed from 1977 through 1990. No summer commercial fishery occurred in 1991 because of staff constraints. In 1992, the summer commercial fishery resumed. In 1994, the fishery was established as superexclusive: any vessel participating in this fishery may not participate in any other BSAI king crab fishery. Later, a vessel moratorium put into place before the 1996 season was intended to precede a license limitation program. Community Development Quota (CDQ) groups were allocated a portion of the summer harvest beginning in 1998. Although CDQ allocation was in place, no harvest occurred until the 2000 season. The North Pacific License Limitation Program (LLP) went into effect for the Norton Sound crab fishery January 1, 2000. The program states a vessel which exceeds 32 feet in length, overall, must hold a valid crab license issued under LLP by National Marine Fisheries Service (NMFS) (Menard et al. 2011).

The state sets guideline harvest levels (GHL) under state regulation and in accordance with established acceptable biological catch (ABC) limitations[1] set by the North Pacific Fishery Management Council (NPFMC). The GHL for Norton Sound RKC are set in regulation as being contingent on predicted legal male biomass (5 AAC 34.915). Beginning in 1999, Alaska Board of Fisheries (board) regulation, 5 AAC 34.915, designates a threshold biomass level of 1.5 million pounds of legal male RKC for the Norton Sound summer commercial fishery to open. If legal male biomass is 1.5–2.5 million pounds, the harvest rate is not to exceed 5%. If the legal biomass is 2.5 million pounds or more, the harvest rate is not to exceed 10%. Estimated available abundance and subsequent threshold levels were primarily based on data from 7 triennial trawl and 4 summer pot surveys conducted prior to 1999. Additional years of data from trawl surveys (6), winter pot surveys (27), and fishery harvests (34) are now available and used for estimating crab biomass.

ABUNDANCE ESTIMATES

Norton Sound RKC reconstructed abundance levels have varied considerably over the course of the fishery (Figure 4). Exceptionally high abundances were seen in the late 1970s (approximately 4.12 million legal crab in 1976), followed by a precipitous drop in 1982 (0.5 million legal crab). High abundances in the late 1970s were the result of exceptionally strong recruitments, which were also observed for other king crab stocks in the eastern Bering Sea (Zheng and Kruse 2000; 2006). Poor recruitment was estimated for Norton Sound RKC before the commercial fishery began. Because it takes 6–7 years for RKC to recruit into the mature population, it is unlikely that the decline was initiated by heavy fishing seen in 1979–1981 (NPFMC 2011). Even without fishing, the estimated number of recruits would not have been able to sustain the high abundance observed in the late 1970s. Since the rapid decline in the

[1] Some literature also references the term Annual Catch Limit (ACL), which is synonymous with ABC for crab stocks.

early 1980s, the population gradually recovered to an estimated 0.84 million legal crabs in 1991 (Figure 4). Since 1996, the population level has nearly tripled.

BIOMASS PREDICTION MODEL

Annually since 1999, predicted biomass has been used to determine acceptable harvest levels under the GHL for the upcoming fishing season. Currently, information exists to calculate reliable estimates of biomass; however, other essential life history and recruitment information is lacking and prevents the ability to model spawner-recruit relationships. In lieu of spawner-recruit relationships, simulation modeling is used for predicting available biomass to meet ABC and GHL criteria. The simulation model used for Norton Sound RKC is a length-based synthesis model (Zheng et al. 1998). The model is a male-only age/size-structured model that combines multiple sources of survey, catch, and mark-recovery data using a maximum likelihood approach to estimate abundance, recruitment, catchability of the commercial pot gear, and parameters for selectivity and molting probabilities. Necessary biological parameters that are currently unknown for Norton Sound RKC, such as mortality rates, are substituted with information from other Alaskan stocks. For instance, instantaneous natural mortality has been assumed to be constant over time and the model parameter is based on the Bristol Bay RKC parameter (NPFMC 2011). Abundances are converted to biomass for GHL estimations using an average weight of legal RKC of 3 pounds.

RETROSPECTIVE ANALYSIS

A retrospective analysis was recently conducted to investigate performance of the model used to predict future crab abundance and determine GHL (NPFMC 2011). This analysis was based on the understanding that parameters in the RKC abundance prediction model are adjusted annually and are improved by additional data. The 2011 version of the model was used to predict abundance estimates of legal male crab for historical years. These estimates were compared with those from the previous versions of the model. "Actual" crab abundance was estimated by reconstructing historical crab abundances using spawner-recruit relationships and the entire suite of data through 2011 (Figure 5). If the 2011 version of the model is superior to the older models, then the retrospective predicted estimates should be closer to the "actual" reconstructed crab abundance. On average (2000–2008), historical model versions predicted estimates that were 37% higher than "actual" reconstructed historical estimates, whereas the most recent version of the model predicted estimates that were 61% higher (Table 1; Figure 6).

The retrospective analysis reconstructs abundance, using the version of the model developed in each of the terminal years 2000–2011, for all previous years. For example, the model version developed for 2000 was used to estimate abundance in years 1975–1999. The same was done for each of the other model versions developed since 2000. This analysis shows that each time new data are added to the model, estimates of reconstructed historic abundance become lower, i.e., the assessment tends to overestimate abundance, particularly in the most recent year (Figure 5). Estimates stabilize after more than 17 years of subsequent data are collected. Therefore, historical model estimates of years prior to 1984 are robust and are only minimally influenced by additional data collected; recent year estimates are variable and more strongly influenced by subsequent data collection. Additionally, the periodic trawl survey data have a particularly strong influence on the model.

Table 1.–Predicted abundance using historical versions of the Norton Sound red king crab abundance prediction model compared to the current version, and the reconstructed "actual" abundance.

	Historical Models' Predicted Abundance	Current Model's Predicted Abundance	Reconstructed Abundance
2000	1.414	1.521	0.893
2001	1.258	1.488	0.779
2002	1.032	1.400	0.761
2003	1.054	1.445	0.898
2004	1.577	1.692	1.026
2005		1.713	0.981
2006	1.620	1.574	0.876
2007	1.049	1.350	0.931
2008	1.493	1.760	1.116
2009	1.647	1.663	1.305
2010	1.694	1.694	1.477

Note: Abundance is in millions of crab.

Norton Sound RKC model problems exposed in the retrospective analysis have been a difficulty since the inception of this model in 1999 (NPFMC 2011). Model authors suspect that this overestimation is primarily due to overestimation of larger size groups by the model. Based on the retrospective analysis, more dramatic adjustments will be made in upcoming modeling efforts to address overestimation by the model, which will affect management of the fishery under current regulations.

NORTON SOUND RED KING CRAB HARVEST STRATEGY

Objective: Address the need for realignment of GHLs of Norton Sound RKC commercial harvests and associated exploitation rates, given changes in model estimation and increased knowledge since regulation initiation in 1999 (related to board Proposal 381).

Based on retrospective analysis and reconstructed abundances, harvest rates since GHL establishment have ranged from 9.4–17.2%, exceeding the maximum GHL harvest rate of 10% (Table 2; Figure 7). This occurred because the prediction model used to set harvest amounts preseason is now believed to have projected higher than "actual" abundance and the estimated exploitation rate is subsequently higher. Even with these higher "actual" exploitation rates, models and abundance reconstructions indicate that the population has seen an increasing trend since 1996 (Figures 4, 5, and 6) and exploitation rates at this level do not appear to be detrimental to this stock. Additionally, while the prediction model framework has remained essentially the same since inception, model parameters have been adjusted annually in attempts to try to improve model fit. Based on the retrospective analysis, more dramatic adjustments will be made in upcoming modeling efforts to address overestimation by the model.

Table 2.–Comparison of 2000–2010 reconstructed biomass and actual harvest compared to expected harvests and harvest rates under Proposal 381 and the alternative. Expected harvest rates are gradated within a threshold range to reflect the relative magnitude of the biomass within the associated biomass range, consistent with current management practices.

Year	Reconstructed Biomass (lbs.)	Actual Harvest (lbs.)	Actual Harvest Rate	Expected Harvest Rate – Prop 381	Expected Harvest – Prop 381 (lbs.)	Expected Harvest Rate – Alternative	Expected Harvest – Alternative (lbs.)
2000	2,680,137	312,824	11.7%	17%	455,623	11%	294,815
2001	2,338,317	288,199	12.3%	16%	374,131	9%	210,449
2002	2,284,455	259,602	11.4%	16%	365,513	9%	205,601
2003	2,695,056	267,207	9.9%	17%	458,160	11%	296,456
2004	3,077,370	340,746	11.1%	18%	553,927	13%	400,058
2005	2,941,899	400,804	13.6%	17%	500,123	12%	353,028
2006	2,626,923	451,748	17.2%	16%	420,308	10%	262,692
2007	2,793,819	312,875	11.2%	17%	474,949	11%	307,320
2008	3,347,730	395,135	11.8%	19%	636,069	14%	468,682
2009	3,913,890	397,587	10.2%	20%	782,778	15%	587,084
2010	4,431,030	417,304	9.4%	20%	886,206	15%	664,655
Average	3,011,875	349,457	11.80%	17.55%	537,071	11.82%	368,258
Total	33,130,626	3,844,031			5,907,785		4,050,839

Regulations for setting GHL were established in 1999 (5 AAC 34.915), with consultation from NMFS, but prior to implementation of the current crab model. Regulations were intentionally conservative due to a paucity of data for Norton Sound RKC. Although information gaps remain, considerable knowledge has been gained in the past 13 years. GHL regulations have not been subsequently modified. There is concern that unnecessary restrictions to the Norton Sound RKC fishery and hardship to commercial fishermen could occur if regulations are not updated to better reflect current knowledge and models of Norton Sound RKC abundance.

Option A.–Status Quo

Specific Action Recommended to Implement the Objective

No action would be taken. The board regulation, enacted in 1999, for the Norton Sound summer RKC fishery (5 AAC 34.915) designates a threshold biomass level of 1.5 million pounds of legal male red king crab for the summer commercial fishery to be open. If legal male biomass is 1.5–2.5 million pounds, the harvest rate is not to exceed 5%. If the legal biomass is 2.5 million pounds or more, the harvest rate is not to exceed 10%.

Benefits

If changes are not adopted, regulations would be consistent over time and would avoid confusion for fishermen. Regulations would remain very conservative and harvest levels would be low, ensuring stock sustainability.

Detriments

In light of the retrospective analysis, it is expected that the crab prediction model will be substantially modified so that predicted values will more closely resemble those generated postseason in abundance reconstructions. Given current thresholds established for the GHL, substantial reductions in commercial harvests would be expected. If previous prediction models had more accurately assessed actual abundance (here reconstructed abundance is used as a proxy for actual abundance), commercial harvests from 2000–2010 would have been significantly reduced (Figure 8; Table 3). On average, annual harvest would have been reduced by approximately 70,000 pounds of RKC, though there would have been considerable variation in the reduction among years. Across the 11 years analyzed, approximately 762,000 pounds would not have been harvested, leading to a fishery loss of approximately $2 million. Moreover, the exvessel value in this fishery has increased in recent years and, if this trend continues, future foregone harvest would be more economically significant (Figure 9).

Table 3.–Comparison of actual harvest with that which would have been allowable based on reconstructed biomass.

Year	Actual Harvest (lbs)	Allowable Harvest Based on Reconstructed Abundance (lbs)	Harvest Difference (lbs)	Exvessel Value (Price/lb)	Harvest Difference Value to Fishery
2000	312,824	268,014	44,810	2.29	$102,616
2001	288,199	116,916	171,283	2.34	$400,803
2002	259,602	114,223	145,379	2.81	$408,516
2003	267,207	269,506	-2,299	3.09	-$7,103
2004	340,746	307,737	33,009	3.13	$103,318
2005	400,804	294,190	106,614	3.18	$339,033
2006	451,748	262,692	189,056	2.26	$427,266
2007	312,875	279,382	33,493	2.84	$95,120
2008	395,135	334,773	60,362	3.20	$193,158
2009	397,587	391,389	6,198	3.17	$19,648
2010	417,304	443,103	-25,799	3.73	-$96,230
Average	349,457	280,175	69,282		$180,559
Total	3,844,031	3,081,924	762,107		$1,986,144

Option B.–Revise Guideline Harvest Level Thresholds: Proposal 381

Specific Action Recommended to Implement the Objective

Despite fishing at a higher exploitation rate throughout the past decade than was allowed at the 10% maximum legal male harvest rate limit (5 AAC 34.915. *Norton Sound Section red king crab harvest strategy*), the crab stock has been stable; suggesting that the historical harvest rate above 10% has been sustainable. The new stock assessment model reduces the population estimate and amount of crab available for harvest. Proposal 381 attempts to align harvest rates with those observed in recent years while mitigating expected decreases in annual guideline harvest levels from the new stock assessment model. Under proposal 381, a threshold biomass level of 1 million pounds of legal male RKC would be required for the summer commercial fishery to be open. If legal male biomass is 1–2 million pounds, the harvest rate is not to exceed 5%. If the legal biomass is 2–4 million pounds, the harvest rate is 15–20%, progressively (Table 4).

Benefits

Proposal 381 would help to avoid potential problems with upcoming alterations to model parameters by allowing more harvest, particularly for years in which biomass is higher. This effort would help maintain market viability by not dramatically reducing the harvest on what is expected to be large crab biomass. Exploitation rates slightly higher than 10% have been demonstrated as being sustainable for Norton Sound RKC; abundance levels appear to be increasing or stable for over a decade.

Table 4.–Comparison of current (status quo) exploitation rates allowable under given modeled biomass/GHL and those recommended by Proposal 381.

Status Quo		Revisions per Proposal 381	
Modeled Biomass	*Exploitation Rate*	*Modeled Biomass*	*Exploitation Rate*
< 1.5 million lbs.	0	<1 million lbs.	0
1.5–2.5 million lbs.	Up to 5%	1-2 million lbs.	Up to 5%
> 2.5 million lbs.	Up to 10%	2-4 million lbs.	15–20%, progressively

Detriments

If Proposal 381 had been implemented for years 2000–2010, proposed changes would have increased harvest (Figure 10). Most harvest rates under this scenario, for this time period, would have been 17% or higher, while the actual harvest rates were primarily below 17% (Table 2). While the intent of the proposal is to maintain harvest rates that have shown to be sustainable, the proposal, as written, could actually increase harvest rates and may or may not be sustainable. Additionally, Proposal 381 includes harvest rates above that which is allowable under NPFMC guidelines (18%), would be classified as overfishing levels (OFLs), and would incur penalties on the fishery if achieved. State regulations must fall within federal parameters in this extended jurisdiction fishery, including maintaining harvest rates below 18%.

Option C.–Revise Guideline Harvest Level Thresholds: Alternative

Specific Action Recommended to Implement the Objective

An alternative has been formulated that would maintain the intent of Proposal 381, align with federal regulations, and better reflect harvest levels observed since 2000. The alternative proposed includes an additional threshold level that would allow maximum harvest in large biomass years up to 15% (Table 5). A threshold biomass level of 1.5 million pounds of legal male RKC would be required for the summer commercial fishery to be open. If legal male biomass is 1.5–2 million pounds, the harvest rate is not to exceed 5%. If the legal biomass is 2–2.5 million pounds, the harvest rate is not to exceed 10%. If the legal biomass is 2.5 million pounds or more, the harvest rate is not to exceed 15%.

The department manages for harvest rates within a threshold range contingent upon biomass levels. For example, within the alternative scenario, if the projected biomass was 2.5 million pounds, management would likely aim for an exploitation rate of 11%, whereas, if the projected biomass was 3.5 million pounds, management may aim for an exploitation rate of 15%. All abundance levels above 3.5 million pounds would also see an exploitation rate up to 15%. Although the alternative would have allowed maximal harvest rates above those observed in 2000–2010, since the department adjusts harvest levels within a threshold range, realized harvest levels would have likely been similar to those observed (Figure 11). While the average exploitation rate would have been similar to the average observed 2000–2010, the overall harvest would be slightly higher since large biomass years would be allowed to exploit up to 5% more crab biomass than allowable under the current regulation (Table 2). Biomass levels below 1.5 million pounds have not been observed in this fishery; therefore, it is not advisable to reduce the lower end of the threshold level below what is already set in regulation. Without further evidence at low biomass levels, it is unknown if even marginal harvest on such low biomass would be sustainable. Maximum allowable harvest rate under the alternative is well below 18% and would align with federal regulations.

Table 5.–Comparison of current regulations, proposed regulation and an alternative to Proposal 381.

Status Quo		Revisions per Proposal 381		Alternative	
Modeled Biomass	*Exploitation Rate*	*Modeled Biomass*	*Exploitation Rate*	*Modeled Biomass*	*Exploitation Rate*
< 1.5 million lbs.	0	<1 million lbs.	0	<1.5 million lbs.	0
1.5–2.5 million lbs.	Up to 5%	1–2 million lbs.	Up to 5%	1.5–2 million lbs.	Up to 5%
> 2.5 million lbs.	Up to 10%	2–4 million lbs.	15–20%, progressively	2–2.5 million lbs.	Up to 10%
				2.5–3.5 million lbs.[a]	Up to 15%

[a] Abundances above 3.5 million pounds would have a maximum harvest rate of 15%.

SUMMARY

Proposal 381 identifies some important detriments to the Norton Sound RKC fishery that may arise if GHL regulations are not updated to be consistent with current data and knowledge of the stock. It is expected that future harvest would be reduced without some revision to current GHL regulations, despite stable or growing crab biomass. Some modification of Proposal 381 would be necessary for implementation under federal regulations as outlined in the alternative option. As the alternative is developed to maintain harvest levels and not to increase summer commercial harvest, except for years of very high abundance, it is not expected to impact population sustainability, subsistence harvest, or winter commercial harvest opportunities.

Performance Measures

Crab biomass will continue to be monitored using data from subsistence and commercial harvests, winter pot surveys, and the triennial trawl survey. Additionally, a research project is currently being conducted to study crab movement, growth, and size composition, and will greatly improve our understanding of Norton Sound RKC. Predictive crab models will continue to be developed by the Crab Plan Team, under supervision of the Science and Statistical Committee of NPFMC. The department will continue to work closely with federal collaborators on model development and crab research.

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FIGURES

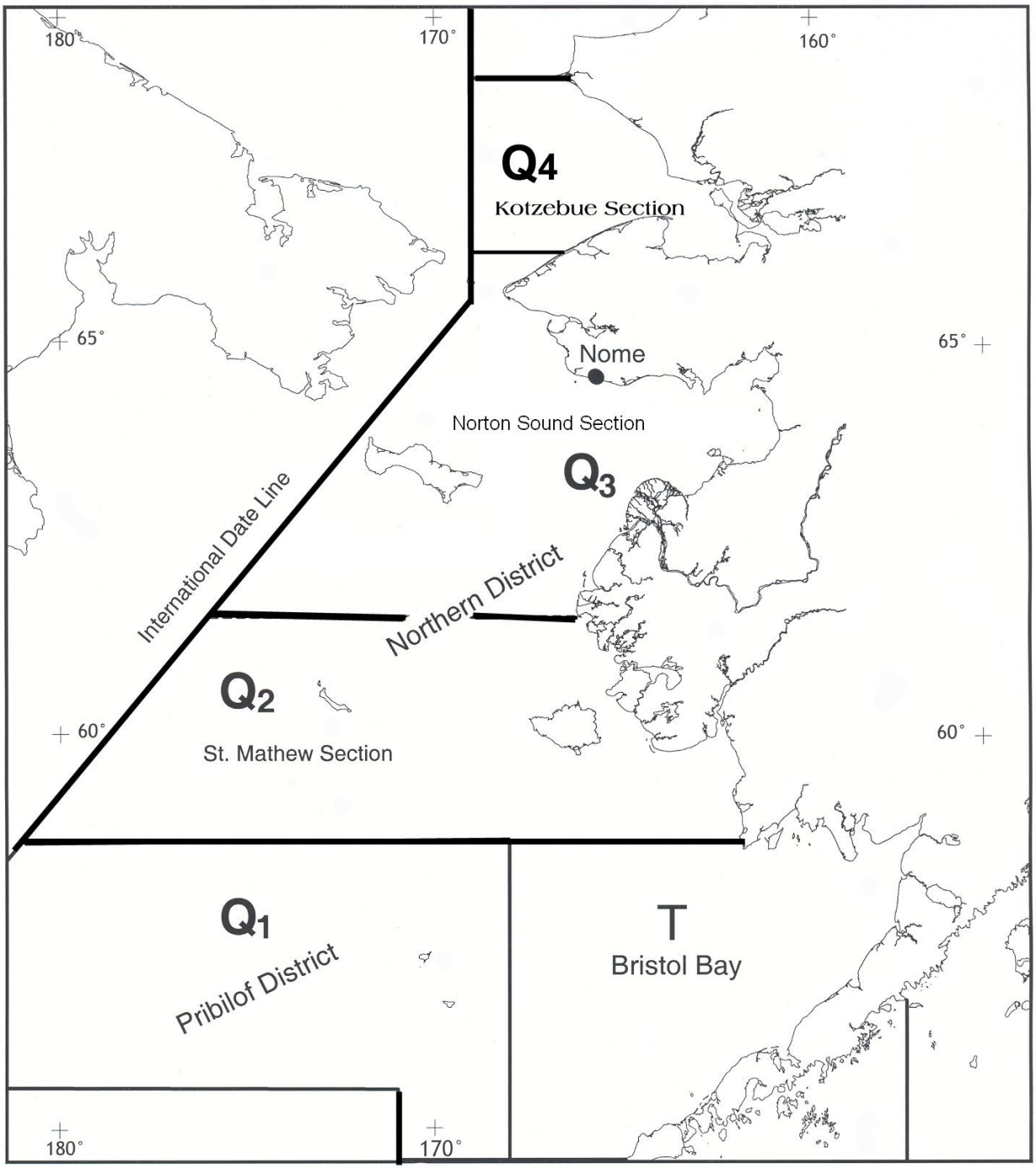


Figure 1.–King crab commercial fishing districts and section of Registration Area Q.

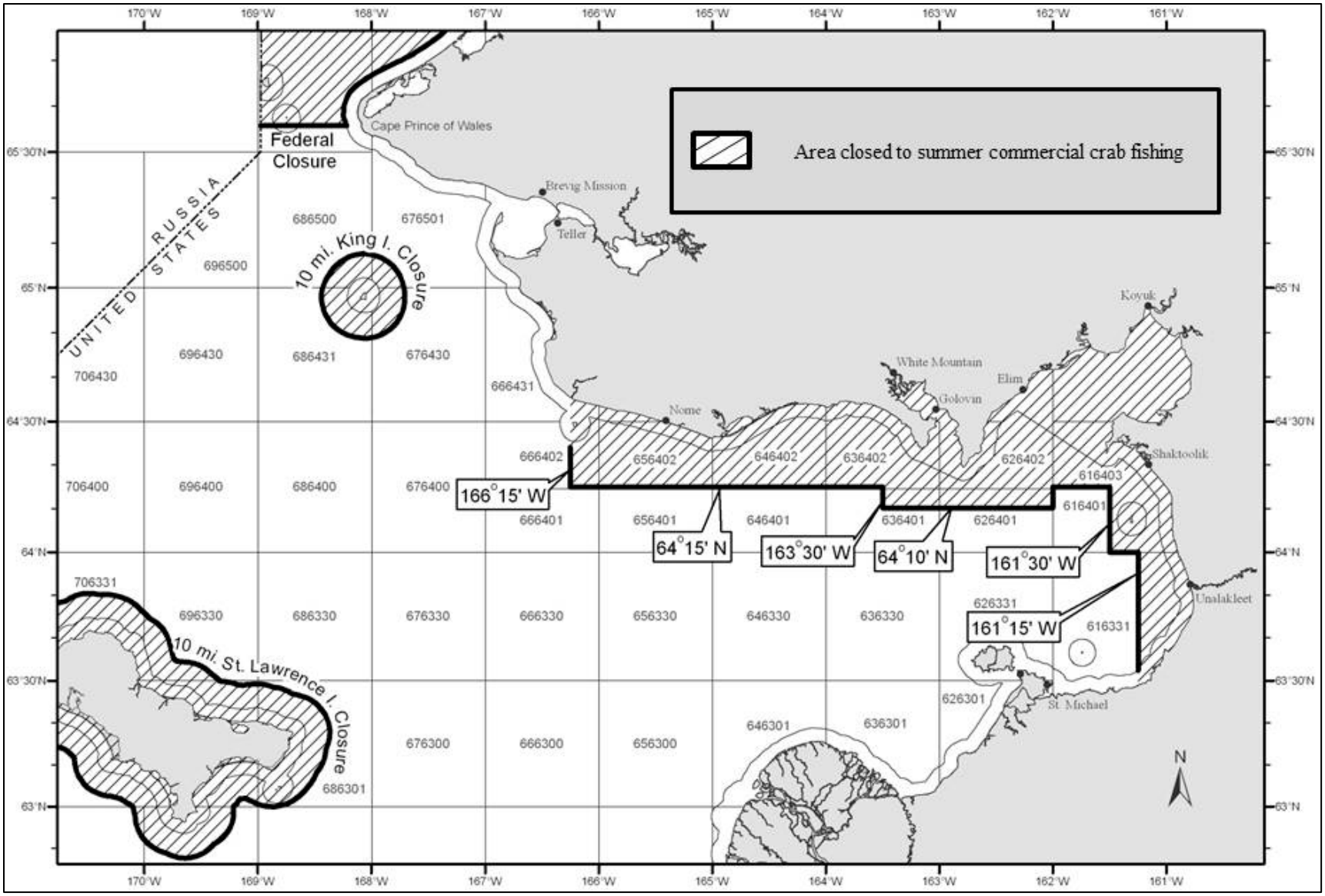
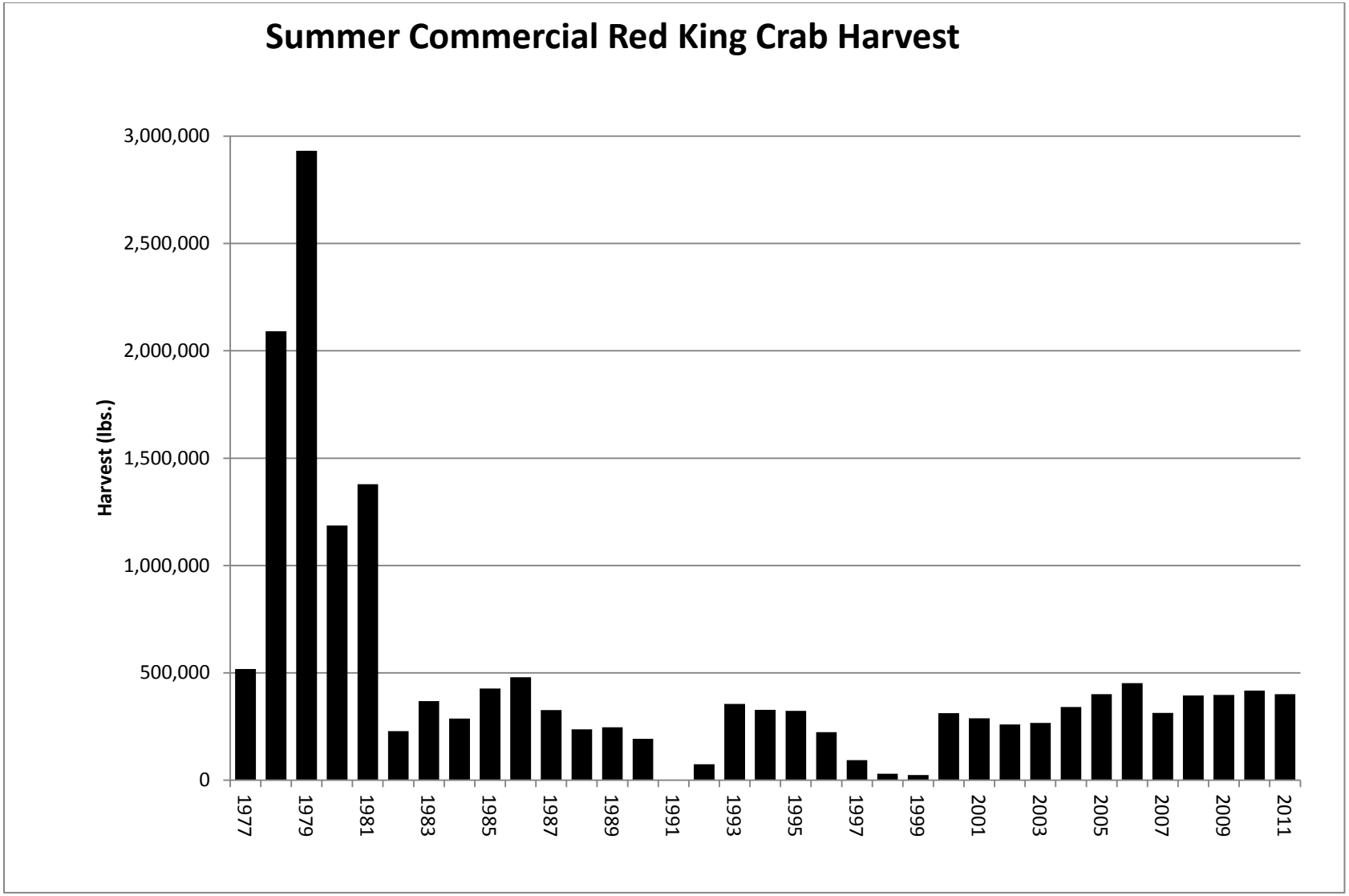
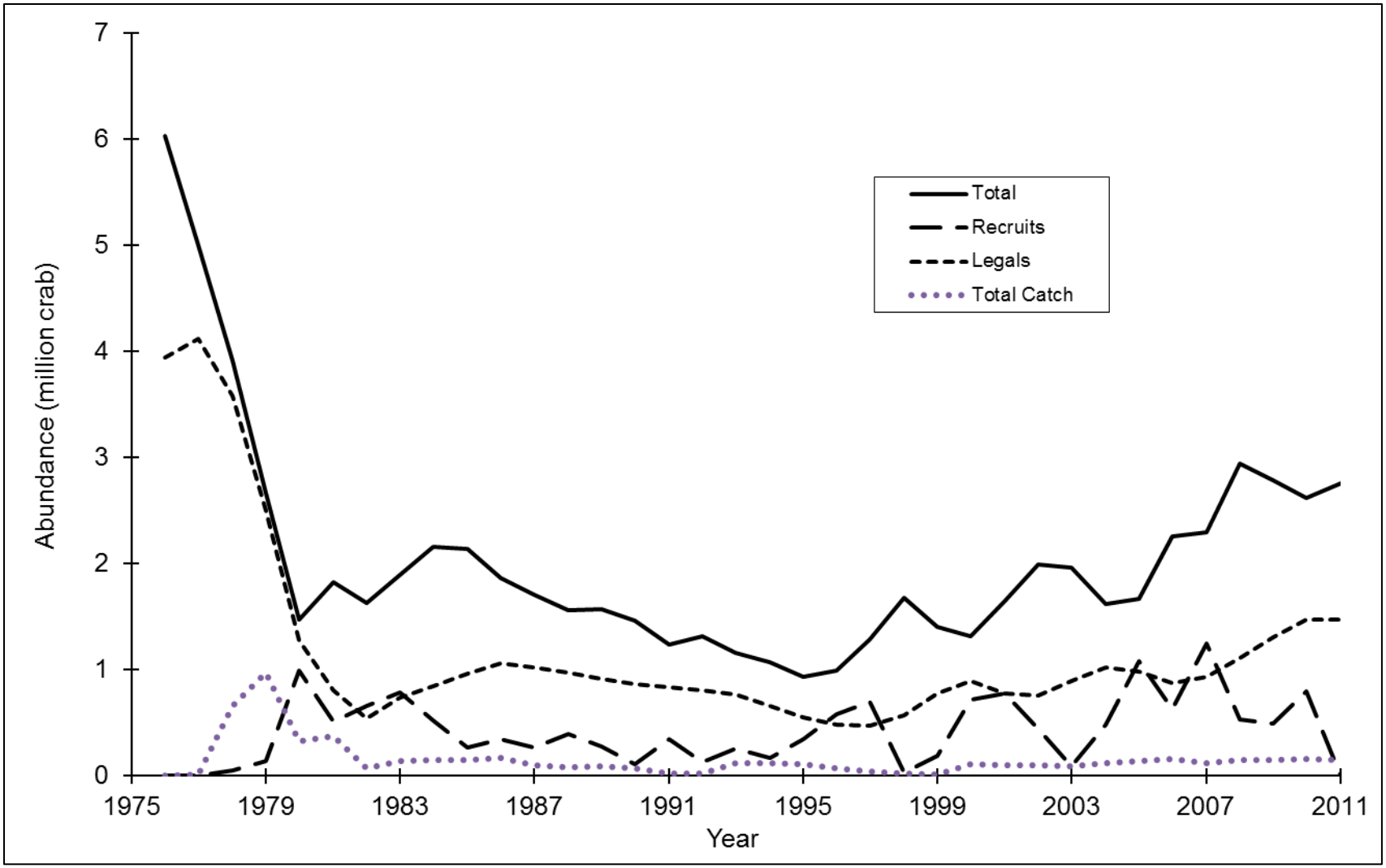


Figure 2.–Map of Norton Sound statistical areas, with waters closed to Norton Sound summer commercial crab fishery designated.



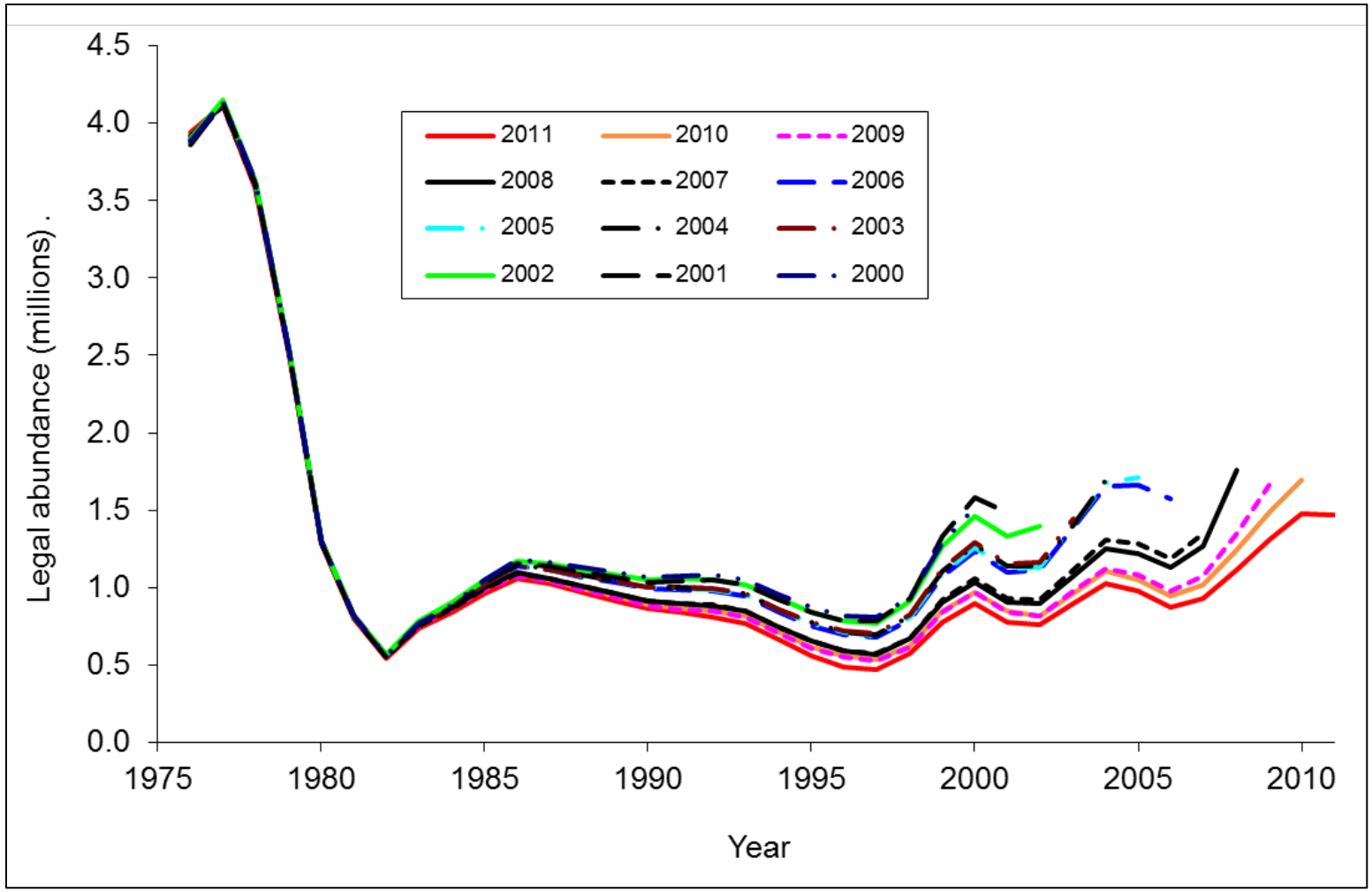
Note: No commercial fishery occurred in 1991.

Figure 3.–Historical harvest of Norton Sound red king crab in the summer commercial fishery.



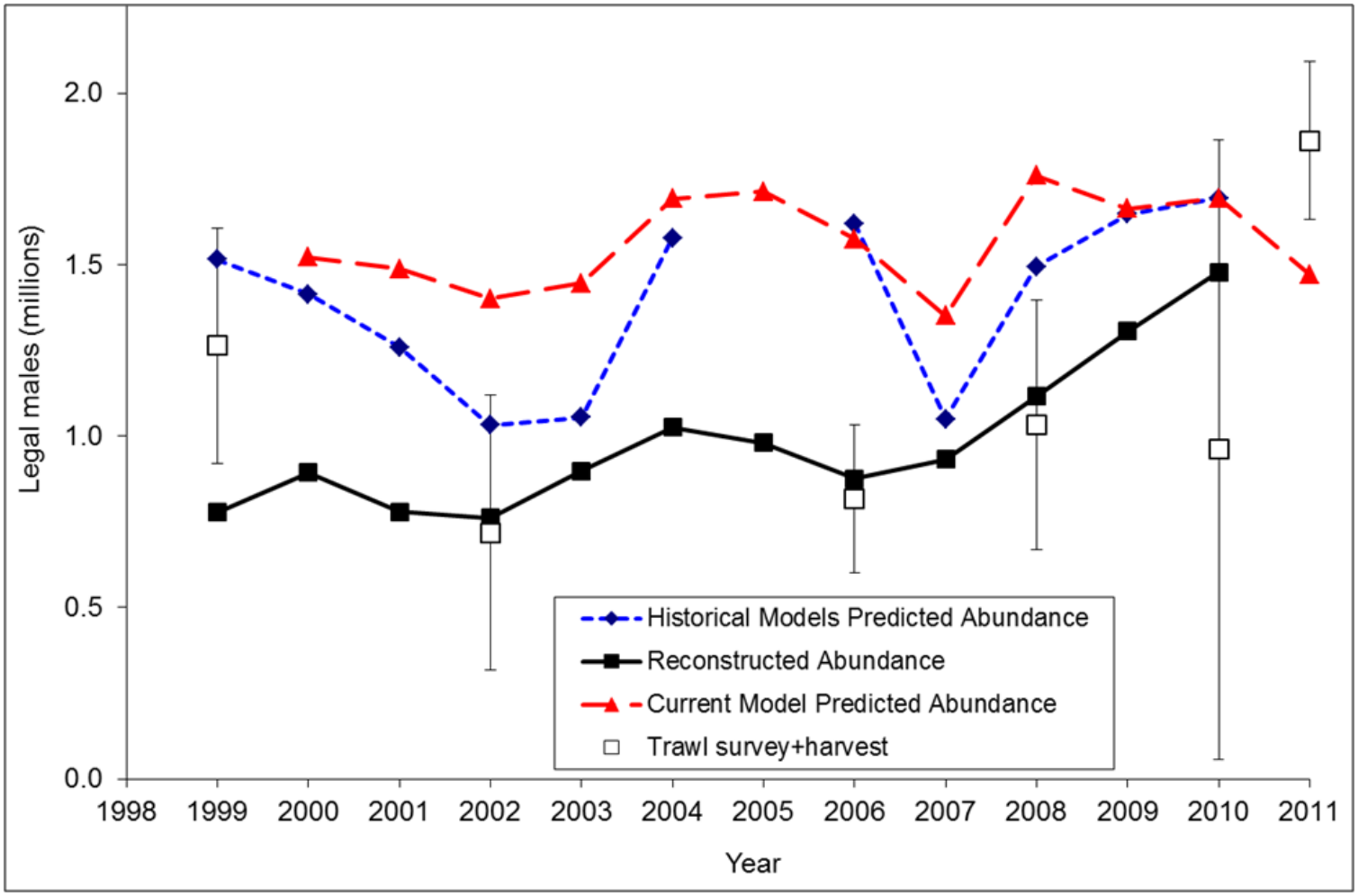
Note: Total population is composed of sublegal, recruits and legal males.

Figure 4.–Total catch of Norton Sound red king crab in the summer commercial fishery compared to reconstructed abundances (in millions of crab) for total population, recruits, and legal males.



Note: Each line indicates reconstructed abundance for historical years based on each of the terminal years 2000–2011. Legend shows the year in which the assessment was conducted.

Figure 5.–Comparison from the retrospective analysis of legal male abundance estimates of Norton Sound red king crab from 1976 to 2011.



Note: Estimates of triennial trawl survey and harvest data are also included.

Figure 6.–Comparison of estimates of legal male crab abundance, years 1999–2010, based on historical versions of the model, the current (2011) version of the model and reconstructed abundance estimates.

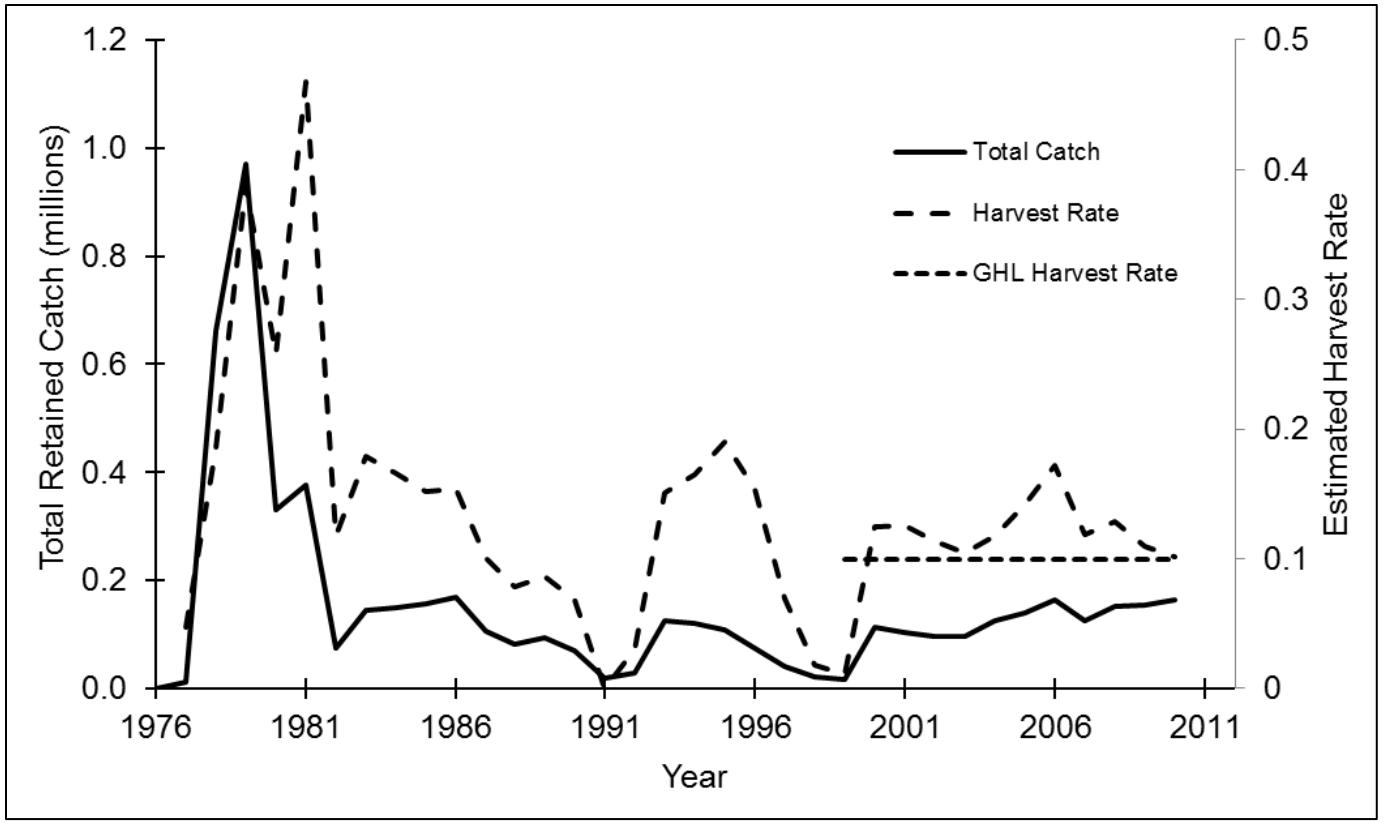


Figure 7.–Norton Sound red king crab commercial catch in millions of crab, "actual" harvest rate predicted by hindcasting and 10% maximum harvest level allowed by current regulations.

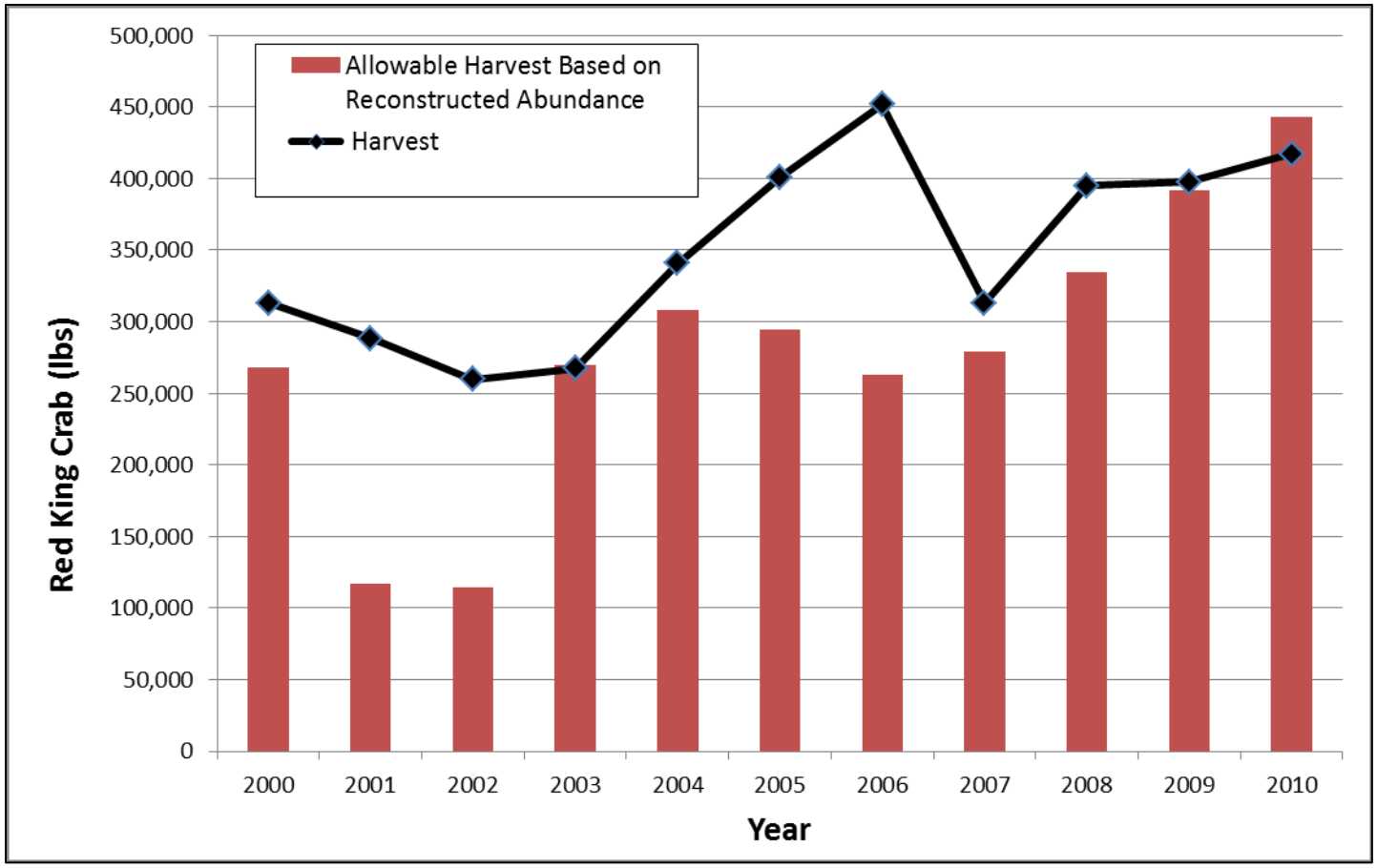
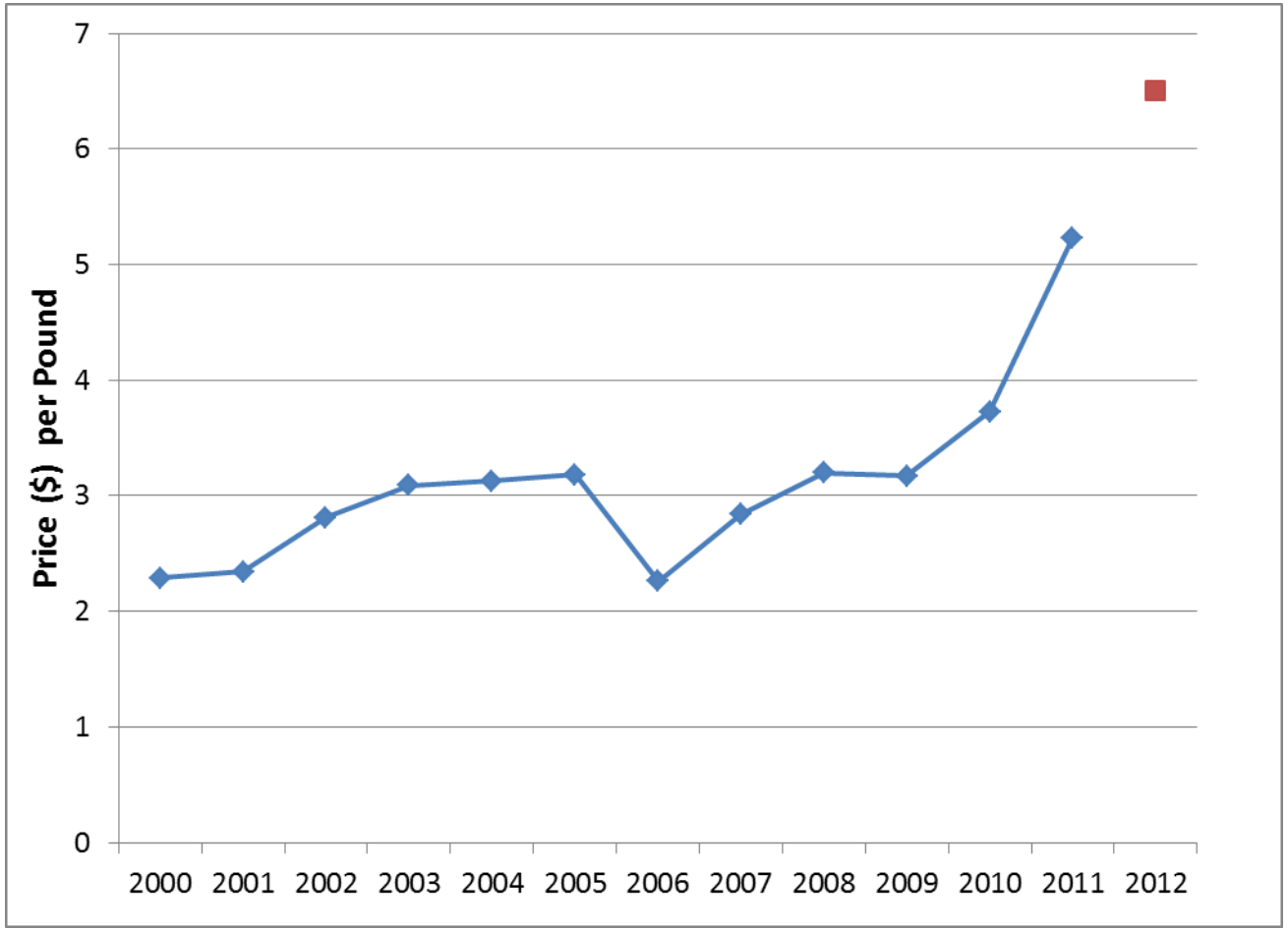
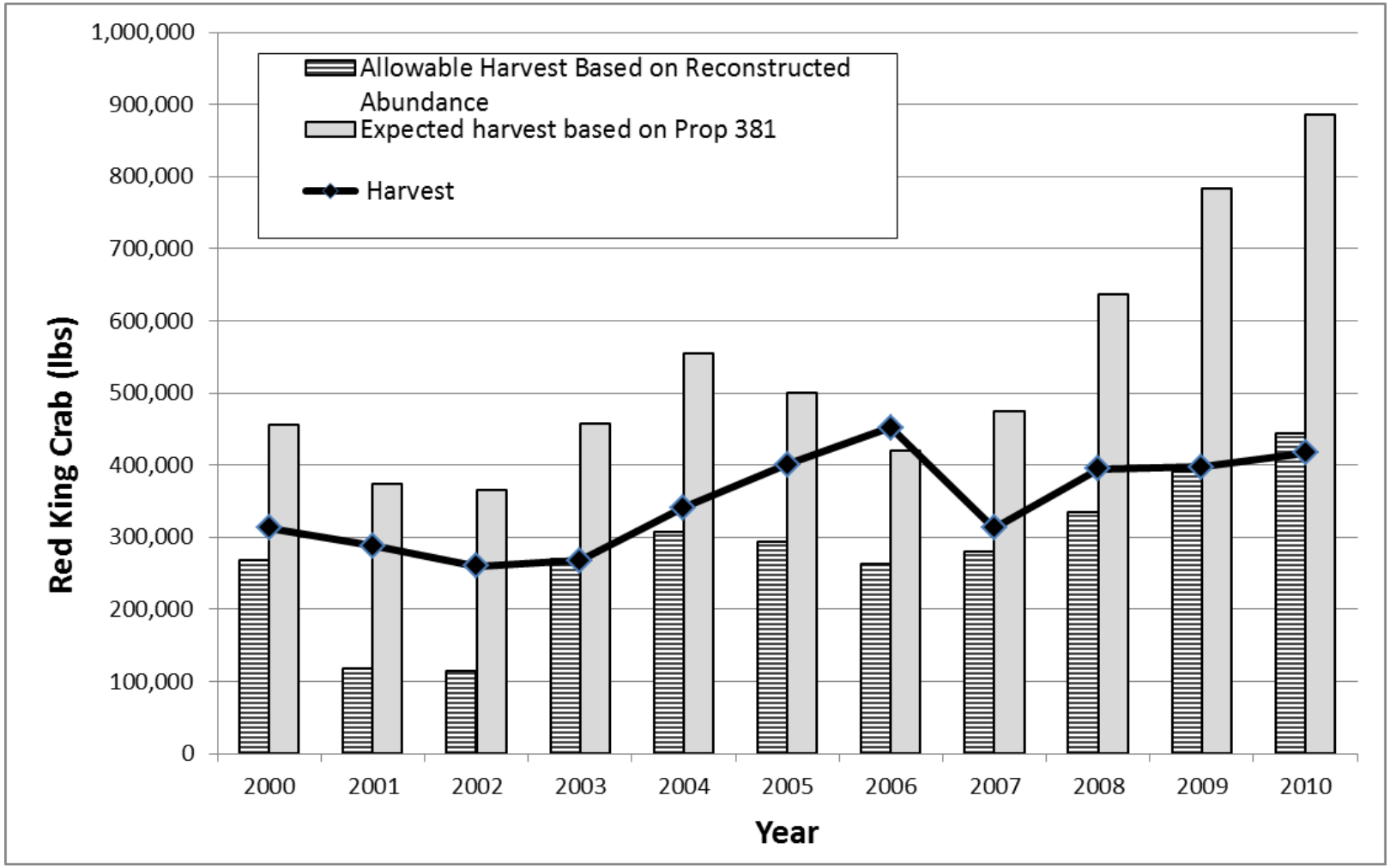


Figure 8.–Comparison of harvest actually taken in 2000–2010 and harvest that would have been allowable based on the reconstructed abundance and the current GHL thresholds.



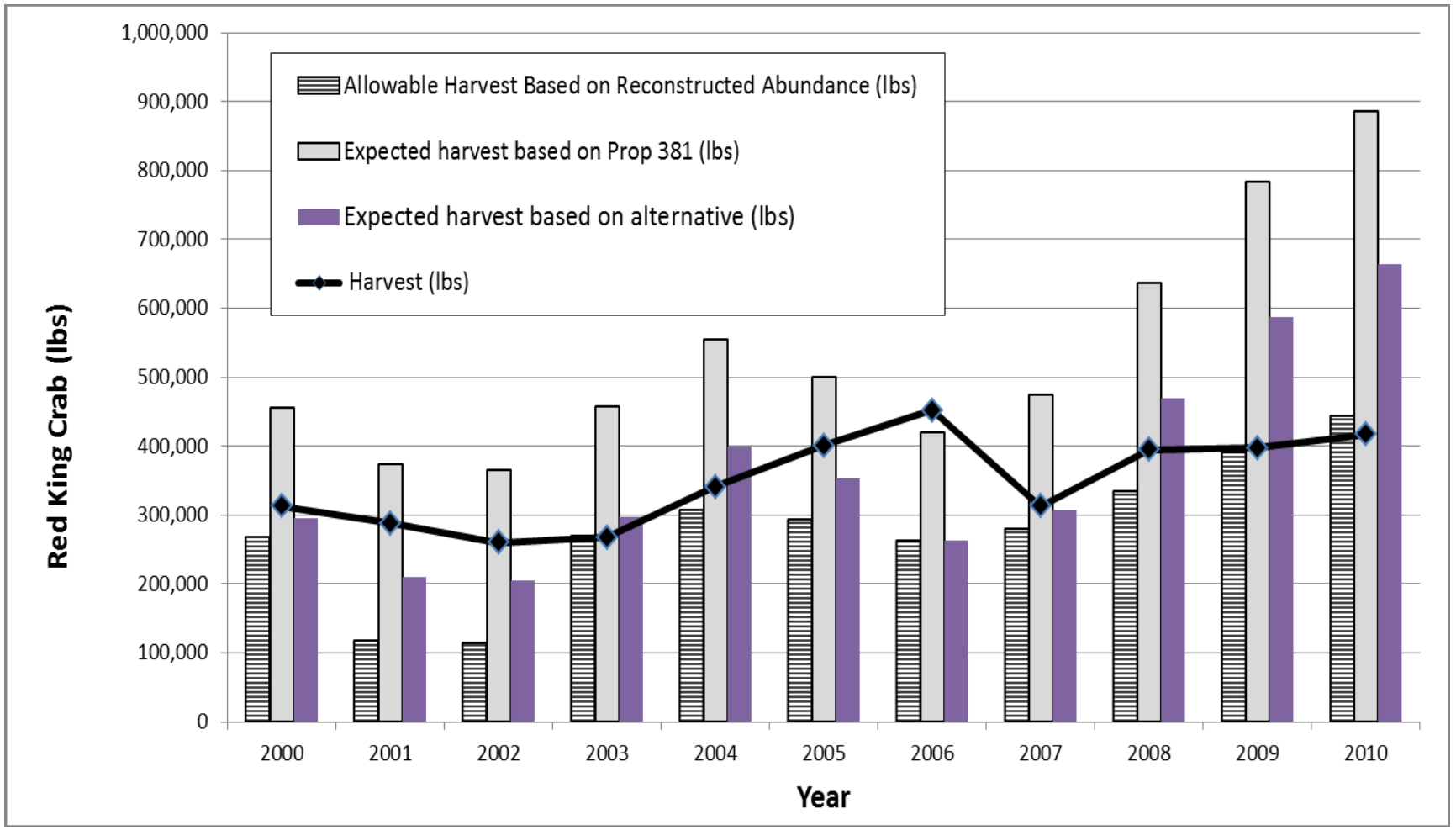
Note: The red square representing 2012 is the exvessel value of Norton Sound in the 2012 winter crab fishery. It is likely that the summer value would be similar.

Figure 9.–Exvessel value (dollar per pound) for Norton Sound red king crab, 2000–2011.



Note: Expected harvest rates are gradated within a threshold range to reflect the relative magnitude of the biomass within the associated biomass range, consistent with current management practices.

Figure 10.–Expected red king crab harvest under Proposal 381 for years 2000–2010 compared to actual harvest, and allowable harvest under current regulations and reconstructed abundances.



Note: Expected harvest rates are gradated within a threshold range to reflect the relative magnitude of the biomass within the associated biomass range, consistent with current management practices.

Figure 11.–Comparison of actual harvest from 2000–2010 to maximum allowable harvest that could have occurred based on reconstructed biomass and current regulations, expected harvest under Proposal 381, and expected harvest under the alternative.