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Northern Southeast Inside Subdistrict Sablefish Management Plan and Stock Assessment for 2022

by

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and

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Alaska Department of Fish and Game **Division of 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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TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

This report provides an overview of the stock assessment, harvest strategy, and regulations effective for the 2022 Northern Southeast Inside (NSEI) sablefish (*Anoplopoma fimbria)* commercial fishery. The NSEI sablefish commercial fishery is scheduled to open August 15 and close November 15. The 2022 NSEI sablefish commercial fishery annual harvest objective is 1,233,633 round pounds and is based on decrements from an acceptable biological catch of 1,443,314 round pounds. The annual harvest objective is allocated to 73 limited entry Commercial Fisheries Entry Commission C61A permits through an equal quota share (EQS) system, resulting in a 2022 EQS of 16,899 round pounds for each permit holder.

Key words: sablefish, black cod, *Anoplopoma fimbria*, stock assessment, annual harvest objective, AHO, catch per unit effort, CPUE, Northern Southeast, Chatham Strait, NSEI, mark–recapture, tagging

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) evaluates stock status and establishes the Northern Southeast Inside (NSEI) acceptable biological catch (ABC) and subsequent annual harvest objective (AHO). The NSEI Subdistrict management area (Figure 1) consists of all waters as defined in 5 AAC 28.105(a)(2).

The 2022 NSEI Subdistrict commercial sablefish fishery AHO is 1,233,633 round pounds (Table 1). There are 73 valid Commercial Fisheries Entry Commission (CFEC) permits for 2022, which is the same number as 2021. The individual equal quota share (EQS) is 16,899 round pounds, an 8.4% increase from the 2021 EQS of 15,587 round pounds (Table 1). The AHO is based on the sablefish ABC (Table 2) with decrements made for sablefish mortality in other fisheries (Table 3).

The recommended 2022 ABC is 1,443,314 round pounds (F_{ABC} = 0.056), a 15% increase from the 2021 ABC and the maximum allowable increase in a given year (Table 2). The increase in the ABC is attributed to a series of relatively strong recruitment events occurring between 2013 and 2016 and a substantial increase in the longline survey catch per unit effort (CPUE) in the last two years. The large increase from last year's assessment is the result of the growth of the 2013–2016-year class fish and a large increase in the estimated size of the 2016-year class relative to last year. Furthermore, spawning stock biomass has increased dramatically as fish from the 2013–2016-year classes mature. Fishery catch and ex-vessel value remain depressed as these younger, smaller fish are less valuable and may be released at sea (Figure 2). The CPUE in the longline survey declined slightly from 2021 but remains well above recent rates (Figure 3). Though recent high catch rates of small sablefish across multiple geographic areas signal increasing trends for sablefish stocks (Goethel et al. 2021), the department maintains a precautionary approach to setting harvest limits. Estimates from the 2021 stock assessment suggest sablefish spawning stock biomass remains at suppressed levels compared to the 1980s and 1990s. The ABC determination process uses a statistical catch-at-age model, which was first implemented in 2020. The model reduces the reliance on the annual mark-recapture project to estimate recruitment, abundance, and spawning stock biomass of NSEI sablefish by integrating multiple indices of abundance and biological data (e.g., catch, mark-recapture abundance estimates, longline survey and fishery CPUE, longline survey length and age compositions). As in previous years, maximum ABC is defined by F_{50}, the fishing mortality rate that reduces spawning biomass to 50% of equilibrium unfished levels.

The process leading to the determination of the ABC, AHO, and EQS includes compiling fishery and survey data, running the stock assessment, and accounting for additional sources of mortality through decrements. Although the ABC is determined prior to the AHO and EQS, this report is organized to make management-related information accessible to stakeholders and improve documentation of the assessment process by organizing this report into the following sections:

1. 2022 Sablefish Management Plan: details the decrements process leading to the AHO and EQS and effective regulations for the 2022 NSEI fishery.
2. 2021 Sablefish Stock Assessment and 2022 ABC Determination: highlights stock assessment data inputs, methods, results, and subsequent analyses that informed the recommended ABC. Full details on the stock assessment may be found in Sullivan et al. 2020.

2022 SABLEFISH MANAGEMENT PLAN

ANNUAL HARVEST OBJECTIVE DETERMINATION

The 2022 AHO was determined by making the following decrements from the recommended ABC (1,443,314 round pounds, Tables 2 and 3):

- estimated sablefish bycatch mortality in the commercial Pacific halibut fishery,
- ADF&G longline survey removals,
- sport fishery guided and unguided harvest,
- mortality from fishery deadloss, and
- subsistence and personal use harvest.

Bycatch mortality in the halibut fishery

Sablefish caught in NSEI during the Pacific halibut individual fishing quota fishery prior to the sablefish fishery season opening (August 15) must be released; however, because not all are expected to survive, bycatch mortality is estimated. Prior to 2003, a 50% bycatch morality rate was applied as bycatch sablefish were permitted to be retained as bait. In 2003, the Alaska Board of Fisheries disallowed retaining bycatch sablefish for bait, and a 25% bycatch mortality rate was assumed for all sablefish caught and released due to the larger hook size in the Pacific halibut fishery. Released sablefish bycatch is calculated as the product of the 3-year average of the sablefish to Pacific halibut ratio from the International Pacific Halibut Commission (IPHC) annual survey and the 3-year average of the Pacific halibut catch in areas greater than 99 fathoms in NSEI.

ADF&G longline survey removals

In 2022, no NSEI permit holders will participate in the NSEI longline survey due to budgetary instability and deficit given the low prices of sablefish in 2020 and 2021 (Tables 3 and 4). The survey removal decrement was determined by averaging the survey total harvest from the previous 3 years. Permit holders will likely resume survey participation in 2023.

Sport fish harvest (guided and unguided)

Sablefish sport fish preliminary harvest and release mortality from the guided and unguided sectors are estimated utilizing charter logbooks and the statewide harvest survey (Romberg et al. 2017). Estimates of harvested and released fish are based on the total number of fish and converted to weight using a 3-year average of fish sampled from the guided and unguided sectors. A 10% release mortality rate is applied to the sport fishery; this was based on the 11.7% estimated in Stachura et al. (2012) and modified to account for difference in gear type (rod and reel versus longline) and handling time.

Mortality from fishery deadloss

Deadloss mortality in the directed sablefish fishery was estimated by applying the percentage of dead sablefish (i.e., recorded as predated by sand fleas, sharks, hooking injury, or other cause of mortality) caught on the NSEI longline survey using the recent 3-year average, 0.85% (2019–2021), to the NSEI sablefish commercial AHO.

Personal use and subsistence harvest

A total of 772 personal use and subsistence sablefish permits were issued in 2021. Annual subsistence and personal use harvest of sablefish is estimated from these permits by adding the total number of retained sablefish reported to the proportion of released sablefish reported after applying a 16% discard mortality rate to released sablefish (Gilroy and Stewart 2013). The Pacific halibut fishery is assumed a reasonable proxy for sablefish because the fisheries utilize similar gear and frequently the same vessels and crew participate in both fisheries. Moreover, both species are considered hardy and do not experience barotrauma. The 2021 longline survey average weight (5.1 lb) was applied to this harvest to obtain a decrement total.

In 2015, personal use harvest was limited to an annual limit of 50 fish per household. Since 2018, participants of the personal use fishery have been allowed to use pot gear with no more than 2 pots per permit and a maximum of 8 pots per vessel when 4 or more permit holders are on board the same vessel. Use of pot gear has continued to increase with 68% of permit holders fishing pots.

REGULATIONS

2022 Board of Fisheries Decisions

In March 2022, the Alaska Board of Fisheries adopted new regulations that will be enacted prior to or during the fishing season for the NSEI sablefish commercial fishery. An advisory announcement will be issued at a later date with more information. These new regulations include:

- Full retention requirements and landing requirements using hook-and-line and pot gear for all species of rockfish including thornyhead rockfish.
- Allowing pot gear as a legal gear type in addition to longline gear for the C61A permits, which is contingent upon the approval process through CFEC.
- If pot gear is approved as a legal gear type for the C61A permits, pots must have at least two circular escape rings, with a minimum inside diameter of three and three-fourths inches, installed on opposing vertical or sloping walls of the pot.

Registration and logbook requirements

Fishermen must register prior to fishing [5 AAC 28.106 (b)] and keep a logbook during the fishery. Completed logbook pages must be attached to the ADF&G copy of the fish ticket at the time of delivery. Confidential envelopes for logbook pages may be requested when registering.

Permit holders will receive a personal quota share (PQS) tracking form at the time of registration. This form is used to record the total round weight landed for each delivery. Each permit holder must, upon request, provide the buyer with the total round weight of sablefish the permit holder has landed to date. The department requests that a copy of the completed PQS tracking form is included with the final fish ticket of the season for that permit.

Logbooks must include, by set, the date and time gear is set and retrieved, specific location of harvest by latitude and longitude for start and ending positions, hook spacing, amount of gear (number of hooks and skates) used, depth of set, estimated number or weight of the target species, and the estimated number or weight of bycatch by species. Permit holders must indicate for each set if the target species was sablefish or Pacific halibut and if there was any gear lost. A permit holder must retain all visibly injured or dead sablefish. Sablefish that are not visibly injured or dead may be released unharmed, and the permit holder must record in the logbook, by set, the number of live sablefish released [5 AAC 28.170(f)]. Permit holders must record release reason (e.g., fish are small) and whether their personal quota share has been met.

Tagged sablefish

Fishermen are requested to watch for tagged sablefish, record tag number(s), and attach tags directly in the logbook with the corresponding set information. All tags returned will receive a reward. Tag rewards include a t-shirt and entry into an annual drawing for one $1,000, two $500, and four $250 cash rewards. To qualify for entry in the annual drawing, ADF&G requires the following information: the tag, set location (latitude and longitude), date of capture of the fish, and the name and address of the person recovering the tag.

Sablefish possession and landing requirements

In the NSEI Subdistrict, the holder of a CFEC permit for sablefish may not retain more sablefish from the directed fishery than the annual amount of sablefish EQS specified by the department [5 AAC 28.170 (f)]. However, if a permit holder's harvest exceeds the EQS for that year, by not more than 5%, ADF&G shall reduce the permit holder's EQS for the following year by the amount of the overage. If a permit holder's harvest exceeds the permit holder's EQS by more than 5%, the proceeds from the sale of the overage in excess of 5% shall be surrendered to the state and the permit holder may be prosecuted under AS 16.05.723 [5 AAC 28.170 (j)]. If a permit holder's harvest is less than the permit holder's EQS established for the year, ADF&G shall increase the permit holder's PQS only for the following year by the amount of the underage that does not exceed 5% of the EQS [5 AAC 28.170 (k)]. For the 2022 fishing season, 5% of the annual EQS is 845 round pounds.

Fish ticket requirements

Landed weights must be recorded on a fish ticket at the time of delivery. If a fisherman delivers fish in the round, the total round weight delivered must be recorded on the fish ticket. If a fisherman delivers dressed fish, the fish ticket must include the total landed dressed weight as well as the round weight equivalent, determined by using the standard 0.63 recovery rate. There is a 2% allowance for ice and slime when unrinsed whole iced sablefish are weighed. A fish ticket must be completed prior to the resumption of fishing and each permit holder must retain, on board their vessel, copies of all NSEI sablefish tickets from the current season and their updated PQS tracking form. When delivering fish out of state, a completed fish ticket must be submitted to ADF&G prior to transporting fish out of Alaska.

Bycatch allowances for other species

Full retention and reporting of rockfish *Sebastes*, excluding thornyhead rockfish *Sebastolobus*, is required for internal waters (5 AAC 28.171). The full retention regulation does not apply to thornyhead rockfish at the time of publication but will when the new regulations become effective in 2022. The allowable bycatch that may be legally landed and sold on an NSEI sablefish permit is based on round weight of sablefish and bycatch species or species group on board the vessel:

- All rockfish, including thornyheads: 15% in aggregate, of which 1% may be demersal shelf rockfish (DSR), which includes yelloweye, quillback, canary, tiger, copper, China, and rosethorn rockfish
- Lingcod: 0%
- Pacific cod: 20%
- Spiny dogfish: 35%
- Other groundfish: 20%

All rockfish retained in excess of allowable bycatch limits shall be reported as bycatch overage on an ADF&G fish ticket. All proceeds from the sale of excess rockfish bycatch shall be surrendered to the state. Excess rockfish retained due to full retention requirements may be retained for personal use; however, the pounds must be documented as overage on the fish ticket.

A CFEC permit holder fishing for groundfish must retain all Pacific cod when the directed fishery for Pacific cod is open and up to the maximum retainable bycatch amount (20%) of Pacific cod when a directed fishery for Pacific cod is closed [5 AAC 28.070 (e)]. Pacific cod taken in excess of the bycatch limit in areas open to directed fishing for Pacific cod may be landed on a CFEC miscellaneous saltwater finfish permit designated for the gear that was used. Fishermen with halibut Individual Fishing Quota (IFQ) in regulatory area 2C and a CFEC halibut permit card must retain all halibut over 32 inches in length, up to the amount of their IFQ.

Sablefish live market

The holder of a CFEC or interim use permit for sablefish may possess live sablefish for delivery as live product except that, upon request of a local representative of the department or law enforcement, a permit holder must present sablefish for inspection and allow biological samples to be taken [5 AAC 28.170 (l)].

Prohibitions

The operator of a fishing vessel may not take sablefish in the NSEI area with sablefish from another area on board. Also, the operator of a vessel taking sablefish in the NSEI area shall unload those sablefish before taking sablefish in another area [5 AAC 28.170(a) and (b)].

A vessel, or person onboard a vessel, from which commercial, subsistence, or personal use longline fishing gear was used to take fish in the NSEI or SSEI Subdistricts during the 72-hour period immediately before the start of the commercial sablefish fishery in that subdistrict, or from which that gear will be used during the 24-hour period immediately after the closure of the commercial sablefish fishery in that subdistrict, may not participate in the taking of sablefish in that subdistrict during that open sablefish fishing period. A vessel, or a person onboard a vessel, who has harvested and sold their personal quota share before the final day of the sablefish season in that subdistrict is exempt from the prohibition on fishing longline gear during the 24-hour period immediately following the closure of the sablefish fishery in that subdistrict. In addition, a vessel or a person on board a vessel commercial fishing for sablefish in the NSEI Subdistrict may not operate subsistence or personal use longline gear for groundfish from that vessel until all sablefish harvested in the commercial fishery are offloaded from the vessel.

2021 SABLEFISH STOCK ASSESSMENT AND 2022 RECOMMENDED ABC DETERMINATION

Sablefish are a highly migratory, long-lived species broadly distributed in the North Pacific Ocean. Although research to date suggests that sablefish comprise a single, panmictic population, they are managed as separate stocks in Alaska state and federal waters, British Columbia, and in state and federal waters off the U.S. west coast. After three decades of declining or suppressed spawning stock biomass in the North Pacific, persistent high catch rates of small sablefish in recent years across multiple surveys and fisheries signal strong recruitment and increasing trends for the stock (Goethel et al. 2021).

Despite these positive population trends, we continue to recommend a precautionary approach to setting harvest limits. The target fishing mortality rate of F_{50}, that defines maximum ABC is based on female spawning stock biomass and does not consider the relative economic value of sablefish. Because sablefish begin contributing to the spawning biomass as young as age-3, ABCs can increase quickly even if average fish size is small. These small sablefish are worth significantly less per pound, making them subject to high release rates in NSEI where fishery releases are legal. Taken together, steep annual increases in ABCs in response to large recruitment events can result in low fishery value, and the unobserved fishery releases introduce an uncertain source of mortality into the stock assessment. This story appears to be playing out in NSEI, where an increase in the prevalence of small fish has driven down prices across all size grade categories in recent years. This was readily apparent in last year's assessment where there was a 28% decrease in ex-vessel value between 2019 and 2020 despite a 21% increase in total catch (Figure 2). Catches decreased slightly from 2020 to 2021 (1.6%) while ex-vessel value decreased by 8.9%, with the effects of the COVID-19 pandemic on seafood markets likely contributing to lower ex-vessel values. Furthermore, fishery CPUE estimates have varied widely in recent years likely reflecting different discard practices between vessels and over the course of the fishing season.

In response to these concerns, we introduced a "max 15% change" management procedure in 2020 that constrains the recommended ABC to a 15% annual maximum change. This management procedure was well-received during two stakeholder and industry meetings in April 2020 and 2021 and appears to be supported by the fleet. The "max 15% change" management procedure has been shown to increase fishery stability, maximize catch, and successfully achieve biological goals in long-term simulations conducted by IPHC (https://www.iphc.int/uploads/pdf/srb/srb014/ppt/iphc-2019-srb014-08-p.pdf). The current NSEI harvest policy continues to define maximum permissible ABCs at F_{50}, and recommended ABCs will be constrained to a maximum 15% change between years.

In 2020, we implemented an integrated statistical catch-at-age (SCAA) model for the NSEI stock assessment, which had been in development for several years (Sullivan et al. 2020). The SCAA model is structured similarly to the federal sablefish model (Goethel et al. 2021) and allows for the estimation of recruitment, spawning stock biomass, and abundance. We continue to recommend this modeling framework and made several improvements to the stock assessment to inform the 2021 fishery. This model was used again in 2022 with minor changes.

CHANGES TO THE 2021 NSEI ASSESSMENT RELATIVE TO 2020

Updates to the stock assessment are listed in order of relative impact to results:

1. Fishery CPUE data were updated for both 2020 and 2021. In 2020, the ADF&G Southeast Groundfish Project biologists invested considerable staff time and resources into standardizing the full time series of available logbook data, which should improve the long-term quality and interpretation of this index. In particular, consistent methods for identifying target species by trip and set efforts were developed, which was previously conducted manually.
2. Expanding on the revised fishery CPUE estimates, several versions of fishery CPUE were examined, including nominal estimates and fitted CPUE values from models using soak time and depth. Different models of CPUE produced similar results and models run using the different indices produced similar estimates of ABC.

We made no additional changes to the SCAA model structure or assumptions, estimation of biological reference points, or population dynamics equations. We used status quo methods to update estimates of weight-at-age, maturity-at-age, catch, survey CPUE, mark-recapture abundance, and age/length compositions. For detailed technical information on the SCAA model and data preparation, please see Sullivan et al. (2020) or visit the GitHub repository for this project: https://github.com/commfish/seak_sablefish.

STOCK ASSESSMENT RESULTS AND RECOMMENDATIONS

The SCAA model presents a maximum permissible ABC of 1,595,932 round lb at a target fully-selected fishing mortality of F_{50} = 0.062. This is a 340,876 lb increase (27%) from the 2021 recommended ABC of 1,255,056 round lb and reflects the current projections of increasing biomass (Figure 4). The change in ABC is above 15%, therefore the recommended ABC is set equal to the maximum permissible (15%) of 1,443,314 round lb. To account for legal releases of small sablefish in NSEI, fixed retention probabilities and an assumed discard mortality rate of 16% (Gilroy and Stewart) were incorporated directly into the SCAA model following Sullivan et al. (2019). The mortality from fishery releases under F_{50} is estimated to be 72,190 lb and is incorporated directly into the max ABC calculation.

One particularly challenging aspect of modeling sablefish population dynamics is the identification and estimation of recent year classes. For example, what was originally estimated to be a single "blockbuster" year class in 2014 is now estimated to be a series of relatively strong recruitment events occurring between 2013 and 2016. In this assessment the 2016-year class appears most dominant in that grouping and twice as strong as was estimated in last year's assessment. It now appears as the second strongest recruitment on record (although still a distant second to the 1978-year class). The updated estimate of this year class and the somatic growth of all fish in the 2013–2016-year classes explain the upward trend in biomass and boost to allowable catches.

Age structured assessment are often plagued by positive retrospective bias whereby initial estimates of recent recruitment are overestimated and become downgraded with additional new data. This is often caused by model misspecification of natural mortality, maturity, growth, or selectivity, all unobserved processes that can vary over time. The 2019 assessment model had a particularly high positive retrospective bias (Mohn's rho of 0.30 for spawning biomass), and improvements to selectivity assumptions in in this year's model have largely resolved this retrospective pattern. Mohn's rho remains low in this year's assessment (Figure 5). Ageing error can also play a large role in the identification of year classes because young sablefish are particularly challenging to age (see Appendix B in Sullivan et al. 2020). This may in part explain discrepancies between year class size estimates among assessments. As the stock assessment is refined and updated, it is likely that future recruitment estimates and our understanding of stock size in NSEI will continue to evolve.

The following are other notable results from the 2021 stock assessment:

1. Longline survey CPUE decreased slightly (6%) from 2020 to 2021 but remains well above observed historical CPUEs and is the second largest on record for this index (Figure 2). Fits to fishery CPUE remain poor.
2. Estimates suggest the sablefish spawning stock biomass and abundance remain at a suppressed level compared to the 1980s and 1990s; however, there is now a clear trend of increasing biomass as the 2013–2016-year classes gain in mass and become fully mature (Figure 3).
3. Fits to fishery and survey age and length composition were similar to last year's assessment and although the fits are improved, there remains room for improvement going forward (Figures 6-11).

Due to change over in biometric staff, the model was not modified this year. Here we present a list of recommendations for further model development, many of which were suggested by the original assessment biometrician (Sullivan et al. 2019):

1. There is considerable room for improvement of the mark-recapture estimates of abundance. Most importantly, the current project provides an estimate of abundance that is biased to an unknown degree and direction due to violations of key mark-recapture assumptions. Generating unbiased estimate of abundance in a mark-recapture study relies on accurate records of the number of fish being marked, the number of fish being examined for marks and the number of marks detected (recaptures). The current project relies on fishermen for the recapture event whereby tags are removed from fish prior to being examined at the processors and there is often poor agreement between the number of tags returned and the number of fin clips observed (the secondary mark). This indicates that some fish may have tags removed but are released at sea (over-reporting) while other fish are retained but have their tags removed without reporting (under-reporting). Moreover, this behavior is likely to change over time in relation to discard behavior associated with shifting size composition and price incentives in the fishery. The longline survey conducted by the department currently does not include countbacks whereby accurate estimates of marks and unmarked fish could be obtained (this has only occurred in 2008 and 2010).
   The current SCAA model relies more on the longline survey CPUE than abundance estimates from the mark-recapture project to project trends in abundance over time, and it is not necessary to conduct a mark-recapture project every year (Sullivan et al. 2019). However, the mark-recapture abundance estimates provide the model with the scale of biomass and as such are still an important piece of the assessment. Two key improvements are recommended going forward. Firstly, the next assessment should include a risk analysis to examine the effects of biased abundance estimates on the SCAA output, including biological reference points and management recommendations. Secondly, during years when the mark-recapture project takes place it should be a priority to obtain full countbacks from the department's longline survey to obtain accurate marked:unmarked ratios that would provide a basis for assessing tag reporting in the fishery.
2. Apart from the mechanics of the mark-recapture project, analytical improvements in the mark-recapture assessment may also be possible. The current analysis considers all years as a whole and selects a "best," or optimal, model that is then applied to all years. Given

the length of the time series and changing conditions in the population it is likely that the optimal model for estimating abundance may change from year to year. Along these lines, there is a lack of diagnostics performed on the data to examine equal probability of capture assumptions that may be violated and thus result in biased estimates of abundance. As such, it is suggested that the mark-recapture data be examined for each year separately and an appropriate suite of diagnostics be performed to determine if capture probabilities vary by fish size and location (current models are designed to handle temporal variability). When necessary, stratified abundance estimates should be produced to reduce potential bias.

3. Although not a high priority, there are a lot of data in the mark-recapture experiments that have not been explored, suggesting potential for developing a more sophisticated open-population model. Tagged fish are recovered in noticeable numbers for a decade after tagging which suggests suitability for an open population, Jolly-Seber style model. Open population models (i.e., models that do not assume a closed population) would allow for estimation of survival, immigration/emigration, and potentially recruitment in addition to providing more informed estimates of abundance and uncertainty. Estimates of survival could be extremely useful for refining our understanding of natural mortality, which is one of the most notoriously difficult parameters to deal with in age-structured assessments. Furthermore, a large source of uncertainty in our understanding of this stock involves the movement of fish in and out of Chatham Strait (indeed movement of sablefish remains an issue in most stocks). An open population model has the potential to provide insight on this issue. Given the rarity of long-term data sets of individually marked fish in a long-lived species there is potential for improved understanding of sablefish in general. However, there is evidence that fish have tags removed by fishermen and are then released back into the population, which would violate key assumptions about mark retention. Attempts at an open population model will need to consider this violation in model development.
4. As recommended by the original stock assessment author, a more rigorous analysis of the data weighting methods should be performed.
5. Further work is needed on developing a more informed retention curve (probability of discarding fish based on size) for the fishery, potentially using length distributions from the longline survey and the fishery.
6. Both the maturity-at-age curve and the weight-at-age curves are fixed across all years but both relationships are likely to shift over time owing to density dependent effects and large but sporadic recruitment events. Allowing these curves to vary over time may help length composition and age composition estimates better fit the model. However, assessing maturity in sablefish macroscopically has proven difficult and unreliable at sea (Rodgveller 2018) and a re-examination of that data should be performed before deciding whether modelling maturity-at-age on an annual basis is feasible and warranted.
7. The aging error matrix and the age-length keys are currently taken from the federal assessments. Developing keys specific to Chatham Strait would be beneficial to improving model performance.
8. Implementing the model in a Bayesian framework to better account for uncertainty in model parameters and directly incorporate that uncertainty into the calculation of biological reference points and management recommendations.

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REFERENCES CITED

Gilroy, H. L., and I. J. Stewart. 2013. Incidental mortality of halibut in the commercial halibut fishery (Wastage). Pages 53–60 [*In*] International Pacific Halibut Commission report of assessment and research activities 2012.

Goethel, D. R., D. H. Hanselman, C. J. Rodgveller, K. B. Echave, B. C. Williams, S. K. Shotwell, J. Y. Sullivan, P. F. Hulson, P. W. Malecha, K. A. Siwicke, and C. R. Lundsford. 2021. Chapter 3: Assessment of the sablefish stock in Alaska. [In] Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska, Bering Sea and Aleutian Islands as projected for 2022. North Pacific Fishery Management Council, Anchorage.

Rodgveller, C. J. 2018. A comparison of methods for classifying female sablefish maturity and skip spawning outside the spawning season. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 10: 563-576.

Romberg, W. J., K. S. Sundet, and I. Rafferty. 2017. Alaska statewide sport fish harvest survey, 2017. Alaska Department of Fish and Game, Regional Operational Plan ROP.SF.4A.2017.06, Anchorage.

Stachura, M. M., C. R. Lunsford, C. J. Rodgveller, and J. Heifetz. 2012. Estimation of discard mortality of sablefish (Anoplopoma fimbria) in Alaska longline fisheries. Fishery Bulletin 110(2):271–279.

Sullivan, J., R. Ehresmann, and B. Williams. 2020. Northern Southeast Inside Subdistrict sablefish management plan and stock assessment for 2020. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J20-05, Juneau.

Sullivan, J., A. Olson, and B. Williams. 2019. 2018 Northern Southeast Inside Subdistrict sablefish fishery stock assessment and 2019 management plan. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J19-03, Juneau.

TABLES AND FIGURES

Table 1.–Annual harvest objective (round lb), equal quota share (round lb), reported harvest (round lb), exvessel value, number of permits, and effort (days) for the directed commercial Northern Southeast Inside (NSEI) Subdistrict sablefish fishery, 1985–2022.

Year	Annual harvest objective	Equal quota share[a]	Harvest	Exvessel value (mil)	No. of permits	No. of days
1985	2,380,952	–	2,951,056	$2.0	105	3
1986	2,380,952	–	3,874,269	$2.9	138	2
1987	2,380,952	–	3,861,546	$3.5	158	1
1988	2,380,952	–	4,206,509	$4.5	149	1
1989	2,380,952	–	3,767,518	$2.9	151	1
1990	2,380,952	–	3,281,393	$3.5	121	1
1991	2,380,952	–	3,955,189	$6.9	127	1
1992	2,380,952	–	4,267,781	$4.9	115	1
1993	2,380,952	–	5,795,974	$5.6	120	1
1994	4,761,905	38,889	4,713,552	$9.1	121	30
1995	4,761,905	38,889	4,542,348	$7.7	121	30
1996	4,761,905	38,889	4,673,701	$9.9	121	61
1997	4,800,000	39,300	4,753,394	$11.6	122	76
1998	4,800,000	41,700	4,688,008	$7.4	116	76
1999	3,120,000	28,000	3,043,273	$6.6	112	76
2000	3,120,000	28,600	3,082,159	$7.4	111	76
2001	2,184,000	19,600	2,142,617	$4.6	111	76
2002	2,005,000	18,400	2,009,380	$4.8	109	76
2003	2,005,000	18,565	2,001,643	$4.8	108	93
2004	2,245,000	20,787	2,229,956	$4.5	108	93
2005	2,053,000	19,400	2,026,131	$5.0	106	93
2006	2,053,000	19,550	2,033,786	$5.1	105	93
2007	1,488,000	14,500	1,501,478	$3.8	103	93
2008	1,508,000	15,710	1,513,040	$4.9	96	93
2009	1,071,000	12,170	1,071,554	$3.6	88	93
2010	1,063,000	12,218	1,054,275	$4.4	87	93
2011	880,000	10,602	882,779	$4.9	83	93
2012	975,000	12,342	969,535	$3.6	79	93
2013	1,002,162	12,848	971,499	$2.9	78	93
2014	745,774	9,561	772,258	$3.2	78	93
2015	786,748	10,087	780,615	$3.4	78	93
2016	650,754	8,343	646,328	$3.2	78	93
2017	720,250	9,234	714,400	$3.9	78	93
2018	855,416	10,967	855,598	$3.5	78	93
2019	920,093	11,796	909,341	$3.1	78	93
2020	1,108,003	14,773	1,101,094	$2.1	75	93
2021	1,137,867	15,587	1,083,363	$2.8	73	93
2022	1,233,633	16,899	NA	NA	73	93

[a] The equal quota share program was implemented in 1994.

Table 2.–Summary of key assessment results used to inform management in 2021 and 2022 and 2021. This table includes the estimates of projected total biomass (sablefish aged 2 years and above) and female spawning stock biomass, estimated biological reference points of unfished female spawning biomass ($SB_{100\%}$), female spawning biomass at 50% of unfished levels ($SB_{50\%}$), and the maximum target fishing mortality of F_{50}. Additional values include the maximum permissible Acceptable Biological Catch (max ABC) defined by F_{50}, the estimates of mortality from fishery releases that would result under max ABC and a discard mortality rate of 0.16, and the recommended ABC under the max 15% change management procedure.

Quantity/Status	2021	2022
Projected total (age 2+) biomass (lb)	43,357,877	51,885,665
Projected female spawning biomass (lb)	15,278,067	19,714,244
Unfished female spawning biomass ($SB_{100\%}$, lb)	26,775,615	28,995,917
Female spawning biomass at F_{50} ($SB_{50\%}$, lb)	13,387,807	14,497,958
max $F_{ABC} = F_{50}$	0.0611	0.0617
Recommended F_{ABC}	0.0611	0.0559
Mortality from fishery releases (lb)	59,017	72,190
max ABC (lb)	1,255,056	1,595,932
Recommended ABC (lb)	1,255,056	1,443,314

Table 3.–Decrement types and amounts, 2017–2022. Estimated catch is in round pounds of sablefish.

	Year					
	2017	2018	2019	2020	2021	2022
Acceptable biological catch	850,113	965,354	1,058,037	1,216,743	1,255,056	1,443,314
Decrement Type (round lb)	Estimated Mortality					
Bycatch mortality in halibut fishery[a]	26,136	19,583	18,434	16,207	38,124	35,406
ADF&G longline survey removal decrement (excluding catch retained by permit holders for their equal quota share)[a]	29,290	15,875	26,260	24,698	42,499	95,502
Guided sport fish harvest[b]	43,656	41,179	33,135	35,004	753	33,990
Unguided sport fish harvest[b]	3,911	5,872	11,340	5,280	5,631	9,846
Mortality from fishery deadloss[a]	4,250	5,699	8,046	9,729	10,888	11,085
Mortality from fishery releases[a]	–	–	19,142	–	–	–
Subsistence and personal use harvest[b]	22,621	21,730	21,587	17,821	19,295	23,852
Total decrements	129,863	109,938	137,944	108,740	117,189	209,681
Annual harvest objective	720,250	855,416	920,093	1,108,003	1,137,867	1,233,633
Permit holders	78	78	78	75	73	73
Equal quota share	9,234	10,967	11,796	14,773	15,587	16,899

[a] Projected estimate of mortality for the current season.
[b] Estimate of mortality that occurred during the previous season and is applied as decrement for the current season.

Table 4.–Sablefish harvest (round pounds) from the Northern Southeast Inside Subdistrict (NSEI) longline survey, 1988–2022, survey removal decrement (survey harvest minus the combined harvest allocated to the equal quota shares of permit holders aboard the survey vessels), and the number of permit holders participating in the survey.

Year	ADF&G survey harvest (round lbs)	Survey decrement (round lbs)	No. of permit holders participating in longline survey
1988	25,135	–	–
1989	20,602	–	–
1990	32,513	–	–
1991	24,692	–	–
1992	18,902	–	–
1993	30,992	–	–
1994	24,016	–	–
1995	53,041	–	–
1996	48,066	–	–
1997	51,005	–	–
1998	79,471	–	–
1999	58,924	–	–
2000	88,940	–	–
2001	116,998	–	–
2002	101,873	–	–
2003	111,545	–	–
2004	98,254	–	–
2005	128,042	–	–
2006	105,830	–	–
2007	111,067	–	–
2008	116,816	–	–
2009	111,610	–	–
2010	108,907	76,654	3
2011	117,894	50,866	6
2012	120,505	77,499	3
2013	95,393	77,261	3
2014	103,662	80,814	3
2015	92,888	74,689	3
2016	90,157	53,914	5
2017	91,924	29,290	7
2018	84,055	15,875	7
2019	65,347	26,260	5
2020	118,719	24,698	3
2021	102,439	42,499	2
2022	NA	95,502	0

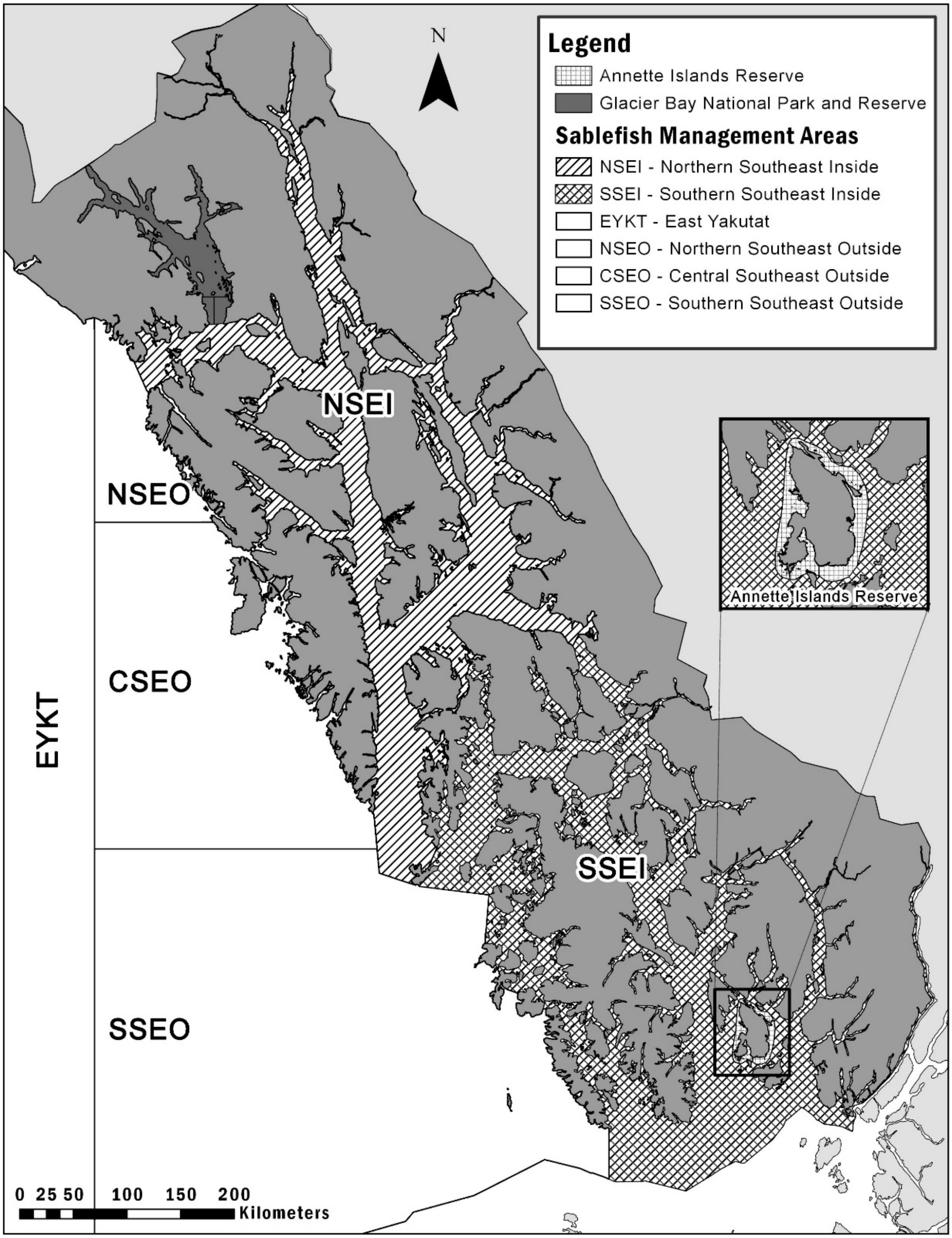

Figure 1.–Northern Southeast Inside (NSEI) and Southern Southeast Inside (SSEI) Subdistricts including restricted waters of Glacier Bay National Park and Preserve and Annette Islands Reserve.

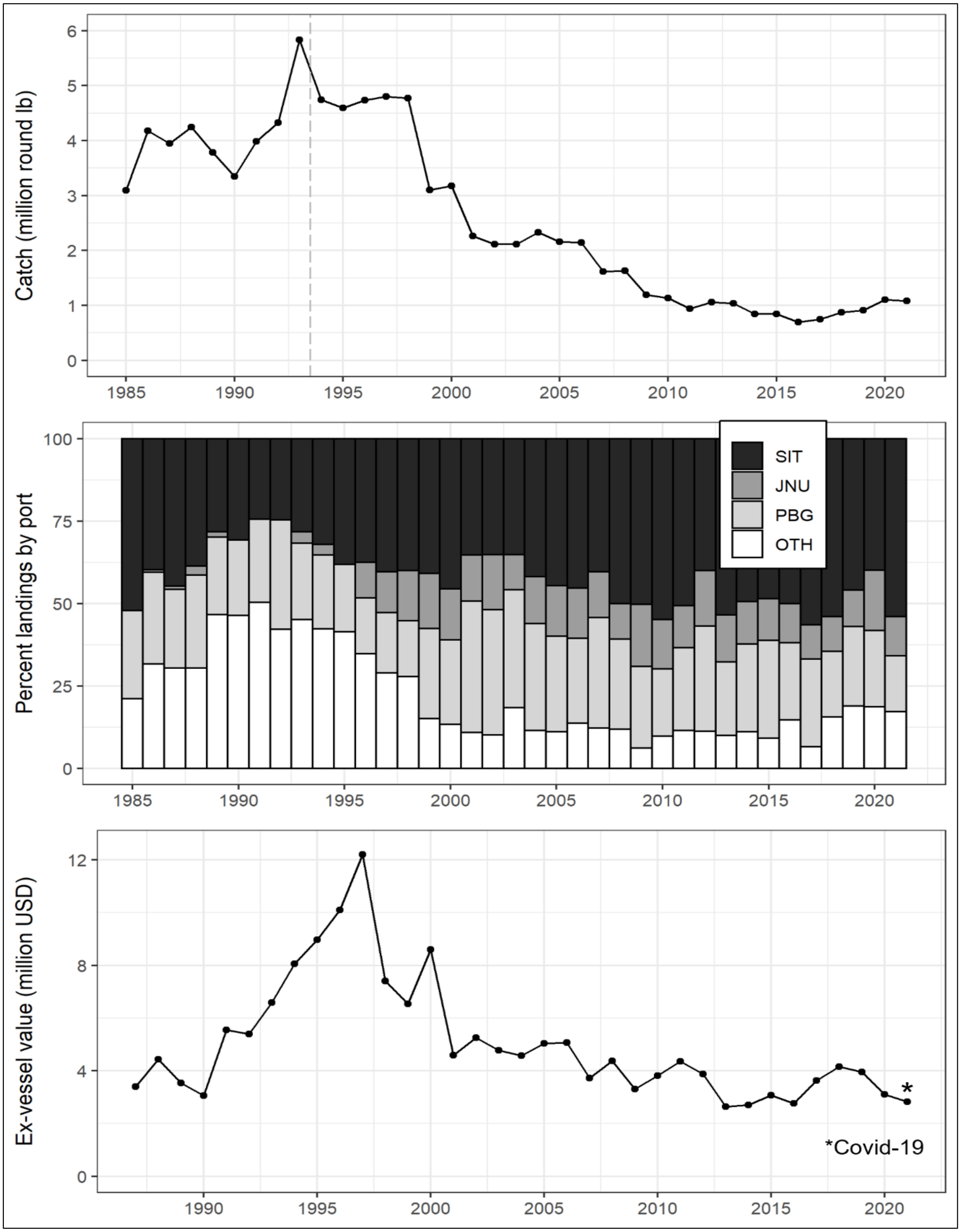

Figure 2.–Catch, landings by port, and ex-vessel value for Northern Southeast Inside (NSEI) Subdistrict commercial sablefish 1985–2021. The asterisk denotes the COVID-19 pandemic and potential effects on ex-vessel value in 2021.

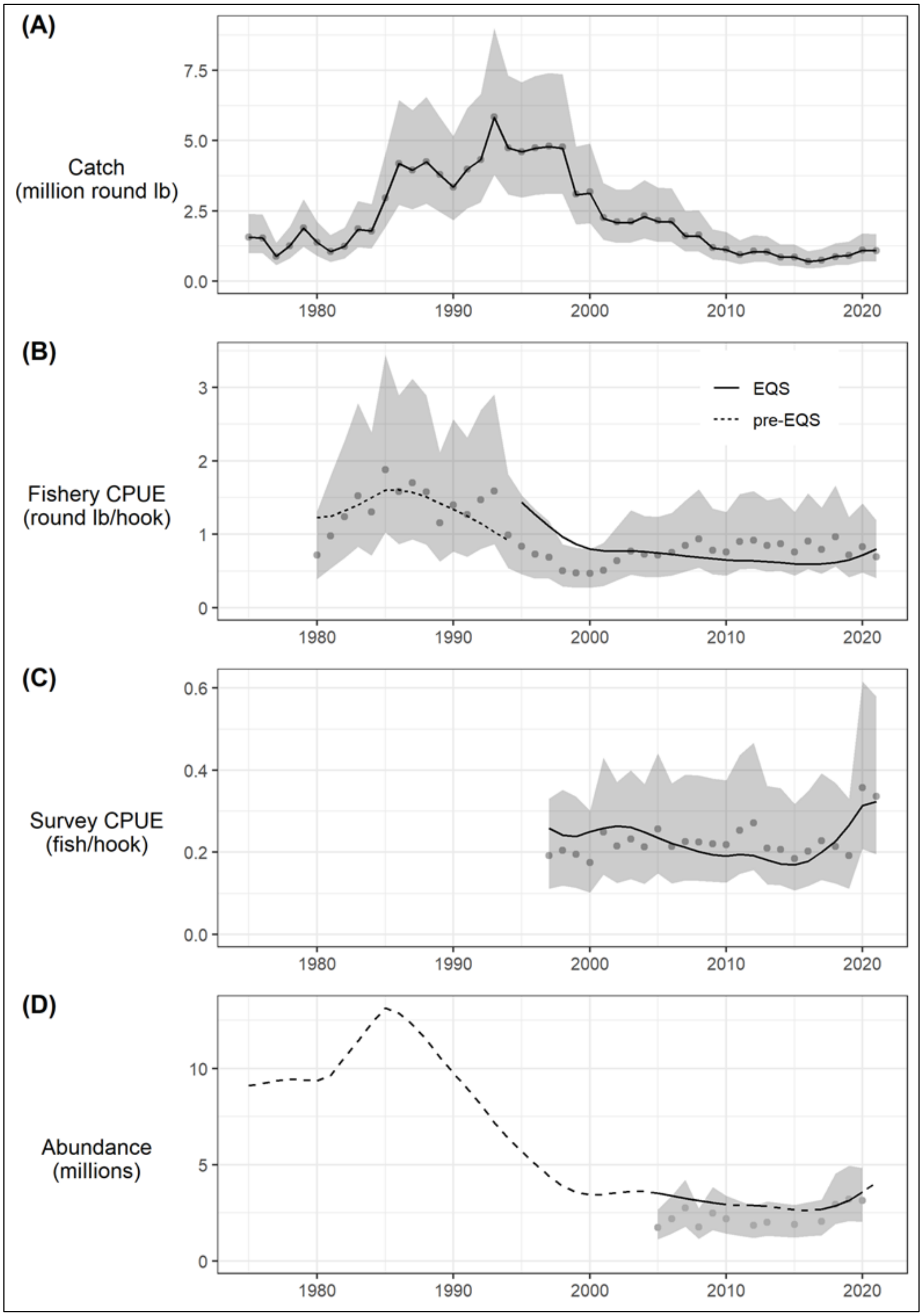

Figure 3.–Fits to indices of catch and abundance with the assumed error distribution shown as shaded grey polygons. Input data are shown as grey points and model fits are shown in black. Indices include (A) harvest (million round pounds); (B) fishery catch per unit effort in round pounds with separate selectivity and catchability time periods before and after the implementation of the Equal Quota Share (EQS) program in 1994; (C) survey catch per unit effort in number of fish per hook; and (D) mark-recapture abundance estimates in millions. Solid and dashed-lines in panel D reflect years for which data were and were not available, respectively.

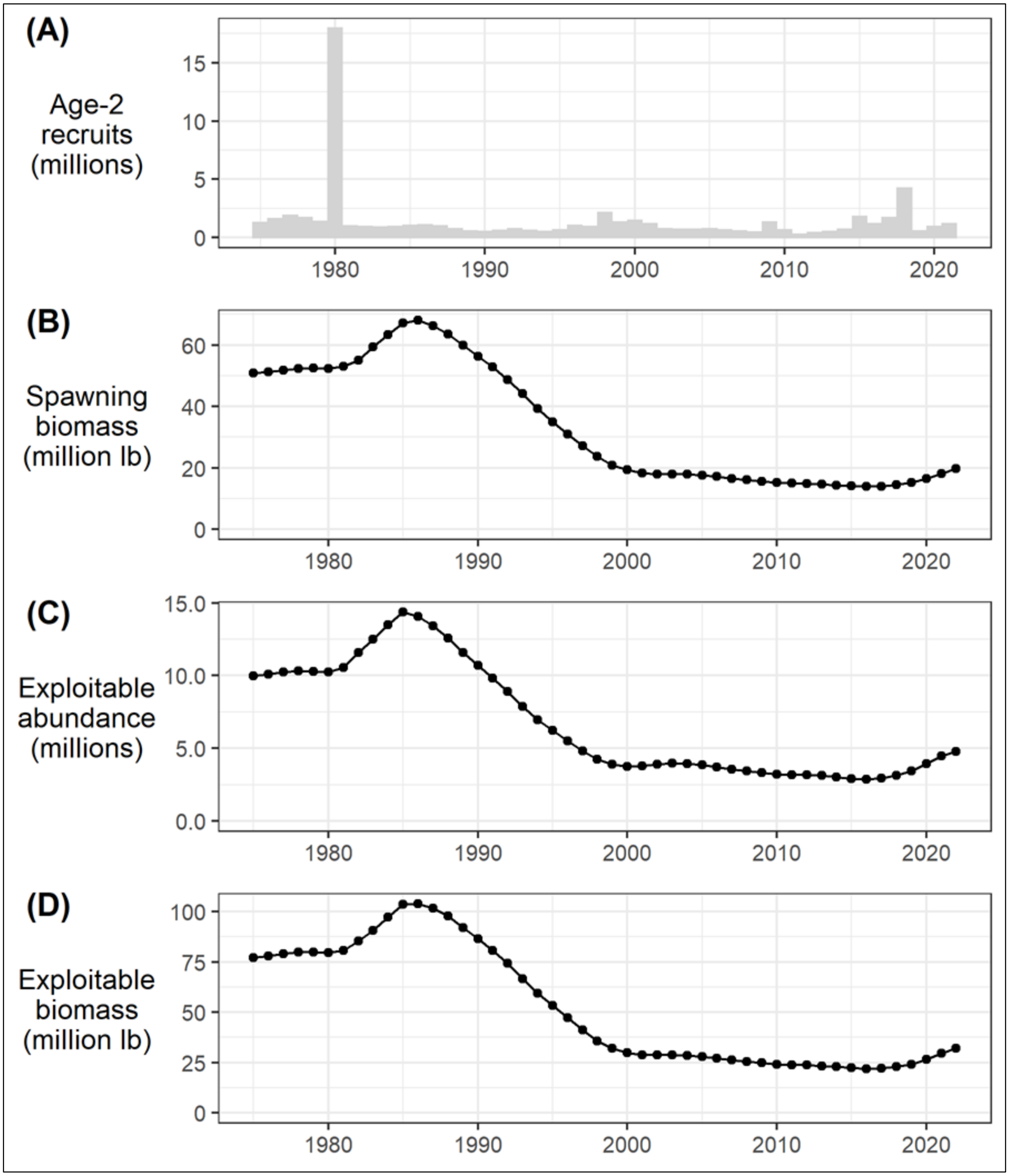

Figure 4.–Model predictions of (A) age-2 recruitment (millions); (B) female spawning stock biomass (million pounds); (C) exploitable abundance (millions); and (D) exploitable biomass (million pounds).

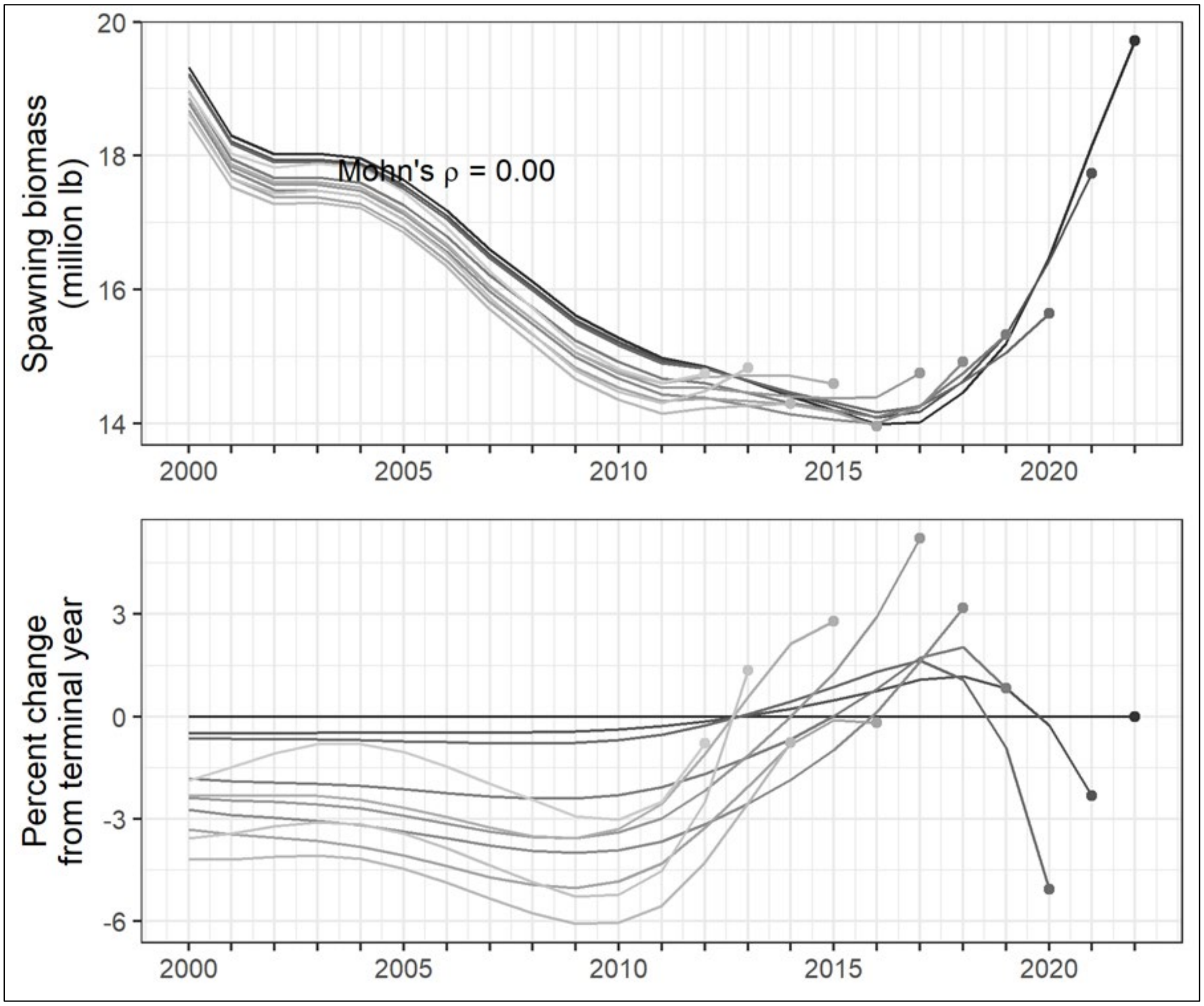

Figure 5.–Mohn’s ρ and retrospective peels of sablefish spawning biomass.

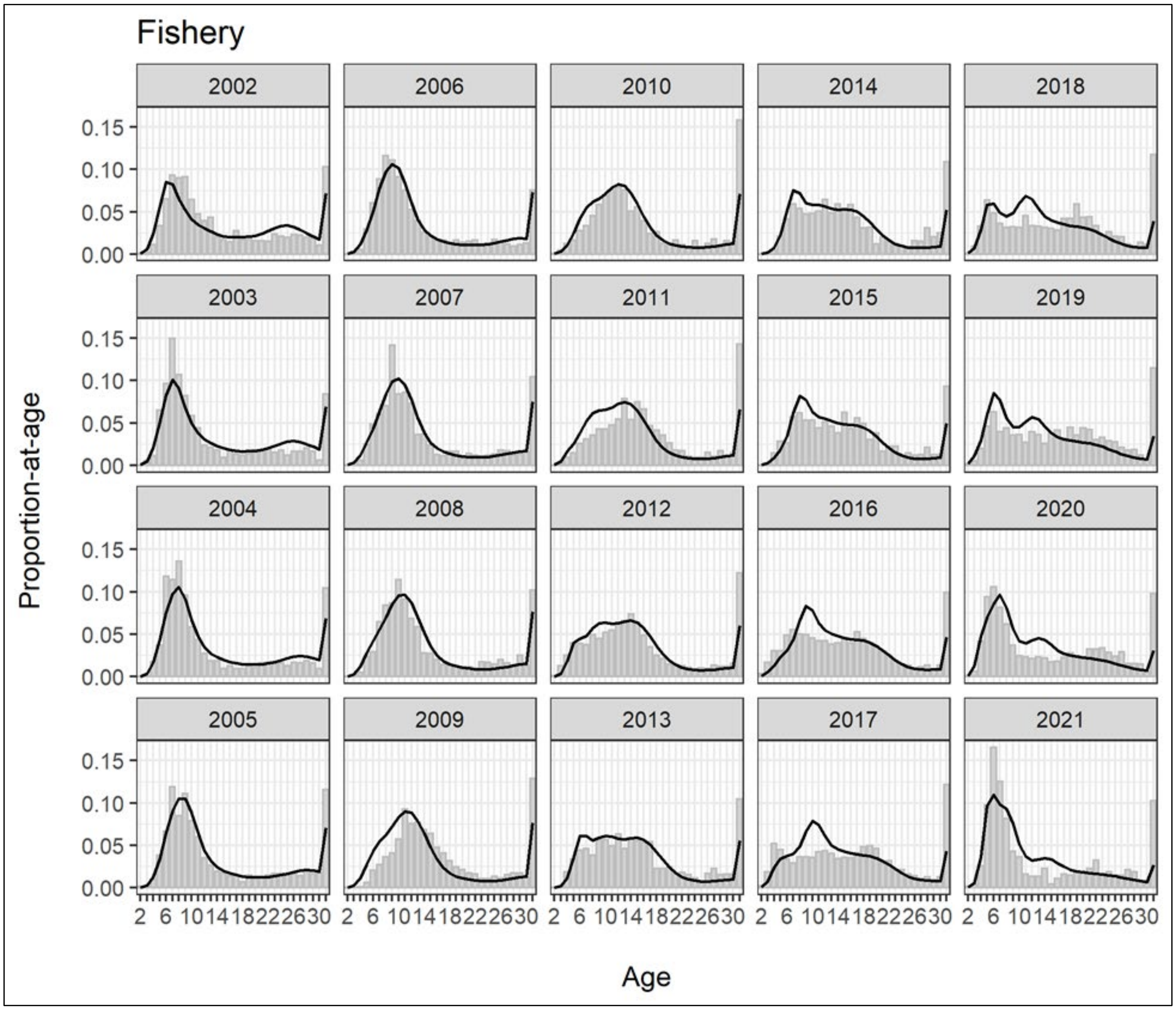

Figure 6.–Fits to fishery age compositions, 2002–2021. Observed (gray bars) and predicted proportions-at-age (black lines) shown.

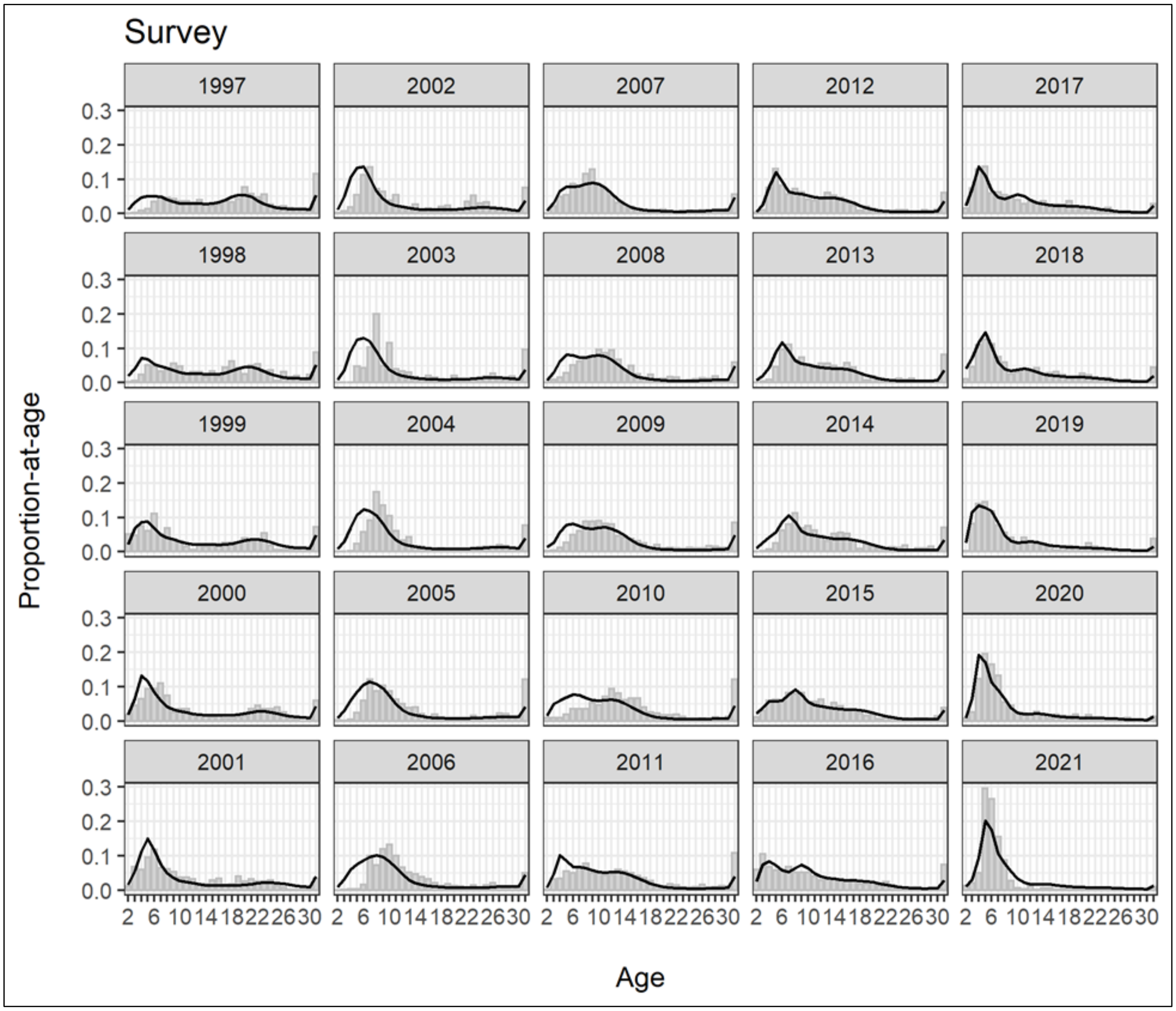

Figure 7.–Fits to survey age compositions, 1997–2021. Observed (gray bars) and predicted proportions-at-age (black lines) shown.

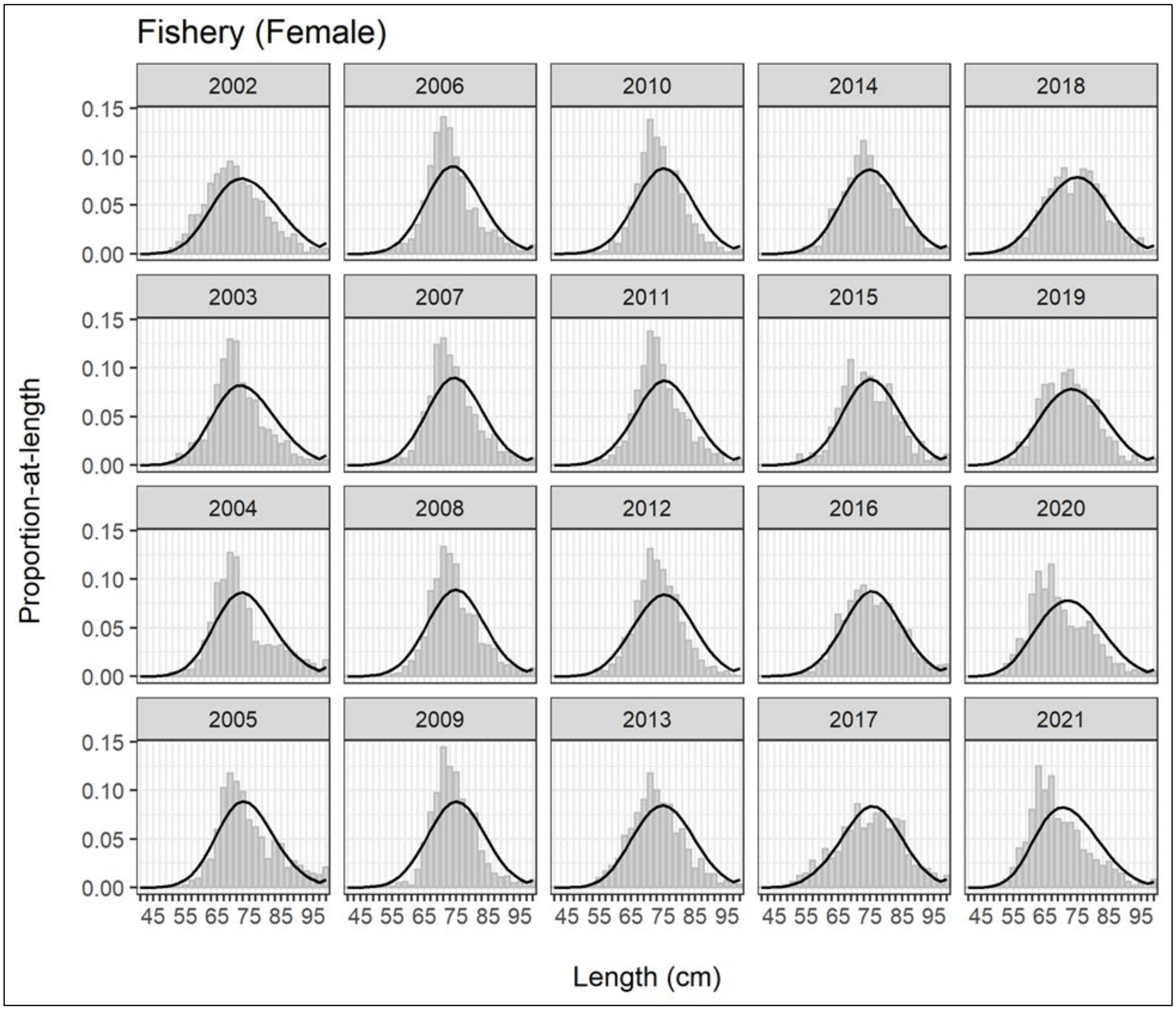

Figure 8.–Fits to female fishery length compositions, 2002–2021. Observed (gray bars) and predicted proportions-at-age (black lines) shown.

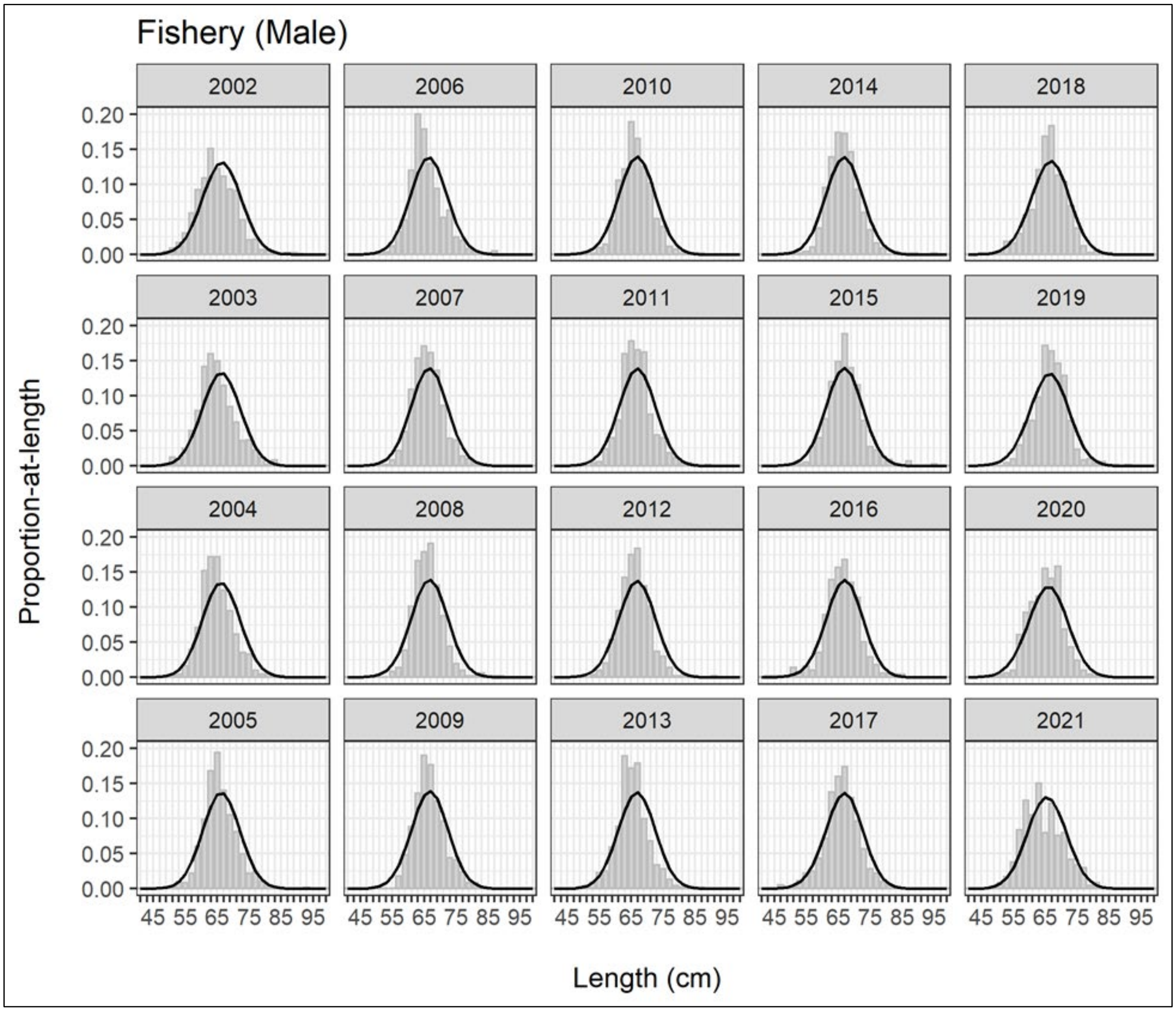

Figure 9.–Fits to male fishery length compositions, 2002–2021. Observed (gray bars) and predicted proportions-at-age (black lines) shown.

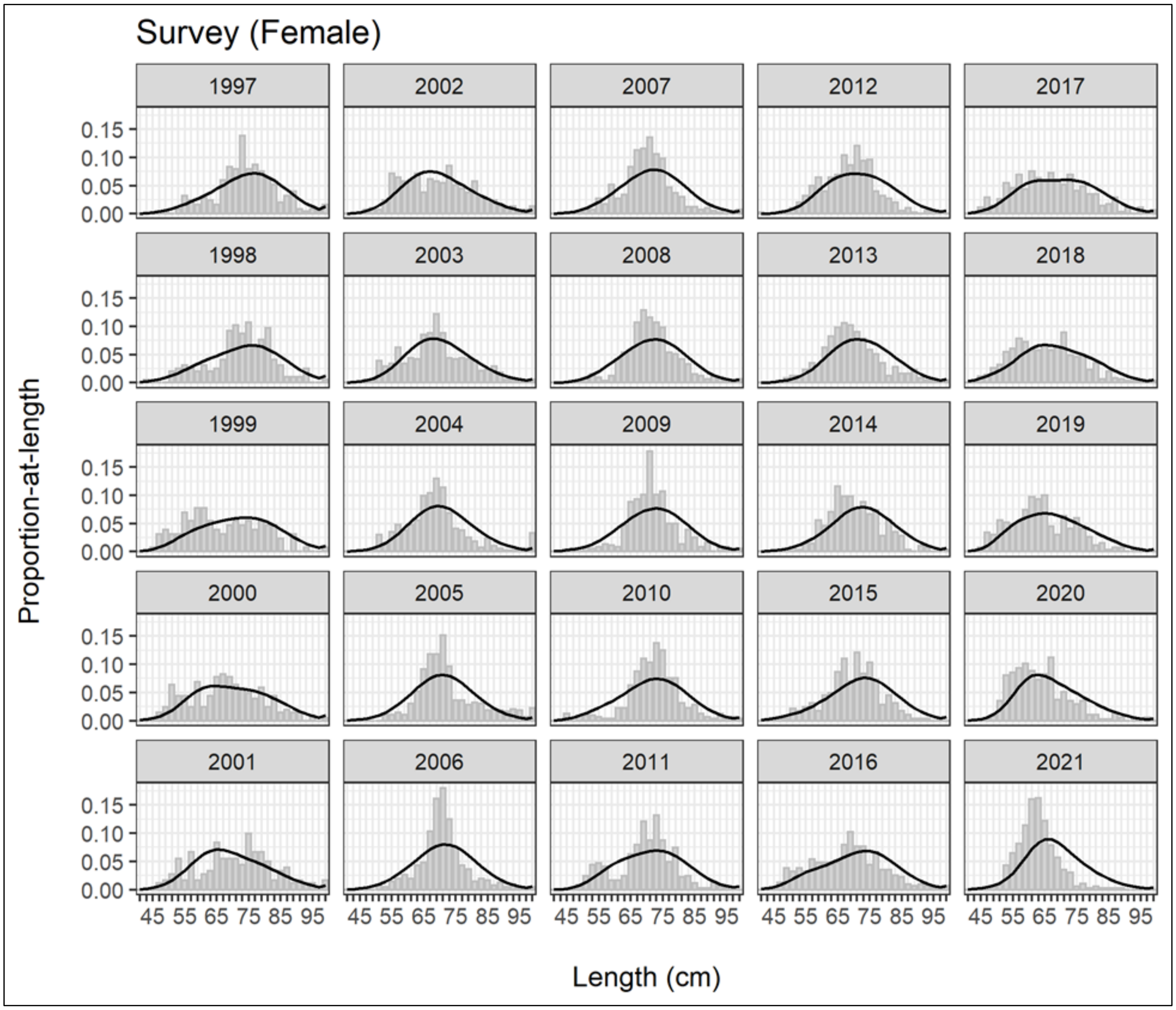

Figure 10.–Fits to female survey length compositions, 1997–2021. Observed (gray bars) and predicted proportions-at-age (black lines) shown.

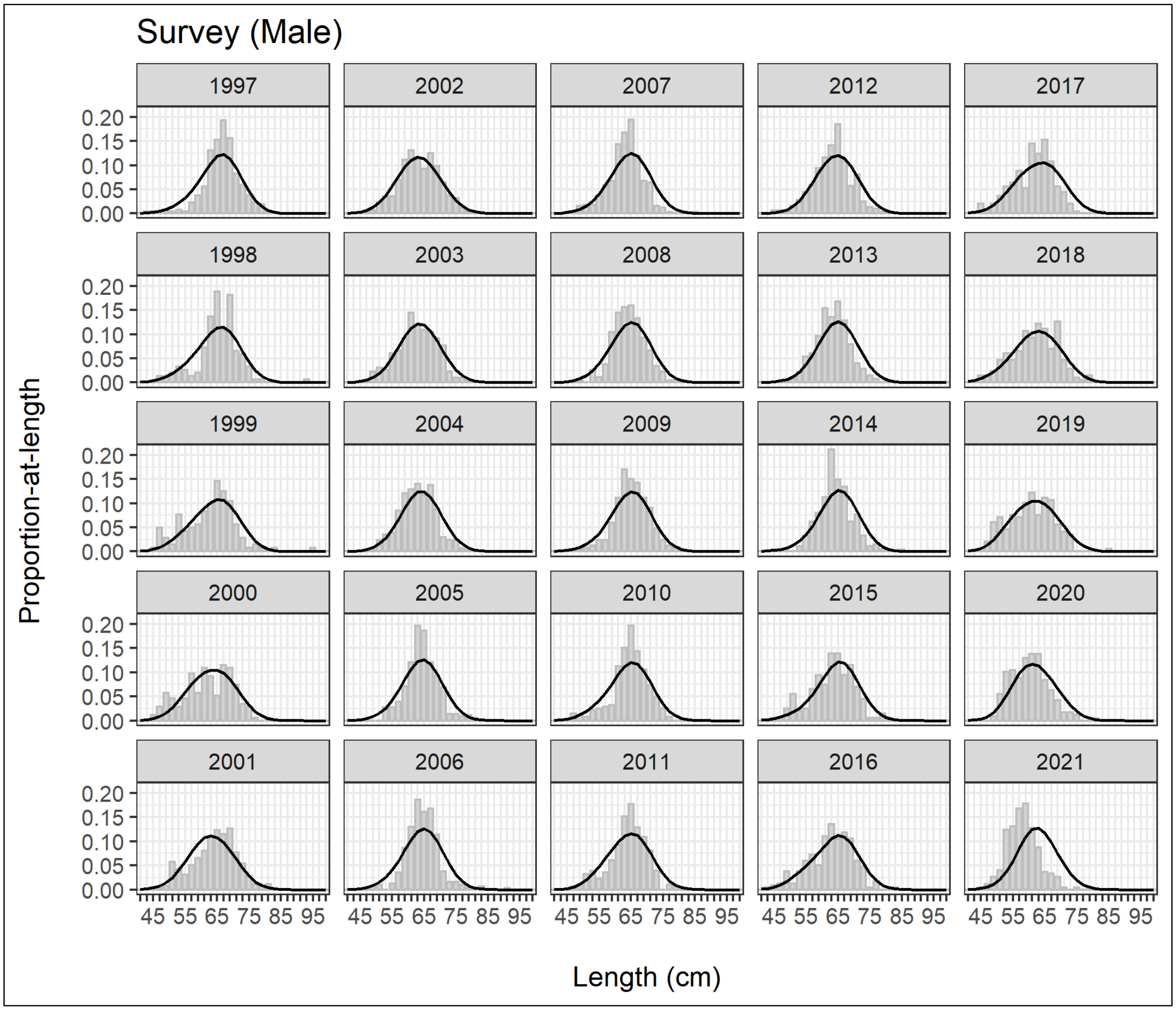

Figure 11.–Fits to male survey length compositions, 1997–2021. Observed (gray bars) and predicted proportions-at-age (black lines) shown.