Development of a preliminary model for the 2026 north Pacific albacore tuna stock assessment[1]

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ABSTRACT

The objective of this working paper is to describe the development of the preliminary model for the 2026 assessment of NPALB. We developed the model in a stepwise fashion by incorporating the data submitted by ALBWG members, previously agreed upon model structure and biological parameters, and the best features of the previously suggested improvements. The model is expected to have a main model period of 1994 – 2024. Three types of data were fitted in this study: fishery-specific catches, size compositions, and abundance indices. The geographic area and spatial stratification of this study followed that of the previous assessments (Pacific Ocean north of the equator (0°) to 55°N and from 120°E to 100°W).

Thirty-five fisheries were defined for this study on the basis of gear, fishing area, season, and unit of catch (numbers or weight), and all catch and effort data were allocated to these fisheries. Note that there were six fleets (S36-S41) that were indices of abundance calculated for a specific range of albacore lengths. Catch was reported and compiled in weight (metric tons) or 1000s of fish. Catch for most fisheries were almost identical to the 2023 assessment.

This working group paper describes the motivations for two main features of the development model. The first decision was to implement time-varying age selectivity for the three fleets with the largest catch amounts, Japanese pole and line (JPPL) areas 3 & 5 (A35) and calendar quarter 2 (Q2), JPPL A35 Q3, and eastern Pacific Ocean surface fleet (EPOSF). The models that had time-invariant and time-varying selectivity both had very similar fits to the F10 Japanese longline (JPLL) index of abundance (which was used in the 2023 benchmark assessment) and estimates of recruitment and spawning stock biomass. There were improvements in the fits to the length composition data, thus the additional complexity to selectivity forms was adopted. The second decision was to use the F10 index of abundance over the new S36 JPLL index of abundance calculated from data spanning all the ISC areas and Q2. The models fit well to either the F10 or S36 index of abundance, and the fits to the length composition data were very similar. Additionally, models fit to either index had very similar estimates of recruitment and spawning stock biomass. However, an ASPM conducted on the S36 index model could not estimate unfished recruitment (R0) parameter. Thus, the development model will proceed fitting to the F10 index which seems to contain information on the population scale. This development model is considered to be a reasonable starting point for further investigation in the upcoming albacore working group meeting.

INTRODUCTION

The Albacore Working Group (ALBWG) of the International Scientific Committee for Tuna and Tuna-like species in the North Pacific Ocean (ISC) is responsible for conducting stock assessments of North Pacific albacore tuna (NPALB). The previous two assessments were conducted in 2020 and 2023 (ALBWG 2020, 2023).

This working group paper focuses on two steps in preparation for the 2026 benchmark assessment. The first step was to identify the form and parameterization of time-varying selectivity that best fit the length composition data while providing stable parameter estimates. The second step was to evaluate the use of the new Japanese longline (JPLL), quarter 2, spatiotemporal index of abundance from the entire ISC area. Previous assessments in 2020 and 2023 fit to the Japanese longline index of abundance from area 2, quarter 2 (Figure 1).

METHODS

Model structure

The model time period covered 1994-2024, and the areas of the northern Pacific Ocean are shown in Figure 1. The 2023 benchmark stock assessment had the same start year, and covered the same spatial area (ALBWG 2023) as used here. The stock assessment used a fleets-as-areas approach and did not explicitly model any spatial processes (e.g. movement or area-specific growth). Fleets were defined to be specific to country, gear type, area and calendar quarter. The goal with these definitions as to implicitly account for spatial differences.

Data

There were 35 fishery fleets (Table 1), defined based on country, fishing gear, spatial area (see Figure 1), calendar quarter, and catch unit (mt or numbers of fish). All fleets had catch data, most fleets had size composition data, and two fleets had indices of abundance (Table 1). The fleet 10 index of abundance was from Japanese longline, area 2, quarter 2 and described in Matsubara et al. (2025a). The fleet 34 index of abundance was from fleet 34 eastern Pacific Ocean surface fleet (Kuriyama and Teo 2025).

There were six additional survey fleets (S36-S41) which were standardized indices of abundance from Japan and Chinese Taipei. S36 was an index of abundance calculated from Japanese longline data from quarter 2 and all the ISC areas (Matsubara et al. 2025b). This spatiotemporal index of abundance was calculated from adult fish ranging from 80-100 cm. The index was also calculated for 5 cm length bins for fleets S38-S41. Yeh and Chang (2025) also used size-specific spatiotemporal models to develop a size-specific, juvenile abundance index from Taiwanese longline fisheries S37. The S37 fleet will be considered in sensitivity model runs at the ALBWG modeling meeting.

Catch data for the 35 fishery fleets were updated through 2024. Japanese longline catch data from the northern and southern areas are shown in Figures 2 and 3, respectively. Japanese pole and line data had some of the highest annual catch amounts (Figure 4). The EPO surface fleet (Figure 5) also had high catch values, particularly towards the beginning of the modeling period. Catch data from the other longline fleets are shown in Figure 6.

The two primary indices of adult abundance under consideration for the 2026 assessment were F10 JPLL A2 Q2 and S36 JPLL all ISC area data. The updated F10 index of abundance included data from 2022-2024 and resulted in different annual estimates (Figure 7). The S36 index of abundance had larger differences between the high and low values than F10 (Figure 8).

Size composition data were also updated through 2024. Similar to previous assessments, F26 Taiwan longline size composition data prior to 2003 were dropped, as the data collection protocols were variable in this time period.

Model specifications

Many of the stock assessment specifications for the model presented for the development models were used in the 2023 benchmark assessment (ALBWG 2023). These specifications include:

- Fixed, sex- and age-specific natural mortality (Figure 9). Age-specific values were calculated from a combination of meta-analyses (Kinney and Teo 2016; Teo 2017) and results from a study of tagging data which estimated non-specific M of 0.45-0.5 yr^{-1} (Ichinokawa et al. 2008).
- Fixed sex-specific growth (Figure 10; Chen et al. 2012; Xu et al. 2014)
- Beverton-Holt stock recruitment relationship
    - Fixed steepness of 0.9
    - Fixed sigmaR, standard deviation of ln recruitment, of 0.46
    - Estimated R0, unfished recruitment
    - Estimate SR_regime value for the offset from the stock-recruitment relationship prior to the main modelling period
- Estimated recruitment deviations for 1994-2024.
- Estimated initial fishing mortality for F26 TWLL area 3 & 5.

Selectivity parameterizations were similar to those used in the 2023 benchmark assessment (see Table 1). Length selectivities were estimated as cubic splines for F1 JPLL A13 Q1 and F17 JPLL A4. Length selectivities were estimated as double normal for the rest of the fleets. Length selectivities were mirrored for F17 and F30 (Figure 11), F19 and F35 (Figure 12), and F26, F26 and F31 (Figure 13). Age selectivities were estimated with the empirical age form for F3, F19-F22, and F34 (Table 1). Both length and age selectivities were not sex-specific.

The length composition data were filtered to have a minimum initial input sample size of 0.1. The highest input sample size was 545.39 and a variance adjustment value of 0.27522 was applied to all fleets. This was to scale the maximum input sample size to be about 150.

The modeling platform Stock Synthesis was used for this assessment. The 2023 assessment used version 3.30.14 and this assessment used 3.30.24. There was no difference in model estimates from these two Stock Synthesis versions.

Model development steps

The model development process involved making two decisions. The first decision was to estimate age-based selectivity as time-invariant (referred to as invariant) or time-varying. The 2023 benchmark assessment estimated time-varying age selectivity with time blocks (ALBWG 2023). The motivation for time-varying age selectivity is to fit the size composition data as well as possible. Year-to-year variability can be high, particularly for some of the fleets with the largest catch amounts like JPPL A35 Q2 and Q3. Estimating process variability in the model can provide more accurate removals of catch-at-age in the population dynamics model.

The time block estimation approach seemed to be too unstable for this development model. As a result, time-varying age selectivities were instead estimated with the two-dimensional autoregressive option (2DAR; Xu et al. 2019). Sigma for this 2DAR selectivity option (controls the variability around the selectivity deviations) was fixed at 1 for ages 1-5 for the fleets F20 JPPL A35 Q2, F21 JPPL A35 Q3, and F34 EPOSF. A sigma value of 0.5 was also evaluated but did not seem to provide enough flexibility to improve the fits to the length composition data.

The second decision involved identifying an index of abundance among the two primary candidates F10 and S36. This decision was based on a series of model diagnostics, including overall model fit, R0 profiles, and age-structured production models (ASPM).

RESULTS

Time-invariant vs time-varying selectivity

Given the current model specifications (e.g. size composition variance adjustment value of 0.27522), the model results were very similar between the two selectivity parameterizations.

Model estimates were:

- lnR0: 12.072 (invariant) and 12.054 (time-varying)
- InitF_F26: 1.385 (invariant) and 1.548 (time-varying)
- SR_regime: 0.013 (invariant) and 0.061 (time-varying)
- RMSE for F10: 0.238 (invariant) and 0.236 (time-varying)

The time-varying model had the best fit to the length comp data, and the invariant model had a length composition fit 264 negative log likelihood (NLL) units higher (i.e., poorer). The time-varying model also had the best fit to the F10 index of abundance, and the invariant model had a model fit t the F10 index that was 0.308 NLL units higher. The fleet-specific length composition fits are shown in Table 2. As expected, time-varying selectivity had the best fit to the length composition data for F20, F21 and F34 (Table 2).

Spawning stock biomass and recruitment estimates were similar between the invariant and time-varying models (Figure 14). The fits to the F10 and S36 indices are shown in Figure 15. Note that the model is fit to only F10 and the plot for S36 shows only the expected values. The selectivity at age derived from selectivity at length for the two models are shown in Figure 16.

Fits to the length composition data were improved for the time-varying models for F20 JPPL A35 Q2 (Figure 17). The improvements were generally seen for the year and quarter combinations with the highest sample sizes like 1996s2, 1997s2, 2002s2, 2013s2, and 2018s2 to name a few (Figure 17). Fits to the length compositions for F21 JPPL A35 Q3 are shown in Figure 18. Time-varying selectivity had improved fits to the length composition data, particularly for year and season combinations with multi modal distributions (e.g. 1996s3, 1997s3, 2003s3, and 2014s3). Fits to the length composition data are shown in Figure 19.

Conclusion: Time-invariant vs time-varying selectivity

While the results were overall similar between the two models, the improvements in the size composition fits were sufficient to proceed with the time-varying model as the development model.

Time-varying selectivity model diagnostics

An age-structured production model (ASPM) was conducted to evaluate the production function of the model. Ideally, the catch data and estimated productivity relationship can explain the changes in the observed population (i.e. the index of abundance). The ASPM results (Figure 20) indicate that the catch trends and a production function can explain the general trend in the index. The scale of the ASPM is higher (R0=12.40) than that estimated in the full base model (R0=12.05).

A likelihood profile on R0 values (11 to 13 in steps of 0.2) showed that population scale R0 was informed by length composition data more than the survey data (Figure 21). Values of R0 ranging from 11.8-12.4 were supported by the survey data, and values ranging from 12-12.2 were supported by the length composition data.

The fleet-specific length composition likelihood values indicate that a number of fleets contained information on R0 (Figure 22). Large fisheries like JPPL, EPOSF, and TWLL contained information although there was not agreement on the R0 values that best fit each data component. Fleets that did not contain information on R0 are shown in Figure 23.

Index of abundance F10 or S36

The models had the same model configurations (i.e. time-varying age-based selectivity for F20, F21, F34) but used F10 as the index of abundance or S36 as the index.

Model estimates were:

- lnR0: 11.976 (F10index) and 12.054 (S36index)
- InitF_F26: 1.548 (F10index) and 1.548 (S36index)
- SR_regime: 0.061 (F10index) and 0.068 (S36index)

The model estimates were also similar in this scenario. The fits (or expected values) were all relatively close to the index of abundance observations (Figure 24). Estimates of spawning stock biomass and recruitment were also similar (Figure 25). The selectivity at age derived from selectivity at length (Figure 26) and fits to the length composition data were visually identical (Figure 26). At this point it would be difficult to make an objective argument to select one index over the other.

However, the in contrast to the F10 index (see above), the S36 index does not seem to contain information on population scale. The R0 estimate for the ASPM for the S36 index model was estimated at the upper bound of 20. The ASPM estimate of spawning stock biomass is about 400,000,000 mt (Figure 27). Therefore, the ASPM model diagnostics for the models fitting to the

F10 index versus the S36 index shows that the changes in catch is consistent with the trends in the F10 index but not the S36 index.

In conclusion, although the model seems to fit the data comparably well between the F10 and S36 index models, the lack of information on population scale in S36 would strongly suggest that the F10 index would be the more appropriate index to use for the assessement. Thus, for the upcoming working group meeting the time-varying model fit to F10 will be considered a reasonable starting place for the discussions on further model development.

In addition to the preliminary model, we have several preliminary suggestions for model improvements and sensitivities to investigate:

Things to correct or conduct

- F17 variance adjustment duplicated, need to change to 18
- Vanuatu data now available in all catch units, will change fleet structure
- Fix S36 expected value size composition to use 80-100 box selectivity (instead of 80-120 as currently implemented)
- Increase signa-R to 0.6 during model development, with tuning done at a later stage
- Some parameters for the age selectivity for F3_JPLL_A13_Q3_wt, F19_JPPL_A35_Q1 and F20_JPPL_A35_Q2 need to be estimated instead of fixed during development
- Estimated parameters for F25_USLL_A24 suggest that the selectivity should be flat-top asymptotic selextivity.

Sensitivities to investigate

- Alternative length composition weighting values
  - Single and multiple fleet downweighting
- Further evaluation of the 5 cm bin JPLL indices of abundance
  - Haikun has ideas about how to calculate synthetic 5 cm size compositions from the index data
- TWLL as the juvenile index
- Combinations of index values
- Fit to the conditional age-at-length data
- Fit to the sex-specific size composition data
- Re estimate growth to the sex-specific age and length data
- Superyears for the China and Vanuatu composition data
- Experiment with made up values to S36 index of abundance to see if specific values are preventing scale from being estimated in ASPM.

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TABLES

Table 1: Table of fleet definitions. Fisheries are Japanese longline (JPLL), Japanese pole and line (JPPL), United States longline (USLL), Chinese Taipei longline (TWLL), Korea longline (KRLL), China longline (CNLL), Vanuatu longline (VULL), other fleets longline (OTHLL), eastern Pacific Ocean surface fleet (EPOSF), and Japan, Chinese Taipei, Korea miscellaneous gear (JPTWKR). Data column indicates fleets with size composition data or index of abundance. Data sets not fit in the model are indicated with *. Estimated selectivities were length-specific or in some cases length and age-specific. Selectivities were also mirrored for some fleets, and fleets with ^ had time-varying age selectivity estimated in the development model.

Fleet number	Fleet name	Fishery	Area	Quarter	Unit	Data	Selectivity
1	F1_JPLL_A13_Q1_wt	JPLL	1 & 3	1	wt	Size	Length
2	F2_JPLL_A13_Q2_wt	JPLL	1 & 3	2	wt	Size	Length
3	F3_JPLL_A13_Q3_wt	JPLL	1 & 3	3	wt	Size	Length & Age
4	F4_JPLL_A13_Q4_wt	JPLL	1 & 3	4	wt	Size	Length
5	F5_JPLL_A13_Q1_num	JPLL	1 & 3	1	num		Mirror1
6	F6_JPLL_A13_Q2_num	JPLL	1 & 3	2	num		Mirror2
7	F7_JPLL_A13_Q3_num	JPLL	1 & 3	3	num		Mirror3
8	F8_JPLL_A13_Q4_num	JPLL	1 & 3	4	num		Mirror4
9	F9_JPLL_A2_Q1_wt	JPLL	2	1	wt	Size	Length
10	F10_JPLL_A2_Q2_wt_9624	JPLL	2	2	wt	Size, Index	Length
11	F11_JPLL_A2_Q3_wt	JPLL	2	3	wt	Size	Length
12	F12_JPLL_A2_Q4_wt	JPLL	2	4	wt	Size	Length
13	F13_JPLL_A2_Q1_num	JPLL	2	1	num		Mirror9
14	F14_JPLL_A2_Q2_num	JPLL	2	2	num		Mirror10
15	F15_JPLL_A2_Q3_num	JPLL	2	3	num		Mirror11
16	F16_JPLL_A2_Q4_num	JPLL	2	4	num		Mirror12
17	F17_JPLL_A4_num	JPLL	4	All	num	Size	Length
18	F18_JPLL_A5_num	JPLL	5	All	num	Size	Length
19	F19_JPPL_A35_Q1	JPPL	3 & 5	1		Size	Length & Age
20	F20_JPPL_A35_Q2	JPPL	3 & 5	2		Size	Length & Age^
21	F21_JPPL_A35_Q3	JPPL	3 & 5	3		Size	Length & Age^
22	F22_JPPL_A35_Q4	JPPL	3 & 5	4		Size	Length & Age
23	F23_JPPL_A24	JPPL	2 & 4	All		Size	Length
24	F24_USLL_A35	USLL	3 & 5	All		Size	Length
25	F25_USLL_A24	USLL	2 & 4	All		Size	Length
26	F26_TWLL_A35	TWLL	3 & 5	All		Size	Length
27	F27_TWLL_A24	TWLL	2 & 4	All			Mirror17
28	F28_KRLL	KRLL	All	All			Mirror17
29	F29_CNLL_A35	CNLL	3 & 5	All		Size*	Mirror26
30	F30_CNLL_A24	CNLL	2 & 4	All		Size*	Mirror17
31	F31_VULL_mt	VULL	All	All	mt		Mirror26
32	F32_VULL_num	VULL	All	All	num		Mirror26
33	F33_OTHLL	OTHLL	All	All			Mirror26
34	F34_EPOSF_xx24	EPOSF	All	All		Size, Index*	Length & Age^
35	F35_JPTWKR_DNMisc	JPTWKR	All	All		Size*	Mirror19

Table 2: Delta negative log likelihood values for the length composition data for each fleet with time-invariant and time-varying age-based selectivity. Values of 0 indicate that the model had the minimum NLL of the two models compared.

Fleet	invariant	time-varying
F1_JPLL_A13_Q1_wt	12.064	0
F2_JPLL_A13_Q2_wt	8.481	0
F3_JPLL_A13_Q3_wt	0	12.794
F4_JPLL_A13_Q4_wt	4.316	0
F9_JPLL_A2_Q1_wt	0.287	0
F10_JPLL_A2_Q2_wt_9624	1.648	0
F11_JPLL_A2_Q3_wt	2.657	0
F12_JPLL_A2_Q4_wt	1.634	0
F17_JPLL_A4_num	0.474	0
F18_JPLL_A5_num	0	0.366
F19_JPPL_A35_Q1	0	0.238
F20_JPPL_A35_Q2	66.651	0
F21_JPPL_A35_Q3	86.407	0
F22_JPPL_A35_Q4	0	0.348
F23_JPPL_A24	0	0.083
F24_USLL_A35	0	0.495
F25_USLL_A24	0.841	0
F26_TWLL_A35	0	6.327
F34_EPOSF_xx24	99.319	0

FIGURES

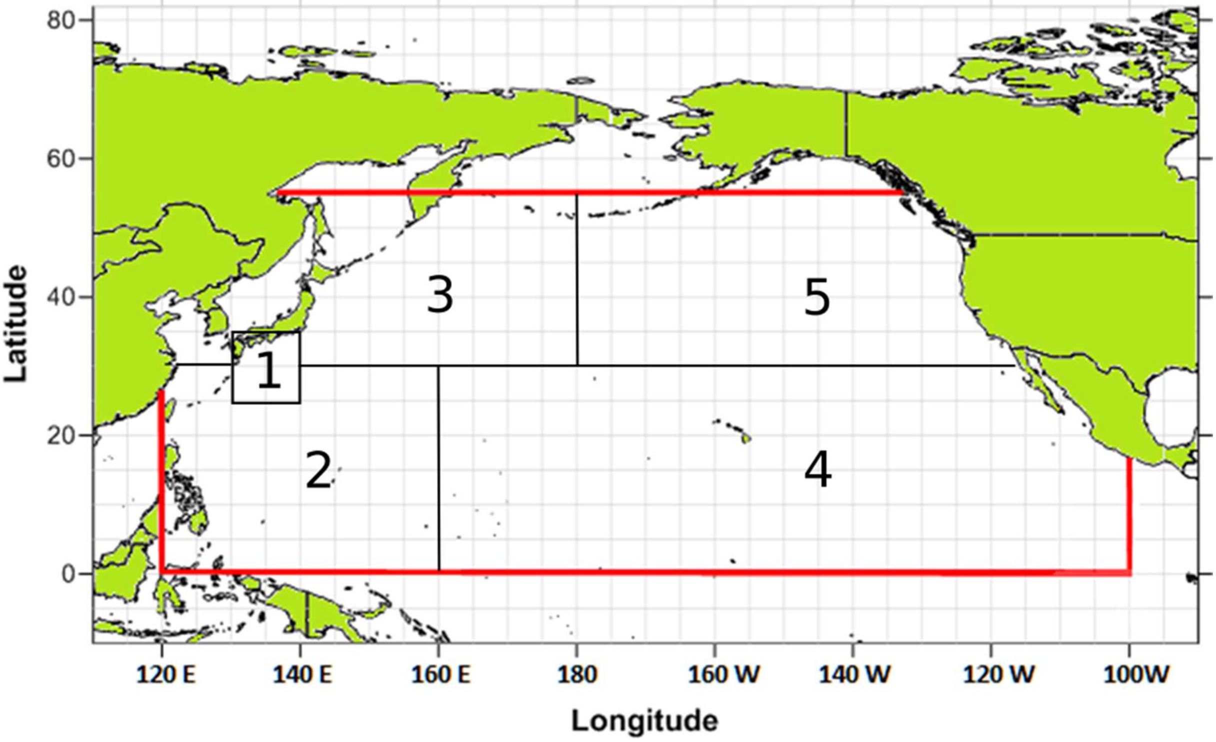


Figure 1: Japanese longline catch data used in the 2023 benchmark (solid line) and 2026 benchmark assessment (dashed line) from the northern areas.

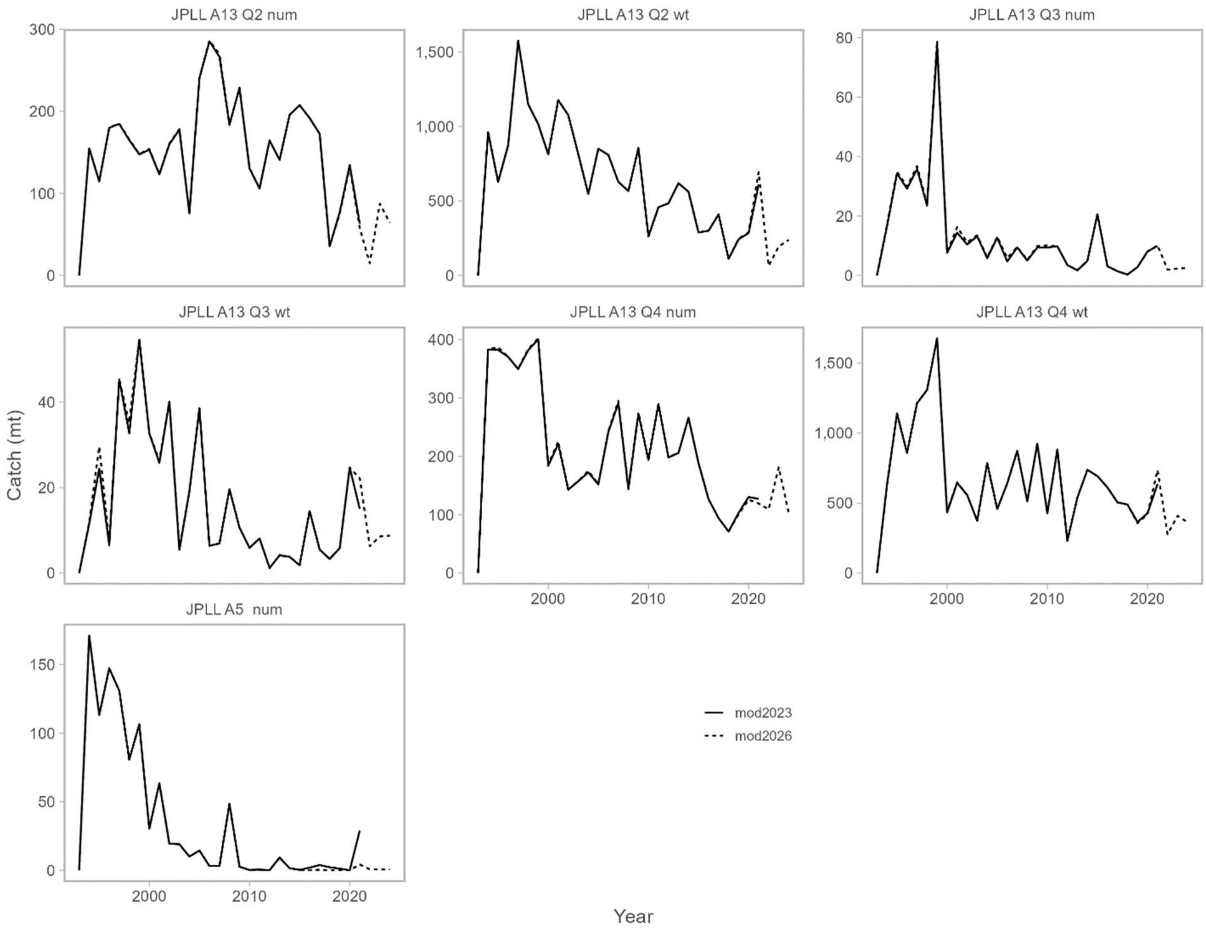


Figure 2: Japanese longline catch data used in the 2023 benchmark (solid line) and 2026 benchmark assessment (dashed line) from the northern areas.

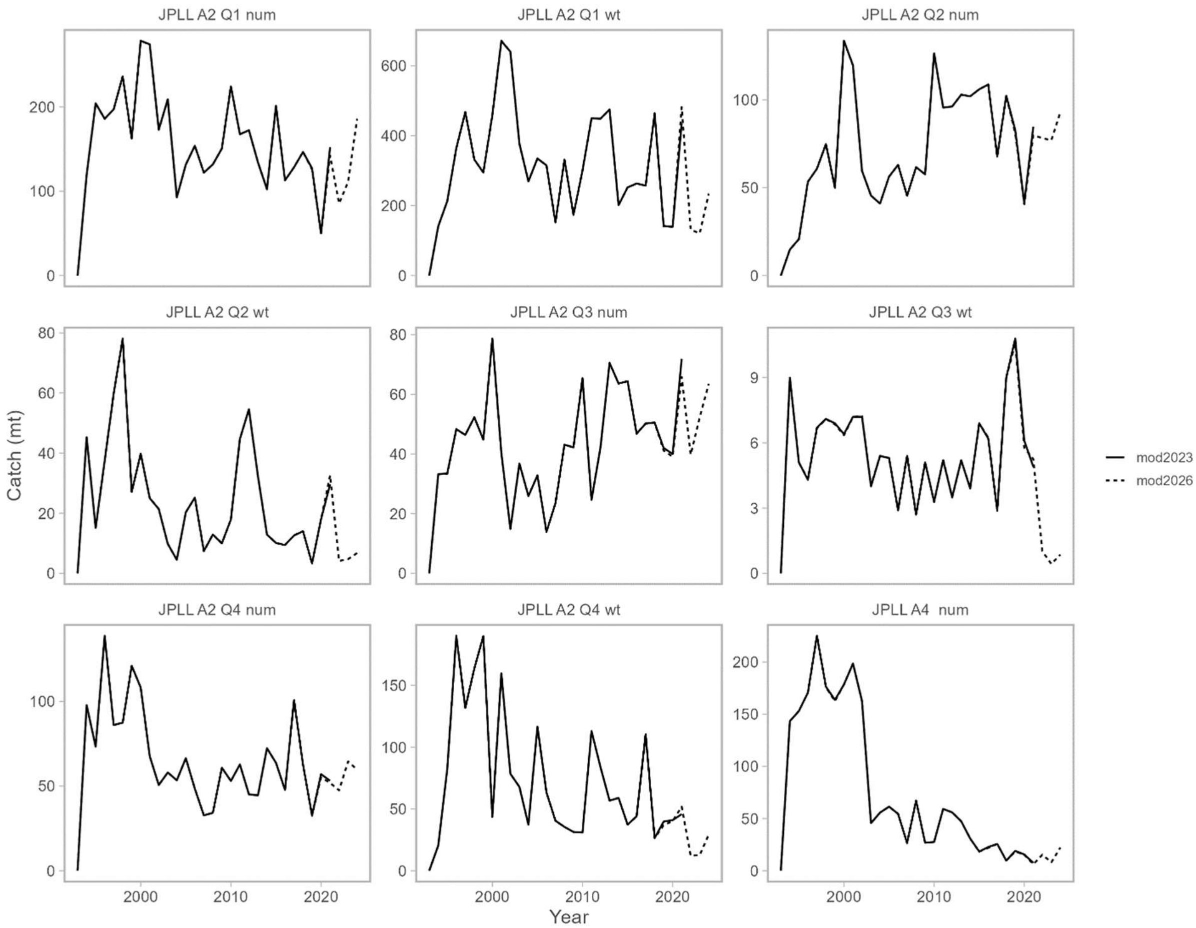


Figure 3: Japanese longline catch data used in the 2023 benchmark (solid line) and 2026 benchmark assessment (dashed line) from the southern areas.

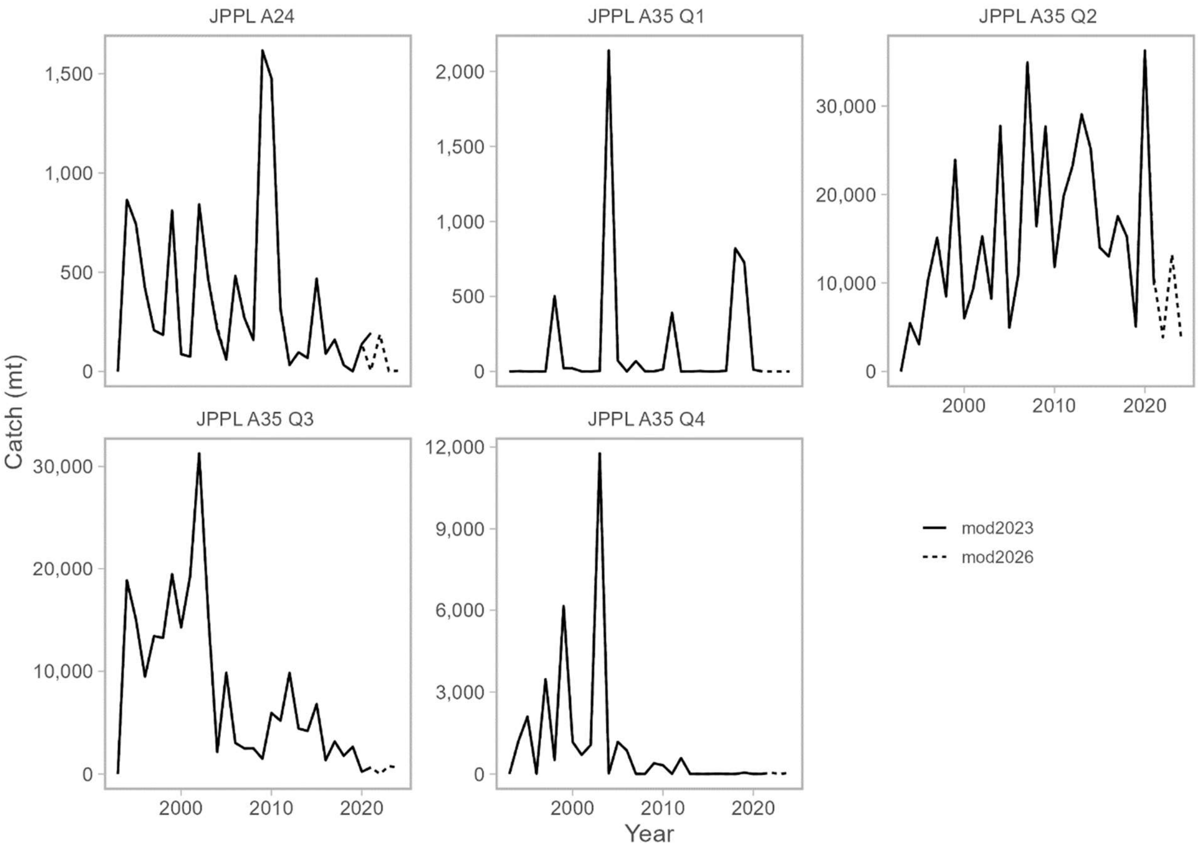


Figure 4: Japanese pole and line catch data used in the 2023 benchmark (solid line) and 2026 benchmark assessment (dashed line).

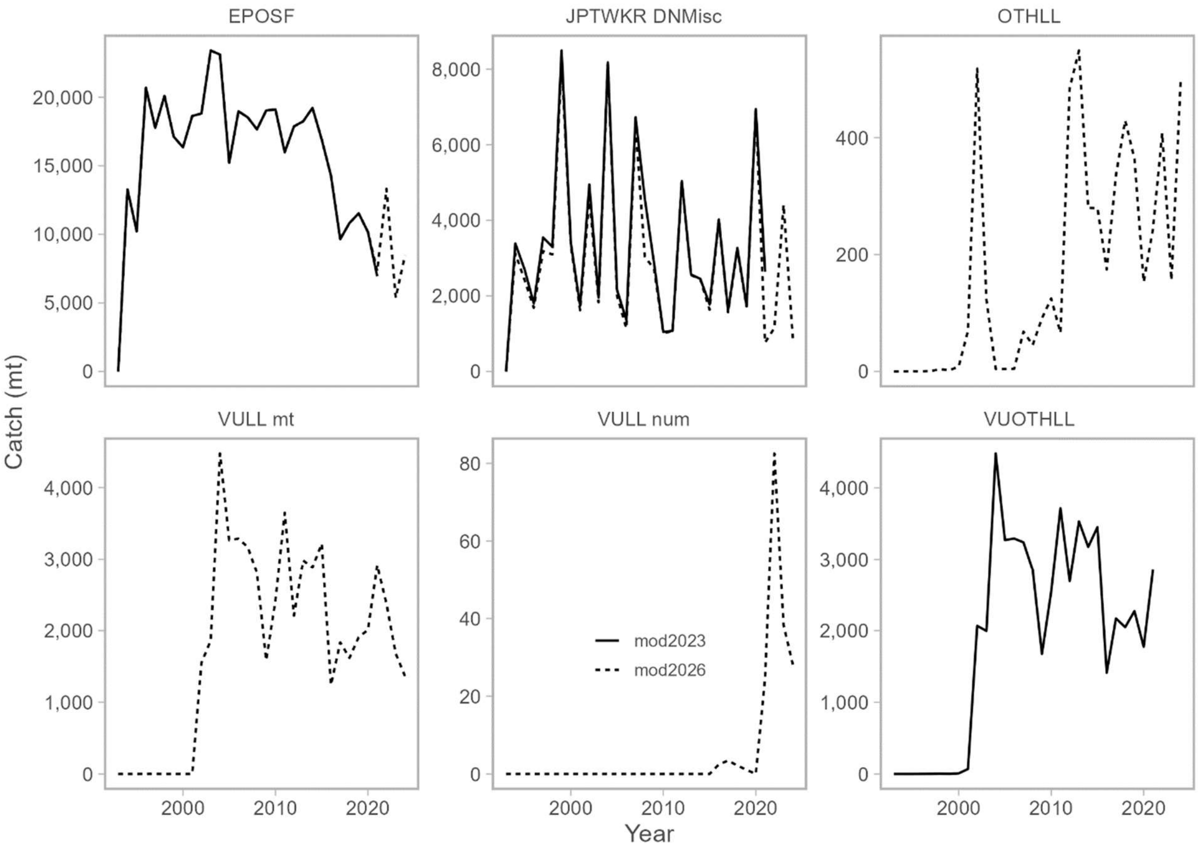


Figure 5: Catch data used in the 2023 benchmark (solid line) and 2026 benchmark assessment (dashed line) from the EPO surface, Japan Taiwan Korea miscellaneous, other longline, and Vanuatu longline fleets.

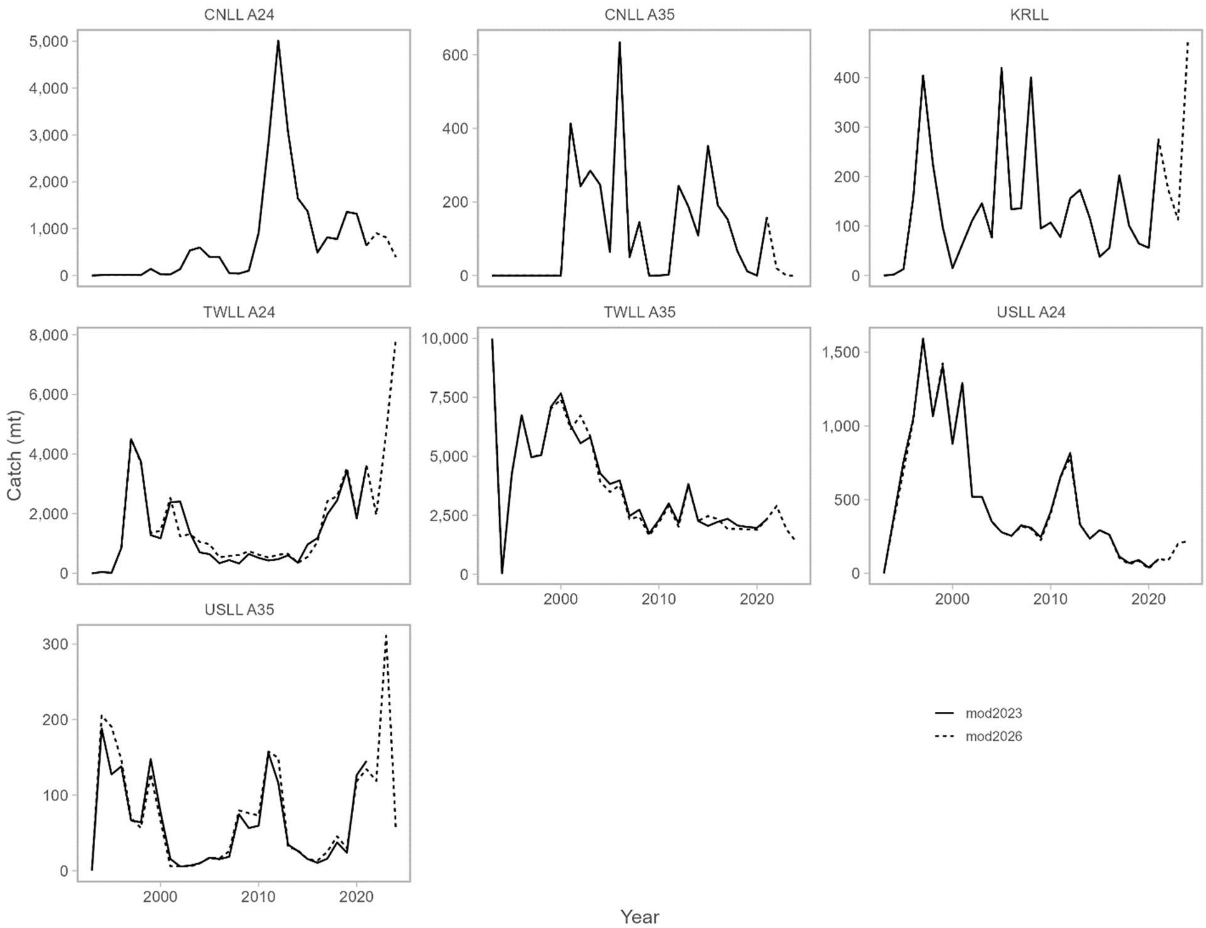


Figure 6: Catch data used in the 2023 benchmark (solid line) and 2026 benchmark assessment (dashed line) from the China longline, Korea longline, Taiwan longline, and US longline fleets.

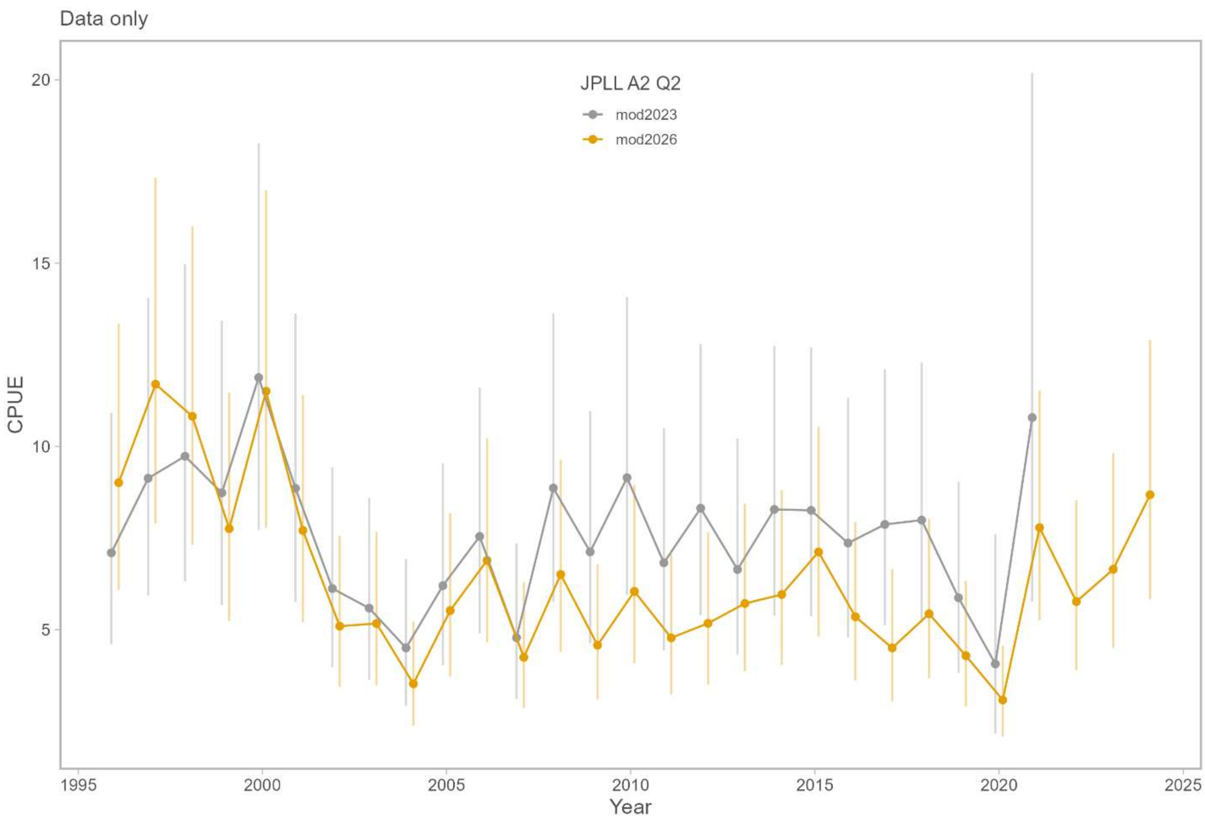


Figure 7: CPUE data used in the 2023 benchmark (gray) and 2026 benchmark assessment (orange) from the Japanese longline, area 2, quarter 2 fleet. Vertical bars show the 95% confidence intervals.

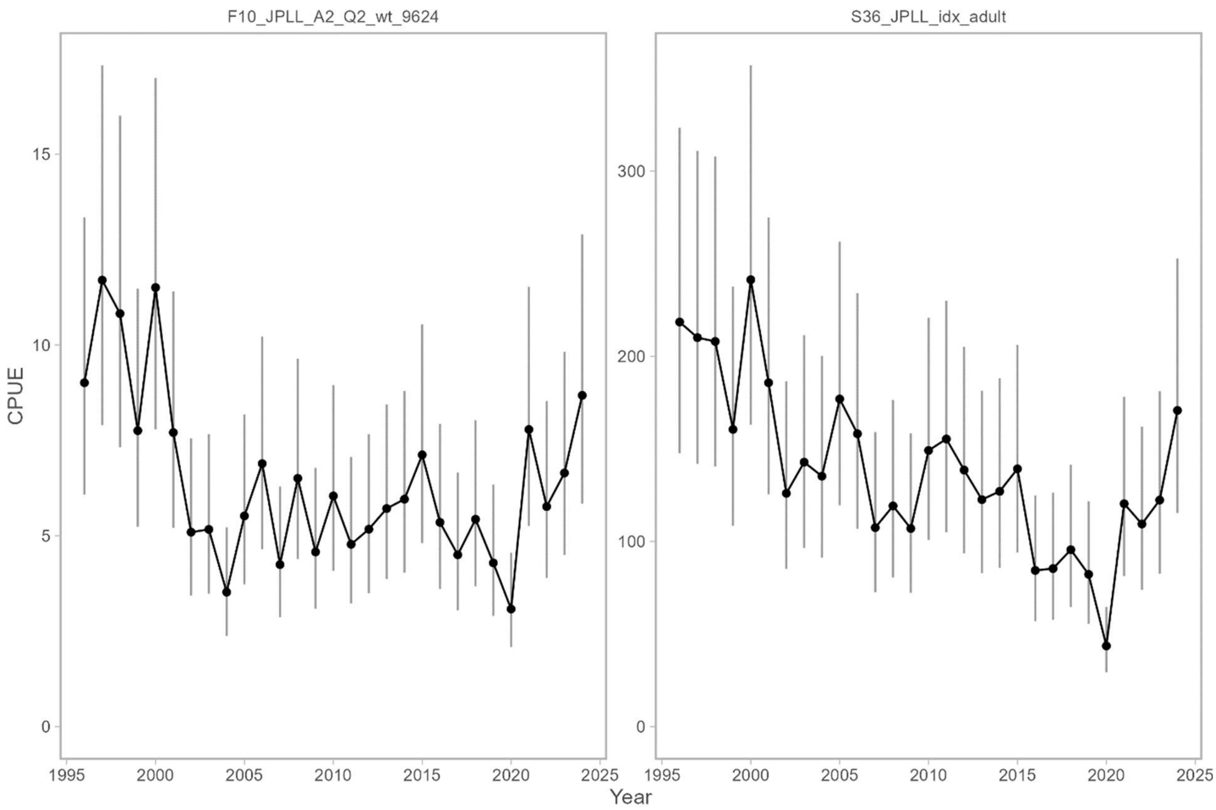


Figure 8: Candidate CPUE data for the 2026 benchmark assessment from Japanese longline area 2, quarter 2 (left) and Japanese longline all ISC area, quarter 2 (right). Vertical bars show 95% confidence intervals.

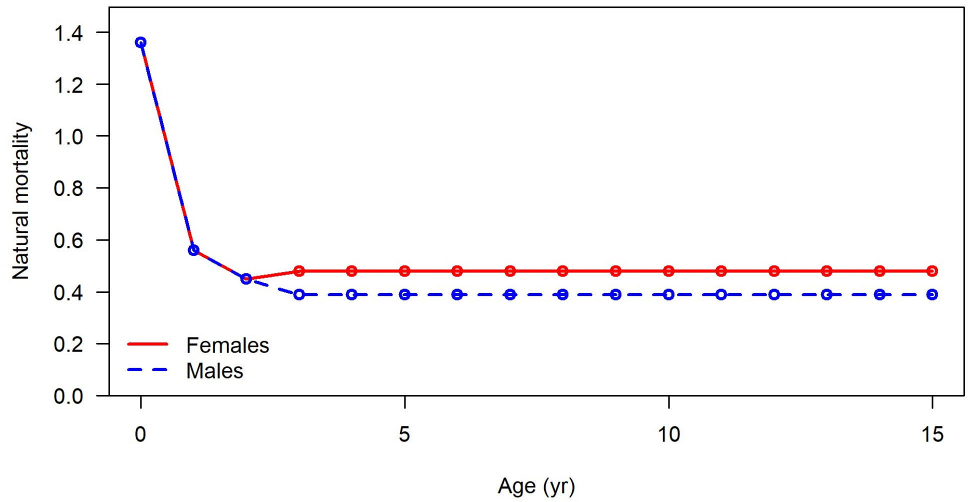


Figure 9: Natural mortality at age for females (red) and males (blue).

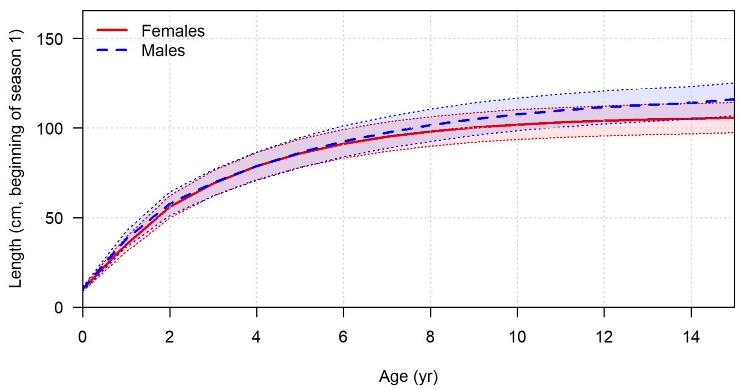


Figure 10: Length at age relationship for females (red) and males (blue).

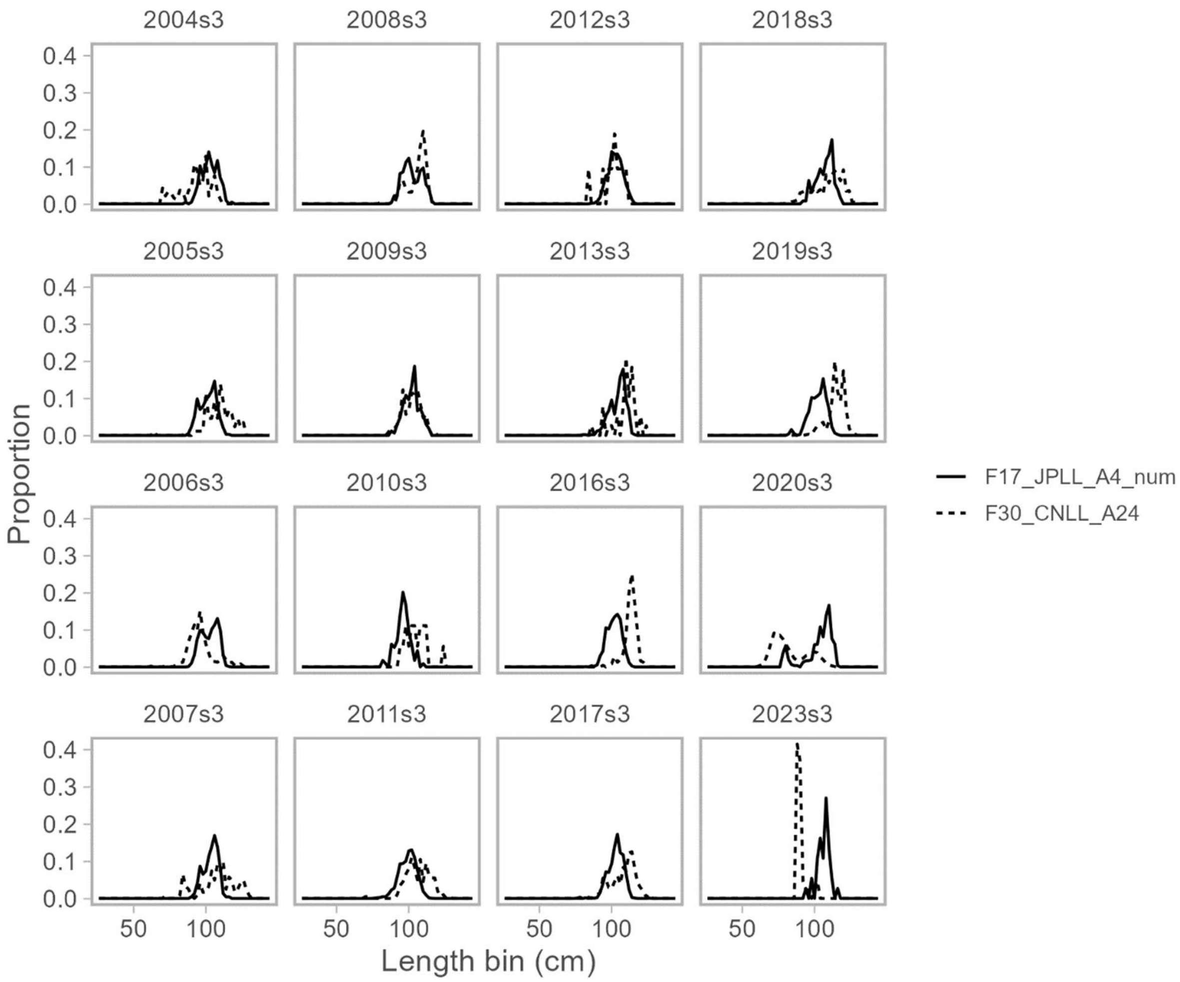


Figure 11: Length compositions for F17 (solid lines) and F30 (dashed lines) to illustrate the similarities between the length compositions. Length selectivity for F17 was mirrored for F30.

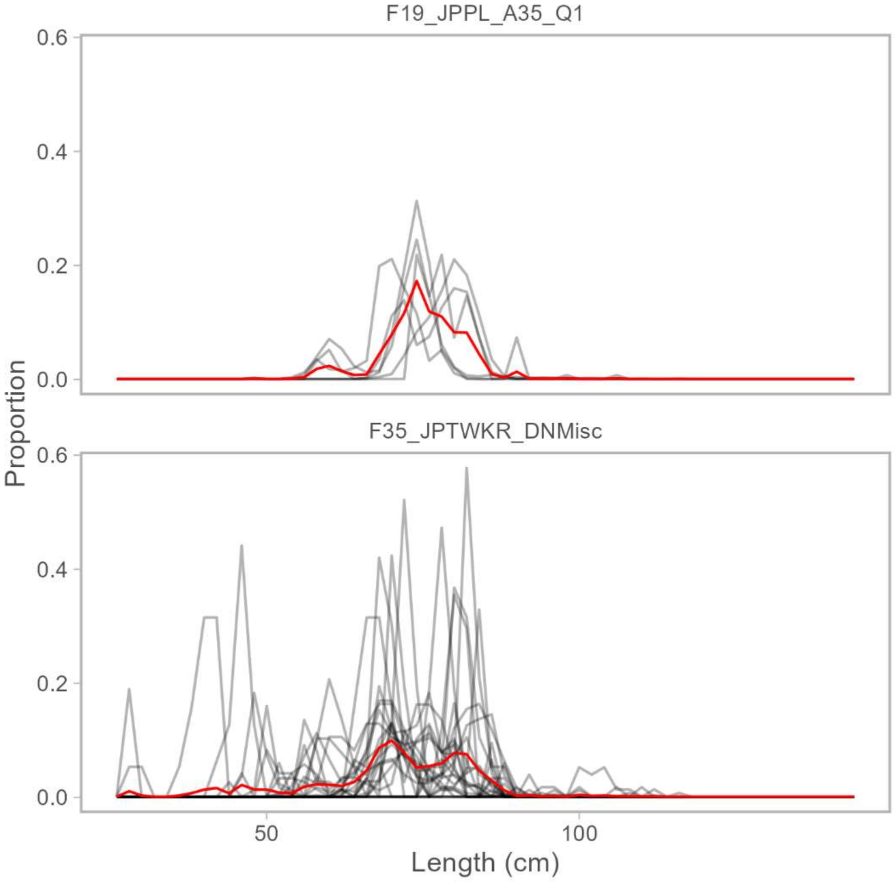


Figure 12: Length compositions for F19 (top) and F35 (bottom) to illustrate the similarities between the length compositions. The average size composition is shown as a red line. Length selectivity for F19 was mirrored for F35.

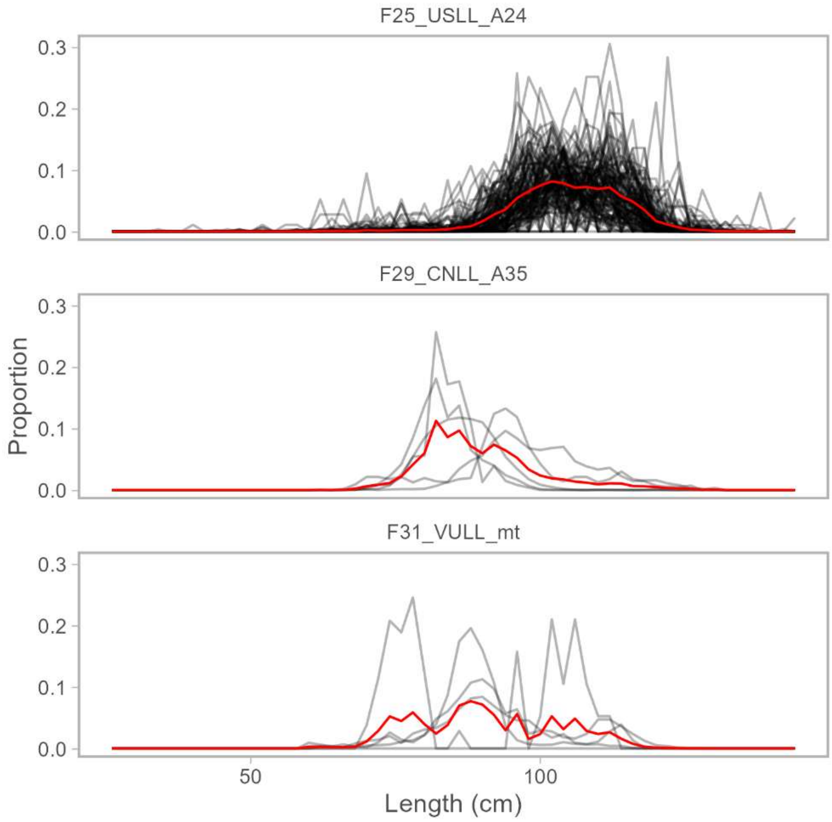


Figure 13: Length compositions for F25 (top), F29 (middle) and F31 (bottom) to illustrate the similarities between the length compositions. The average size composition is shown as a red line. Length selectivity for F25 was mirrored for F29 and F31.

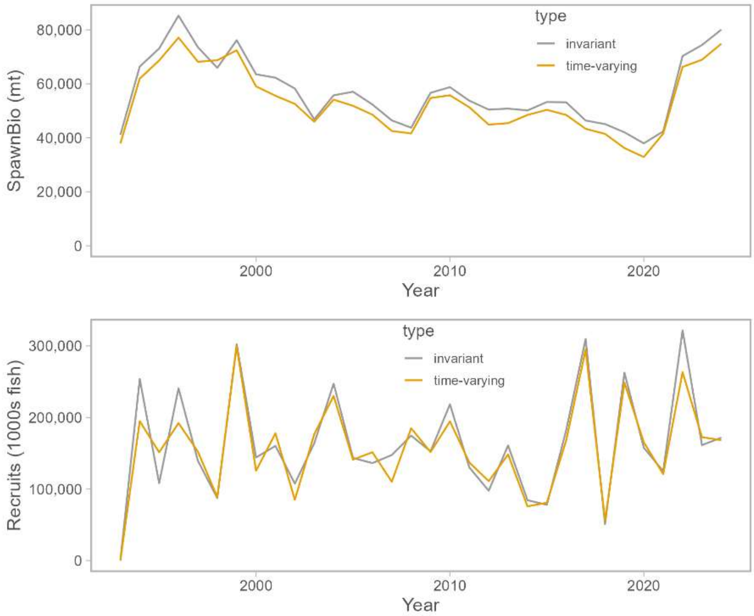


Figure 14: Spawning stock biomass (mt; top) and recruitment (1000s fish; bottom) estimates from the time-invariant selectivity (gray) model and the time-varying selectivity (orange) model.

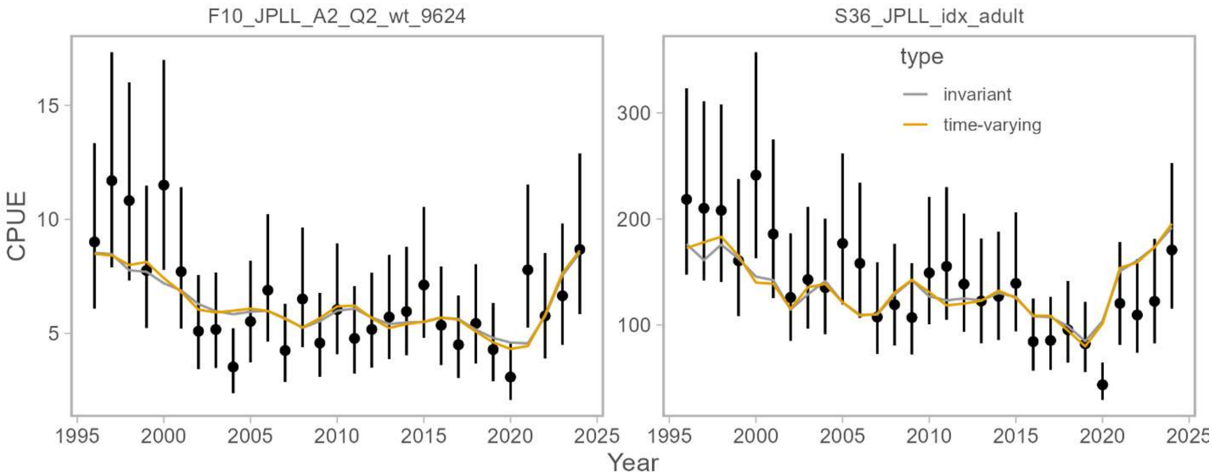


Figure 15: Index of abundance fits to F10 (left panel) and expected values for S36 (right) for the invariant (gray) and time-varying (orange) models. Note, these models did not fit to the S36 index of abundance.

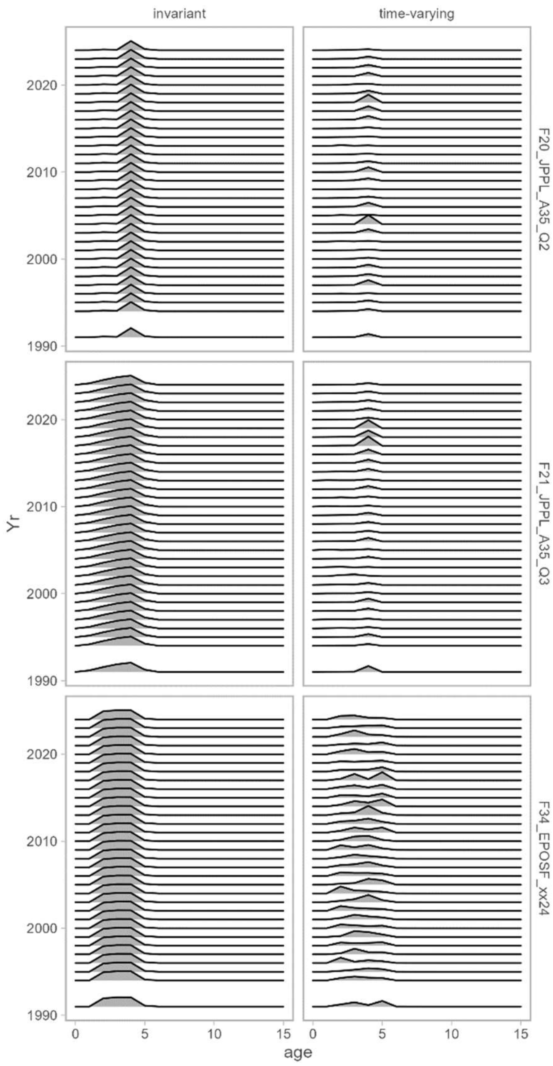
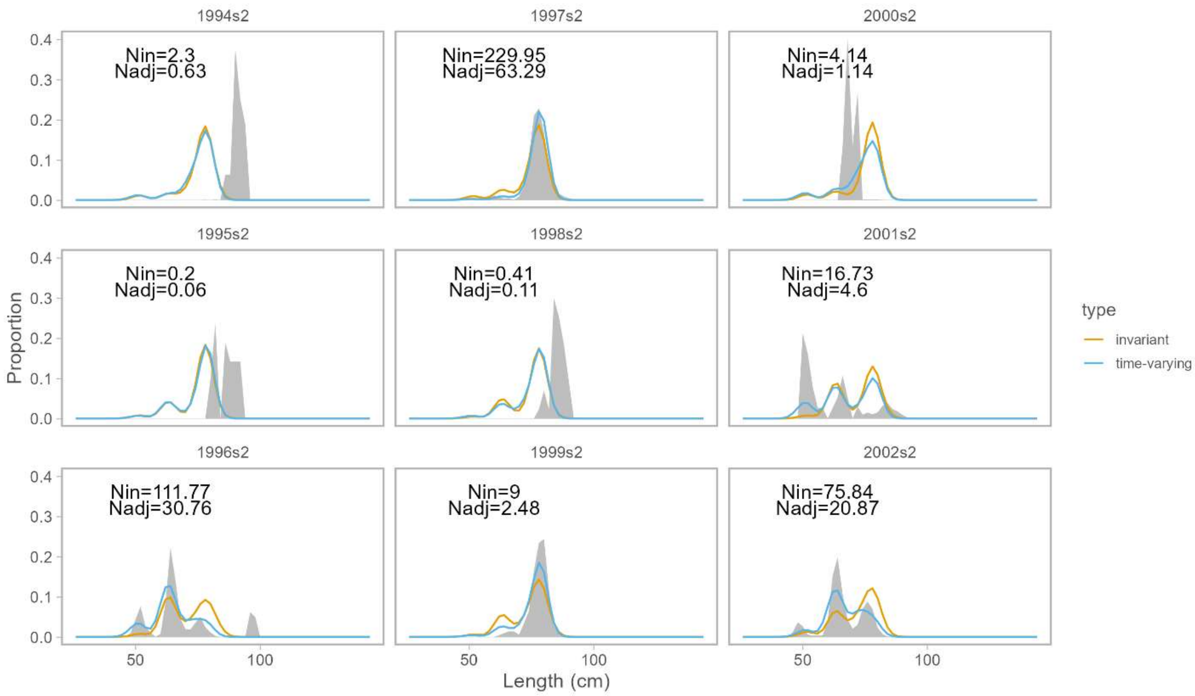
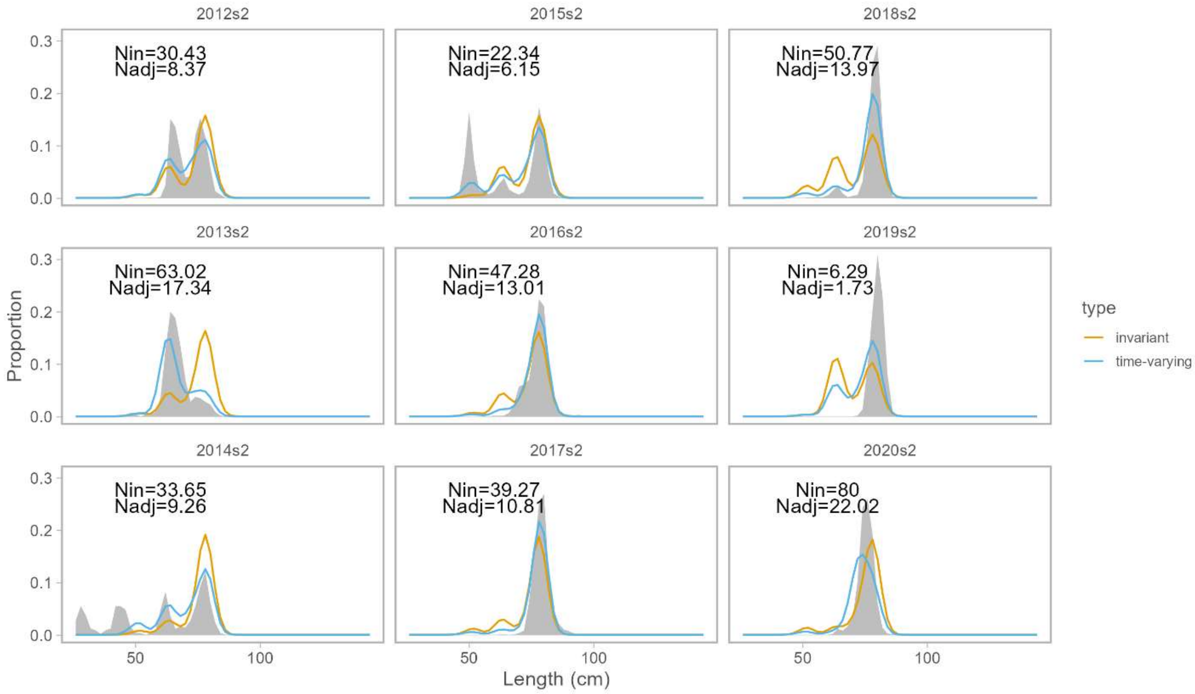


Figure 16: Selectivity at age derived from selectivity at length for F20, F21, and F34 for the invariant (left) and time-varying (right) models.



1994s2
Nin=2.3
Nadj=0.63
1997s2
Nin=229.95
Nadj=63.29
2000s2
Nin=4.14
Nadj=1.14
1995s2
Nin=0.2
Nadj=0.06
1998s2
Nin=0.41
Nadj=0.11
2001s2
Nin=16.73
Nadj=4.6
1996s2
Nin=111.77
Nadj=30.76
1999s2
Nin=9
Nadj=2.48
2002s2
Nin=75.84
Nadj=20.87
Proportion
Length (cm)
type
invariant
time-varying



2012s2
Nin=30.43
Nadj=8.37
2015s2
Nin=22.34
Nadj=6.15
2018s2
Nin=50.77
Nadj=13.97
2013s2
Nin=63.02
Nadj=17.34
2016s2
Nin=47.28
Nadj=13.01
2019s2
Nin=6.29
Nadj=1.73
2014s2
Nin=33.65
Nadj=9.26
2017s2
Nin=39.27
Nadj=10.81
2020s2
Nin=80
Nadj=22.02
Proportion
Length (cm)
type
invariant
time-varying

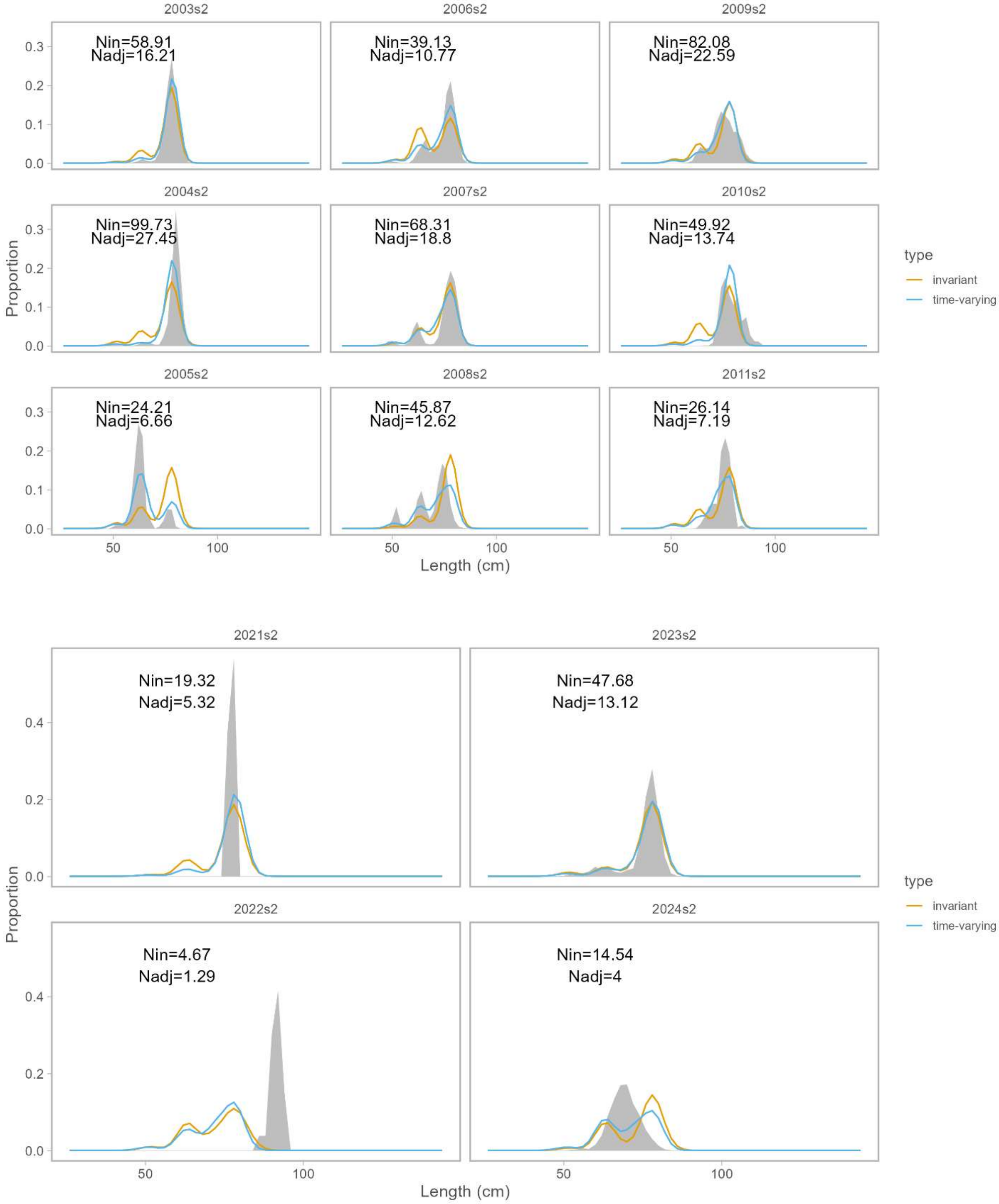
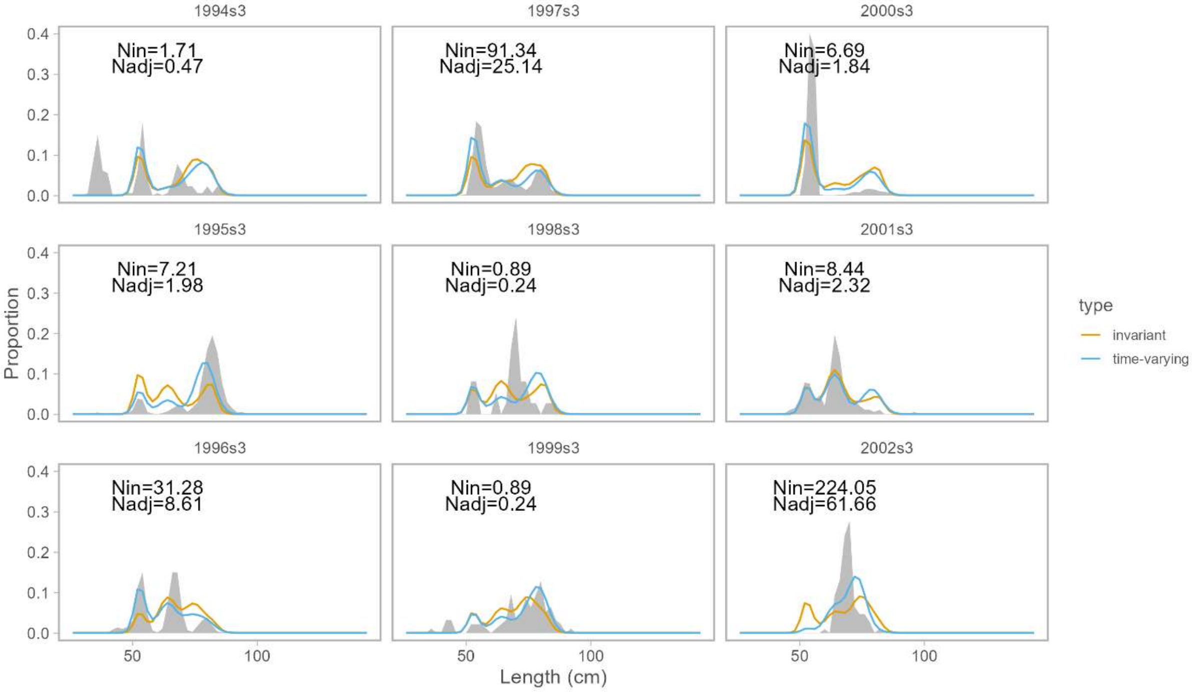
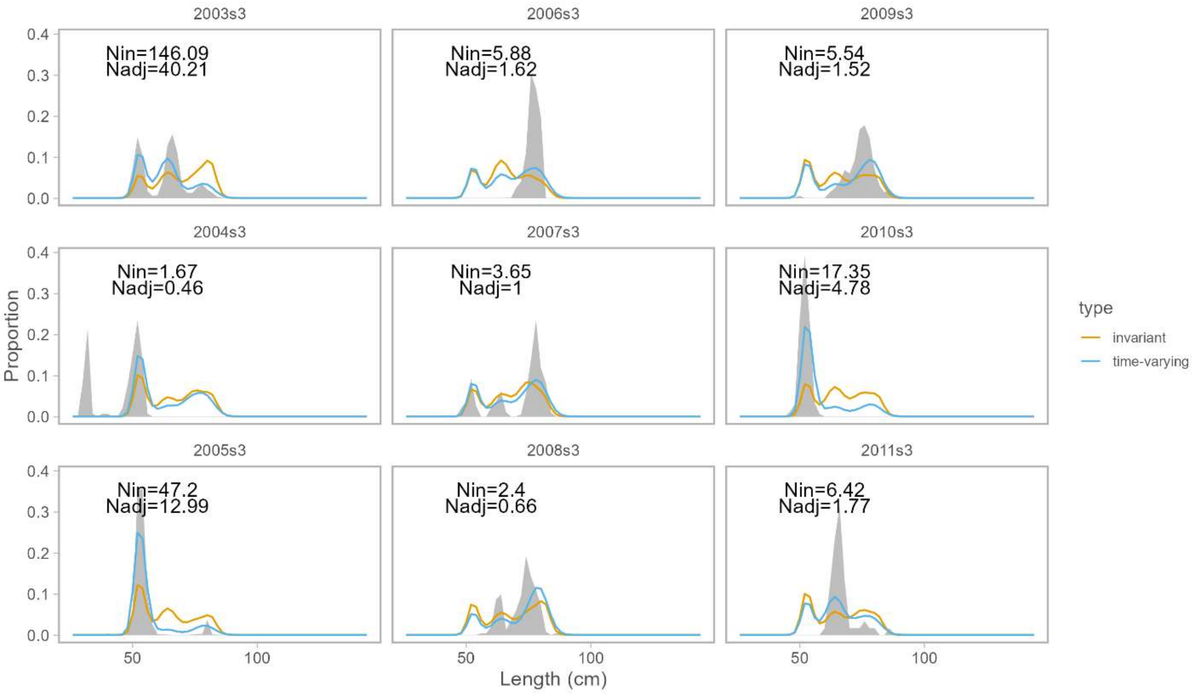


Figure 17: Invariant (orange) and time-varying (blue) model fits to the length composition data for F20 JPPL A35 Q2. Panels are arranged by year and season (by row) and input and adjusted sample size values are shown in the top left of each panel.


1994s3
Nin=1.71
Nadj=0.47
1997s3
Nin=91.34
Nadj=25.14
2000s3
Nin=6.69
Nadj=1.84
1995s3
Nin=7.21
Nadj=1.98
1998s3
Nin=0.89
Nadj=0.24
2001s3
Nin=8.44
Nadj=2.32
1996s3
Nin=31.28
Nadj=8.61
1999s3
Nin=0.89
Nadj=0.24
2002s3
Nin=224.05
Nadj=61.66
Proportion
0.0
0.1
0.2
0.3
0.4
50
100
Length (cm)
type
invariant
time-varying


2003s3
Nin=146.09
Nadj=40.21
2006s3
Nin=5.88
Nadj=1.62
2009s3
Nin=5.54
Nadj=1.52
2004s3
Nin=1.67
Nadj=0.46
2007s3
Nin=3.65
Nadj=1
2010s3
Nin=17.35
Nadj=4.78
2005s3
Nin=47.2
Nadj=12.99
2008s3
Nin=2.4
Nadj=0.66
2011s3
Nin=6.42
Nadj=1.77
Proportion
0.0
0.1
0.2
0.3
0.4
50
100
Length (cm)
type
invariant
time-varying

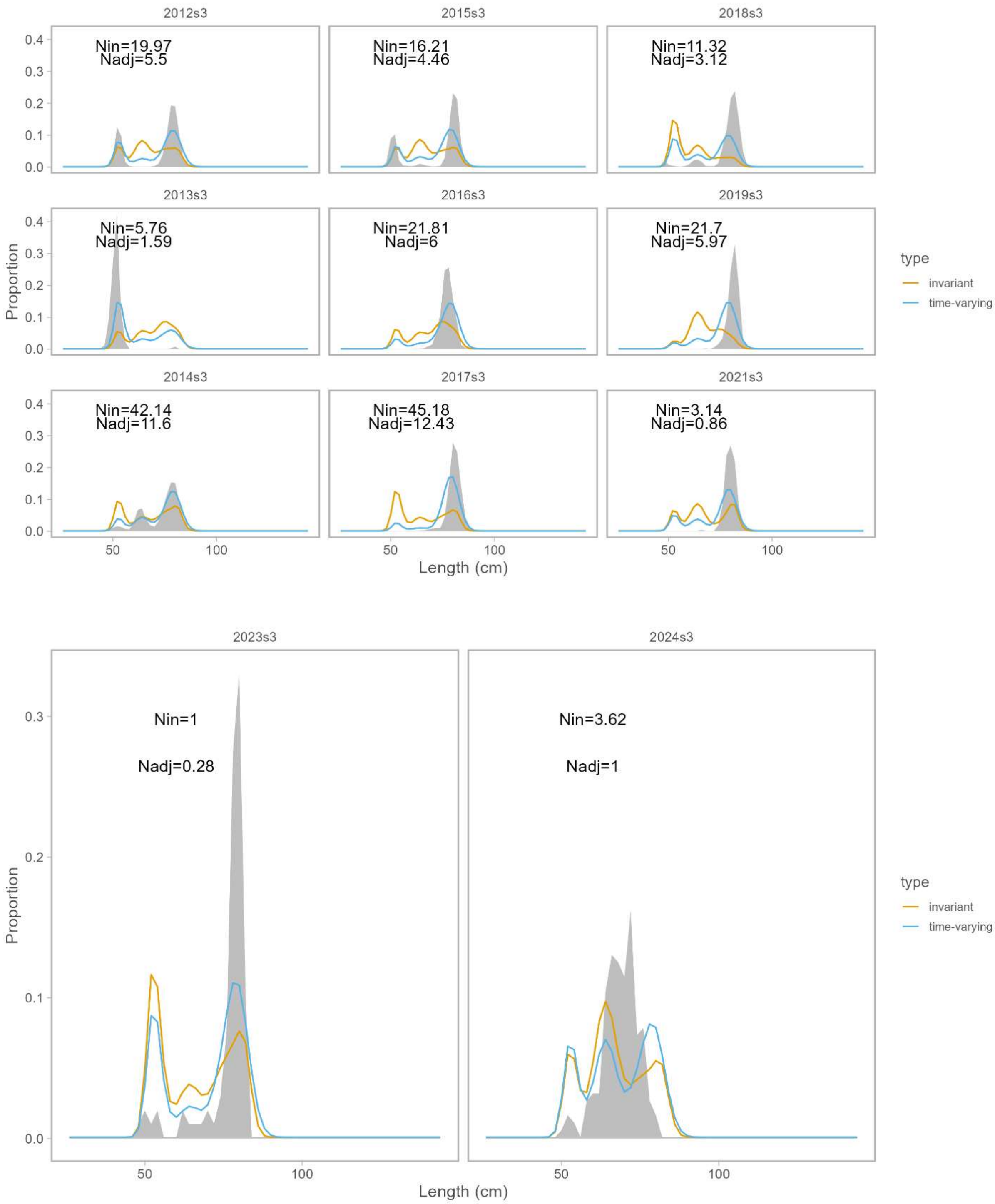
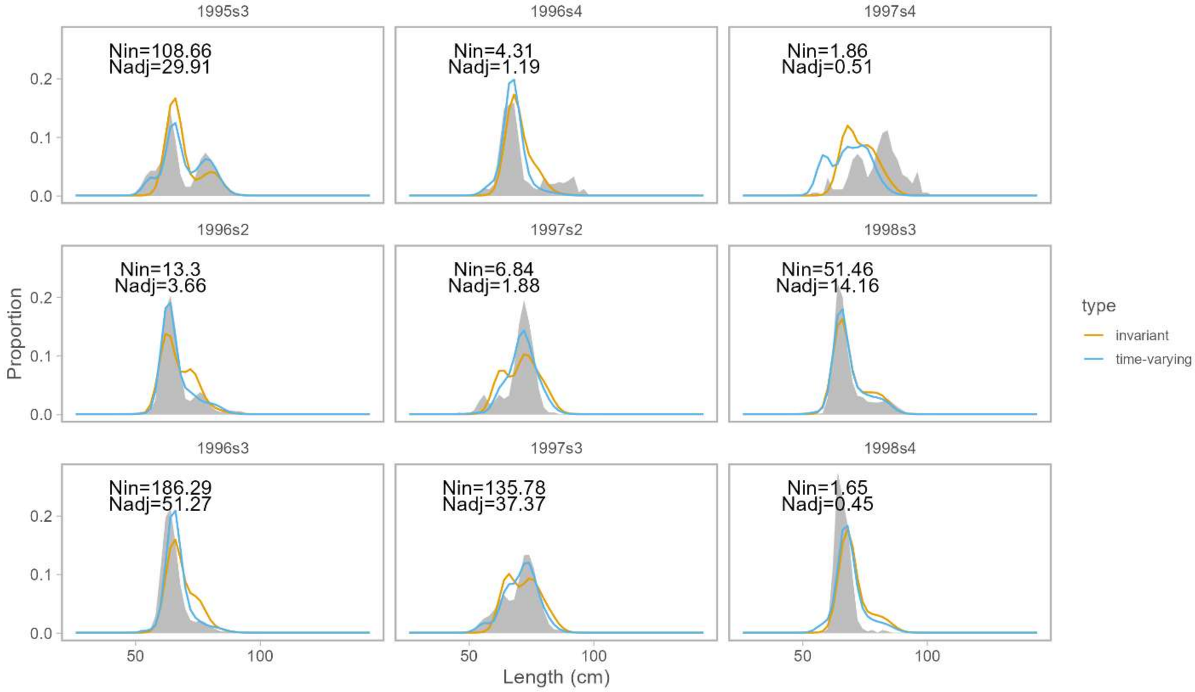
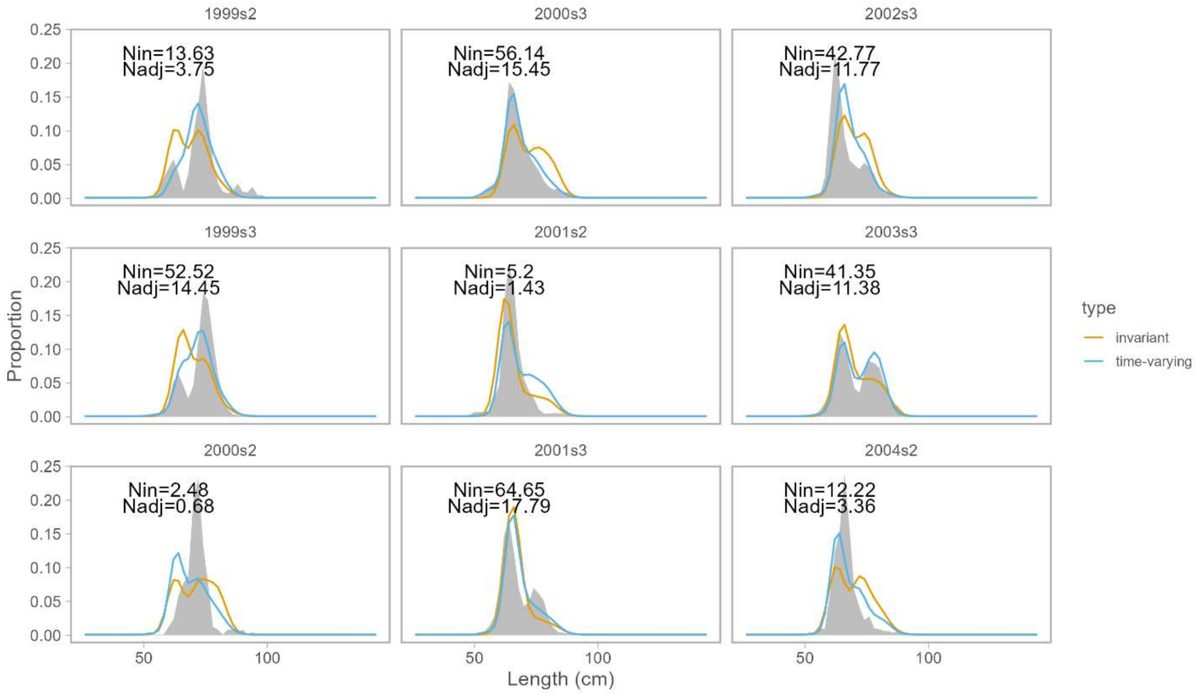


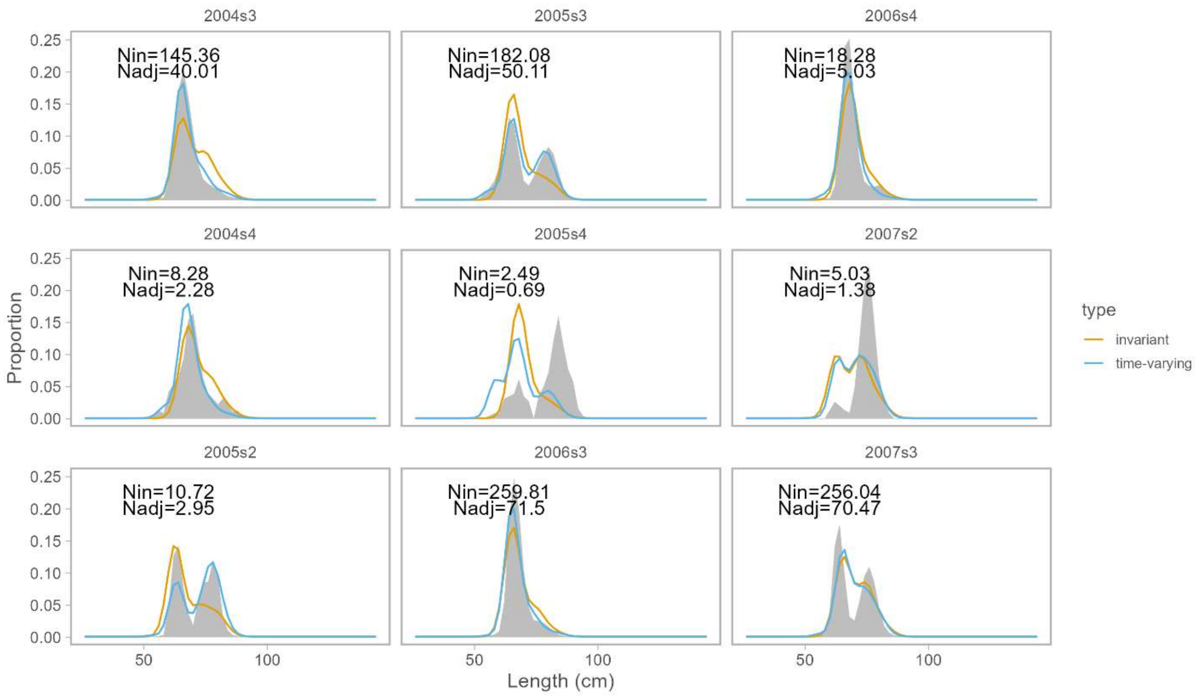
Figure 18: Invariant (orange) and time-varying (blue) model fits to the length composition data for F21 JPPL A35 Q3. Panels are arranged by year and season (by row) and input and adjusted sample size values are shown in the top left of each panel.

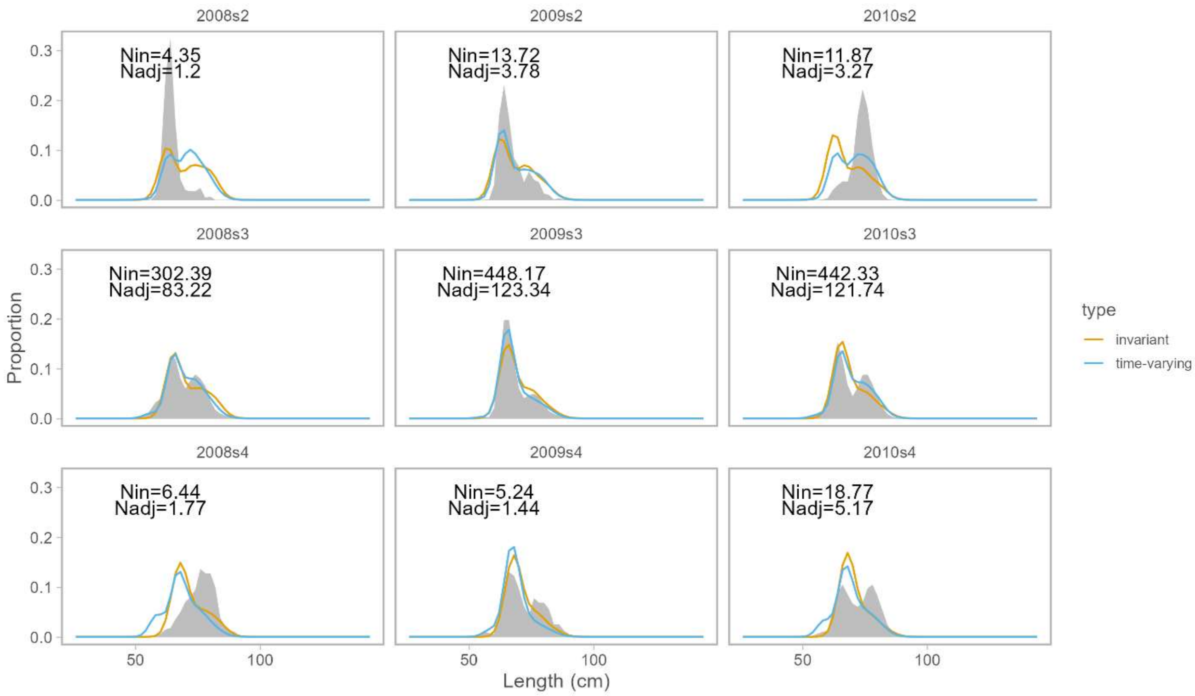


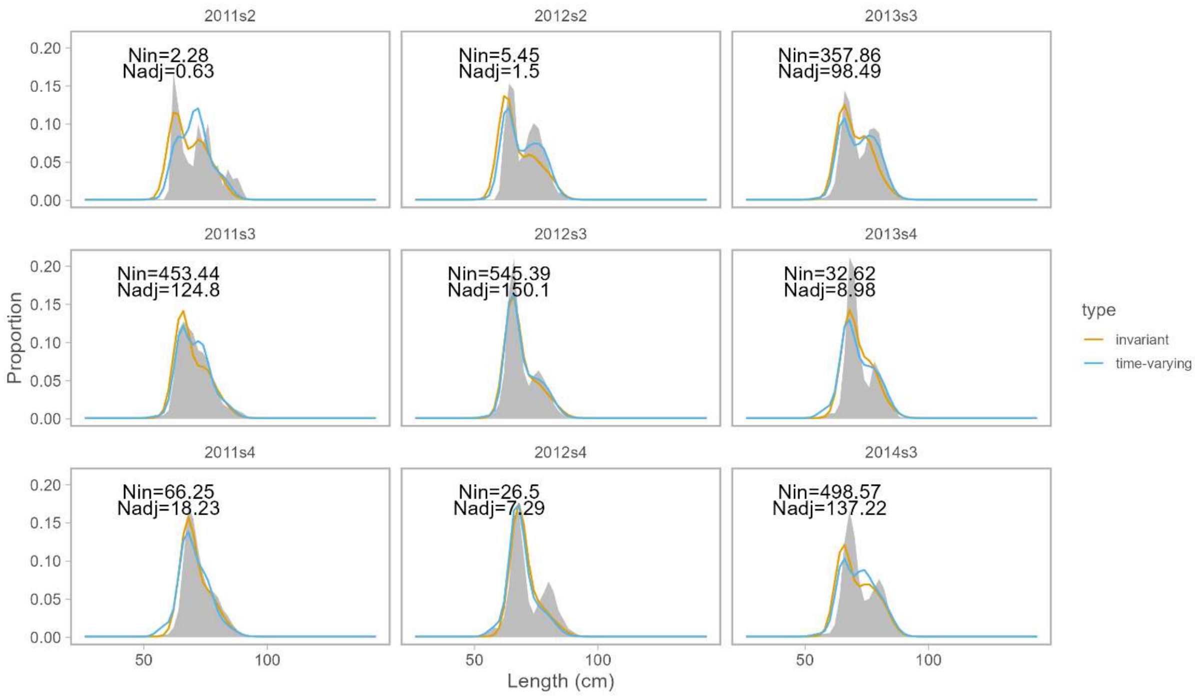
1995s3
Nin=108.66
Nadj=29.91
1996s4
Nin=4.31
Nadj=1.19
1997s4
Nin=1.86
Nadj=0.51
1996s2
Nin=13.3
Nadj=3.66
1997s2
Nin=6.84
Nadj=1.88
1998s3
Nin=51.46
Nadj=14.16
1996s3
Nin=186.29
Nadj=51.27
1997s3
Nin=135.78
Nadj=37.37
1998s4
Nin=1.65
Nadj=0.45
Proportion
Length (cm)
type
invariant
time-varying



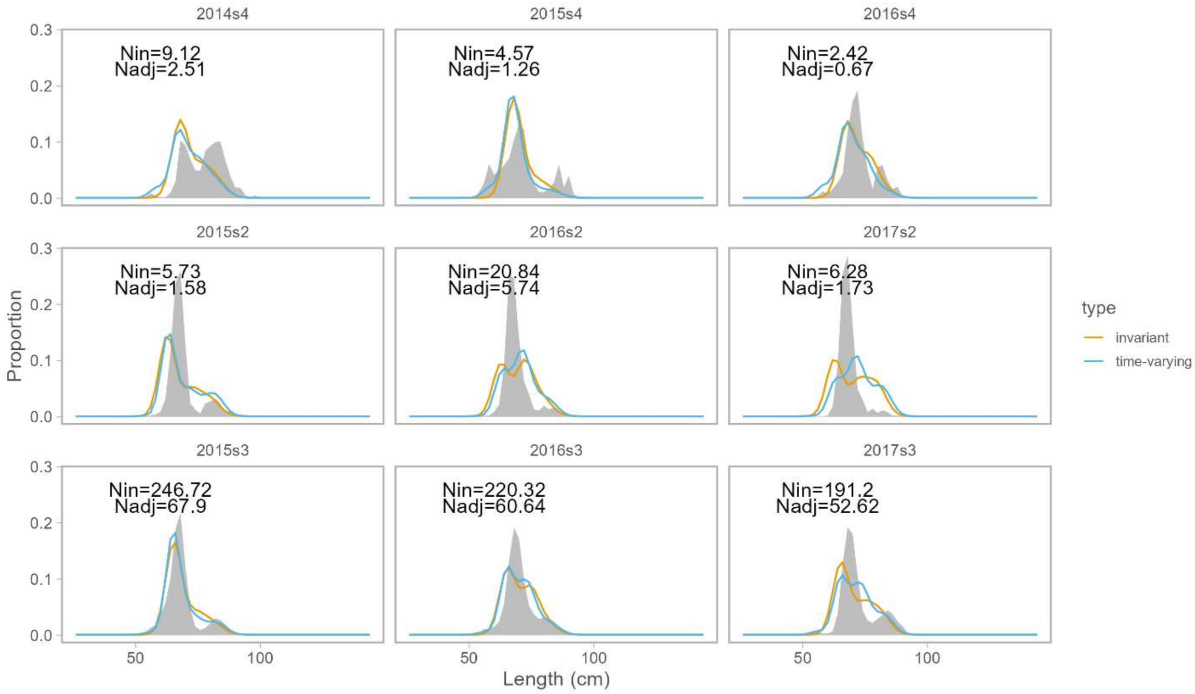
1999s2
Nin=13.63
Nadj=3.75
2000s3
Nin=56.14
Nadj=15.45
2002s3
Nin=42.77
Nadj=11.77
1999s3
Nin=52.52
Nadj=14.45
2001s2
Nin=5.2
Nadj=1.43
2003s3
Nin=41.35
Nadj=11.38
2000s2
Nin=2.48
Nadj=0.68
2001s3
Nin=64.65
Nadj=17.79
2004s2
Nin=12.22
Nadj=3.36
Proportion
Length (cm)
type
invariant
time-varying


2004s3
Nin=145.36
Nadj=40.01
2005s3
Nin=182.08
Nadj=50.11
2006s4
Nin=18.28
Nadj=5.03
2004s4
Nin=8.28
Nadj=2.28
2005s4
Nin=2.49
Nadj=0.69
2007s2
Nin=5.03
Nadj=1.38
2005s2
Nin=10.72
Nadj=2.95
2006s3
Nin=259.81
Nadj=71.5
2007s3
Nin=256.04
Nadj=70.47
0.25
0.20
0.15
0.10
0.05
0.00
Proportion
50
100
Length (cm)
type
invariant
time-varying


2008s2
Nin=4.35
Nadj=1.2
2009s2
Nin=13.72
Nadj=3.78
2010s2
Nin=11.87
Nadj=3.27
2008s3
Nin=302.39
Nadj=83.22
2009s3
Nin=448.17
Nadj=123.34
2010s3
Nin=442.33
Nadj=121.74
2008s4
Nin=6.44
Nadj=1.77
2009s4
Nin=5.24
Nadj=1.44
2010s4
Nin=18.77
Nadj=5.17
0.3
0.2
0.1
0.0
Proportion
50
100
Length (cm)
type
invariant
time-varying



2011s2
Nin=2.28
Nadj=0.63
2012s2
Nin=5.45
Nadj=1.5
2013s3
Nin=357.86
Nadj=98.49
2011s3
Nin=453.44
Nadj=124.8
2012s3
Nin=545.39
Nadj=150.1
2013s4
Nin=32.62
Nadj=8.98
2011s4
Nin=66.25
Nadj=18.23
2012s4
Nin=26.5
Nadj=7.29
2014s3
Nin=498.57
Nadj=137.22
Proportion
Length (cm)
type
invariant
time-varying



2014s4
Nin=9.12
Nadj=2.51
2015s4
Nin=4.57
Nadj=1.26
2016s4
Nin=2.42
Nadj=0.67
2015s2
Nin=5.73
Nadj=1.58
2016s2
Nin=20.84
Nadj=5.74
2017s2
Nin=6.28
Nadj=1.73
2015s3
Nin=246.72
Nadj=67.9
2016s3
Nin=220.32
Nadj=60.64
2017s3
Nin=191.2
Nadj=52.62
Proportion
Length (cm)
type
invariant
time-varying

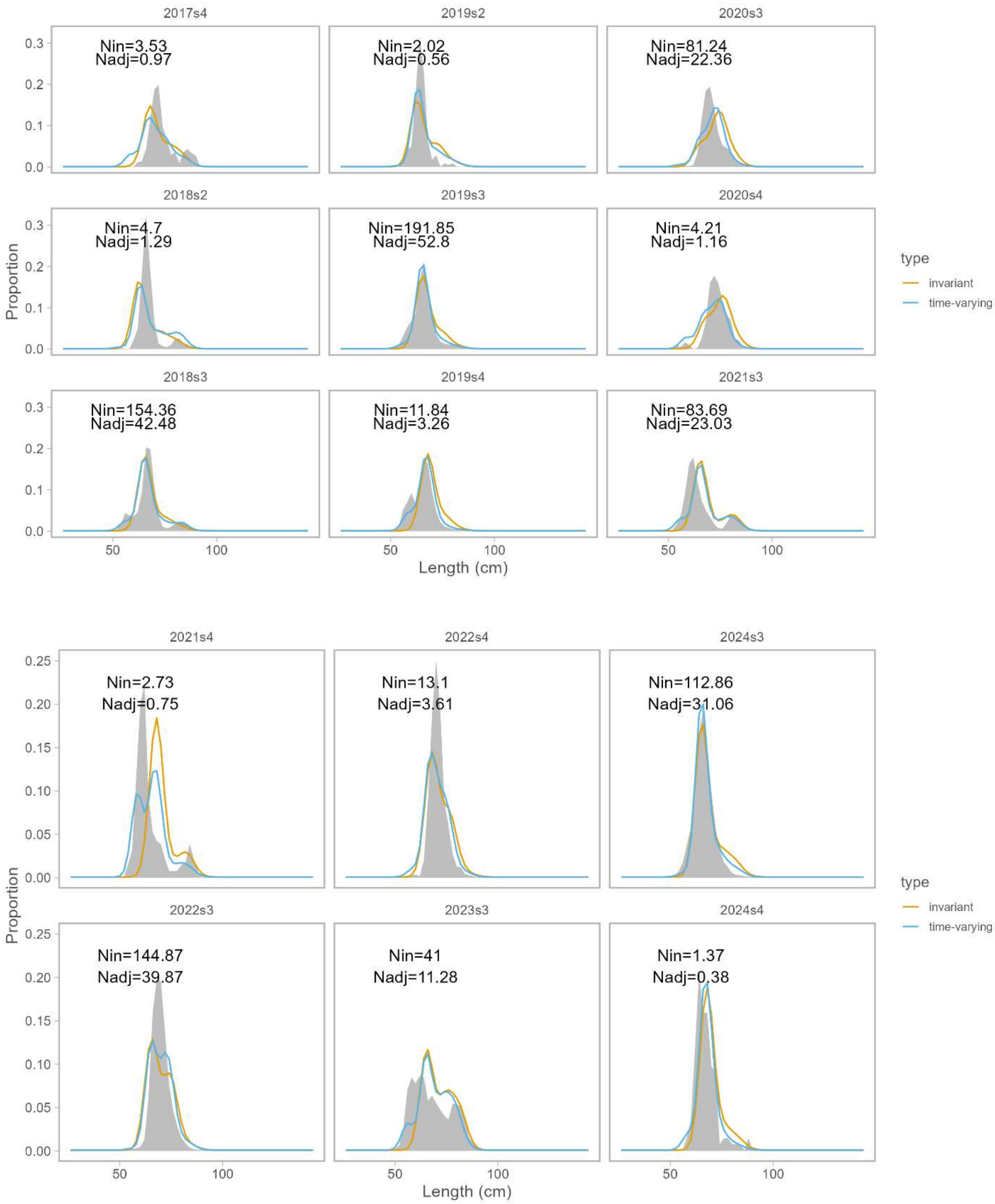


Figure 19: Invariant (orange) and time-varying (blue) model fits to the length composition data for F35 EPOSF. Panels are arranged by year and season (by row) and input and adjusted sample size values are shown in the top left of each panel.

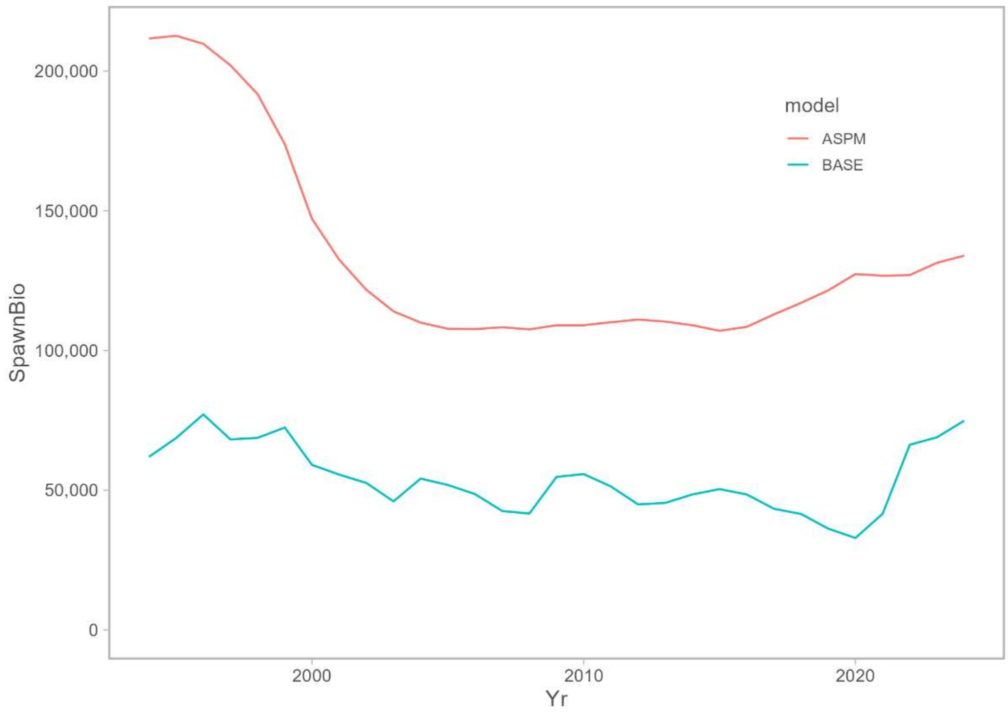


Figure 20: Spawning stock biomass estimates from the time-varying selectivity model (blue) and the ASPM (red).

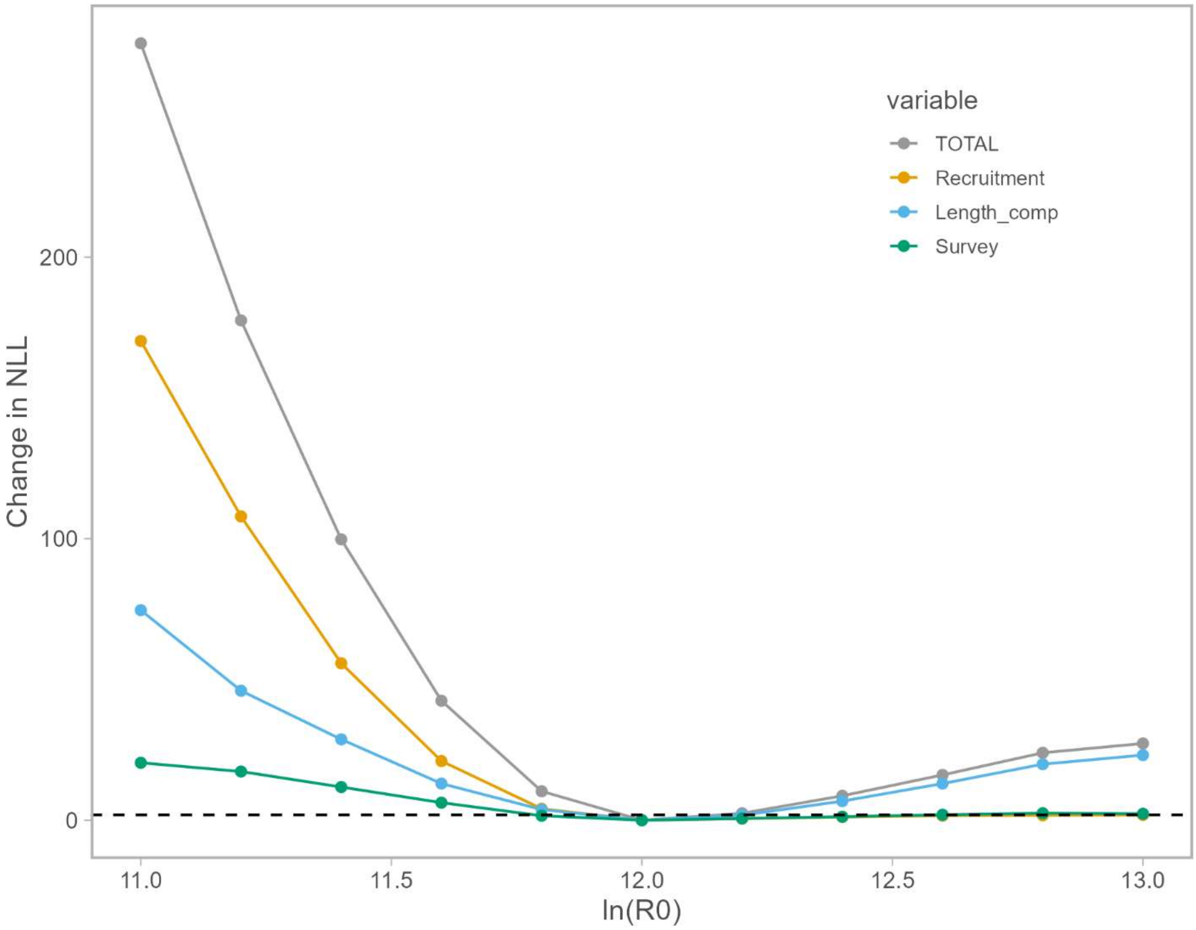


Figure 21: Likelihood profile across fixed values of R0. Values within 1.92 units of the MLE (dashed horizontal line) are within the 95% confidence interval.

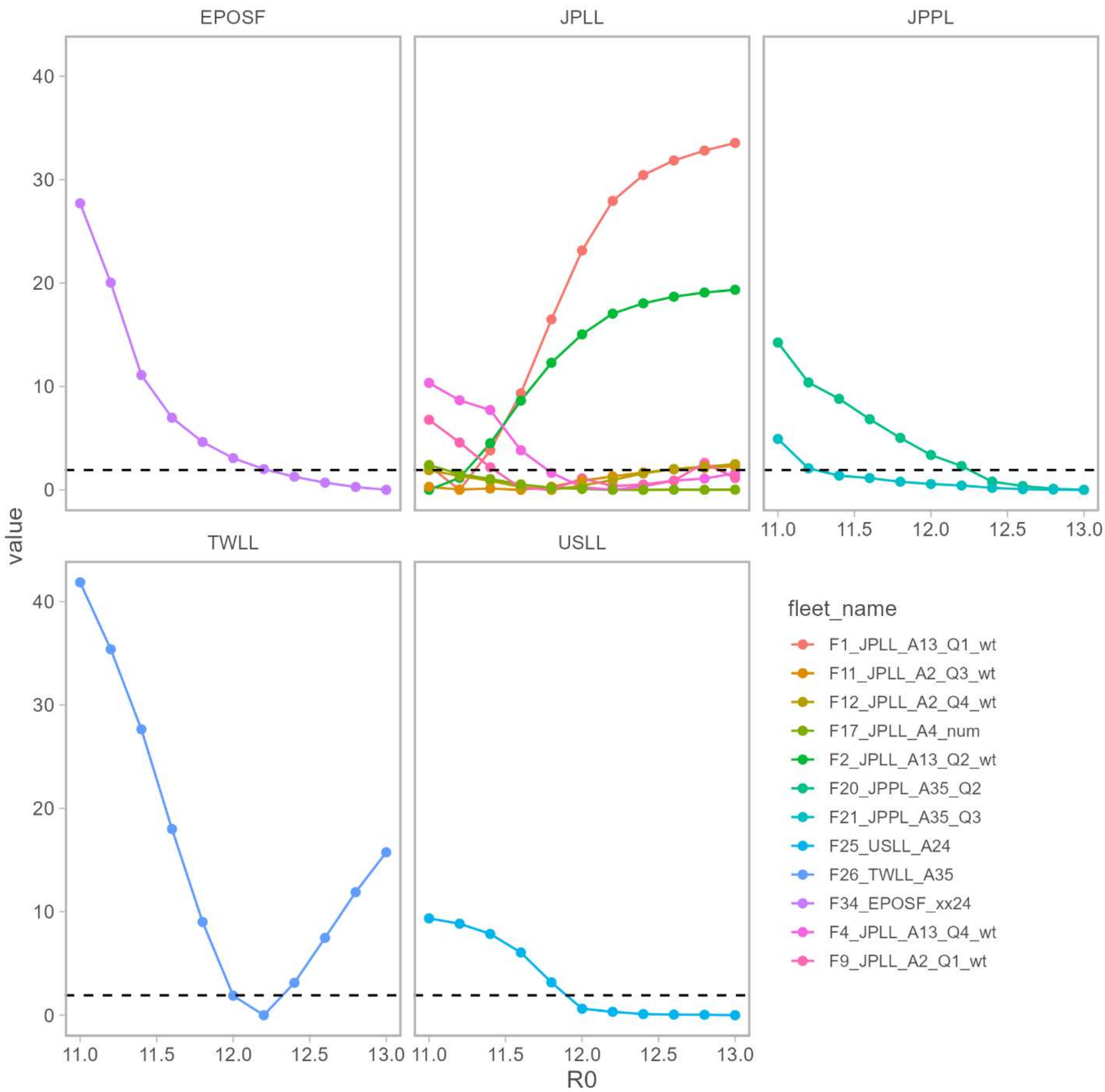


Figure 22: Fleet-specific length composition likelihood values across fixed values of R0. Values within 1.92 units of the MLE (dashed horizontal line) are within the 95% confidence interval. The panels are arranged by fishery.

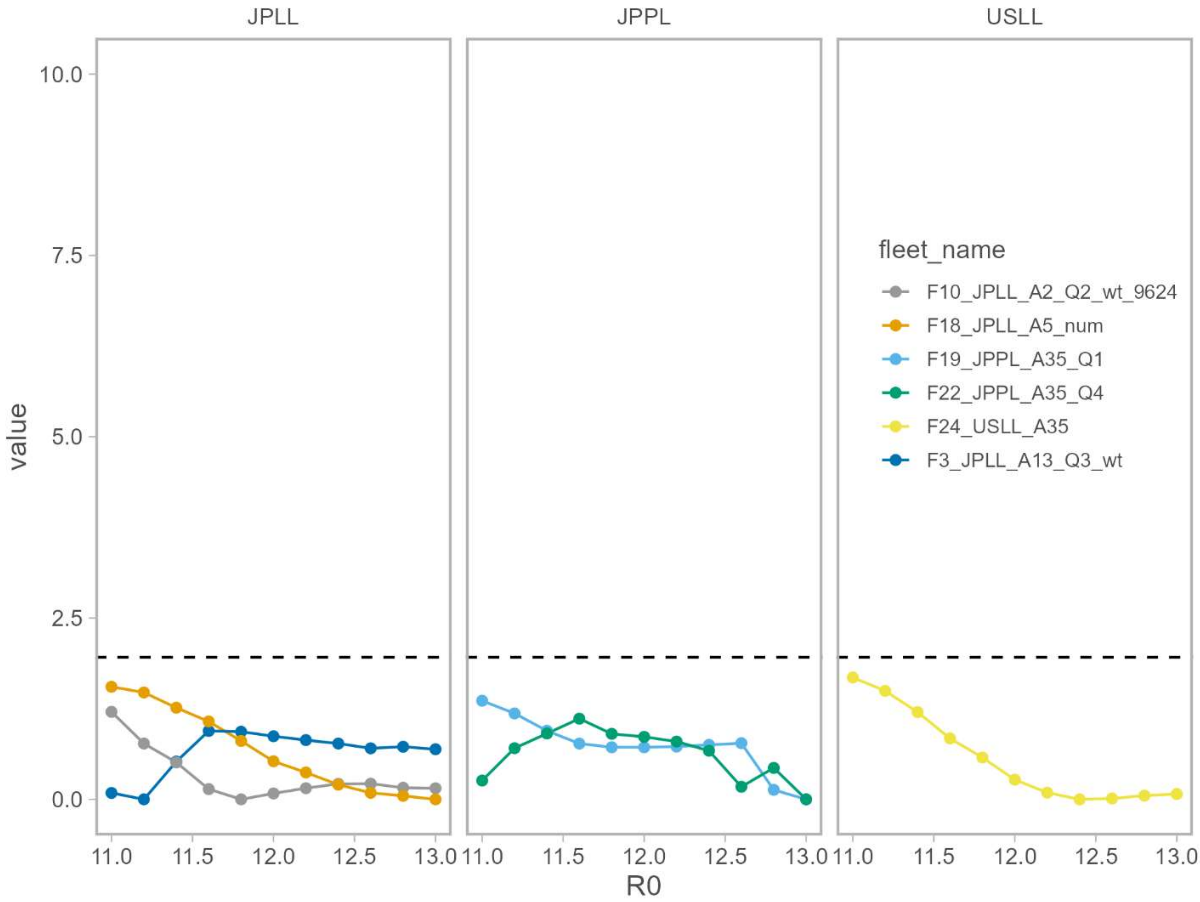


Figure 23: Non-significant fleet-specific length composition likelihood values across fixed values of R0. Values within 1.92 units of the MLE (dashed horizontal line) are within the 95% confidence interval. The panels are arranged by fishery.

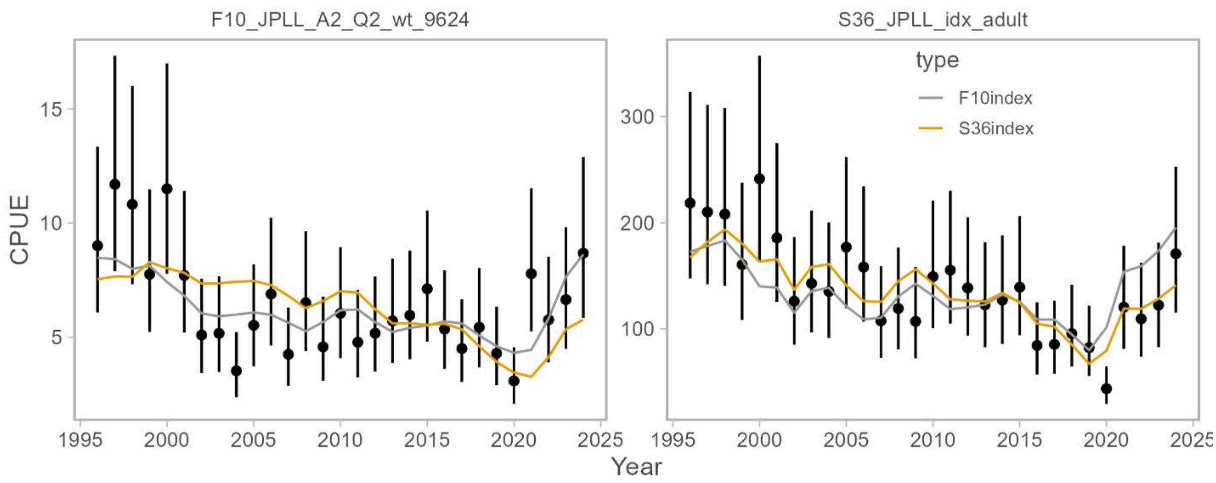


Figure 24: Fits (or expected values) to the F10 (gray) and S36 (orange) indices of abundance. The F10 model only fit to the F10 index, and the S36 model only fit to the S36 index.

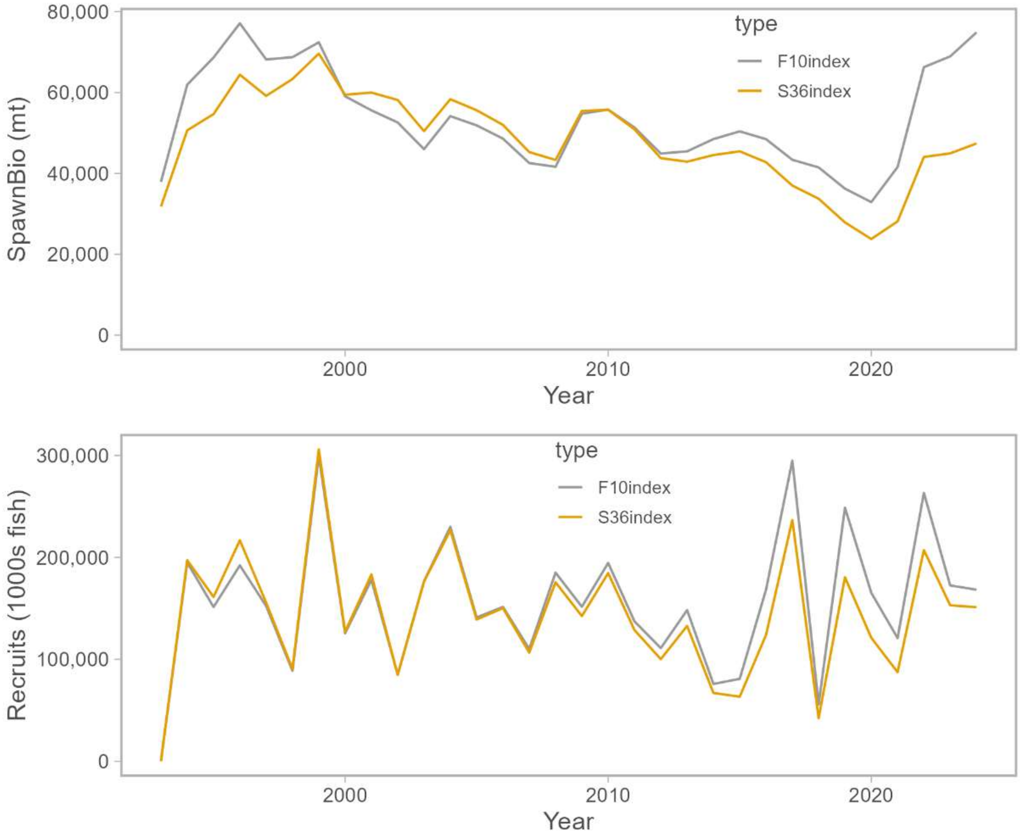


Figure 25: Spawning stock biomass (top) and recruitment (bottom) estimates for the F10 (gray) and S36 (orange) models.

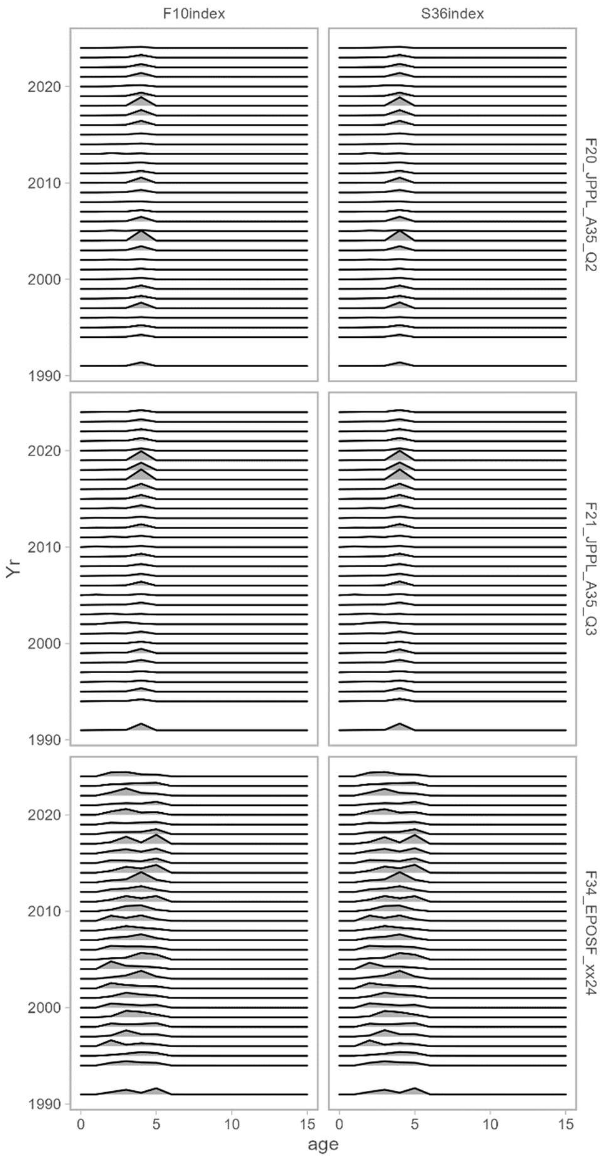


Figure 26: Selectivity at age derived from selectivity at length for F20, F21, and F34 for the F10 (left) and S36 (right) index models.

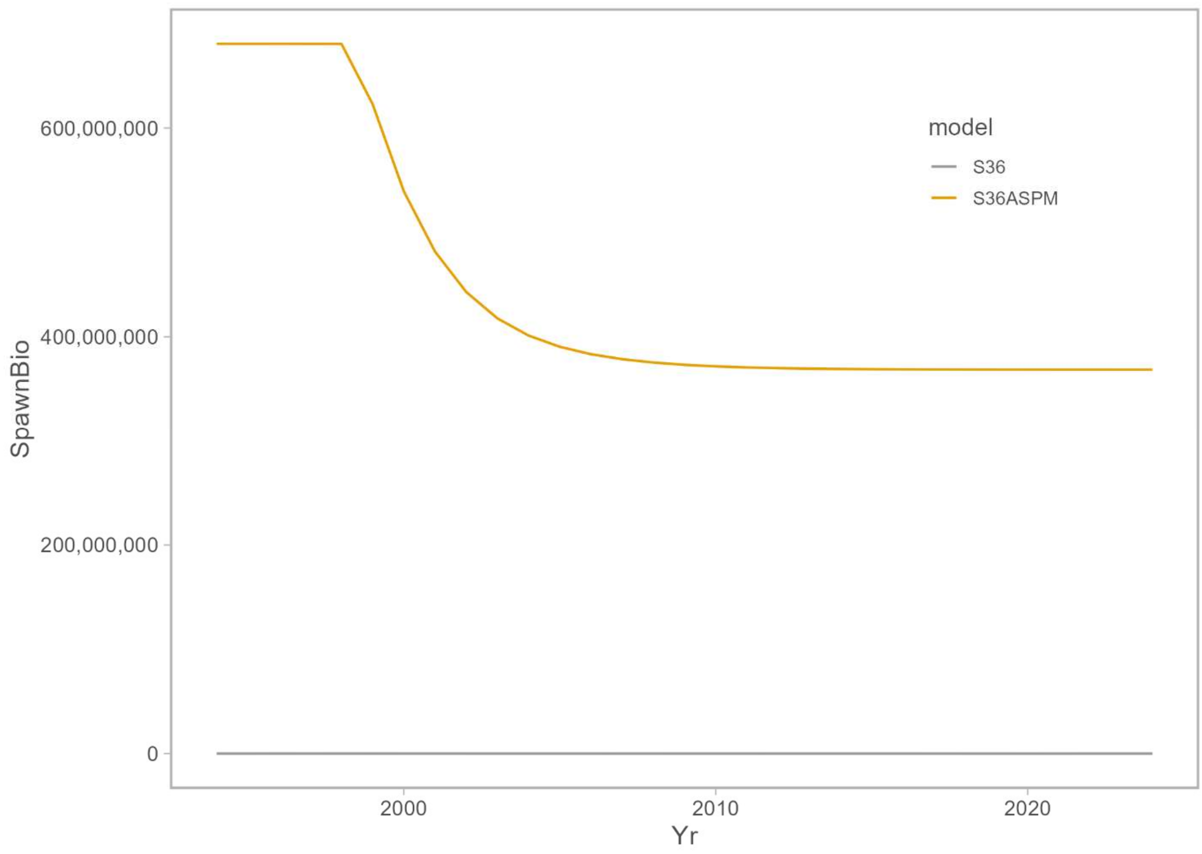


Figure 27: Spawning stock biomass estimates from the S36 index model (gray) and the corresponding ASPM (orange). Note the scale of the y-axis values.