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SCIENTIFIC COUNCIL AND STACFIS SHRIMP ASSESSMENT MEETING –SEPTEMBER 2024

A Provisional Assessment of the Shrimp Stock off West Greenland in 2024

by

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Summary

The West Greenland Stock of *Pandalus borealis* was assessed from indices of biomass density based on catch and effort data from fishing fleets, biomass and stock-composition information from a research trawl survey, catch data, and information on the distribution of the stock as revealed by fishery logbooks. The assessment framework incorporates a logistic stock-recruitment model, fitted by Bayesian methods, that uses CPUE and survey series as biomass indicators, and includes as removals catch data, assumed free of error, as well as a term for predation by Atlantic cod, using available series of cod biomass.

In 2023, there has been an abnormal spatial distribution of sea ice north of 66°N in Greenland EEZ, which prevents trawling of most planned stations during the survey. Due to poor coverage in the northern survey area, it is uncertain if this year's survey results reflect the stock trajectory and status. Hence, it was assumed that the commercial important areas in north wasn't covered properly during the survey. To compensate for the un-surveyed area, an average of the past five-year values of biomass and density in the un-surveyed stratum/strata, were used in place of missing values for 2023 assessment of the West Greenland shrimp stock The spatial distribution of sea ice was not abnormal in 2024, nevertheless there might be a tendency to later retrench of the sea ice over the past years (e.i in June/July than in May/early June). In the more northern western regions, sea ice prevents trawling at all stations during the survey in 2024, but the results are assumed to be representative for the stock situation.

CPUEs were standardized by linearized multiplicative models including terms for vessel, month, gear type, year, and statistical area. In the recent three years the CPUE of the coastal fleet decreased slightly while the CPUE of the offshore fleet increased from 2016 to 2017. In the subsequent years CPUE of both the offshore fleet and the combined index have declined and is in 20 at the lowest value since 2013. CPUE for the inshore fleet have remained stable over the most recent years.

Standardized CPUE for the Canadian fleet fishing in Div. 0A has not been updated since 2011 because it is not possible to receive new logbook information from Canada.

The survey index of total biomass remained fairly stable from 1988 to 1997. It then increased until 2003. Subsequent values were consecutively lower, with the second lowest level in the last 22 years occurring in 2014. Over the following years biomass increased until 2020 and has since been declining.. In 2024 overall survey biomass as well as fishable biomass is below their 20-year median, respectively.

For the offshore regions, fishable biomass is below the 20-year median, while inshore is above its lower quartile. Areas north of 66°N have had almost three-quarters of the offshore biomass but due to this year's poor survey coverage in those areas, biomass estimates in those areas are associated with uncertainties. Nevertheless, the proportions of fishable biomass in the offshore area and inshore are 77% and 23% respectively.
Proportion fishable of the survey biomass were in 2023 somewhat at the lower quartile for the last 20 years, owing to relatively large proportions of pre-recruits and age-2 shrimps in the stock, mainly in offshore regions. Proportion of both males and females of fishable biomass are at their 20-year median.

Overall, the number of age 2 shrimps, declined in 2024, and is below their 20-year mean. The stock composition inshore has historically been characterized by a higher proportion of young shrimps than that offshore. However, over the past years offshore constitutes much higher numbers of both age-2 shrimp as well as number of pre-recruits. In 2024, the numbers of age-2 shrimp was almost at the same value inshore and offshore, while the numbers of pre-recruits were higher offshore than inshore.

The stock is in 2024 composed by a relatively high number of females, almost only in offshore regions, where the numbers are well above the 20-year upper quartile.

The quantitative assessment adopted by NAFO shows a stock that has been declining for a decade—albeit from levels that were probably not sustainable—has probably been fished over its MSY mortality from 2011 to 2014, but now appears to be close to its MSY level.

Introduction

The stock of the northern shrimp (*Pandalus borealis*) off West Greenland is distributed in NAFO Subarea 1 and the eastern margin of NAFO Div. 0A, and within this area is assessed as one unit. A Greenlandic fishery exploits the stock in Subarea 1 up to 76°00'N (Div. 1A–1F); a Canadian fishery is restricted to Div. 0A.

In 2002 a quantitative assessment framework based on a biological model of shrimp stock dynamics (Hvingel and Kingsley 2002) was adopted by STACFIS and Scientific Council. Input data series include a swept-area index of fishable biomass from an annual research trawl survey, a series of standardized indices of fishery CPUE and a series of past catches. The model was modified in 2011 to give more weight to the survey index of biomass and less to the fishery CPUE (Kingsley 2011).

Up to 2014 an externally calculated index series of 'effective' biomasses of Atlantic cod —i.e., corrected for the partial overlap of its distribution with that of the shrimps—was also included. In 2014 and until 2018 this was replaced by the inclusion of the four biomass index series on which it had been based as well as the series of overlap indices (Kingsley 2014). The biomass indices are generating a series of estimated biomasses, and this is multiplied by the overlap series to generate a series of 'effective' biomasses that are used in estimating the amount cod removed from the shrimp stock each year.

Model estimation of 'True cod' biomass, based on the four cod biomass indices, was found to be overestimated and resulted in an unrealistic removal of shrimp biomass. Therefore, the four cod biomass indices were replaced by an absolute cod biomass index, modelled in a state-space stock assessment model SAM. More detailed information can be found in Rigét and Burmeister 2019 (d).

The Greenland survey acts as tuning fleet in the SAM assessment. The survey has a coverage from NAFO Div. 1A in the north to Div. 1F in the south and covers the period from 1992 until today.

Due to the lack of survey in 2021, no new data covering fishable shrimp biomass, cod biomass and overlap factor were available as input index to the assessment model. As a consequence, the models need to have input data for cod biomass as well as overlap factor, different scenarios based on average cod biomass and overlap factor for the past two, three, four, five and ten years was applied (all results are not shown in the paper). Further, larger uncertainty was added to the estimation of estimated overlap and effective cod biomass in 2021.

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```
for (i in Present.Year:Present.Year)
{      Past.cod[i] <- True.cod[i] * Est.Overlap.2021  #Past.cod is 'effective cod' to enter #predation function New coding 2021 due to lack of survey info

Est.Overlap.2021 ~ dnorm (0.26,4.21) #New coding 2021 due to lack of survey info
```

In 2024 the survey was conducted with the research ship r/v Tarajoq, and the survey was performed as in all previous years. A more detailed description of the survey and results are found in (Burmeister et al 2024). Consequently, the standard model was used for 2024 assessment.

The quantitative model was fitted to the input data and short-term (1-year) and medium-term (three-year) projections of stock development were made for annual catches from 60 000 to 100 000 tons under assumptions that the cod stock, allowance made for its overlap with shrimp distribution, might be at 17 000 tons. The median estimate for 2024 was 17 000 tons. The associated risks of transgressing reference parameters—maximum sustainable yield levels of biomass (B_{msy}) and mortality (Z_{msy})—as well as a precautionary limit set at 30% of B_{msy} were estimated.

This assessment refers also, although qualitatively, to information on the distribution of the Greenland fishery derived from logbooks. Trawl time, and catches, were assigned to statistical areas covering the West Greenland shrimp grounds, and series of indices of how widely the fishery was distributed were calculated (Burmeister, 2024). The assessment also refers to indices that summarize survey information on the distribution of the stock and its structure (Kingsley 2008b; Kingsley 2015; Kingsley 2016; Burmeister et al. 2016; Burmeister and Rigét 2017; Burmeister and Rigét 2018, Burmeister and Rigét 2019; Burmeister and Rigét 2020; Burmeister at al. 2022, Burmeister et. al, 2023; Burmeister at al. 2024).

Environment

The mean survey bottom temperature—weighted by area, increased quite abruptly from a mean of 1.83°C in 1990–96 to 3.5°C in 1997–2014. From 2015 temperature have continuously declined to low at 2.1°C in 2018 but has since slightly raised each year to 3°C since 2022. In 2024 area weighted average bottom temperature valued 3.3°C. At about the same time as the mean bottom temperature increased, the shrimp stock started a more protracted shift in its distribution, into shallower water and into more northerly areas. In the mid-1990s, most of the survey biomass was between 300 and 400 m, with a significant amount deeper than 400 m. Now, a majority is between 200 and 400 m, with a significant amount between 200 to 300 m (Burmeister and Rigét 2020; Burmeister et al., 2023; Burmeister et al., 2024). This move into shallower water looks like a continuing trend since the early 2000s.

Since 2019 the cod stock estimation was done by a state-space model (SAM) (Rigét & Burmeister,2020; Nielsen &Berg, 2014). The SAM model includes catch-at-age date from the commercial fishery and the Greenlandic survey catch-at-age data as the tuning fleet (Burmeister & Rigét, 2021). Catches from the commercial fishery have been low over almost two decades, and mainly restricted to NAFO Div. 1F. The cod stock biomass has been increasing since 2017 and was estimated to 56 000 t in 2024 and composed of many year-classes. This estimate is considered uncertain because of the lack of input data for both the commercial fishery (2021 and 2022) and survey data (2021). The cod biomass is mainly distributed in southern regions of West Greenland where there is a lower density of shrimps, and the 'effective' cod stock appeared to be low.

The estimated overlap between the cod and the shrimp stock varied over time, peaked at a high value (0.888) in 2011, dropped significantly in 2012, and have since averaged at 0.257. In 2023 the estimated overlap, based on the average of the most recent three years was 0.3013 resulting an estimated 'effective' cod stock at 17 Kt (Fig. 6). The cod biomass remained comparable in 2024, the overlap between cod and shrimp changes only little to 0.2981, and 2024 'effective' cod is estimated to 17 Kt which is comparable to 2023(Table 2 and Fig.6).

Stocks of Atlantic cod in West Greenland continue to fluctuate and while forecasting the biomass and distribution of cod on the West Greenland shrimp ground is important in predicting the dynamics of the stock of Northern shrimp and in managing the fishery, it remains an insoluble problem. The stock-dynamic model used in the assessment allows for flexible and comprehensive consideration of possible developments of the cod stock.

Stock Size, Composition and Distribution

The survey index of total biomass remained stable from 1988 to 1997. It then increased until 2003. Subsequent values were consecutively lower, with the second lowest level in the last 21 years occurring in 2014 (Figure 6). Since 2015 biomass has increased, dropped little in 2022 and continuing its decline in 2024.

In 2023, there has been an abnormal spatial distribution of sea ice north of 66°N in Greenland EEZ, which prevents trawling of many planned stations during the survey. Due to poor coverage in the northern survey area, it is uncertain if this year's survey results reflect the stock trajectory and status. To compensate for the un-surveyed area, an average of the past five-year values of biomass and density in the un-surveyed stratum/strata, were used to replace missing important values for 2023 assessment of the West Greenland shrimp stock.

The spatial distribution of sea ice was within its normal in 2024, despite there have been a tendency where sea ice is melting later, than what was observed in the period from 2010 – 2021.

In 2024 overall survey as well as fishable biomass are below their 20-year lower quartile. The number and biomass of males and females are at lower values than in 2023 and is in 2024 below their 20-year lower quartile.

Survey Measures of Stock Size

	Biomass (Kt)					Number (bn)		
	Survey							
	Disko B. & Vaigat	Offshore	Total	Fishable	Female	Male	Female	Age 2
2024 value[1]	80.8	145.8	226.5	212.6	97.9	31.7	10.8	2.8
20-year[2] upper quartile	92.7	295.1	351.5	327.4	135.4	56.2	15.4	6.2
20-year median	79.1	239.1	312.2	279.0	119.7	52.9	13.3	5.1
20-year lower quartile	68.7	191.7	273.1	250.4	102.9	39.5	11.9	4.1
2024 rank	10.9	2.9	3.5	3.7	2.9	4.1	4.2	2.9
2023 value	73.1	239.1	312.2	274.9	116.9	54.4	13.3	5.1

[1] survey estimates of stock size for 2011, 2012, 2014, 2018, 2019, 2020,2022 and 2024 were adjusted for incomplete coverage of the offshore strata by applying the mean offshore density to the survey strata not covered, and adding the corrected offshore estimate to that for Disko Bay and Vaigat

[2] 20-year percentiles, and 2024 rank, are referred to the 20 preceding years, i.e. 2004–2023.

In the inshore area, comprising Disko Bay and Vaigat, the estimated survey biomass increased from 2023 to 2024 and is close to its 20-year median. The offshore biomass in 2014 was close to its lowest for 20 years, followed by ups and downs from 2015 to 2017. Remained almost stable in 2018, increases until 2020 to value above its 20-year upper quartile, but have dropped since 2022, and is now at a value below its past 20-year lower quartile. Relative to stock size, 2017-2019 values indicated some sign of an incoming recruitment pulse, which could explain the increase of the fishable male biomass in the most recent years. Despite high numbers of both age-2 and pre-recruit shrimps in the past years, fishable biomass did not increase in 2024. Pre-recruits and age-2, both in numbers and of total surveyed tons in 2024, were considerably lower than last year and well below their 20-year lower quartile, (Fig. 2a). Prospects for short-term recruitment are presumably poor.

Survey Measures of Stock Composition

Overall	Number ('000/survey ton)		Biomass (%)			
	Age 2	14–16.5 mm	Fishable, of survey	Fishable males, of survey	Females, of survey	Females, of fishable
2024 value	12.5	18.3	93.9	50.7	43.2	46.0
20-year[1] upper quartile	22.9	33.3	92.9	54.1	41.2	45.1
20-year median [1]	17.4	26.4	91.7	52.1	38.7	42.6
20-year lower quartile[1]	10.8	23.2	90.7	49.3	36.7	39.8
2024 rank[1]	8.0	0.0	18.2	7.1	16.1	14.8
2023 value	16.2	42,8	88.0	50.6	37.5	42.5

[1] quartiles and 2024 rank generally referred to 20 preceding years 2004–2023.

The overall stock composition in 2024 is marked, by a higher proportion of males in the survey and in the fishable biomass and is little lower than its 20-year median; females has composed a lower proportion of the fishable biomass in the most recent years but is in 2024 above its 20-year upper quartile. Relative to stock size the number of age-2 shrimps is below its 20-year median, and the relative number of large pre-recruits are below the 20-year lower quartile, so prospects for short-term recruitment are presumably poor.

Disko Bay and Vaigat	Number ('000/survey ton)		Biomass (%)			
	Age 2	14–16.5 mm	Fishable, of survey	Fishable males, of survey	Females, of survey	Females, of fishable
2024 value	14.0	20.2	92.4	52.4	40	43.3
Upper quartile[1]	26.2	34.4	91.4	51.3	45.5	49.8
Median[1]	32.3	33.8	89.9	48.9	40.4	45.4
Lower quartile[1]	24.9	31.6	88.6	45.8	34.3	39.3
2024 rank[1]	5.4	1.7	18.1	14.2/18	9.3/18	8.1/18
2023 value	13.4	41.5	88.3	50.2	38.1	43.2

[1] percentiles and 2024 rank are referred to the 20 preceding years, i.e. 2004–2023.

Differences between the stock compositions offshore and inshore—in Disko Bay and Vaigat—have tended to be maintained over time. For the age-2 and pre-recruit index, relative to survey biomass, the inshore used to have higher values than those of the offshore and has historically averaged higher proportions of smaller shrimps, which also was the case in 2022. Nevertheless, numbers of both age-2 shrimps and pre-recruits have over the past years been considerably higher in offshore regions compared to Disko Bay & Vaigat. In 2024 numbers of both age-2 shrimp and pre-recruits relative to biomass are little higher in Disko Bay & Vaigat, than in offshore regions. Males constitute a higher proportion of the total biomass inshore, than compared to offshore regions, whereas females composes a higher proportion offshore.

Both inshore and offshore stock still seems to be biased toward smaller shrimps (pre-recruits and fishable males), but only Disko Bay & Vaigat have in 2024 a little higher proportion of fishable males than of fishable females.

Offshore	Number ('000/survey ton)		Biomass (%)			
	Age 2	14–16.5 mm	Fishable, of survey	Fishable males, of survey	Females, of survey	Females, of fishable
2024 value	11.7	17.3	94.7	49.8	45	47.5
Upper quartile[1]	18.5	31.0	94.0	55.4	43.4	47.3
Median[1]	13.3	24.1	92.8	53.3	37.6	41.8
Lower quartile[1]	7.4	20.4	90.8	49.0	36.7	40.0
2024 rank[1]	8.9	3.0	15.5	6.8/19	15.7/19	14.2/19
2023 value	17.0	43.2	88.0	50.7	37.3	42.4

[1] percentiles and 2024 rank are referred to the 20 preceding years, i.e. 2004–2023.

Compared with values for the previous 20 years, offshore fishable biomass is below the 20-year lower quartile, while in Disko Bay & Vaigat above. While fishable-female proportions of the survey biomass are high in offshore regions and above its 20-year upper quartile, the proportion is at the 20-year median inshore. Fishable-males proportion is at the 20-year lower quartile offshore, but well above the 20-year upper quartile inshore.

It is uncertain what the limits are for any of these stock-composition parameters to conduce to a 'healthy' stock with good potential for maintaining itself. For some of the statistics, past information is limited to 2005–2024 period, in which some years were characterized by a decline in the stock. There are relatively high numbers of pre-recruits offshore, which are assumed to enter the fishery within the next one to two years; lower numbers of fishable males to recruit to the spawning stock; and, concomitantly, relatively high proportions of spawning females in the fishable biomass, so the stock is assumed to be in a "safe condition". The perception of the stock inshore is somewhat reversed. Inshore is having higher numbers of age-2 shrimps and pre-recruits to recruit to the spawning stock in the future, also relatively high proportions of males in the fishable biomass. Overall, the stock is assumed to be in a fair condition.

Measures of Biomass Distribution within SA1

	Of offshore (%)						Of total (%)
	North	W1–2	W3–4	W5–7	W8–9/W10	Distribution Index	Disko B. and Vaigat
2024 value	45.5	33.4	11.0	9.4	0.7	55.7	35.8
20-year[1] upper quartile	38.3	36.4	22.0	20.2	0.5	46.4	31.6
20-year[1] median	33.1	33.9	18.4	12.7	0.3	34.3	25.6
20-year[1] lower quartile	26.8	31.1	15.3	8.4	0.1	26.2	20.8
2024 rank	19.2	9.3	2.7	6.5	15.2	15.2	17
2023 value	34.7	34.9	13.0	17.4	0.1	31.6	24.0

[1] percentiles and 2024 rank are referred to the 20 preceding years, i.e. 2004–2023.

Within the offshore area, the trajectories have been different and since 2000 the distribution of the survey biomass has contracted and 'moved' northwards (Fig. 3). The southernmost area had collapsed already in 2004–2007 and only little biomass is available in that region. The proportion of biomass in most northern regions and areas West of Disko Bay & Vaigat (W1-W2), comprise in total approx. 80% of the total biomass. Biomass has in most recent years been increasing in W4 (Holsteinsborg Dyb), declined in 2023, is very low in 2024, and as result of this the proportion of biomass in those regions is well below its 20-year lower quartile. In the more northern regions, their proportions of biomass are well above the 20-year upper quartile . In the central regions (W5-W6) a larger proportion of biomass has been observed over the past years and again in

2023, whereas biomass in that region was low in 2024 and its proportion of the total biomass is well below the 20-year median. A few years ago, Disko Bay & Vaigat constitute about 25% of the total biomass, but the proportion dropped to a low value in 2019 and remained below the 20-year lower quartile in both 2020 and 2022. Since 2023, the proportion of the total biomass has increased in Disko Bay & Vaigat, and is in 2024 well above its 20-year upper quartile.

Fishery

The CPUE (relative biomass series) based on re-coded shrimp model (Rigèt et al 2018) with time variant catchability and with the years 2003 to 2006 removed, in general, follow the survey estimate of fishable biomass. From the beginning of 1990s both indices increased until 2002. From 2007 the indices decreased to 2013-2014 followed by an increase until 2017. From 2018 to 2023, CPUE indices continued a decrease to a 2024 low value, considerably below what have been observed since 2013 (CPUE for 2024 is only preliminary half year data) (Fig. 6).

During the last 20 years the survey biomass index has fluctuated more than observed in the CPUE index.

The distribution of the fishery, like that of the survey biomass, has varied over time (Fig. 5). In the 1990s over half the catches were taken south of Holsteinsborg Dyb, but southern areas have subsequently lost their shrimp stock and the fishery in Greenland waters is now concentrated in NAFO Divisions 1A and 1B. In recent years, the offshore fishery has been extending its range northwards and recent years have seen some exploitation of grounds even north of 73° N (Burmeister and Rigét 2022, Burmeister 2023, Burmeister 2024).

Between 1997 and 2003 the exploitation ratio—of catch to fishable biomass—declined from about 50% to about 25% (Fig. 1) as the catches, although steadily increasing, failed to keep up with the more rapidly increasing biomass (Fig. 6). While catches were high in 2004–2008 the ratio increased as biomass declined while catches did not, and from stayed above average as catches were not been brought down to match the lowness of biomass estimates. However, since 2015 catches have reflected the ups and downs in biomass, and the exploitation ratio has remained at an average of 35%.

Results of the Quantitative Assessment

The median estimate of the *MSY* was 118 Kt with quartiles at 98.3 and 144.2 Kt; an estimated mode is at 97.2 Kt.

The model estimates show that the stock biomass has decreased in every year from 2004 to 2014 even though catches since 1990 appear to have been sustainable. The trend stopped in 2015. Fishable biomass at end 2024 is estimated to be lower than the most recent years value and is almost at B_{msy} (3% below B_{msy}). With a low effective cod biomass at 17 Kt and catches projected at 102 500 t, total mortality in 2024 is estimated to be below the MSY level and the mortality risk at 35% exceeds a management threshold of 53.3%.

Table: *P. borealis* in West Greenland: model estimates of stock status at end of, or during, 2024.

Biomass ratio $B/Bmsy$ (median estimate, %)	96.6
Prob. $B<Bmsy$ (%)	55.3
Prob. $B<Blim$ (%)	0.0
Mortality ratio $Z/Zmsy$ (median estimate, %)	103.6
Prob. $Z>Zmsy$ (%)	53.3
Prob. $B<Bmsy80\%$ (%)	26.5

With a mortality risk (i.e. that estimated mortality will exceed Z_{msy}) criterion of 35% is observed, catches of 80 Kt are predicted to be sustainable, provided that the effective cod biomass makes only moderately large gains in the coming years.

Risks associated with eight possible catch levels for 2024, with an 'effective' cod stock at 16 000 t, 17 000 t and 18 000 t, are estimated to be:

16 000 t cod	Catch option ('000 tons)							
Risk of:	65	70	75	80	85	90	95	100
falling below Bmsy end 2025 (%)	51.0	52.2	51.8	52.9	53.1	53.4	53.5	54.8
falling below Blim end 2025 (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
exceeding Zmsy in 2025 (%)	17.8	22.8	27.7	32.5	37.3	42.0	46.3	50.1
exceeding Zmsy in 2026 (%)	17.3	22.0	26.8	32.0	36.6	41.3	46.0	50.0
falling below Bmsy 80% end 2025 (%)	25.4	25.5	25.8	27.1	27.2	27.5	28.1	28.5

17 000 t cod	Catch option ('000 tons)							
Risk of:	65	70	75	80	85	90	95	100
falling below Bmsy end 2025 (%)	51.2	51.5	51.8	52.2	53.1	53.6	53.9	55.3
falling below Blim end 2025 (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
exceeding Zmsy in 2025 (%)	18.4	23.2	28.1	32.9	37.7	42.3	46.7	50.4
exceeding Zmsy in 2026 (%)	17.8	21.9	27.0	32.1	36.7	41.8	45.5	49.8
falling below Bmsy 80% end 2025 (%)	25.2	25.5	26.1	26.4	27.2	27.8	28.9	28.7

18 000 t cod	Catch option ('000 tons)							
Risk of:	65	70	75	80	85	90	95	100
falling below Bmsy end 2025 (%)	51.7	51.6	52.0	52.5	53.4	53.3	54.7	54.3
falling below Blim end 2025 (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
exceeding Zmsy in 2025 (%)	18.9	23.6	28.5	33.4	38.2	42.7	46.9	50.8
exceeding Zmsy in 2026 (%)	18.1	22.9	27.7	33.0	37.0	42.2	46.0	50.0
falling below Bmsy 80% end 2025 (%)	24.8	25.8	25.6	27.1	27.3	28.1	27.8	28.8

Predation by cod can be significant and have a major impact on shrimp stocks. Currently the cod stock in West Greenland is at a low level compared to the period before the collapse in the beginning of 1990s, but has since 2010 shown a slow, but progressive increase. A large cod stock that would significantly increase shrimp mortality could be established in two ways: either by a slow rebuilding process or by immigration of one or two large year-classes from areas around Iceland, as in the mid-1980s. The question of cod predation is bedeviled by the difficulty of foreseeing the evolution of the stock and complicated by uncertainty as to the overlap between the two species.

Projections of stock development were made under the assumption that the 'effective' cod stock will remain at levels consistent with recent estimates, and that parameters of the stock-dynamic and predation processes, including their uncertainties, will retain the values estimated from the 48-year data series. Eight levels of annual catch were investigated from 65 000 to 100 000 tons (Figs 10–11), (Table 4 and Table 5).

Precautionary Approach

The 'Precautionary Approach' framework developed by Scientific Council defined a limit reference point for fishing mortality, F_{lim}, as equal to F_{msy}. The limit reference point for stock size measured in units of biomass, B_{lim}, is a spawning stock biomass below which unknown or low recruitment is expected. Buffer reference points, B_{buf} and F_{buf}, are also requested to provide a safety margin that will ensure a small risk of exceeding the limits.

The limit reference point for mortality in the current assessment framework is Z_{msy}, i.e. Z-ratio=1 and the risk of exceeding this point is given in this assessment. B_{lim} was set at 30% of B_{msy}. The risks of transgressing B_{lim} under scenarios of different future catches have been estimated (Table 4 and Table 5) and are low.

Model performance

The process error of model fit for the model is shown in Fig 12.d. There is a tendency of the process error increasing in the period from 2006 to 2009, followed by a decline. This could be explained by input index of CPUE, where CPUE data has been removed from the model.

The model was able to produce a reasonable simulation of the observed data (Fig. 11a, 11.b, 11.c). The probability of getting more extreme observation than the realized ones given in the data series on stock size were inside the 90% confidence limit (Table 6). The CPUE series was generally better estimated than the survey series. However, the model did not capture the survey peak around 2004. Otherwise, no major problems in Capturing the variability of the data were detected.

Conclusions

The stock is predicted to be close to its B_{msy} level at end 2024. Given the uncertainty of both stock status and stock-dynamic parameters, the risk of exceeding Z_{msy} should probably not exceed 35%. A quantitative assessment indicates that catching 80 Kt would keep the risk of exceeding Z_{msy} below 35%, assuming certain limits on the evolution of the biomass of Atlantic cod.

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References

BURMEISTER, AD. AND BUCH, T., 2024. The West Greenland trawl survey for *Pandalus borealis*, 2024, with reference to earlier results. *NAFO SCR Doc*. 024/052, Ser. No. N7562. 42 pp.

BURMEISTER, AD 2024. The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2024. *NAFO SCR Doc.* 24/053, Ser. No. 7563. 42 pp.

BURMEISTER, AD. AND BUCH, T., 2023. The West Greenland trawl survey for *Pandalus borealis*, 2023, with reference to earlier results. *NAFO SCR Doc*. 023/045, Ser. No. N7443. 42 pp.

BURMEISTER, AD. 2023**.** Catch table update for the West Greenland shrimp fishery. *NAFO SCR Doc*. 23/047

Ser. No. N7445.5 pp

BURMEISTER, AD 2023. The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2023. *NAFO SCR Doc.* 23/046, Ser. No. 7444. 42 pp.

BURMEISTER, AD., F.F RIGET AND BUCH, T., 2022. The West Greenland trawl survey for *Pandalus borealis*, 2022, with reference to earlier results. *NAFO SCR Doc*. 022/045, Ser. No. N7326.39 pp.

BURMEISTER, AD. 2024**.** Catch table update for the West Greenland shrimp fishery. *NAFO SCR Doc*. 24/064

Ser. No. N7564. 5 pp

BURMEISTER, AD. 2022**.** Catch table update for the West Greenland shrimp fishery. *NAFO SCR Doc*. 22/047

Ser. No. N7328.5 pp

BURMEISTER, AD 2022. The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2022. *NAFO SCR Doc.* 22/048, Ser. No. 7327. 42 pp.

BURMEISTER, AD. and F.F RIGET. 2021a. The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2021. *NAFO SCR Doc.* 21/040, Ser. No. 7238. 42 pp.

BURMEISTER, AD. and F.F RIGET. 2020b. The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2020. *NAFO SCR Doc.* 20/054, Ser. No. 7128. 44 pp.

BURMEISTER, AD. 2020**.** Catch table update for the West Greenland shrimp fishery. *NAFO SCR Doc*. 20/055 Ser. No. N7129.5 pp.

BURMEISTER, AD. and F.F RIGET. 2020a. The West Greenland trawl survey for *Pandalus borealis*, 2020, with reference to earlier results. *NAFO SCR Doc*. 020/053, Ser. No. N7127.39 pp.

BURMEISTER, AD. and F.F RIGET. 2019. The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2019. *NAFO SCR Doc.* 19/044, Ser. No. 7008. 44 pp.

BURMEISTER, AD. 2019**.** Catch table update for the West Greenland shrimp fishery. *NAFO SCR Doc*. 19/045Ser. No. N7009.5 pp.

BURMEISTER, AD. and F.F RIGET. 2019. The West Greenland trawl survey for *Pandalus borealis*, 2019, with reference to earlier results. *NAFO SCR Doc*. 019/043, Ser. No. N7007.39 pp.

BURMEISTER, AD. and F.F RIGET. 2018. The Fishery for Northern Shrimp (*Pandalus borealis*) off West Greenland, 1970–2018. *NAFO SCR Doc.* 18/057, Ser. No. 6871. 44 pp.

BURMEISTER, AD. and F.F RIGET. 2018**.** Catch table update for the West Greenland shrimp fishery. *NAFO SCR Doc*. 18/072 Ser. No. N6872.5 pp.

BURMEISTER, AD. and F.F RIGET. 2018. The West Greenland trawl survey for *Pandalus borealis*, 2018, with reference to earlier results. *NAFO SCR Doc*. 018/055, Ser. No. N6869. 39 pp.

BURMEISTER, AD. and F.F RIGET. 2017. The West Greenland trawl survey for *Pandalus borealis*, 2017, with reference to earlier results. *NAFO SCR Doc*. 017/051, Ser. No. N6720. 39 pp.

BURMEISTER, AD. and M.C.S. KINGSLEY. 2016. The West Greenland trawl survey for *Pandalus borealis*, 2016, with reference to earlier results. *NAFO SCR Doc*. 016/041, Ser. No. N6590. 39 pp.

BURMEISTER, AD. and M.C.S. KINGSLEY. 2015. The West Greenland trawl survey for *Pandalus borealis*, 2015, with reference to earlier results. *NAFO SCR Doc*. 015/043, Ser. No. N6478. 39 pp.

GRUNWALD, E. 1998. Nahrungsökologishe Untersuchungen an Fischbeständen im Seegebiet vor Westgrönland. Ph.D. Dissertation, Christian-Albrechts-Universität, Kiel, Germany. 208 pp.

HOLLING, C.S. 1959. Some characteristics of simple types of predation and parasitism. *Can. Entomol.* **91**: 385–398.

HVINGEL, C. 2004. The fishery for northern shrimp (*Pandalus borealis*) off West Greenland, 1970–2004. *NAFO SCR Doc.* 04/75, Ser. No. N5045.

HVINGEL, C. and M.C.S. KINGSLEY. 2002. A framework for the development of management advice on a shrimp stock using a Bayesian approach. *NAFO SCR Doc.* 02/158, Ser. No. N4787.

KINGSLEY, M.C.S. 2008a. CPU Series for the West Greenland Shrimp Fishery. *NAFO SCR Doc*. 08/62 Ser. No. N5591. 6 pp.

KINGSLEY, M.C.S. 2008b. Indices of distribution and location of shrimp biomass for the West Greenland research trawl survey. *NAFO SCR Doc*. 08/78 Ser. No. N5610. 4 pp.

KINGSLEY, M.C.S. 2011. A provisional assessment of the shrimp stock off West Greenland in 2011. *NAFO SCR Doc*. 11/058, Ser. No. N5983. 23 pp.

KINGSLEY, M.C.S. 2012. A provisional assessment of the shrimp stock off West Greenland in 2012. *NAFO SCR Doc*. 12/046, Ser. No. N6107. 23 pp.

KINGSLEY, M.C.S. 2013. A Naive Simulator for a Harvest Control Rule for the West Greenland Fishery for P. borealis. *NAFO SCR Doc*. 13/055, Ser. No. N6215. 7 pp.

KINGSLEY, M.C.S. 2015. A Stock-Dynamic Model of the West Greenland Stock of Northern Shrimp. *NAFO SCR Doc*. 15/050, Ser. No. N6485. 17 pp.

KINGSLEY, M.C.S. 2016. A Stock-Dynamic Model of the West Greenland Stock of Northern Shrimp. *NAFO SCR Doc*. 16/047, Ser. No. N6596. 16 pp.

PELLA, J.S. and P.K. TOMLINSON. 1969. A generalised stock-production model. *Bull. Inter-Am. Trop. Tuna Comm.* 13: 421–496.

RIGET, F.F., BURMEISTER, AD., Hvingel, C. 2018**.** Improvement of the Greenland shrimp model. *NAFO SCR Doc*. 18/060 Ser. No. N6874. 16 pp.

SCHAEFER, M.B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. *Bull. Inter-Am. Trop. Tuna Comm.*, **1**: 27–56.

SIEGSTAD, H. and M.C.S. KINGSLEY 2014. A preliminary estimate of Atlantic cod (*Gadus morhua*) biomass in West Greenland offshore waters (NAFO Subarea 1) for 2014 and recent changes in the spatial overlap with Northern Shrimp (*Pandalus borealis*). *NAFO SCR Doc*. 14/xxx, Ser. No. Nxxxx. xx pp.

STORR-PAULSEN, M., J. CARL and K. WIELAND. 2006. The importance of Atlantic Cod (*Gadus morhua*) predation on Northern Shrimp (*Pandalus borealis*) in Greenland waters 2005. *NAFO SCR Doc*. 06/68*.* Ser. No. N5318. 16 pp.

WIELAND, K. 2005. Conversion of northern shrimp (*Pandalus borealis*) biomass, recruitment and mean size from previous years (1988–2004) to the new standard trawl used in the Greenland bottom trawl survey at West Greenland in 2005. *NAFO SCR Doc.* 05/75, Ser. No. N5180. 6pp.

WIELAND, K and M. STORR-PAULSEN. 2004. A comparison of different time series of Atlantic cod (*Gadus morhua*) biomass at West Greenland and their potential use for the assessment of Northern shrimp (*Pandalus borealis*) in NAFO Subareas 0+1. *NAFO SCR Doc.* 04/71*,* Ser. No. N5041.

Table 1. *Pandalus borealis* in West Greenland: input data series 1976–2024 for stock-dynamic assessment model.

Year	Sam.obs[]	Overlap[]	Past.Catch[]	Prov.Catch[]	ln.CPUE[]	surv[]	Grunwald[]	Grunwald
1976	120.526	0.579	51.6	NA	0.3898	NA	NA	NA
1977	134.825	0.574	42.3	NA	0.3248	NA	NA	NA
1978	93.64	0.672	42.8	NA	0.08978	NA	NA	NA
1979	92.527	0.67	55.9	NA	-0.0116	NA	NA	NA
1980	60.289	0.68	53.8	NA	0.1748	NA	NA	NA
1981	67.118	0.619	54.3	NA	0.1179	NA	NA	NA
1982	93.318	0.518	56.2	NA	0.3597	NA	NA	NA
1983	55.874	0.461	52.8	NA	0.2368	NA	NA	NA
1984	20.208	0.479	52.8057	NA	0.1749	NA	NA	NA
1985	29.083	0.482	66.2079	NA	0.243	NA	NA	NA
1986	40.675	0.51	76.9	NA	0.2795	NA	NA	NA
1987	90.308	0.604	77.391	NA	0.4113	NA	NA	NA
1988	132.425	0.618	73.616	NA	0.1458	223.1907	NA	NA
1989	102.315	0.37	80.671	NA	0.04976	208.9535	213.7	470.919
1990	40.741	0.289	83.97	NA	0	207.0053	27.8	184.1405
1991	2.038	0.313	91.489	NA	0.04347	146.0081	2.7	19.7905
1992	0.364	0.523	105.487	NA	0.1094	194.1563	0.8	2.8785
1993	0.162	0.6455	91.013	NA	0.1088	216.4703	NA	NA
1994	0.073	0.599	92.805	NA	0.1112	223.1433	NA	NA
1995	0.062	0.483	87.388	NA	0.204	183.2427	NA	NA
1996	0.038	0.28	84.095	NA	0.2456	192.0819	NA	NA
1997	0.052	0.49	78.128	NA	0.2197	167.0946	NA	NA
1998	0.063	0.39	80.495	NA	0.3597	244.2933	NA	NA
1999	0.098	0.496	92.198	NA	0.4801	237.2942	NA	NA
2000	0.241	0.643	97.968	NA	0.5754	280.336	NA	NA
2001	0.309	0.462	102.926	NA	0.5365	280.4643	NA	NA
2002	0.747	0.278	135.172	NA	0.7118	369.4608	NA	NA
2003	1.235	0.398	130.173	NA	0.7939	548.2839	NA	NA
2004	3.935	0.257	149.332	141	0.885	528.3298	NA	NA
2005	4.897	0.074	156.899	140.5	0.9187	494.2	NA	NA
2006	7.153	0.22	157.315	140.2	0.9211	451	NA	NA
2007	12.03	0.139	144.19	135.2	0.9508	336.1	NA	NA
2008	11.743	0.156	153.889	131.6	0.9998	262.6	NA	NA
2009	7.512	0.602	135.458	108.8	0.8991	255.1	NA	NA
2010	5.561	0.315	133.99	138.5	0.8584	318.7	NA	NA
2011	11.504	0.888	123.985	126	0.9045	245.69	NA	NA
2012	18.76	0.305	115.975	110	0.8256	176.44	NA	NA
2013	21.442	0.206	95.381	100	0.6995	218.1	NA	NA
2014	30.044	0.211	88.765	90	0.7716	170.01	NA	NA
2015	36.606	0.2046	72.256	65	0.8172	255.54	NA	NA
2016	36.205	0.079	85.527	82	0.875	201.3461	NA	NA
2017	31.032	0.373	92.37	90	0.9915	284.6407	NA	NA
2018	31.976	0.3841	94.878	101.25	0.9214	279.02	NA	NA
2019	28.234	0.2696	104.314	100	0.8515	311.12	NA	NA
2020	36.445	0.1994	113.758	117	0.749	340.900959	NA	NA
2021	53.02	0.2844	114.569	108	0.8762	NA	NA	NA
2022	49.549	0.3013	118.127	120	0.7777	314.999	NA	NA
2023	50.289	0.3405	113.223	110	0.7272	274.87	NA	NA
2024	56.132	0.2981	NA	102.5	0.5822	212.68	NA	NA

[1] 'effective cod biomass' was not an input data series in 2021; instead, a SAM cod biomass input series were input and used to estimate a cod biomass series which was multiplied by an input overlap series to generate an 'effective cod' series; tabulated are the median resulting estimates (see Kingsley 2014).
[2] Grunwald (1998).
[3] survey estimates of fishable biomass for 2011, 2012, and 2014–2020, 2022, 2023 and 2024 were adjusted for incomplete coverage of offshore strata.
[4] estimates of cod biomass and overlap factor in 2021 are based on average of the most 3 recent years.

Table 2. *Pandalus borealis* in West Greenland: summary of estimates of selected parameters from Bayesian fitting of a surplus production model, 2024.

	Mean	S.D.	25%	Median	75%	Est. mode	Median (2023)
Max.sustainable yield	128.4	55.9	98.3	118.0	144.2	97.2	119.4
B/Bmsy, end current year (proj.)(%)	98.8	27.4	78.6	96.6	116.3	92.1	109.0
Biomass risk, end current year(%)	55.3	49.7	–	–	–	–	–
Z/Zmsy, current year (proj.)(%)	–	–	72.7	103.6	139.4	–	100.3
Carrying capacity	3558	2054	1984	2940	4710	1704	2754
Max. sustainable yield ratio (%)	9.3	5.3	5.5	8.5	12.1	7.0	9.1
Survey catchability (%)	18.6	13.4	9.0	14.9	24.3	7.4	16.4
CPUE(1) catchability	1.1	0.8	0.5	0.9	1.4	0.5	0.9
CPUE(2) catchability	1.6	1.2	0.8	1.3	2.1	0.7	1.5
Effective cod biomass 2024 (Kt)	22.2	38.7	12.7	16.6	21.2	5.3	17.1
$P_{50\%}$ (prey biomass index with consumption 50% of max.)	4.1	7.2	0.2	1.3	4.5	-4.2	1.4
V_{max} (maximum consumption per cod)	2.0	2.3	0.4	1.0	2.9	-1.1	1.1
CV of process (%)	12.2	2.6	10.4	12.0	13.8	11.7	11.8
CV of survey fit (%)	18.5	2.9	16.5	18.3	20.3	17.7	18.3
CV of CPUE (1) fit (%)	7.0	1.4	5.9	6.7	7.7	6.1	6.6
CV of CPUE (2) fit (%)	7.0	1.8	5.7	6.5	7.8	5.6	6.6

Table 3. *Pandalus borealis* in West Greenland: selected[1] correlations (%) between model parameters, 2024.

	Start biom. ratio	*CV cpu*	*CV s*	*CV proc*	*Vmax*	*P50 %*	*Qc1*	*Qc2*	*Qs*	*MSY ratio*	*K*
Max. sustainable yield	26			10			-23	-23	-23	20	32
Carrying capacity	16			12	-16		-72	-71	-72	-69	
Max. sustainable yield ratio (%)	-10	-5		-12	22		81	81	81		
Survey catchability (%)	-44			-20	25	-10	100	100			
CPUE catchability q1	-45			-19	25	-10	100				
CPUE catchability q2											
P50%	16				64						
Vmax	-16		5	-16							
CV of process (%)	14	-7	-26								
CV of survey fit (%)											
CV of CPUE 1 fit (%)											
CV of CPUE 2 fit (%)											

[1] those over 5%

Table 4. *Pandalus borealis* in West Greenland: risks (%) of exceeding limit mortality in 2025 assuming effective cod biomass 16 Kt, 17 Kt and 18 Kt.

Catch	16 Kt		17 Kt		18 Kt	
(Kt/yr)	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
65	17.8	17.3	18.4	17.8	18.9	18.1
70	22.8	22.0	23.2	21.9	23.6	22.9
75	27.7	26.8	28.1	27.0	28.5	27.7
80	32.5	32.0	32.9	32.1	33.4	33.0
85	37.3	36.6	37.7	36.7	38.2	37.0
90	42.0	41.3	42.3	41.8	42.7	42.2
95	46.3	46.0	46.7	45.5	46.9	46.0
100	50.1	50.0	50.4	49.8	50.8	50.0

Table 5. *Pandalus borealis* in West Greenland: risks (%) of exceeding limit mortality in 2025 – 2027 and of falling below B_{msy} or limit* biomass at the end of 2025 – 2027 assuming effective cod biomass 16 Kt, 17 Kt and 18 Kt.

16 000 t cod	**Catch option ('000 tons)**							
Risk of:	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
falling below Bmsy end 2025 (%)	51	52	52	53	53	53	54	55
falling below Bmsy end 2026 (%)	47	49	50	50	51	52	53	54
falling below Bmsy end 2027 (%)	44	45	47	48	50	51	53	53
falling below Blim end 2025 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2026 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2027 (%)	0	0	0	0	0	0	0	1
exceeding Zmsy in 2025 (%)	18	23	28	32	37	42	46	50
exceeding Zmsy in 2026 (%)	17	22	27	32	37	41	46	50
exceeding Zmsy in 2027 (%)	16	21	26	31	36	41	46	50
falling below Bmsy 80% end 2025 (%)	25	26	26	27	27	27	28	29
falling below Bmsy 80% end 2026 (%)	23	24	25	26	28	28	29	31
falling below Bmsy 80% end 2027 (%)	21	24	24	27	27	29	30	32

* limit biomass is 30% of B_{msy}

17 000 t cod	**Catch option ('000 tons)**							
Risk of:	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
falling below Bmsy end 2025 (%)	51	52	52	52	53	54	54	55
falling below Bmsy end 2026 (%)	47	48	49	50	52	53	53	54
falling below Bmsy end 2027 (%)	44	44	47	48	50	52	52	54
falling below Blim end 2025 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2026 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2027 (%)	0	0	0	0	0	0	1	1
exceeding Zmsy in 2025 (%)	18	23	28	33	38	42	47	50
exceeding Zmsy in 2026 (%)	18	22	27	32	37	42	46	50
exceeding Zmsy in 2027 (%)	17	21	26	31	36	41	46	50
falling below Bmsy 80% end 2025 (%)	25	25	26	26	27	28	29	29
falling below Bmsy 80% end 2026 (%)	23	24	26	27	27	28	30	30
falling below Bmsy 80% end 2027 (%)	23	23	25	27	27	29	31	31

* limit biomass is 30% of B_{msy}

18 000 t cod	Catch option ('000 tons)							
Risk of:	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
falling below Bmsy end 2025 (%)	52	52	52	53	53	53	55	54
falling below Bmsy end 2026 (%)	47	48	49	51	52	52	53	54
falling below Bmsy end 2027 (%)	44	45	47	49	50	51	52	53
falling below Blim end 2025 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2026 (%)	0	0	0	0	0	0	0	0
falling below Blim end 2027 (%)	0	0	0	0	0	0	0	1
exceeding Zmsy in 2025 (%)	19	24	28	33	38	43	47	51
exceeding Zmsy in 2026 (%)	18	23	28	33	37	42	46	50
exceeding Zmsy in 2027 (%)	22	26	31	36	41	45	50	53
falling below Bmsy 80% end 2025 (%)	25	26	26	27	27	28	28	29
falling below Bmsy 80% end 2026 (%)	23	25	25	27	27	29	30	31
falling below Bmsy 80% end 2027 (%)	22	23	25	26	28	30	31	32

* limit biomass is 30% of B_{msy}

Table 6. Model diagnostics: Residuals (% of observed value) and probability of getting a more extreme observation (Pr).

	Survey		CPUE1		CPUE2		Process error
Year	resid(%)	Pr	resid(%)	Pr	resid(%)	Pr	
1976			2.741	0.6132			-0.01687
1977			4.433	0.6918			-0.1478
1978			-3.793	0.3272			-0.1599
1979			-7.779	0.182			0.009323
1980			5.68	0.7554			0.03234
1981			-7.489	0.184			0.0518
1982			9.704	0.8748			0.03371
1983			-1.227	0.4358			-0.1116
1984			-3.661	0.3288			-0.03172
1985			0.01959	0.5068			0.01763
1986			-2.684	0.3588			0.05937
1987			10.01	0.8888			-0.06216
1988	5.536	0.5782	-5.177	0.261			-0.1337
1989	11.05	0.7192	-2.564	0.377			-0.0802
1990	15.07	0.7822	-2.633	0.3696			-0.03783
1991	-21.4	0.1366	0.0508	0.5138			0.03791
1992	2.337	0.5404	1.792	0.5808			0.0389
1993	10.4	0.7172	-1.02	0.4574			-0.00424
1994	11.25	0.7256	-3.035	0.361			0.01449
1995	-12.54	0.248	2.102	0.5994			0.02747
1996	-10.38	0.2924	3.683	0.6744			-0.02047
1997	-27.66	0.0754	-2.108	0.4			0.0356
1998	0.193	0.4894	1.61	0.5882			0.1075
1999	-14.47	0.2342	1.863	0.581			0.08776
2000	-4.7	0.3918	4.426	0.7102			0.0409
2001	-10.61	0.297	-5.116	0.262			0.07575
2002	4	0.582	-0.4024	0.483			0.1977
2003	28.97	0.9184					0.1538
2004	19.84	0.8244					0.05236
2005	18.05	0.7964					-0.01713
2006	21.62	0.8488					-0.1198
2007	6.004	0.616			-7.087	0.2006	-0.05418
2008	-11.79	0.2696			4.495	0.713	-0.01091
2009	-10.13	0.3022			-0.7607	0.4604	-0.02362
2010	14.67	0.7704			-2.496	0.3878	0.01883
2011	-8.646	0.331			4.775	0.7208	-0.03412
2012	-34.14	0.0372			4.406	0.701	-0.08614
2013	-6.89	0.346			-2.203	0.3996	-0.0291
2014	-33.76	0.0476			3.1	0.655	0.04211
2015	0.9943	0.513			1.749	0.5856	0.03438
2016	-30.04	0.0672			0.4791	0.5294	0.06779
2017	-1.376	0.4786			6.077	0.7698	0.03861
2018	-2.724	0.4284			-0.2438	0.4806	-0.04935
2019	13.9	0.7556			-1.345	0.4396	-0.05648
2020	26.16	0.901			-8.532	0.1432	0.008338
2021	-0.3688	0.4808			3.915	0.689	0.01561
2022	20.83	0.8654			-3.026	0.352	-0.0422
2023	15.44	0.7864			0.02135	0.5018	-0.08655
2024	-3.164	0.4372			-8.308	0.2618	-0.03399

Figures

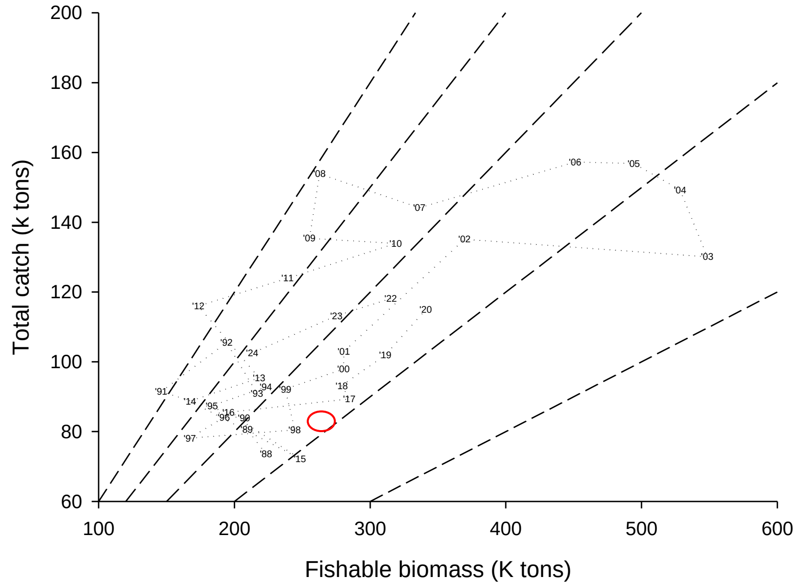

Figure 1. *Pandalus borealis* in West Greenland: catch, fishable biomass and exploitation index, 1976–2024 (2024 catch is provisional).

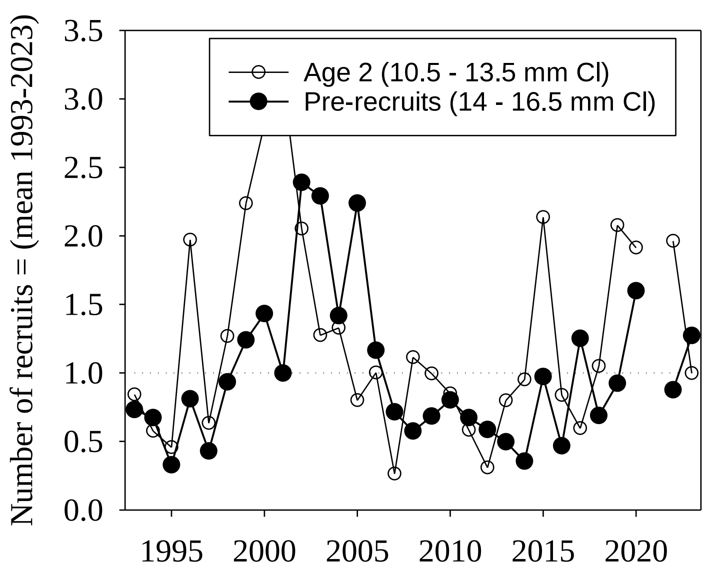

Figure 2. *Pandalus borealis* in West Greenland: number at age 2 and pre-recruits from research trawl survey, 1996–2024.

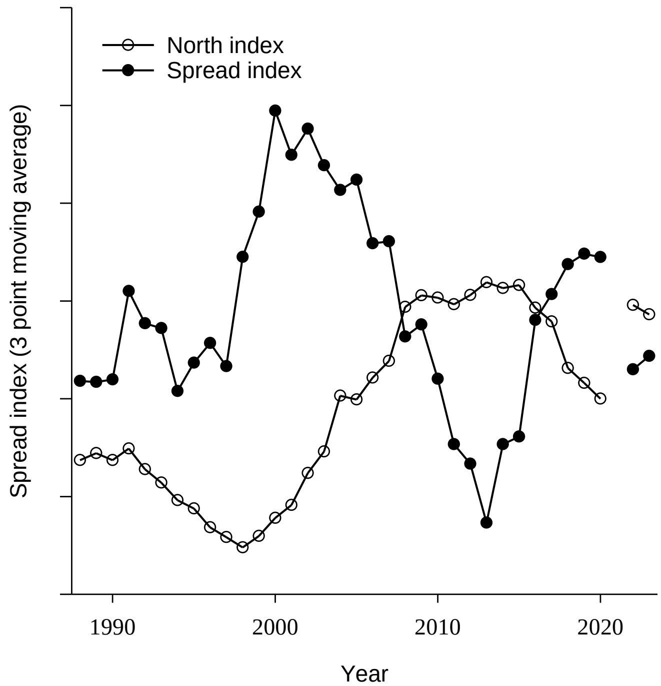

Figure 3. *Pandalus borealis* in West Greenland: indices of distribution of the survey biomass, 1994–2024 (3-point moving means).

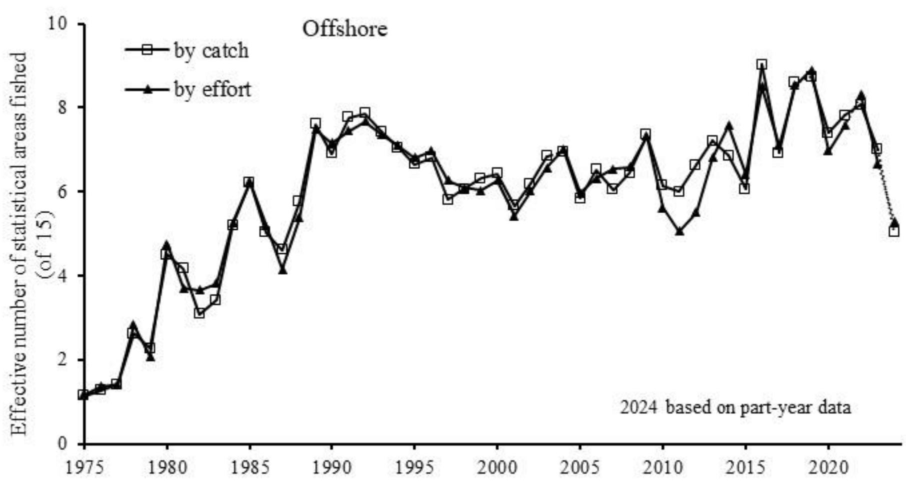

Figure 4. *Pandalus borealis* in West Greenland: indices of the spreadth of distribution of the Greenlandic fishery among 15 statistical areas, from logbook records, 1975–2024. (2024 is preliminary data).

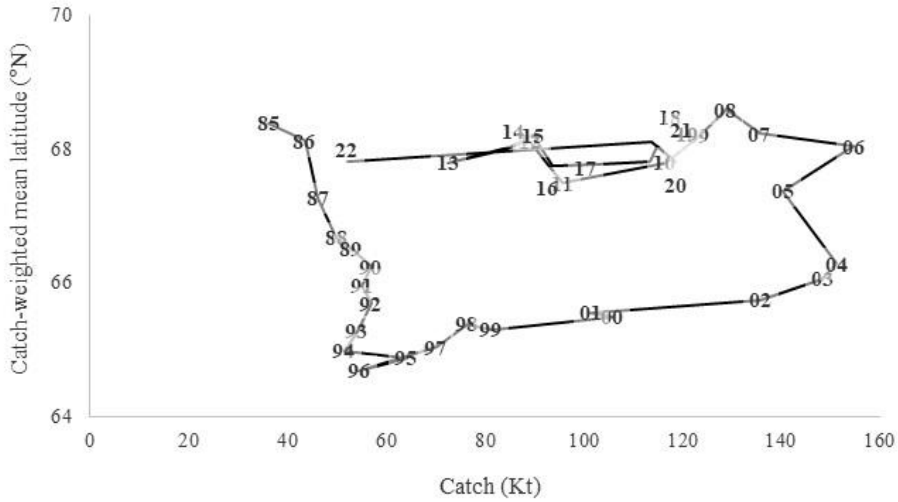

Figure 5. *Pandalus borealis* in West Greenland: mean latitude by weight vs. total weight, for logbook-recorded catch in the Greenland fishery, 1985–2024 (2024 is only preliminary catch).

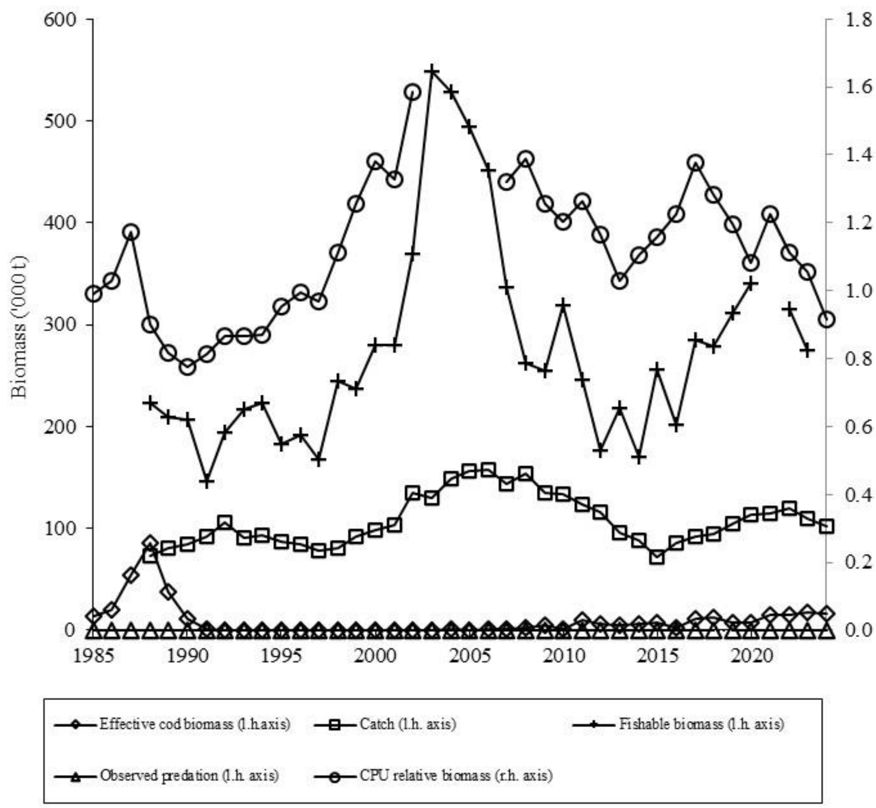

Figure 6. *Pandalus borealis* in West Greenland: thirty-year data series providing information for the assessment model. (2024 catch is projected; effective cod biomass is synthesized from four biomass index series and a series of overlap indices between distributions of cod and shrimps.)

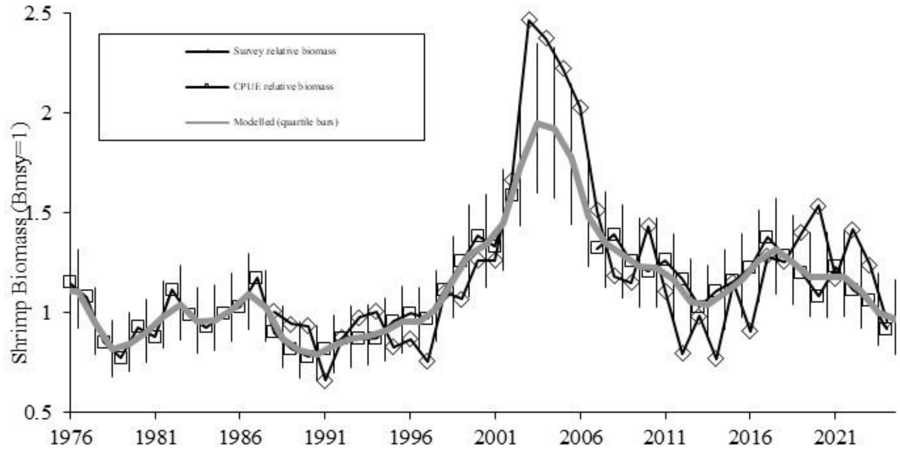

Figure 7. *Pandalus borealis* in West Greenland: modelled shrimp standing stock fitted to survey and CPUE indices, 1976–2024.

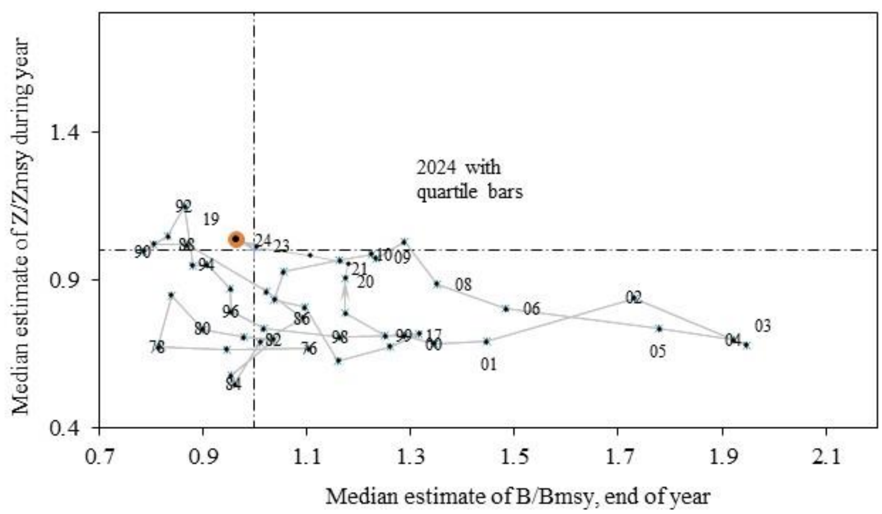

Figure 8. *Pandalus borealis* in West Greenland: median estimates of biomass ratio (B/B_{msy}) and mortality ratio (Z/Z_{msy}) 1976–2024.

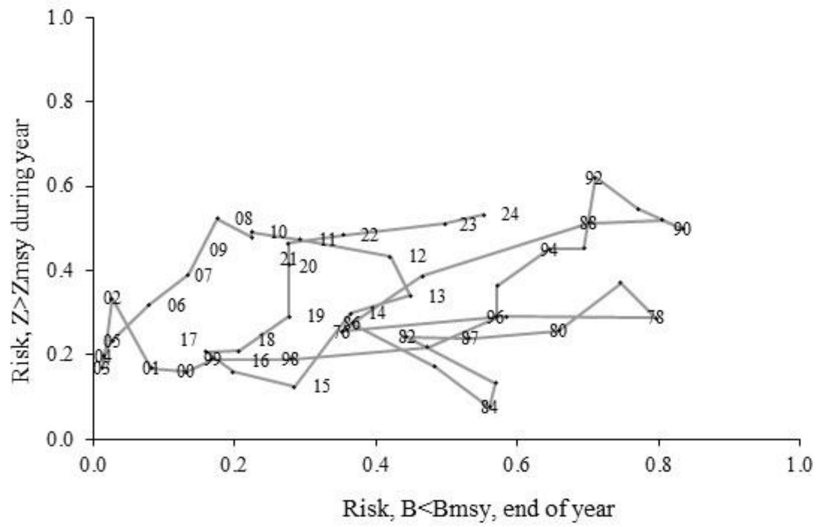

Figure 9. *Pandalus borealis* in West Greenland: annual likelihood that biomass has been below B_{msy} and that mortality caused by fishing and cod predation has been above Z_{msy} 1976–2024.

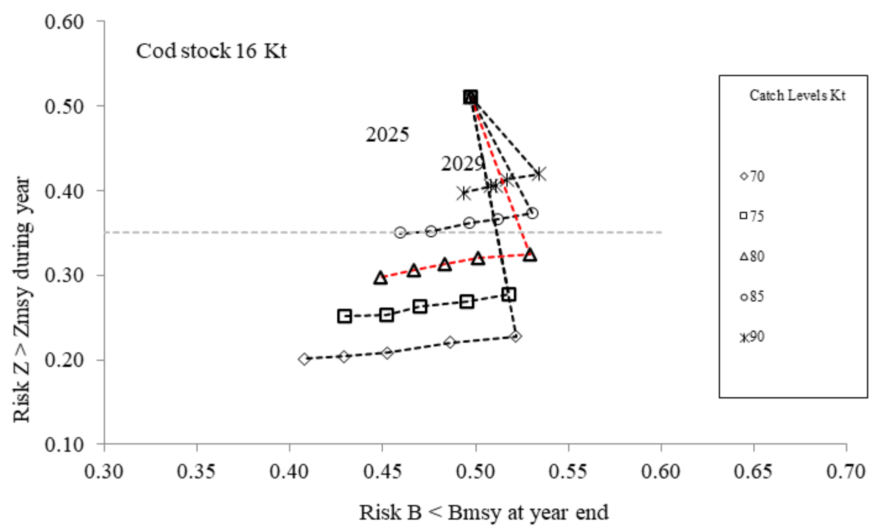

Figure 10a. *Pandalus borealis* in West Greenland: joint 5-year plot 2025–29 of the risks of transgressing B_{msy} and Z_{msy} at catch levels 70–90 Kt/yr; with effective cod biomass 16 Kt.

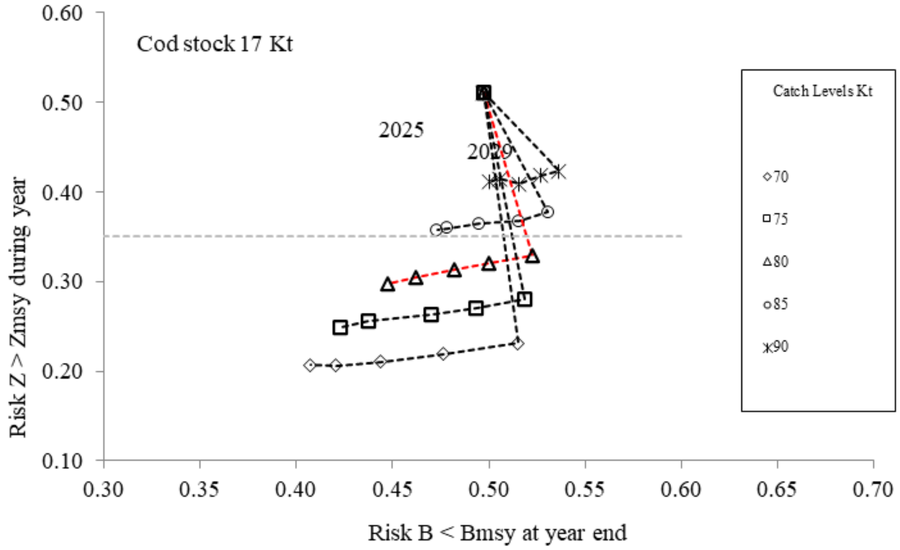

Figure 10b. *Pandalus borealis* in West Greenland: joint 5-year plot 2025–29 of the risks of transgressing B_{msy} and Z_{msy} at catch levels 70-90 Kt/yr; with effective cod biomass 17 Kt.

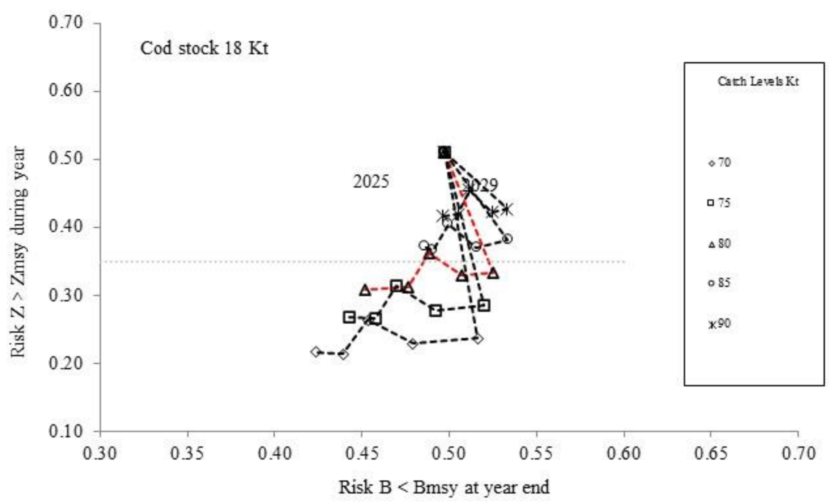

Figure 10c. *Pandalus borealis* in West Greenland: joint 5-year plot 2025–29 of the risks of transgressing B_{msy} and Z_{msy} at catch levels 70–90 Kt/yr; with effective cod biomass 18 Kt.

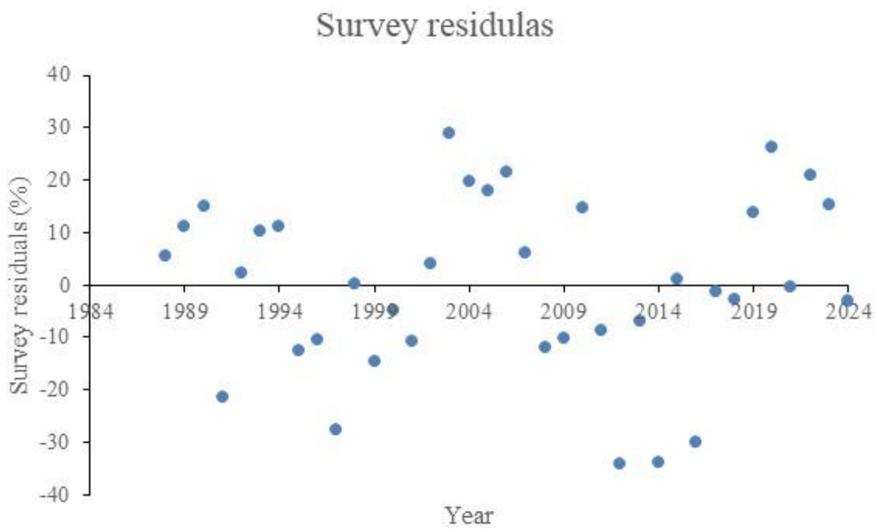

Figure 11a. Model diagnostics: Residuals of survey biomass (% of observed value) 1988 – 2024.

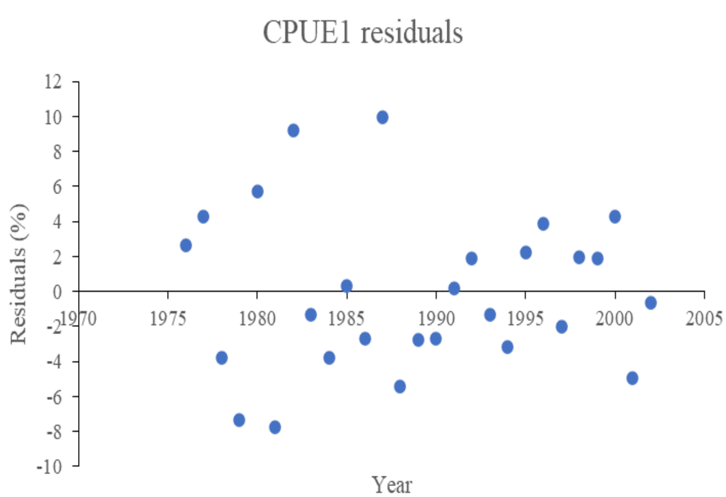

Figure 11b. Model diagnostics: Residuals of CPUE1 (% of observed value) 1976 – 2002.

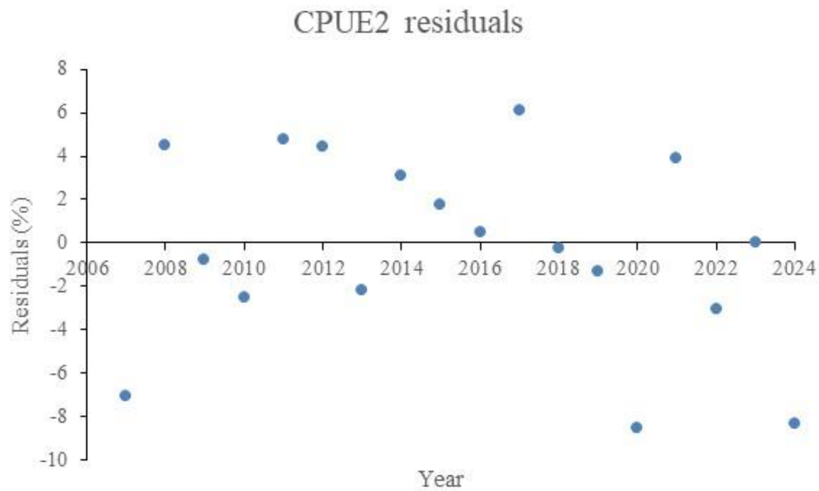

Figure 11c. Model diagnostics: Residuals of CPUE2 (% of observed value) 2007 – 2024.

Figure 11d. Model diagnostics: Process error of fit (CV of process (%) 1994 – 2024.