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@Virtual

Standardized Abundance Indices for Ages 0 and 1 Fish of Chub Mackerel from Northwest Pacific Autumn Surveys up to 2024

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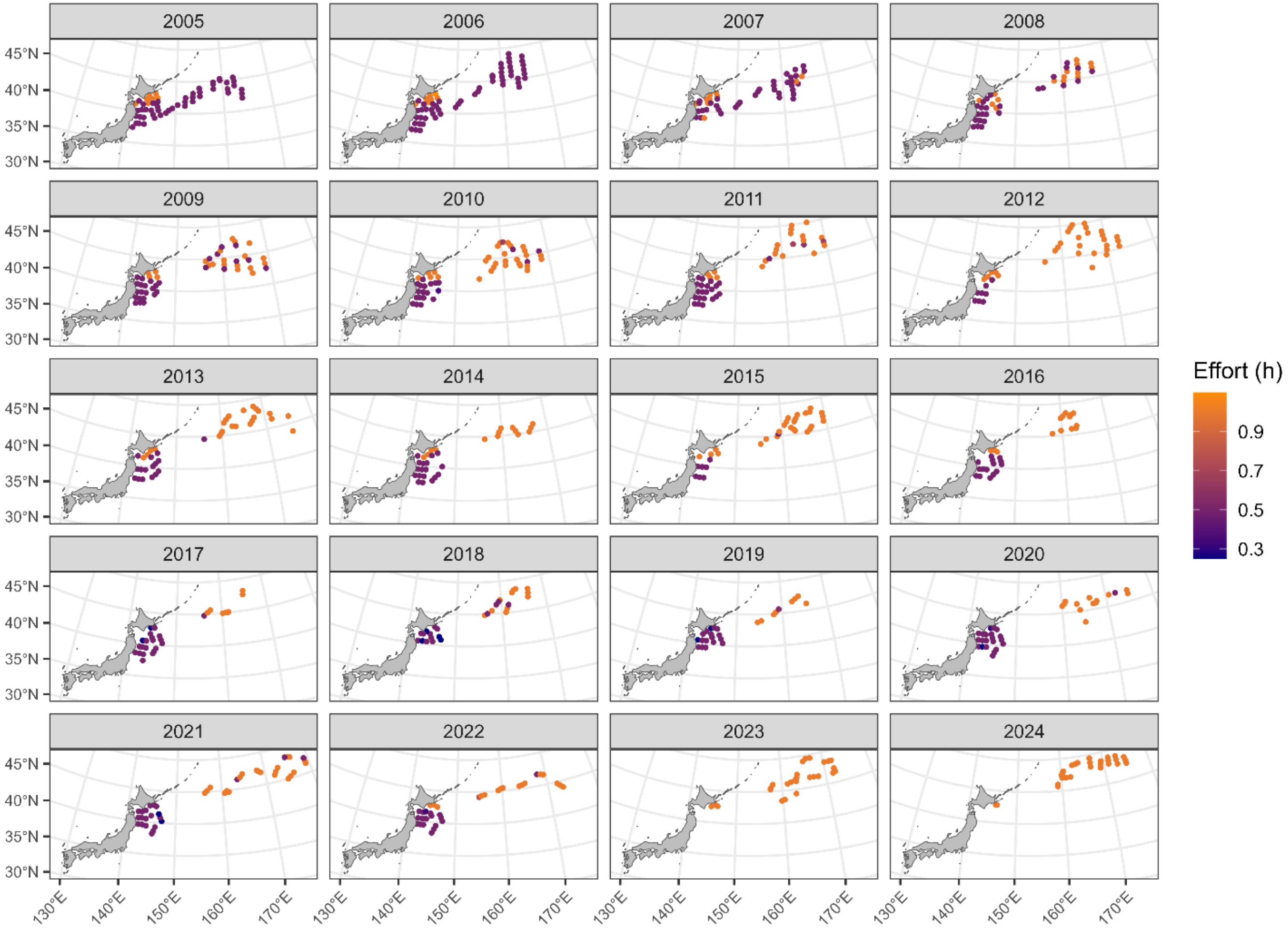
Autumn surveys by Japan

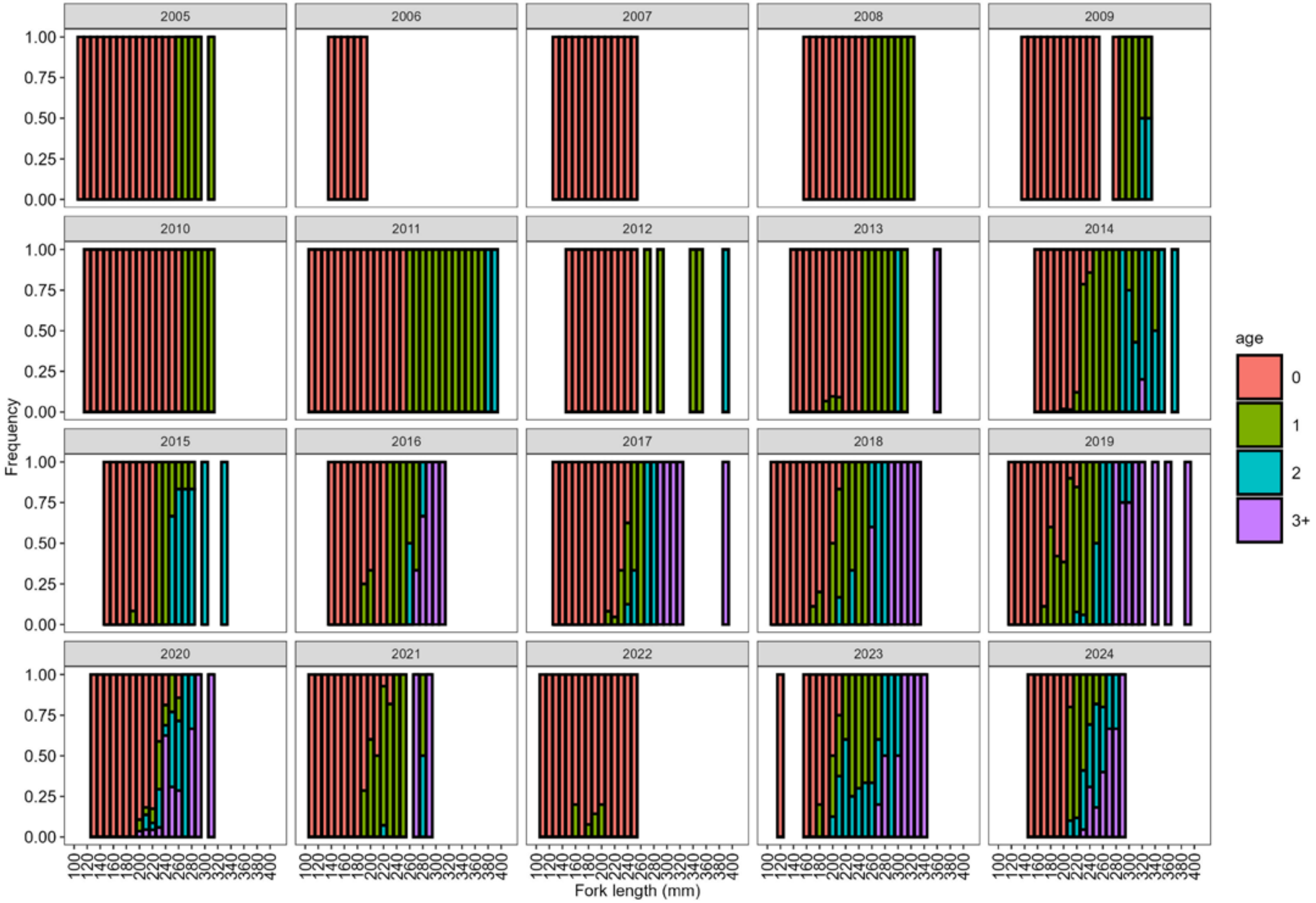
Fig. 1A

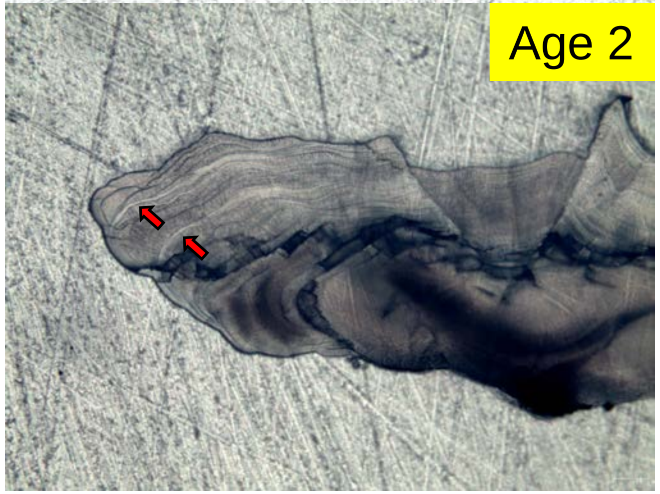


- The standardized CPUE of young-of-the-year (YOY) fish has been used in the Japanese domestic stock and TWG CMSA

Development of Age-Length Key

An age determination was conducted by reading the transverse sections of otoliths for an average of 100 chub mackerel individuals annually





Catch and effort information

Table 1

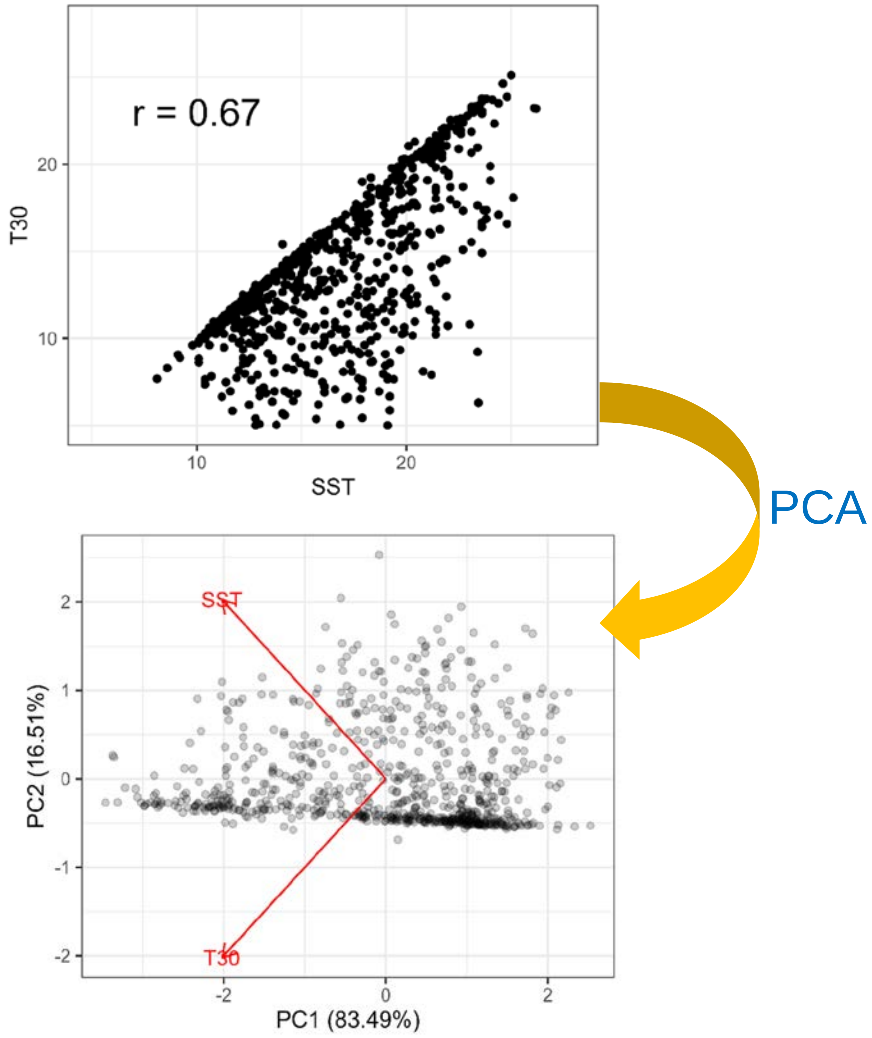
Year	Number of observations (stations)	Total trawling time (h)	Total Catch of age 0 fish (ind)	Number of positive catch (age 0)	% positive catch (age 0)	Total Catch of age 1 fish (ind)	Number of positive catch (age 1)	% positive catch (age 1)
2005	54	30.6	640	14	25.9	50	5	9.3
2006	59	33.1	34	5	8.5	0	0	0
2007	46	28	233	13	28.3	0	0	0
2008	41	28	202	9	22	75	4	9.8
2009	49	34.5	1843.7	22	44.9	14.8	4	8.2
2010	50	39	647.3	19	38	27.7	5	10
2011	44	31.9	114	12	27.3	51	6	13.6
2012	37	33	607.9	16	43.2	6.1	4	10.8
2013	39	31	38953.4	26	66.7	1910.5	24	61.5
2014	32	23	3265.6	23	71.9	7918.6	24	75
2015	34	30	4970.4	18	52.9	116	17	50
2016	29	21.5	36196.8	15	51.7	1412.3	11	37.9
2017	29	17.5	14436.5	14	48.3	965.2	13	44.8
2018	28	18.5	99627.2	26	92.9	13808.4	26	92.9
2019	26	16.6	3801.4	20	76.9	7193.8	20	76.9
2020	35	23.6	21006.7	26	74.3	379.9	24	68.6
2021	43	31.5	24969.5	31	72.1	1029.1	21	48.8
2022	35	25.6	14713.4	26	74.3	1397.8	21	60
2023	27	27	1898.2	8	29.6	1218.3	8	29.6
2024	28	28	2225.8	15	53.6	557.9	12	42.9

- 100~300 individuals of 'mackerel' (chub + blue) were sampled
- The proportions of positive catch were higher than 45% for age 0 and 20% for age 1 from 2013 to 2022, and 53.6% and 42.9% for age 0 and age 1 fish in 2024

*No individuals of age 1 were captured in 2006 and 2007

Principal component analysis (PCA)

Fig. 2



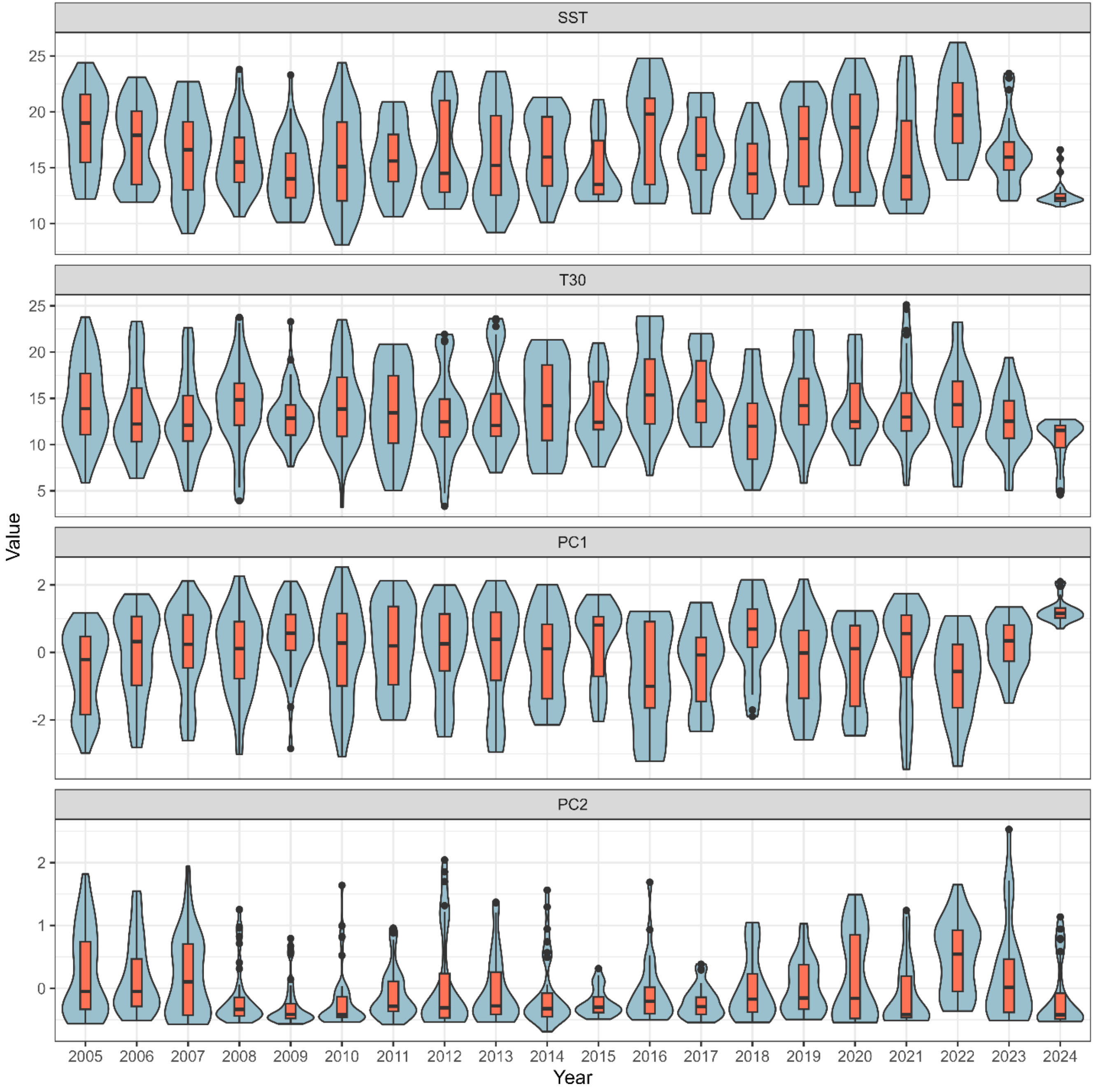
Almost same as the summer survey

- To avoid destabilization of parameter estimates attributed to collinearity in multiple regression, PC1 and PC2 were used for the analysis calculated by PCA
- PC1 was negatively correlated with SST and T30

  -> indicating a common component of SST and T30.
- PC2 was positively correlated with SST but negatively with T30

  ->reflecting a difference between SST and T30.

Fig. 3



- SST, PC1, and PC2 moderately varied over the years, except 2024
- T30 seemed to be relatively stable , except 2024

Model description of the VAST

Same as the summer survey

1st predictor for encounter probability

$$p_1(i) = \beta_1(t_i) + \omega_1(s_i) + \varepsilon_1(s_i, t_i) + \sum_{k_1}^{n_{k1}} \lambda_1(k_1) Q_i(i, k_1)$$

2nd predictor for positive catch rate when encountered

$$p_2(i) = \underbrace{\beta_2(t_i)}_{\text{temporal}} + \underbrace{\omega_2(s_i)}_{\text{spatial}} + \underbrace{\varepsilon_2(s_i, t_i)}_{\text{spatio-temporal}} + \underbrace{\sum_{k_2}^{n_{k2}} \lambda_2(k_2) Q_i(i, k_2)}_{\text{catchability covariate}}$$

The encounter probability transformed the inverse function of logit link

$$r_1(i) = \text{logit}^{-1} p_1(i) \,,$$

The positive catch rate transformed the inverse function of log (i.e., exp)

$$r_2(i) = a_i \times \log^{-1} p_2(i) \,. \qquad (a_i = 1 \text{ in this study})$$

The probability density function

Binomial model

↓

$$\Pr(b_i = B) = \begin{cases} 1 - r_1(i) & \text{if } B = 0 \\ r_1(i) \times g\{B | r_2(i), \sigma_m^2\} & \text{if } B > 0 \end{cases}$$

↑

Function for Gamma distribution

Specific settings for temporal, spatial, and spatio-temporal effects

Changed from the default settings of VAST due to the nature of data and estimated parameters

Age 0

$$p_1(i) = \overset{\text{Fixed effects}}{\beta_1(t_i)} + \omega_1(s_i) + \overset{\text{Turn off}}{\cancel{\varepsilon_1(s_i,t_i)}} + \sum_{k_1}^{n_{k1}} \lambda_1(k_1) Q_i(i,k_1)$$

$$p_2(i) = \underset{\text{Fixed effects}}{\beta_2(t_i)} + \underset{\text{Turn off}}{\cancel{\omega_2(s_i)}} + \underset{\text{IID}}{\varepsilon_2(s_i,t_i)} + \sum_{k_2}^{n_{k2}} \lambda_2(k_2) Q_i(i,k_2)$$

- Turned off spatio-temporal effect in the 1st predictor and the spatial effect in the 2nd predictor, following the *check_fit* function

Age 1

$$p_1(i) = \overset{\text{IID}}{\beta_1(t_i)} + \omega_1(s_i) + \overset{\text{IID}}{\varepsilon_1(s_i,t_i)} + \sum_{k_1}^{n_{k1}} \lambda_1(k_1) Q_i(i,k_1)$$

$$p_2(i) = \underset{\text{IID}}{\beta_2(t_i)} + \underset{\text{Turn off}}{\cancel{\omega_2(s_i)}} + \underset{\text{IID}}{\varepsilon_2(s_i,t_i)} + \sum_{k_2}^{n_{k2}} \lambda_2(k_2) Q_i(i,k_2)$$

- Used random effects for the year effect to treat year with no catch
- Turned off the spatial effect in the 2nd predictor, following the *check_fit* function
- Assumed IID for the first and second predictors

- The number of knots was set as 300

- PC1, PC2, their squared terms, and their 1st order interaction were treated as catchability covariates
  ->assuming to reflect local conditions at observation affecting catchability rather than abundance of the year

Model selection for age 0

Table 3

Rank	PC1	PC1 squared	PC2	PC2 squared	PC1 x PC2	Df	LogLik	AICc	ΔAICc
1	B,G	B,G				31	-2688.03	5439.39	0
2	B,G	B,G	G		G	33	-2686.21	5439.92	0.53
3	B,G	B,G	B			32	-2687.62	5440.64	1.25

- Model selection was conducted using exhaustive search with Akaike Information Criterion with correction (AICc).
- Only PC1 and its squared term were selected in the best model for both binomial (B) and gamma (G) distributions

Model selection for age 1

Table 4

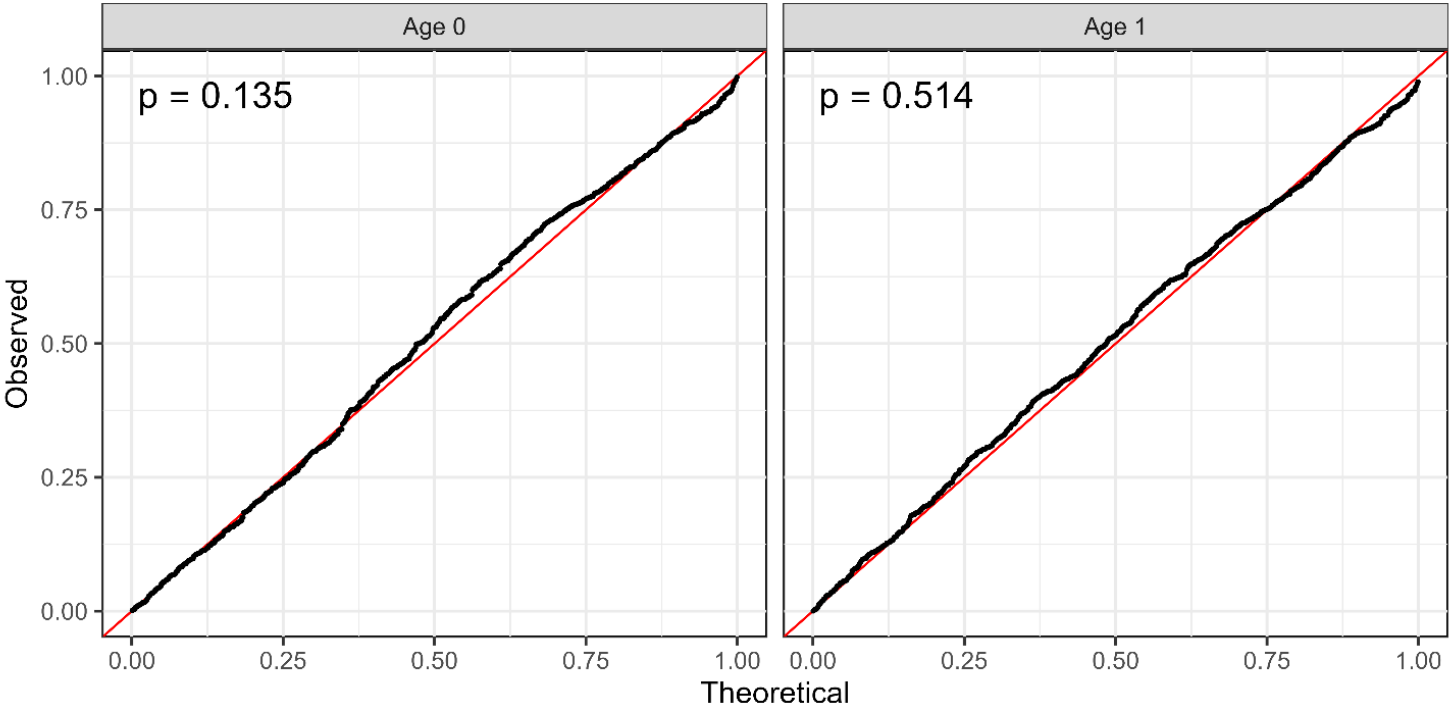
Rank	PC1	PC1 squared	PC2	PC2 squared	PC1 x PC2	Df	LogLik	AICc	ΔAICc
1	B,G	B,G	G	G	G	17	-1538.35	3111.11	0
2	B,G	B,G	B,G	G	B,G	19	-1536.60	3111.7	0.59
3	B,G	B,G	G	G		16	-1540.27	3112.9	1.79

- PC1 and PC1 squared term were selected for B distribution, while all terms were selected for G distribution

Model diagnostics for scaled residuals

- Generated scaled residuals using the R package ‘DHARMa’ (Hartig 2022) for model diagnostics

Fig. 5



Not significantly deviated from the theoretical prediction of the uniform distribution for both age 0 and age 1

Model diagnostics for scaled residuals

Fig. 6A: Age 0

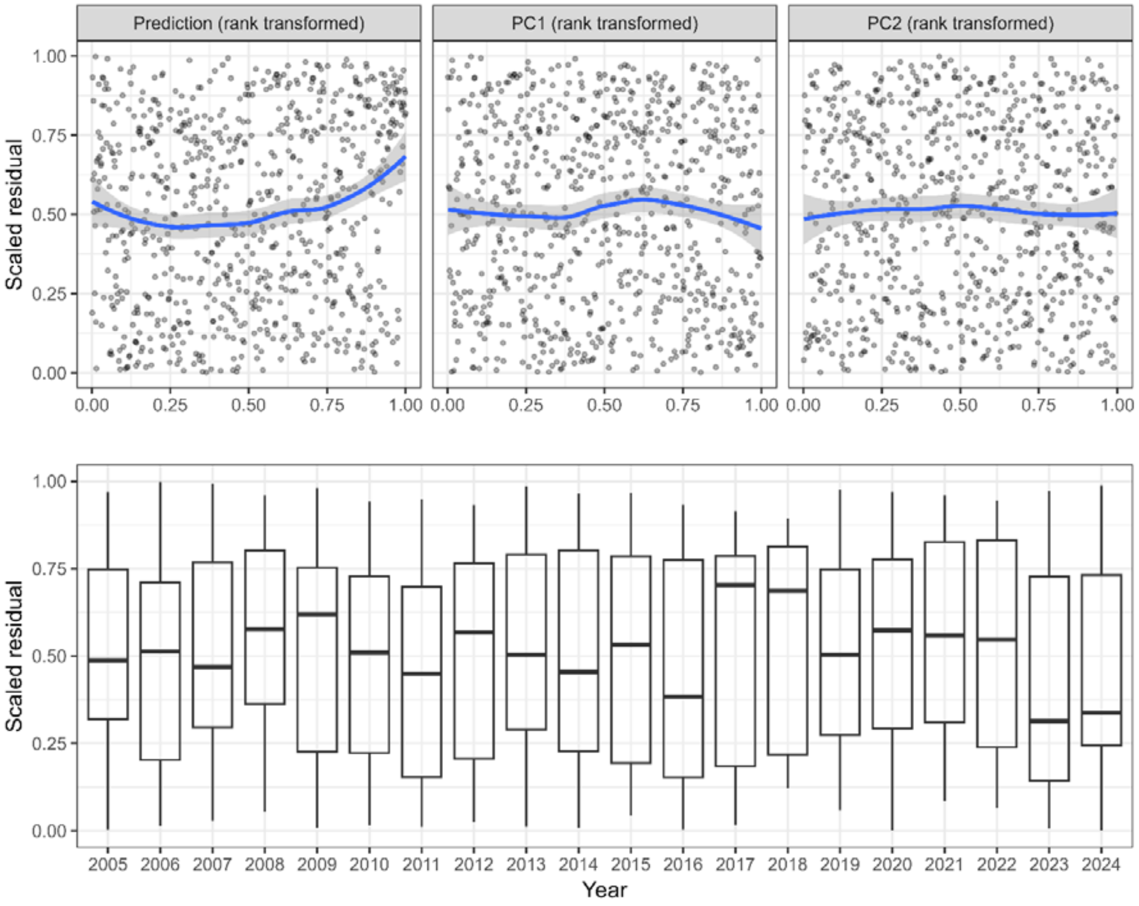
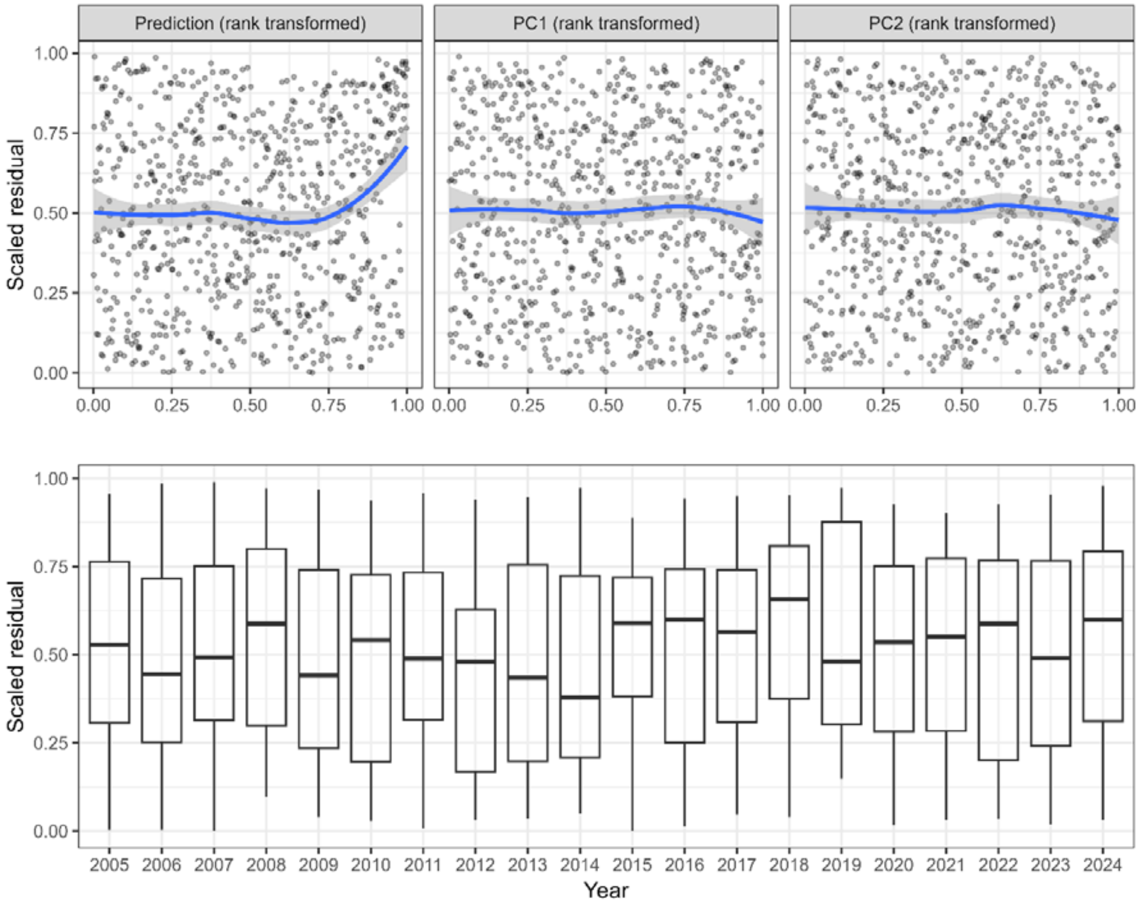


Fig. 6B: Age 1



The averages were not deviated from the theoretical average (0.5) in response to predicted values and covariates

Map of scaled residuals in each year

Fig. 7A: Age 0

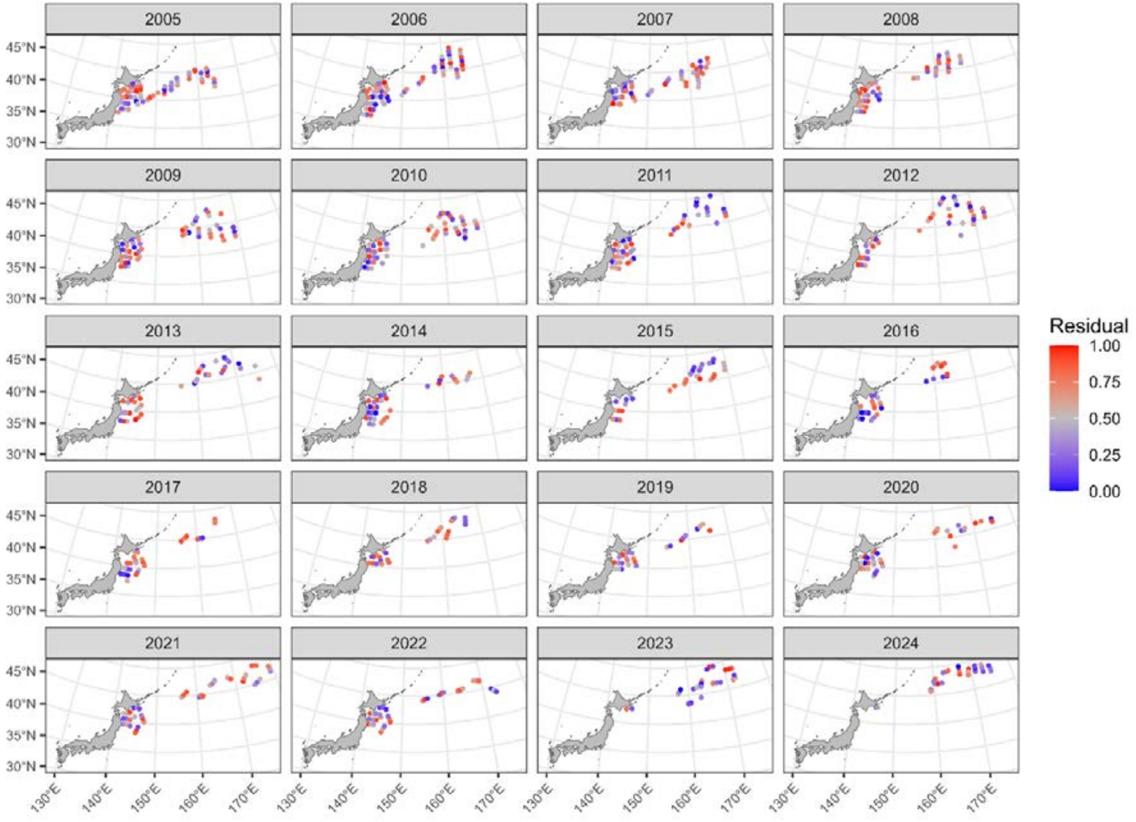
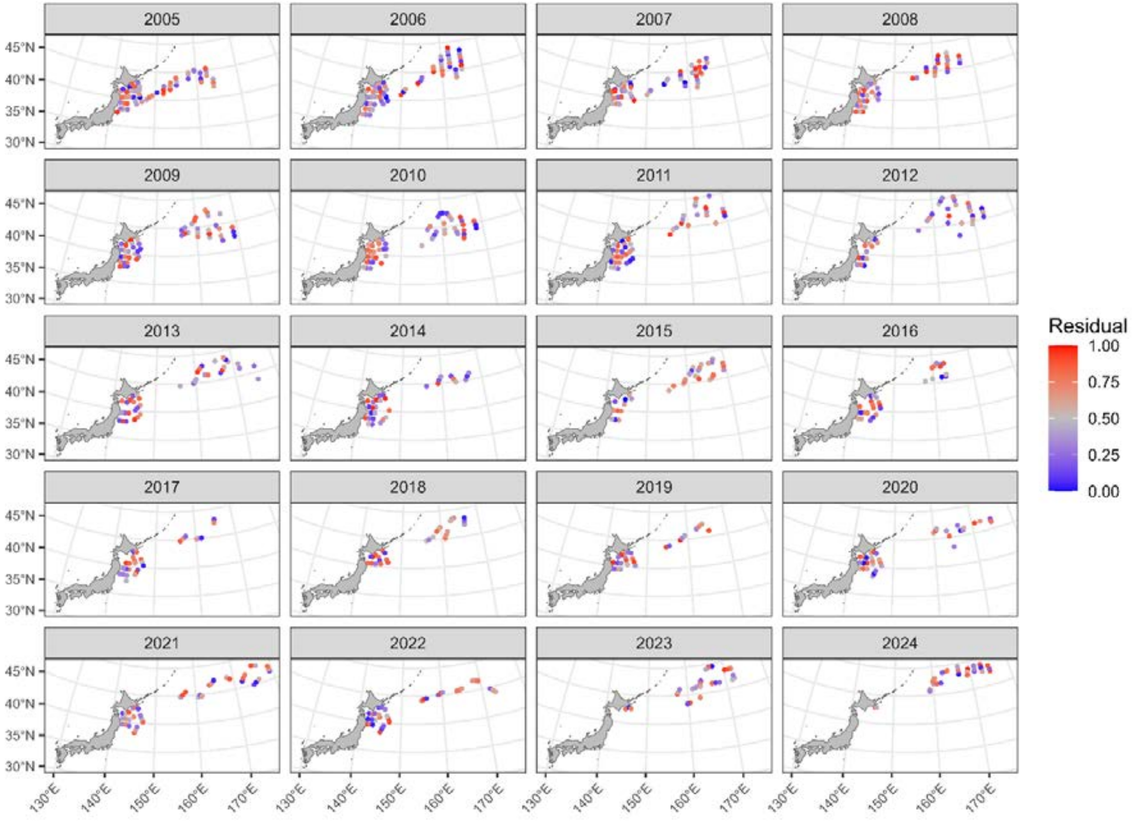


Fig. 7B: Age 1

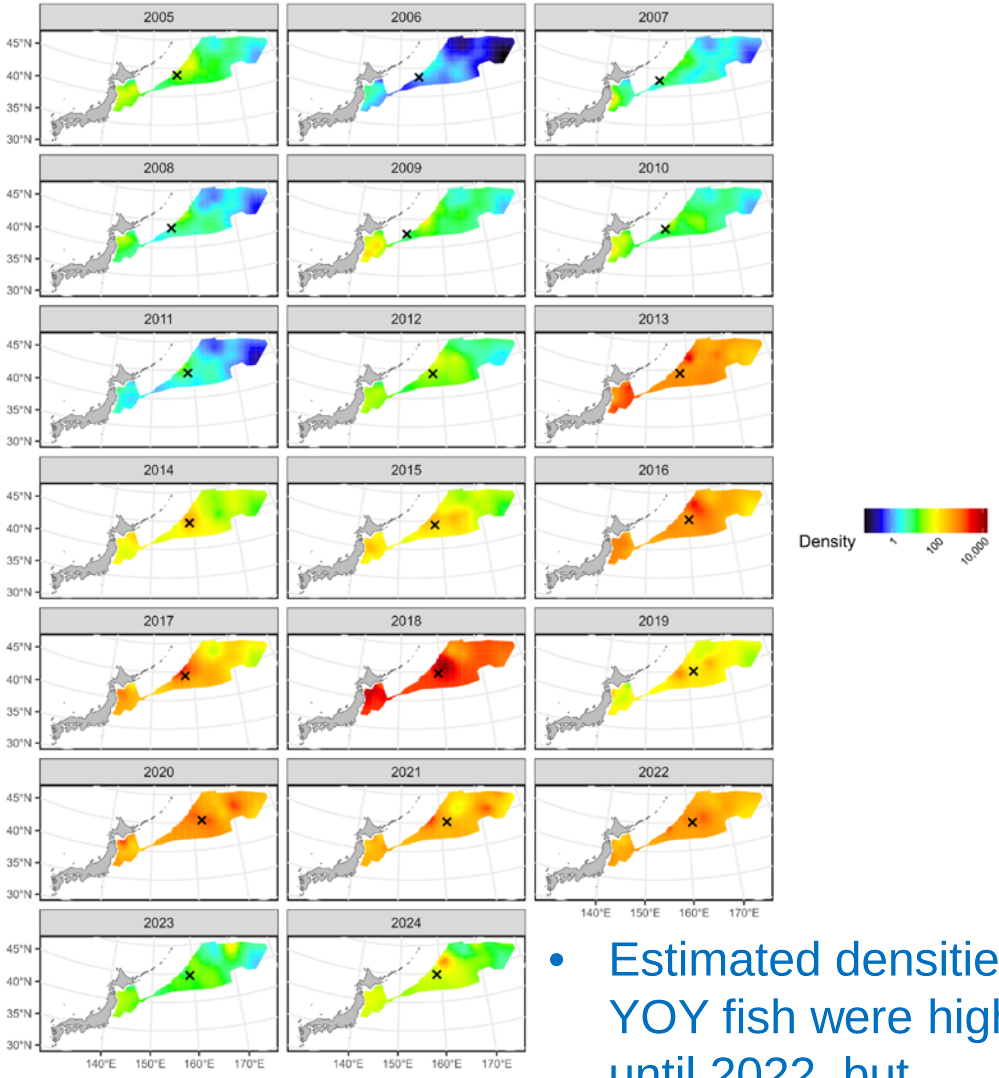


No systematic spatial patterns in scaled residuals

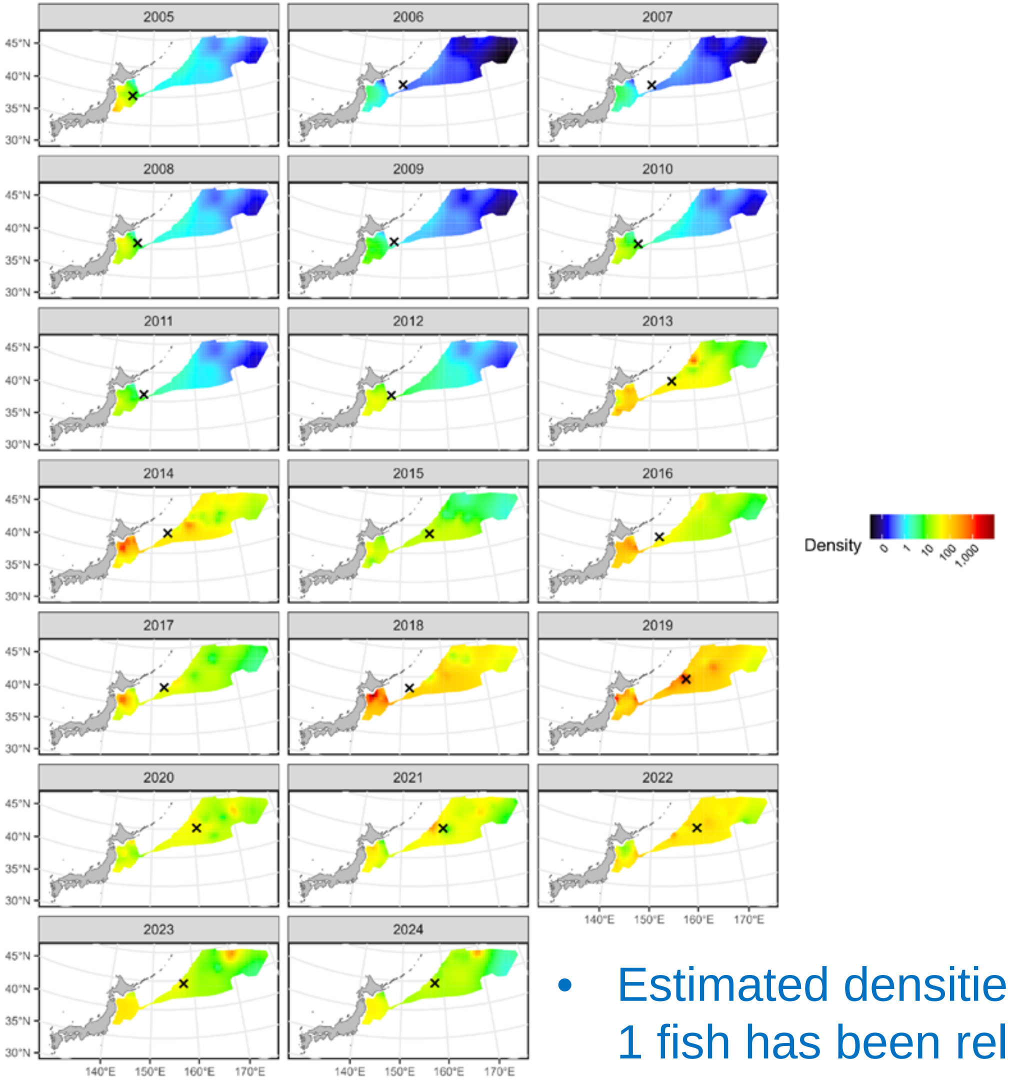
Estimated spatio-temporal distributions of age 0

Fig. 8A

$$d(s,t) = r_1^*(s,t) \times r_2^*(s,t)$$



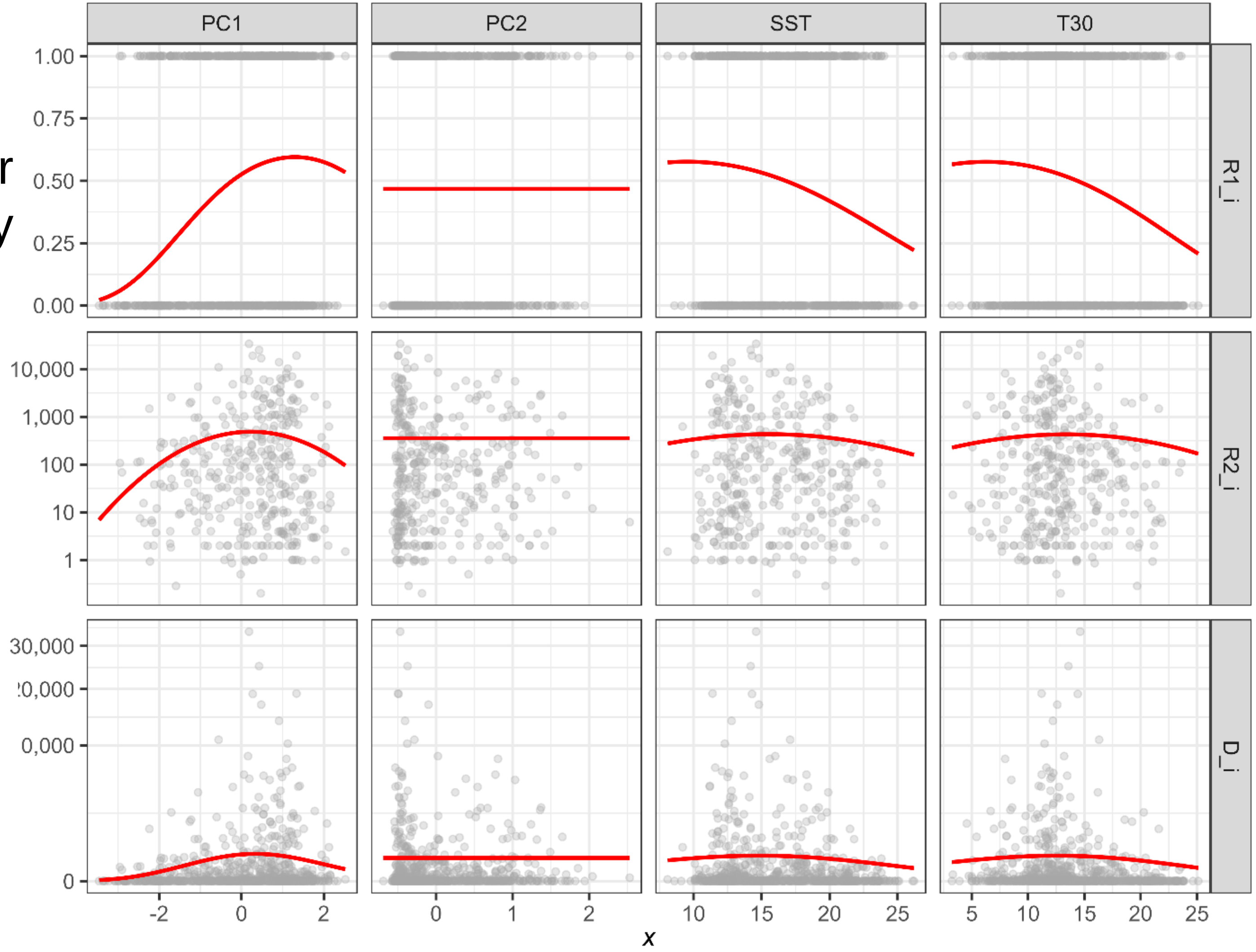
- Estimated densities of YOY fish were high until 2022, but decreased thereafter



- Estimated densities of age 1 fish has been relatively high since 2013

Relationships between covariates and CPUE for age 0

Fig. 9A: Partial dependence plots



Encounter probability

Positive CPUE

Overall CPUE

- The expected CPUE was the highest when SST was 14.9° C and T30 was 12.5° C.

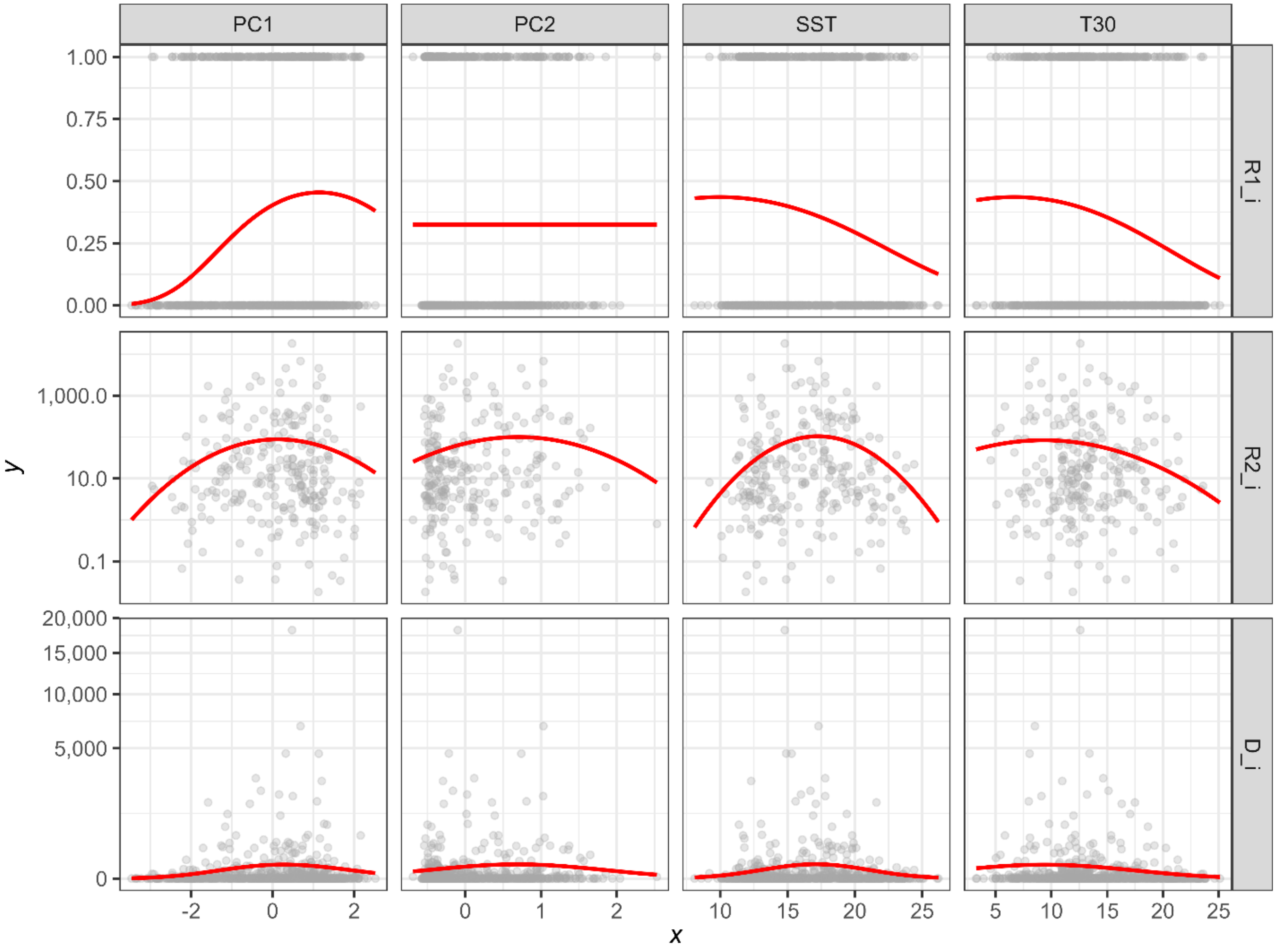
Relationships between covariates and CPUE for age 1

Fig. 9B: Partial dependence plots

Encounter probability

Positive CPUE

Overall CPUE



- The expected CPUE was the highest when SST was 17.1° C and T30 was 9.4° C.

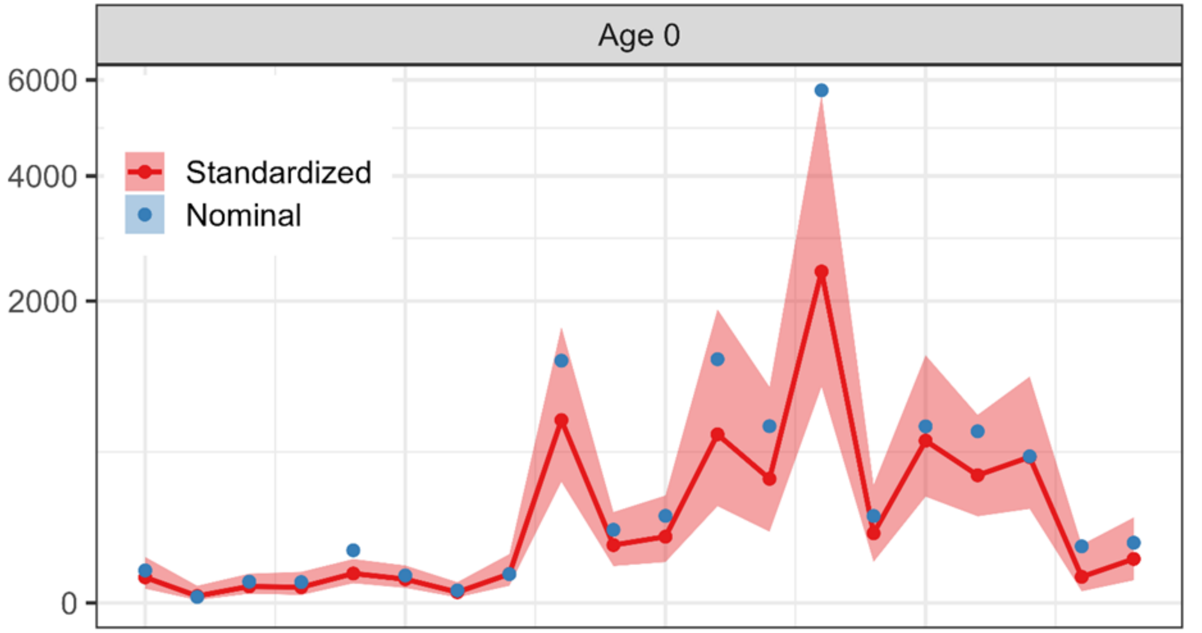
Yearly trends of nominal and standardized CPUE for age 0

area density

Average density (CPUE)

$$I(t) = \frac{\sum_{s=1}^{n_s}\left(a(s) \times d(s,t)\right)}{\sum_{s=1}^{n_s} a(s)} \qquad \frac{\text{Abundance}}{\text{Total area}}$$

Fig. 10



- High values were frequently observed since 2013, although the value of recent years (2023–2024) was on the lowest level since 2013
- This yearly trend of the standardized CPUE was not greatly different from that of nominal CPUE

Yearly trends of nominal and standardized CPUE for age 1

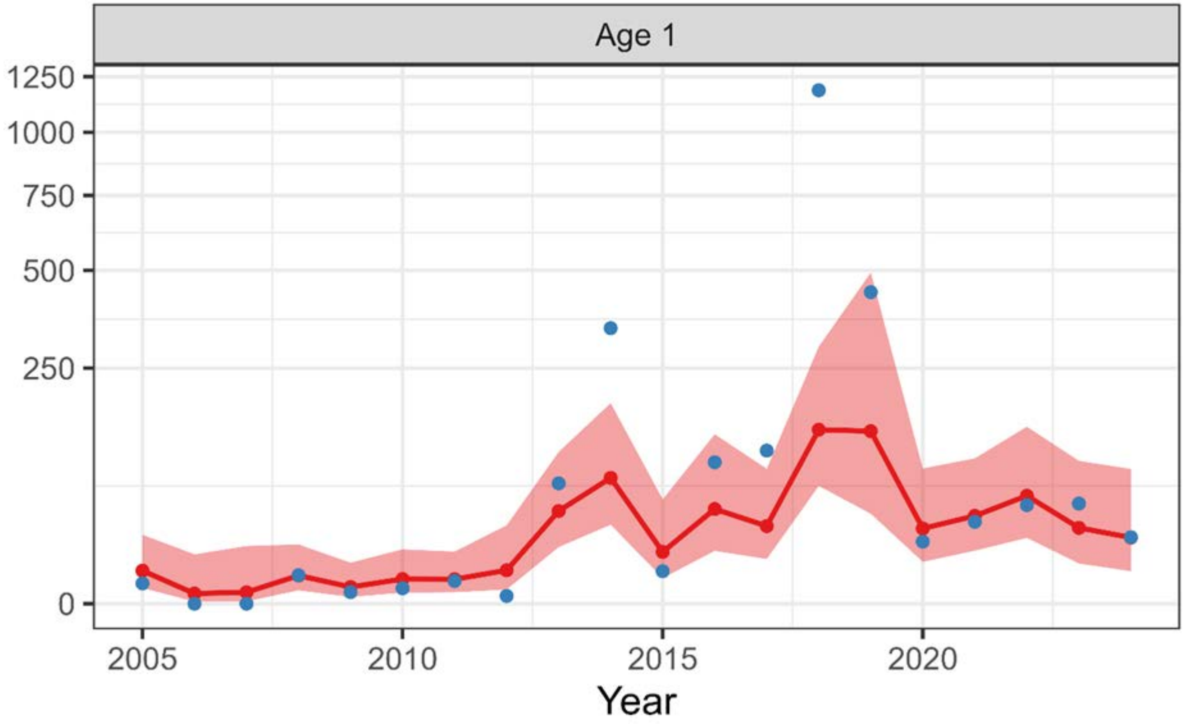
area density

Average density (CPUE)

$$I(t) = \frac{\sum_{s=1}^{n_s}\left(a(s) \times d(s,t)\right)}{\sum_{s=1}^{n_s} a(s)}$$

$$\frac{\text{Abundance}}{\text{Total area}}$$

Fig. 10



- CPUE remained stable at moderate levels in latest four years (2020-2024)
- Extremely high CPUE values over 4,500 individuals/hour were observed and smoothed by the temporal and spatio-temporal effects in 2014-2019.

Values and uncertainties of the nominal and standardized CPUE for age 0

Table 7

Year	Nominal (ind/h)	Standardized (ind/h)	CV	Lower 95%CI	Upper 95%CI
2005	23.24	14.38	0.60	4.45	46.41
2006	0.78	1.05	0.93	0.17	6.47
2007	9.98	5.96	0.59	1.89	18.79
2008	9.54	5.44	0.69	1.39	21.23
2009	60.76	18.98	0.41	8.50	42.38
2010	16.62	12.38	0.47	4.97	30.82
2011	3.48	2.55	0.67	0.68	9.48
2012	18.24	18.39	0.53	6.46	52.36
2013	1287.61	733.51	0.42	321.64	1672.77
2014	117.37	73.51	0.46	29.81	181.27
2015	166.33	96.33	0.49	36.62	253.37
2016	1303.30	623.49	0.57	205.56	1891.11
2017	685.39	337.98	0.57	111.48	1024.67
2018	5765.05	2409.61	0.44	1024.89	5665.20
2019	165.91	106.51	0.54	37.08	305.94
2020	684.06	577.59	0.43	247.82	1346.22
2021	646.41	357.51	0.40	164.65	776.26
2022	471.63	466.89	0.45	193.96	1123.85
2023	70.30	14.94	0.82	2.99	74.54
2024	79.49	42.51	0.68	11.28	160.20

The CV of the standardized CPUE were 0.40−0.69 except for 2006 and 2023

2006: the nominal and standardized CPUEs were the lowest (CV = 0.93)

2023: the number of stations was low (CV = 0.82)

Values and uncertainties of the nominal and standardized CPUE for age 1

Table 8

Year	Nominal (ind/h)	Standardized (ind/h)	CV	Lower 95%CI	Upper 95%CI
2005	1.85	4.91	0.75	1.13	21.42
2006	0.00	0.46	1.61	0.02	10.95
2007	0.00	0.59	1.65	0.02	14.99
2008	3.66	3.57	0.76	0.81	15.78
2009	0.60	1.25	0.92	0.21	7.57
2010	1.07	2.74	0.81	0.56	13.32
2011	2.32	2.70	0.77	0.60	12.22
2012	0.27	5.02	0.87	0.91	27.61
2013	65.17	38.66	0.50	14.43	103.58
2014	341.64	71.26	0.48	28.06	180.99
2015	4.75	12.07	0.72	2.97	49.02
2016	90.05	40.33	0.59	12.59	129.16
2017	105.49	27.14	0.56	8.99	81.92
2018	1186.44	136.28	0.40	62.44	297.44
2019	436.80	134.02	0.66	36.42	493.16
2020	17.36	25.47	0.60	7.89	82.27
2021	30.17	34.70	0.51	12.67	95.06
2022	43.74	52.45	0.50	19.51	141.00
2023	45.12	25.90	0.65	7.30	91.83
2024	19.92	19.70	0.73	4.75	81.73

The CV of the standardized CPUE were 0.40−0.92 except for 2006 and 2007,

No individuals of age 1 fish were captured (CV = 1.61 and 1.65 in 2006 and 2007, respectively)