Standardizing monthly egg survey data as an abundance index for spawning stock biomass of chub mackerel in the Northwest Pacific

Shota Nishijima, Momoko Ichinokawa and Ryuji Yukami

Fisheries Resources Institute,

Japan Fisheries Research and Education Agency

SUMMARY

- We estimated egg abundances from monthly egg density data obtained by research surveys by using VAST.
- The standardized CPUE reached its peak in 2019, but has been on a downward trend since then, reaching its lowest level in 2023 and 2024 since 2005.
- Since we found no serious problems in the diagnostics of the spatio-temporal model, we suggest the estimated index can be used as an SSB abundance index for the forthcoming stock assessment of chub mackerel in the TWG CMSA.

Background of the chub mackerel egg survey data

- In Japan, monthly egg surveys have been intensively conducted off the Pacific coast of Japan in the western North Pacific since 1978
- The objective of this egg survey is to monitor egg abundance of major small pelagic fish species such as Japanese sardine, Japanese anchovy, chub mackerel, etc.
- The survey area roughly covered the major spawning grounds of small pelagic fish off the Pacific coast, mainly inshore waters but also offshore waters related to the warm Kuroshio and cold Oyashio currents
- For example, Kanamori et al (2019) estimate spatiotemporal distribution of egg density of chub mackerel to reveal long-term changes in spawning patterns and spawning grounds
- See Takasuka et al. (2008a, b) and Takasuka et al. (2017) for futher details of the egg surveys

Objective in this working paper

- In this document, we applied the VAST to the egg survey data from 2005 to 2023 to derive egg abundance, which should represent relative SSB.

- We provide important references and diagnostics on this standardization according to the “CPUE Standardization Protocol for Chub Mackerel” as well as estimated values of abundance indices as the input data of forthcoming stock assessment of chub mackerel.

2. Methods| 2.1. The data| data collection and filtering

- In the monthly egg surveys, plankton nets were towed vertically form 150 m depth.
- The number of eggs observed by each sampling was then converted into density (number/m^2) and averaged arithmetically with 30’ latitude × 30’ longitude horizontal square resolution by month as monthly aggregated data.
- We used the data since 2005 when species identification between chub and blue mackerels is conducted.
- In addition, we further filtered the data

Filter applied	Number of observations remaining	Number removed	Number of records with positive catch
Initial dataset	41369	-	3004
Remove records except for Pacific stock	25749	15620	2347
Remove records from August to December	17322	8427	2333

Table 1

2. Methods| 2.1. The data| Summary of survey data

Year	Number of observations (Grids×Months)	Number of positive catches	Proportion of positive catches	Mean density including zero catches	Mean density excluding zero catches
2005	471	67	0.142	45.68	321.09
2006	784	115	0.147	92.45	630.26
2007	894	103	0.115	162.85	1413.46
2008	879	80	0.091	40.73	447.49
2009	877	120	0.137	39.84	291.18
2010	888	111	0.125	76.17	609.35
2011	857	109	0.127	71.99	566.04
2012	878	106	0.121	129.68	1074.15
2013	890	112	0.126	122.25	971.48
2014	946	111	0.117	65.17	555.44
2015	907	104	0.115	66.96	583.99
2016	879	118	0.134	50.05	372.80
2017	834	145	0.174	166.86	959.73
2018	903	176	0.195	267.43	1372.08
2019	974	176	0.181	317.16	1755.18
2020	886	148	0.167	155.37	930.11
2021	903	122	0.135	90.24	667.93
2022	931	126	0.135	141.67	1046.78
2023	913	87	0.095	23.97	251.52
2024	828	90	0.109	26.81	246.68

Table 2

The number of observations did not systematically vary over years.

The spatiotemporal distribution of survey efforts and average egg density

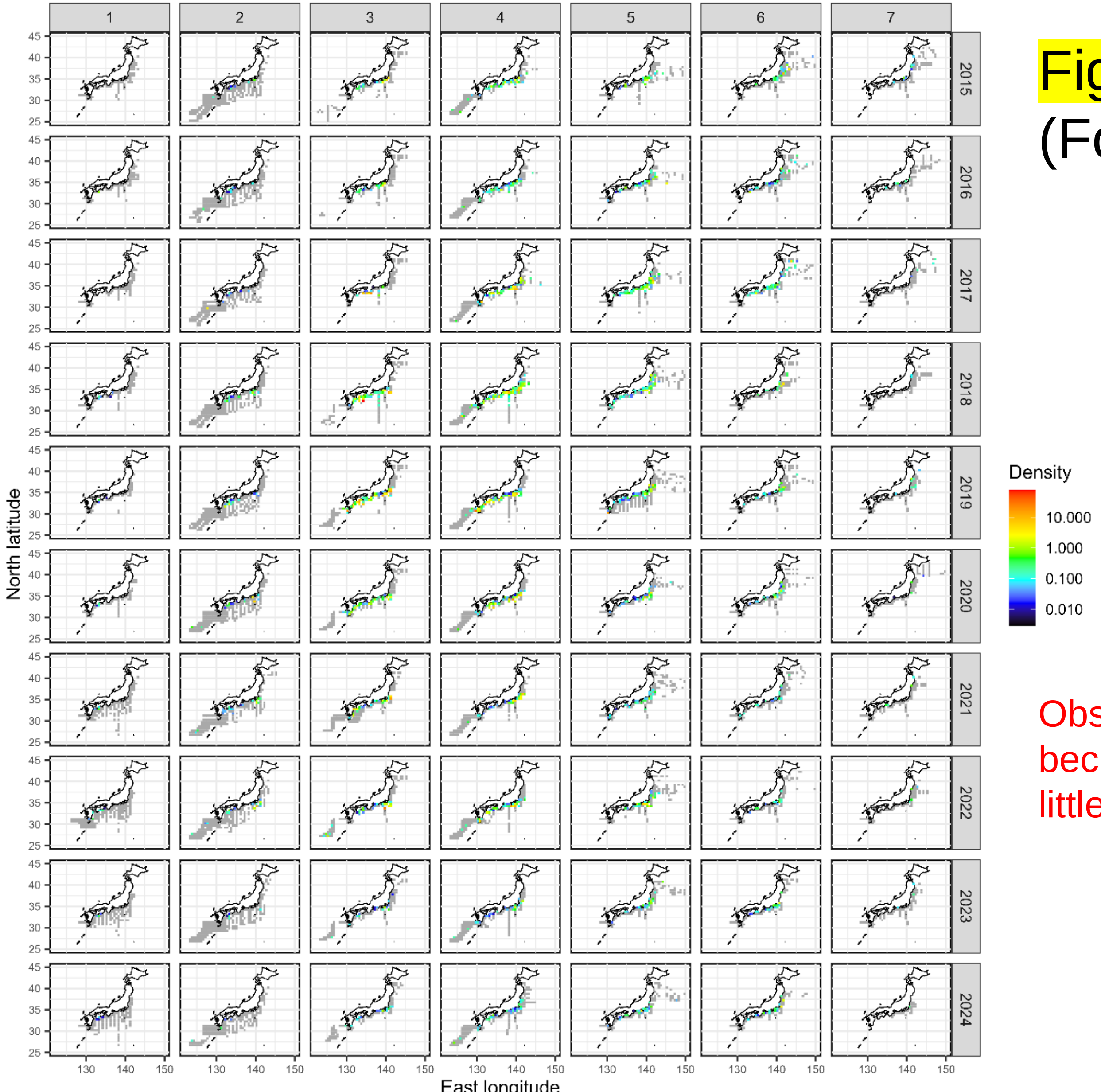
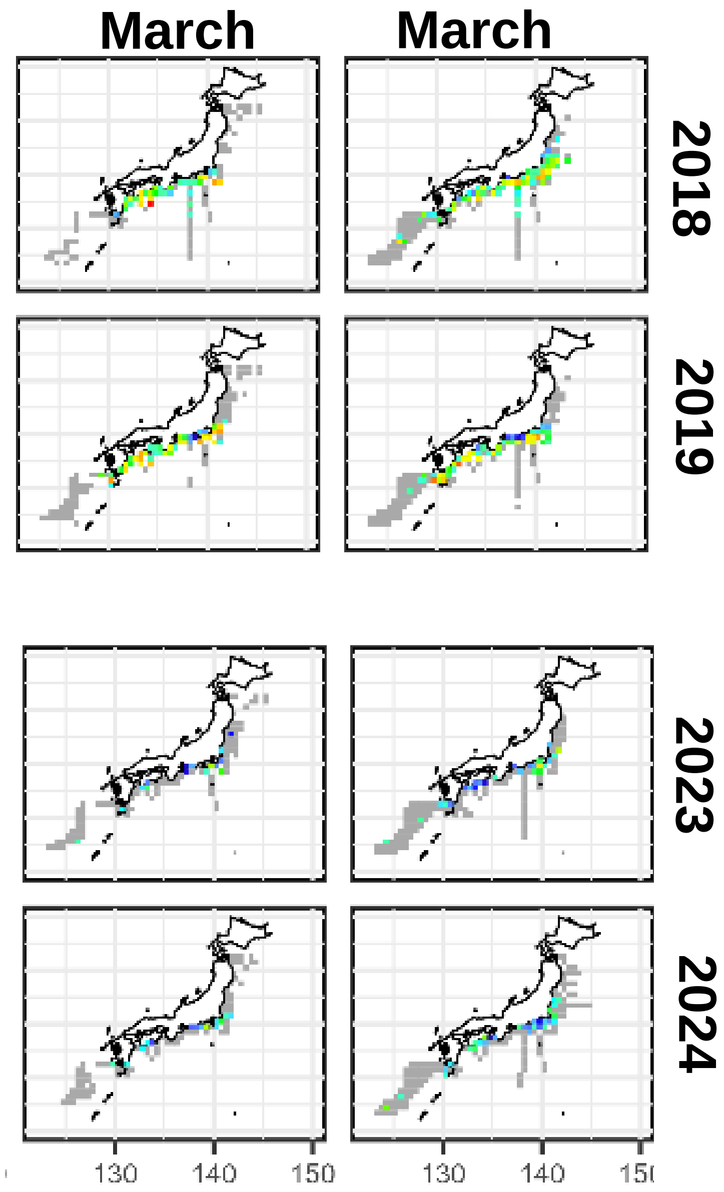


Fig. 1
(For 2014-2024)

Observed egg densities became very low regardless little change in sampling efforts



Explanatory variables and response variables

Applied the seasonal VAST model (Thorson et al. 2020)

- Time step is month with consideration for the fixed effects of year and month

Variables	Number of categories	Detail	Note
Year	20	2005–2024	Estimated as fixed effects
Month	7	January to July	Estimated as fixed effects
Spatial random factor	100	100 knots	Estimated as random effects using GMRF
Spatio-temporal random factor	14,000	100 knots times 140 timesteps	Estimated as random effects using GMRF

Table 3

Revised: The column of "Year × Month" was deleted from the initial version

Relationship between explanatory and response variables

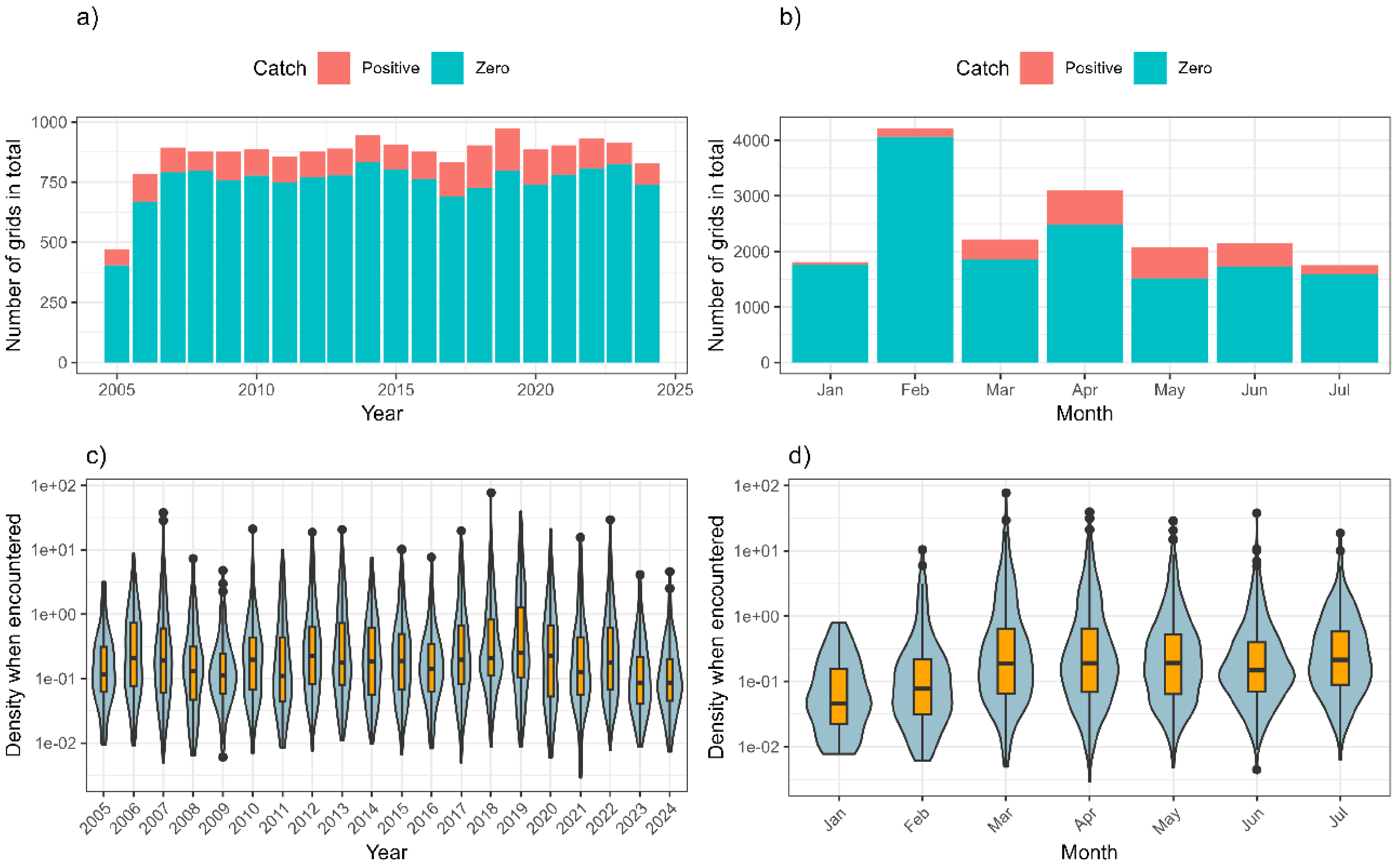


Fig. 2

Higher likelihood of positive catch from April to June

Higher density when encountered from March to July

2. Methods| Full model description

- The model includes two components

1. the encounter probability $p_{t,i}$ for time step *t* at location *i*
2. the expected egg density $d_{t,i}$ when spawning eggs are encountered.

$$\text{logit}\, p_{t,i} = \beta_t{}^{(p)} + L_\omega{}^{(p)}\omega_i + L_\varepsilon{}^{(p)}\varepsilon_{t,i},$$ Binomial distribution

$$\log d_{t,i} = \beta_t{}^{(d)} + L_\omega{}^{(d)}\omega_i + L_\varepsilon{}^{(d)}\varepsilon_{t,i},$$ Gamma distribution

β_t : the time step specific coefficients
L_ω : spatial random effects
L_ε : spatio-temporal random effects.

$$\beta_{\mathrm{t}} = \mu_\beta + \beta_m(m_t) + \beta_y(y_t),$$

μ_β : the intercept, which represents the average across all years and months
$\beta m(m_t)$: the effect of month m
$\beta_y(y_t)$: the effect of year.

These parameters are estimated as fixed effects.

2. Methods| Yearly trend extraction

$\widehat{D}_{t,s}$: monthly egg densities in time t at location s
$=$ the encounter probability $p_{t,i}$ for time step t at location i
$\times$ exp(the expected egg density $d_{t,i}$ when spawning eggs are encountered),

$$\hat{I}_t:\ \text{Monthly egg abundances} = \sum_s a_s \widehat{D}_{t,s}$$

a_s : area associated with location s.

$\hat{I}_y$: annual estimates of egg abundance by summing up monthly egg abundance from January to July $= \sum_t \hat{I}_{y_t}$

3. Results and Discussion | AIC

VAST model	AIC
Seasonal model considering monthly distribution shifts	107020.0
No seasonal model ignoring monthly distribution shifts	107845.1

- This suggests that the spatial distributions of chub mackerel eggs shifted monthly.

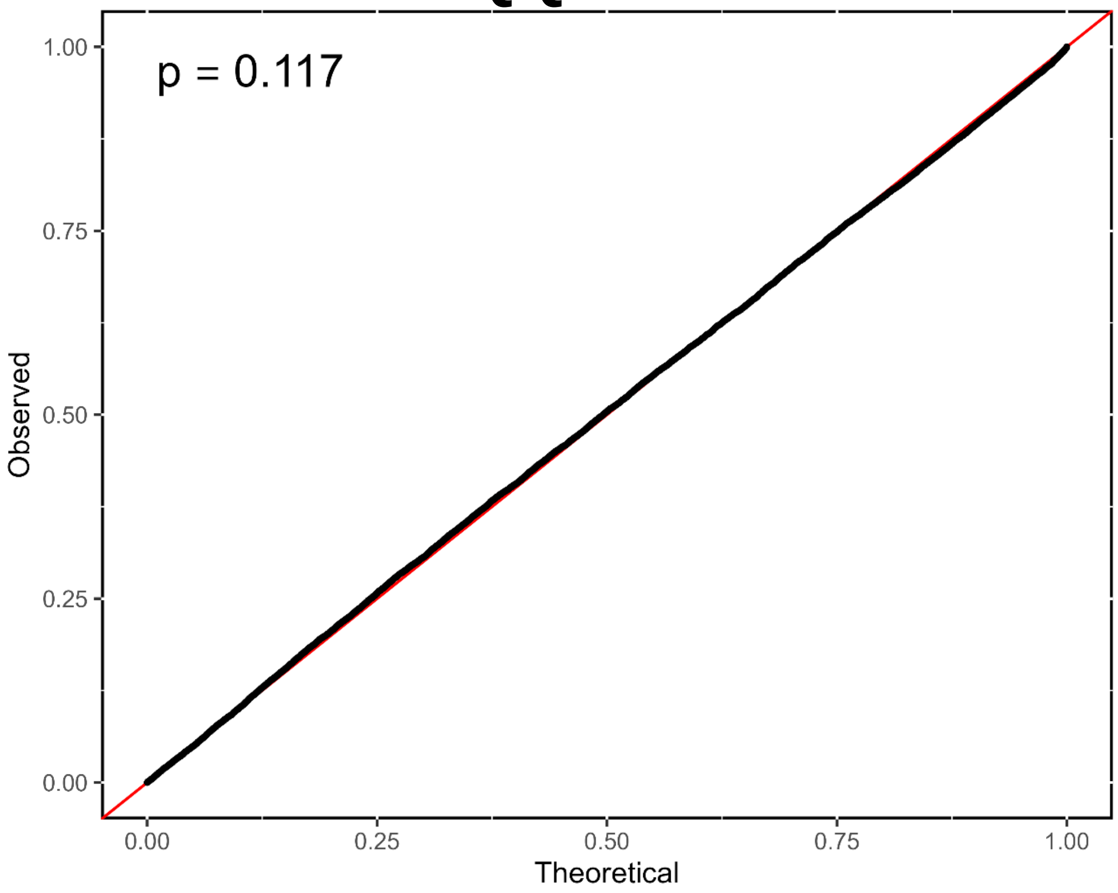
Model diagnostics

- The parameter estimates in the seasonal VAST model were stable as the final gradients of all parameters were nearly zero (absolute values were less than 0.01).

Parameter	MLE	SD	final gradient
ln_H_input	0.318	0.125	2.28E-10
ln_H_input	0.335	0.132	-1.14E-07
beta1_ft	-7.170	0.867	2.58E-09
gamma1_cp	0.731	0.289	6.38E-09
gamma1_cp	2.126	0.303	3.05E-09
gamma1_cp	2.806	0.303	-2.60E-09
gamma1_cp	2.717	0.308	-9.42E-09
gamma1_cp	2.227	0.303	-5.12E-09

A part of Table 4

QQ Plot



- the distribution assumption is met

Map of the standardized residuals

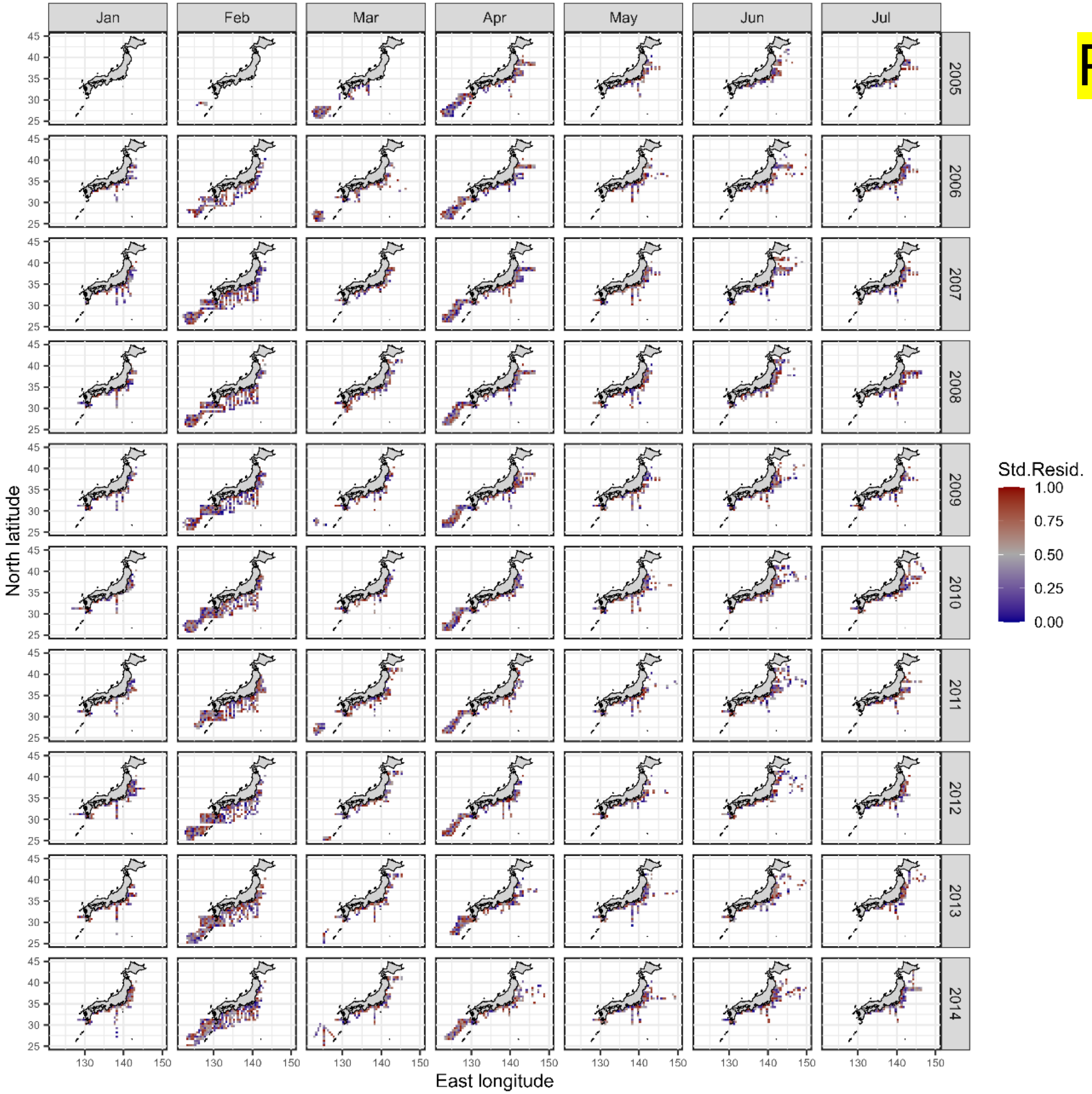


Fig. 4 (2005-2014)

Map of the standardized residuals

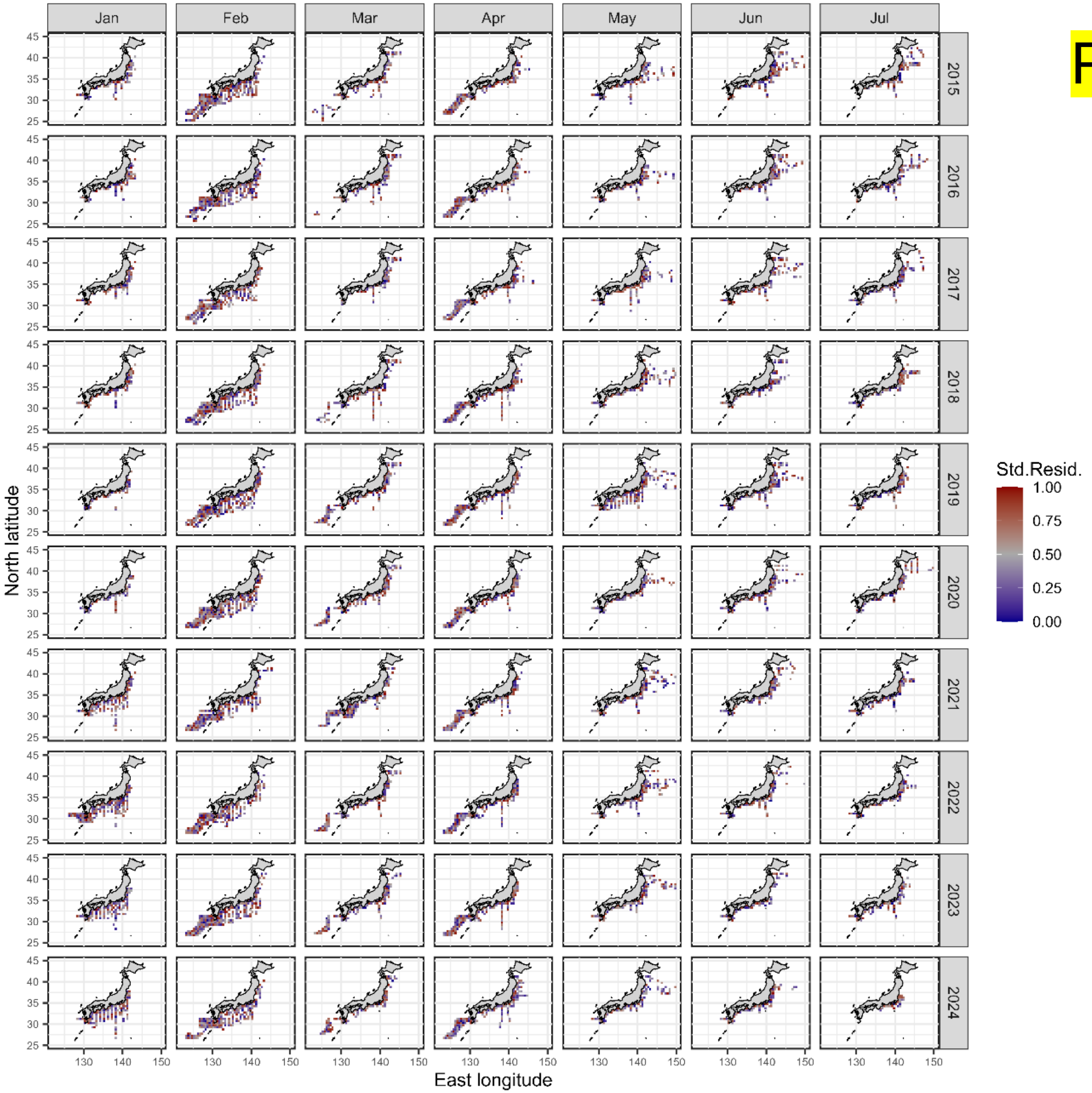
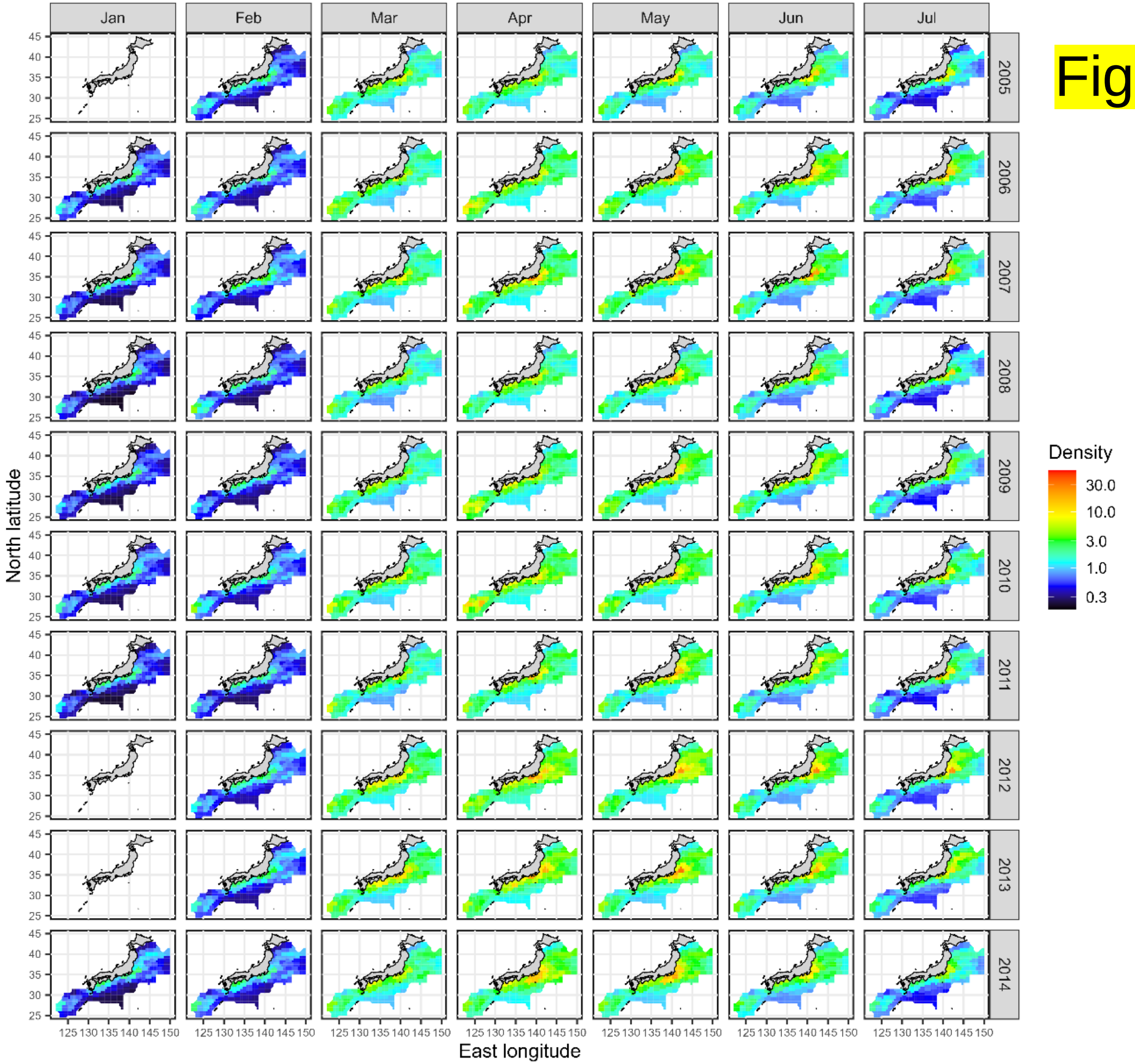


Fig. 4 (2015-2024)

There were no apparent systematic biases in the spatio-temporal distribution of standardized residuals.

Map of standardized egg densities

Fig. 5 (2005-2014)



Map of standardized egg densities

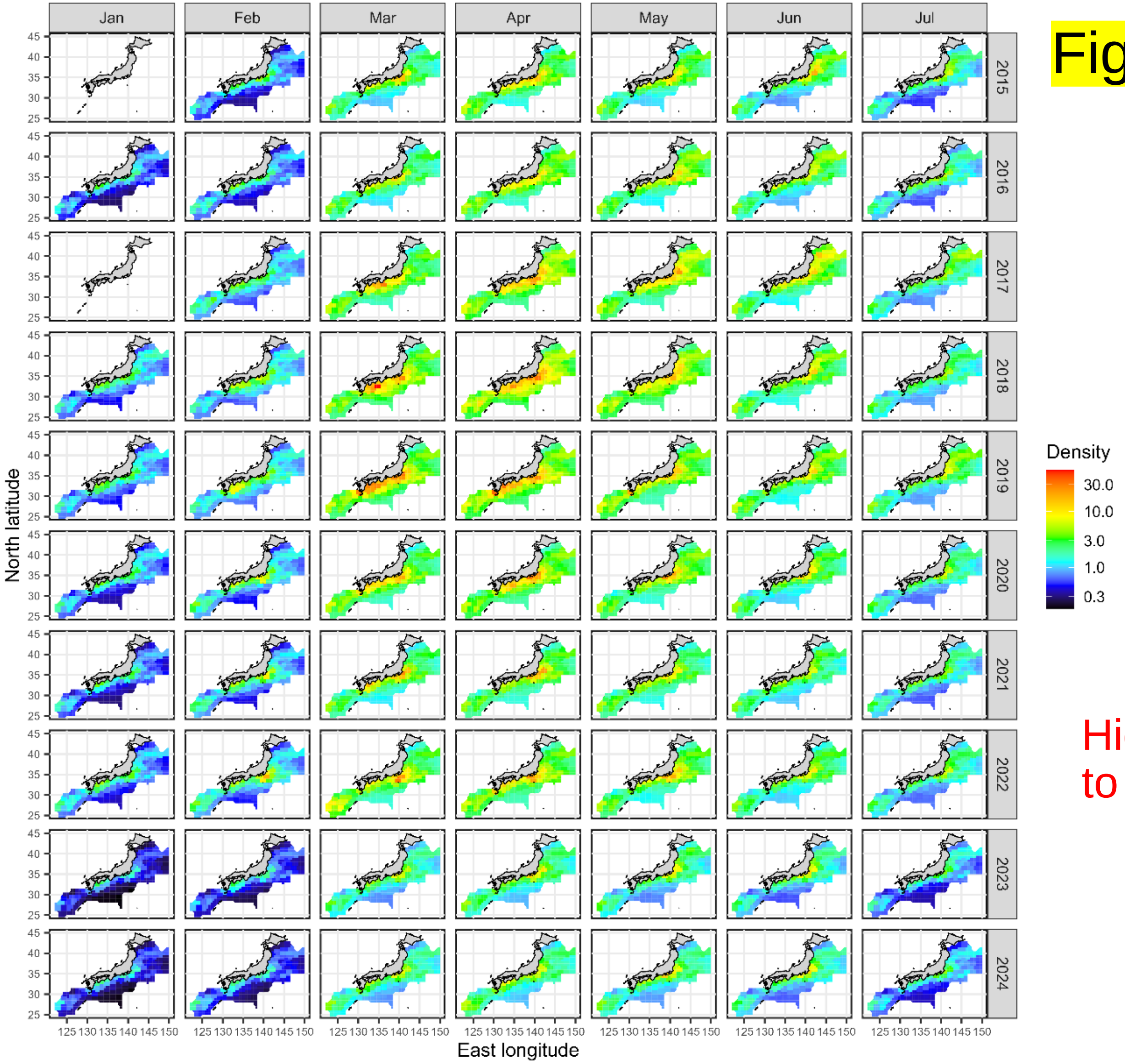


Fig. 5 (2015-2024)

High density grids in orange or red are shown from March to June until 2022, but disappear in 2023 and 2024

Monthly egg abundance in each year

Fig. 6

Recently, egg quantities were high in March and April, but in the last two years they have not been caught during this period and have remained low since then.

Standardized yearly trend

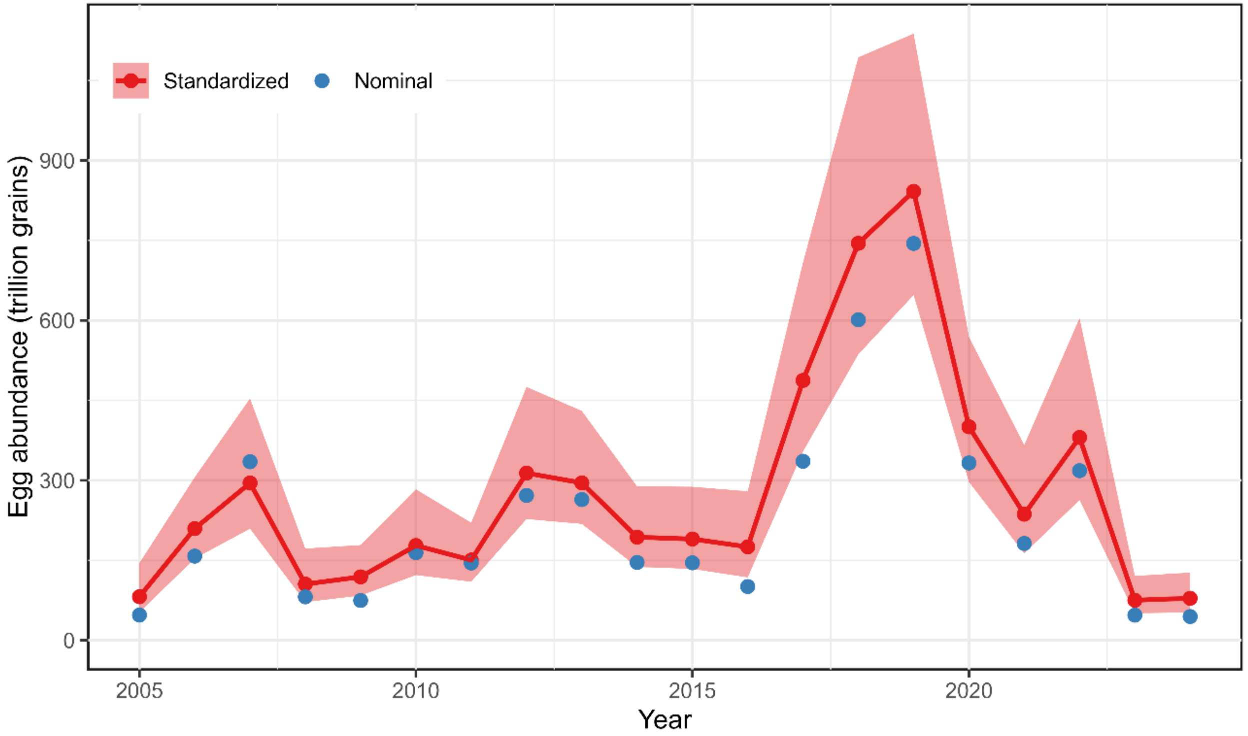


Fig. 7

The standardized egg abundance in 2024 was as low as that in 2023, the lowest on record (very slightly higher in 2024)

- The standardized index is particularly useful because it was derived from the intensive, large-scale surveys of spawning eggs, used the cutting-edge VAST models and had good model diagnostic results.
- Propose the estimated index can be used as an SSB abundance index for the forthcoming stock assessment of chub mackerel in the TWG CMSA.