The following supplement accompanies the article

Climate change shifts the spawning ground northward and extends the spawning period of chub mackerel in the western North Pacific

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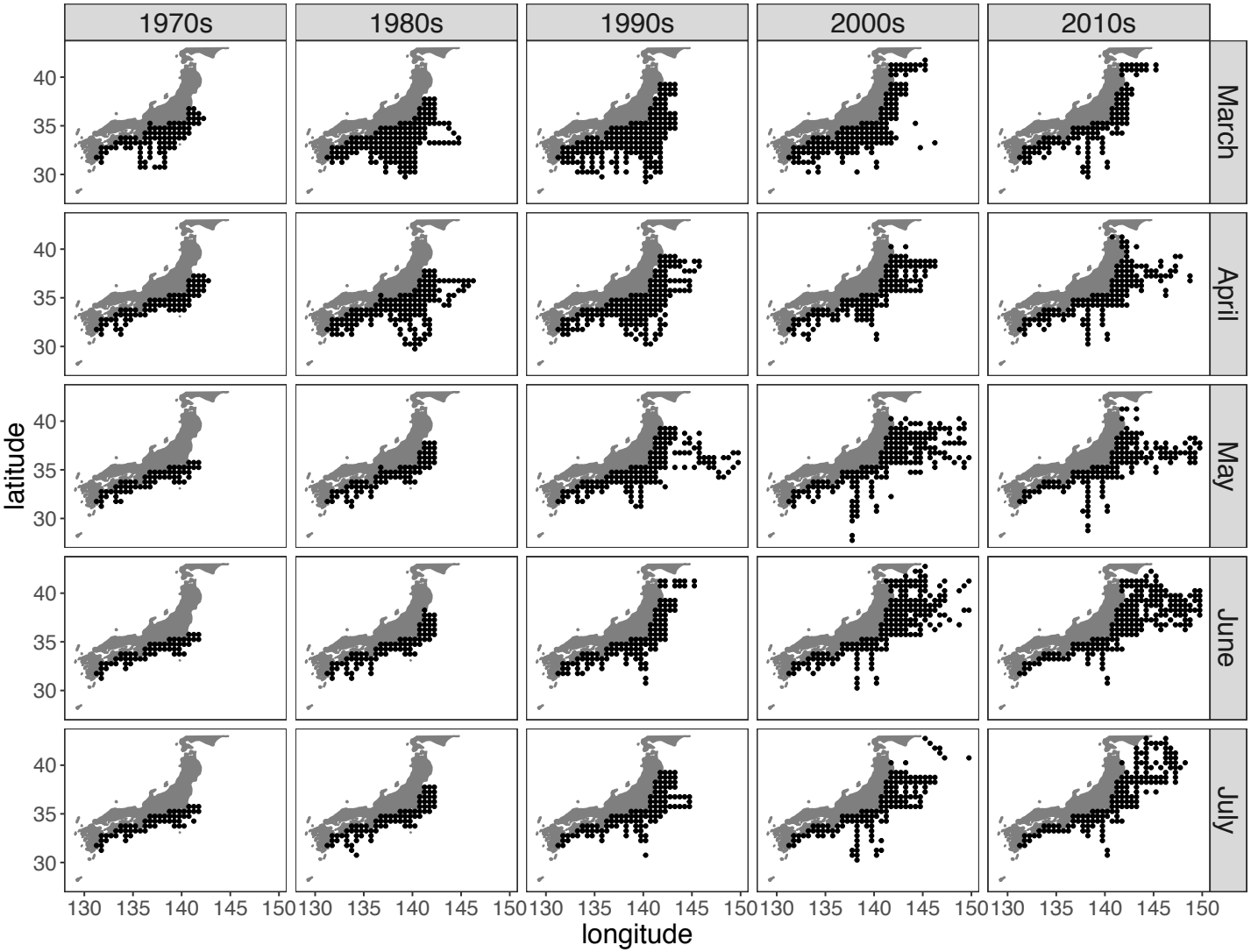

Fig. S1

Survey design and spatial distribution of raw egg density of chub mackerel *Scomber japonicus* in the western North Pacific.

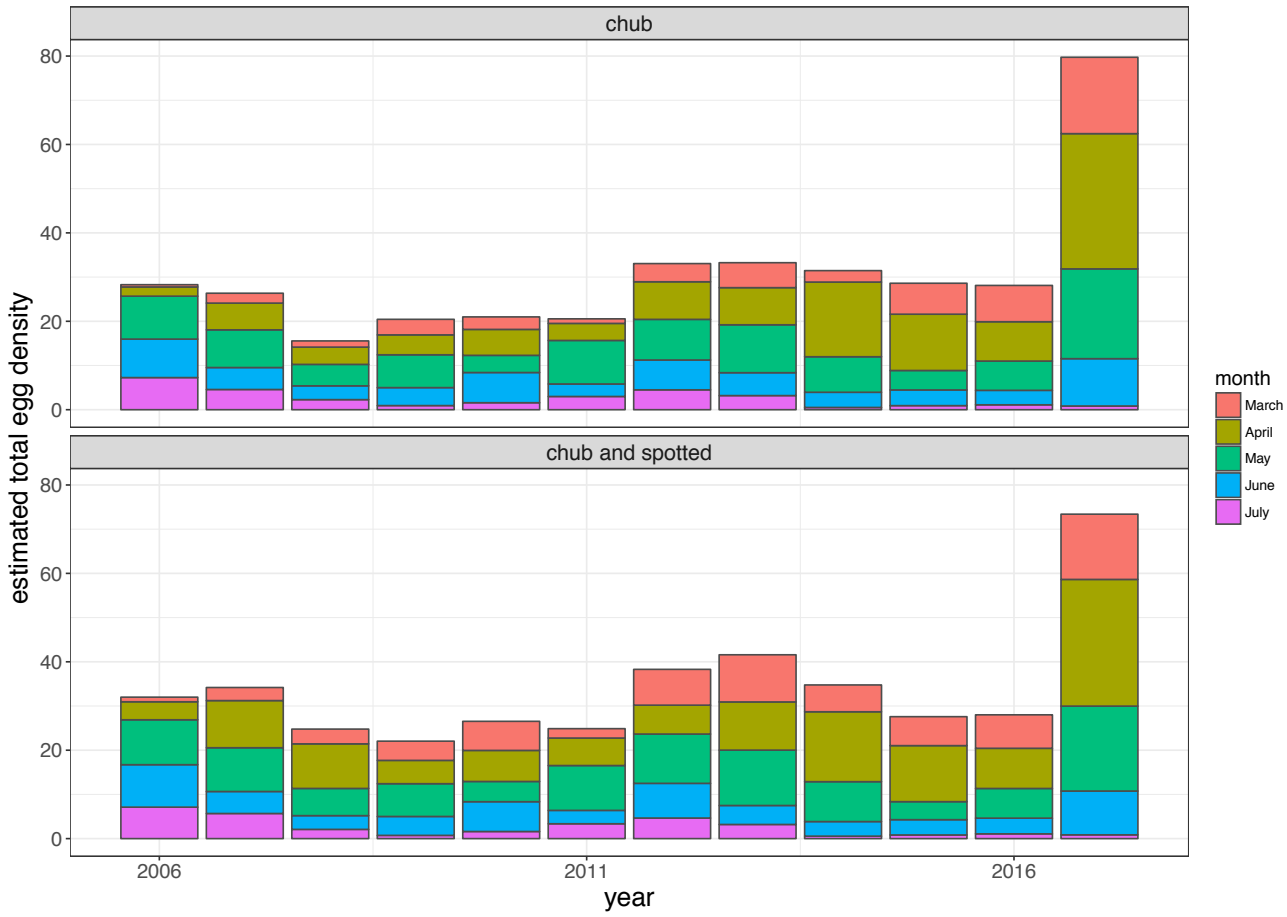

Fig. S2

Long-term changes in the index of abundance $\widehat{D}$ from March to July of chub mackerel *S. japonicus* (upper) in the western North Pacific, and chub mackerel and spotted mackerel *S. australasicus* (lower) in the western North Pacific. The x-axis is year and the y-axis is the index of abundance.

Fig. S3

Long-term changes in the index of abundance $\widehat{D}$ from March to July of chub mackerel *S. japonicus* (red) in the western North Pacific, and chub mackerel and spotted mackerel *S. australasicus* (blue) in the western North Pacific. The x-axis is year and the y-axis is the index of abundance.

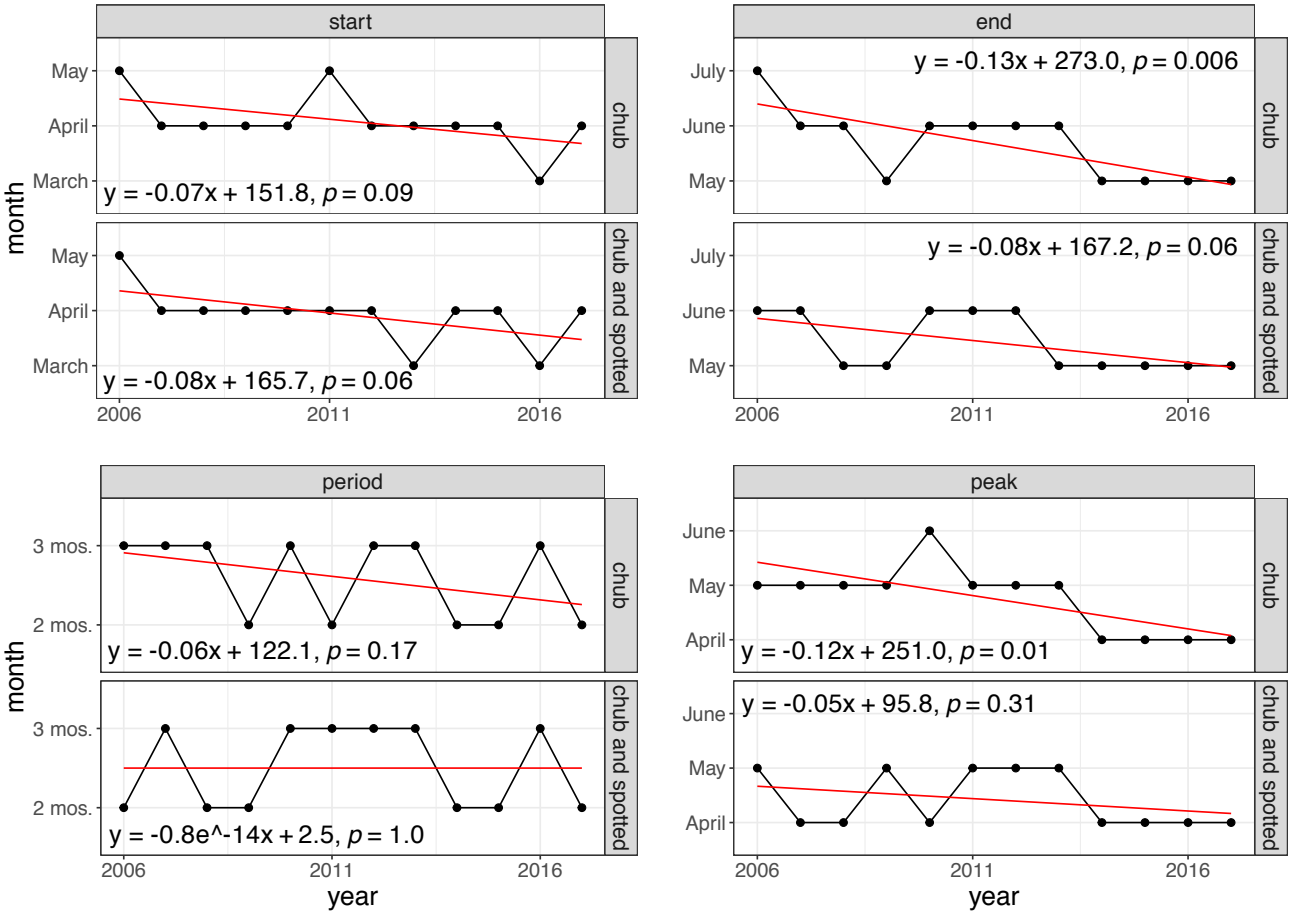

Fig. S4

Long-term changes in spawning patterns (start, end, period, and peak of spawning) of only chub mackerel and both chub and spotted mackerel with linear regression lines. The x-axis is year and the y-axis is month. The start and end of spawning were defined as 25 and 75 percentile in the histogram of monthly changes in the index of abundance in each year, and differences between the start and end was defined as period. The peak was defined as the mode of the histogram of monthly changes in the total of index of abundance in each year.

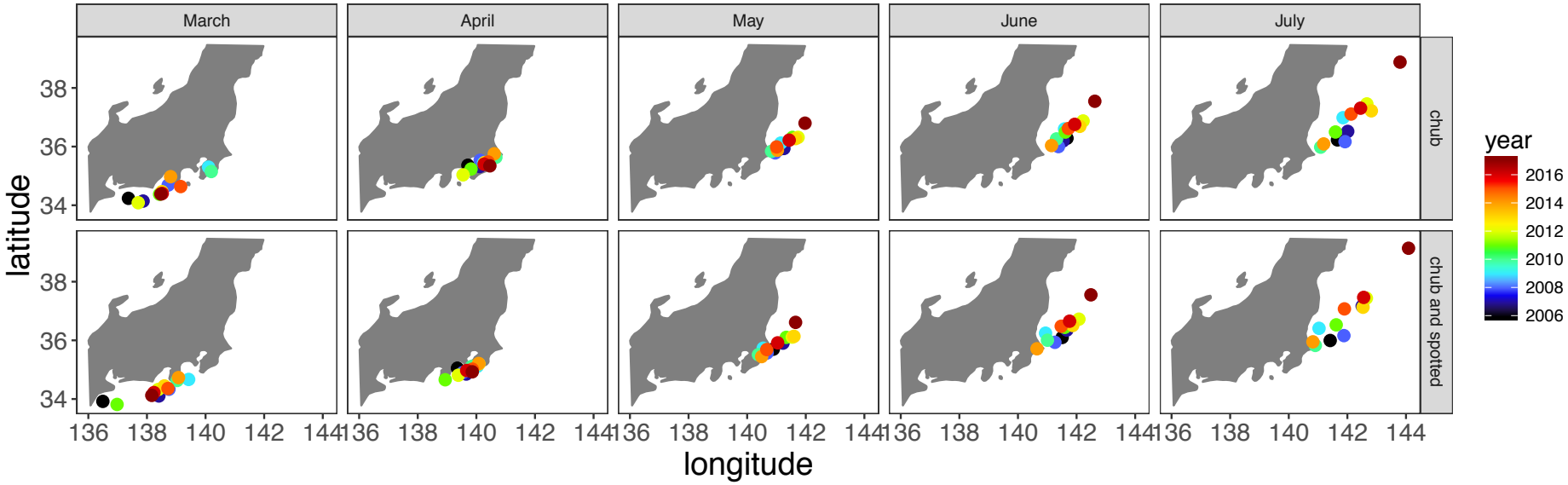

Fig. S5

Long-term changes in the Centre of Gravity (COG) of the estimated egg density in each month; upper is only chub mackerel, and lower is chub and spotted mackerel. The x-axis is the longitude and the y-axis is the latitude.

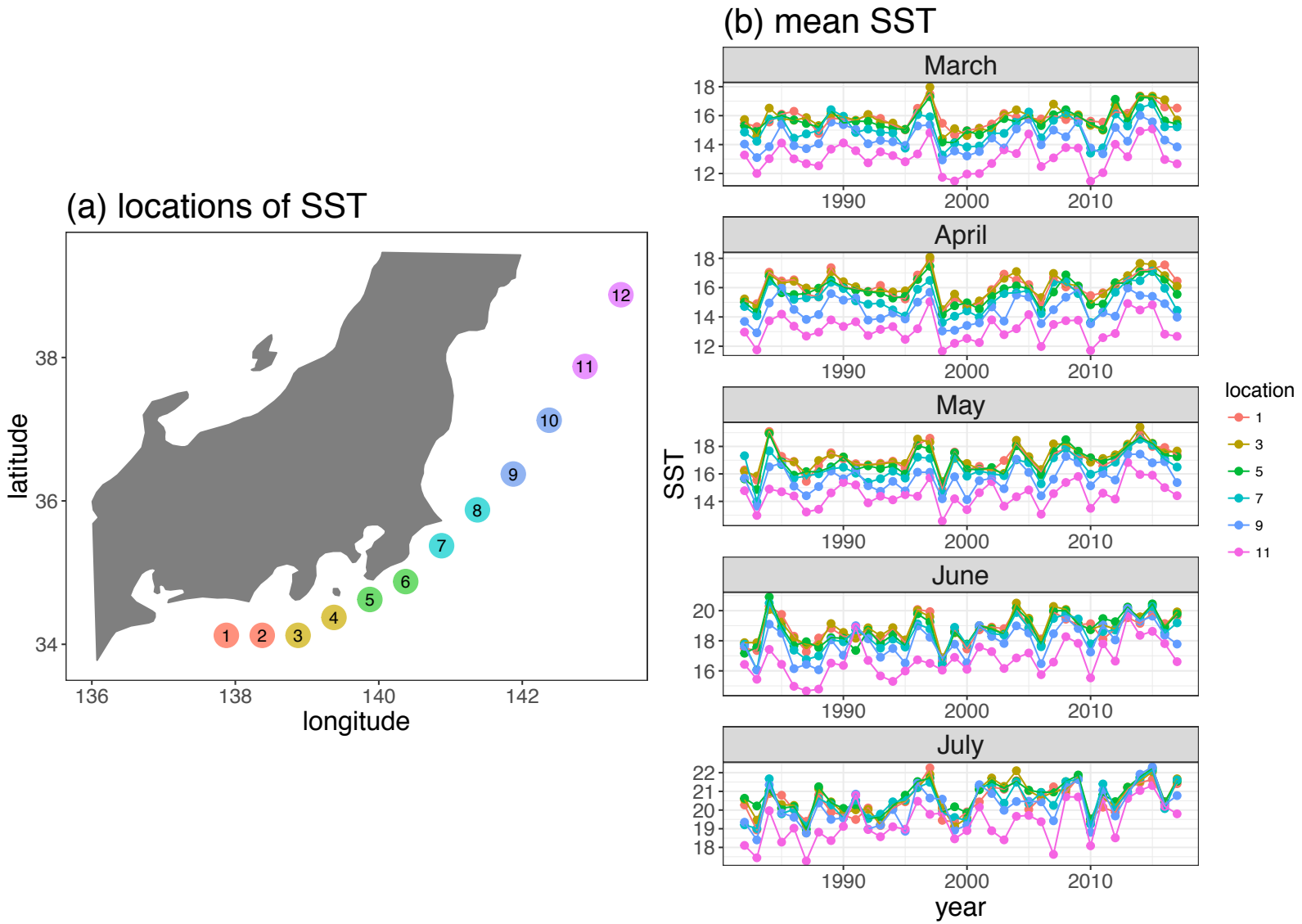

Fig. S6

(a) 12 locations by 0.5' longitude reflecting the result of long-term changes in the COG (Fig. 4), and (b) long-term trend of monthly mean SST in each location.

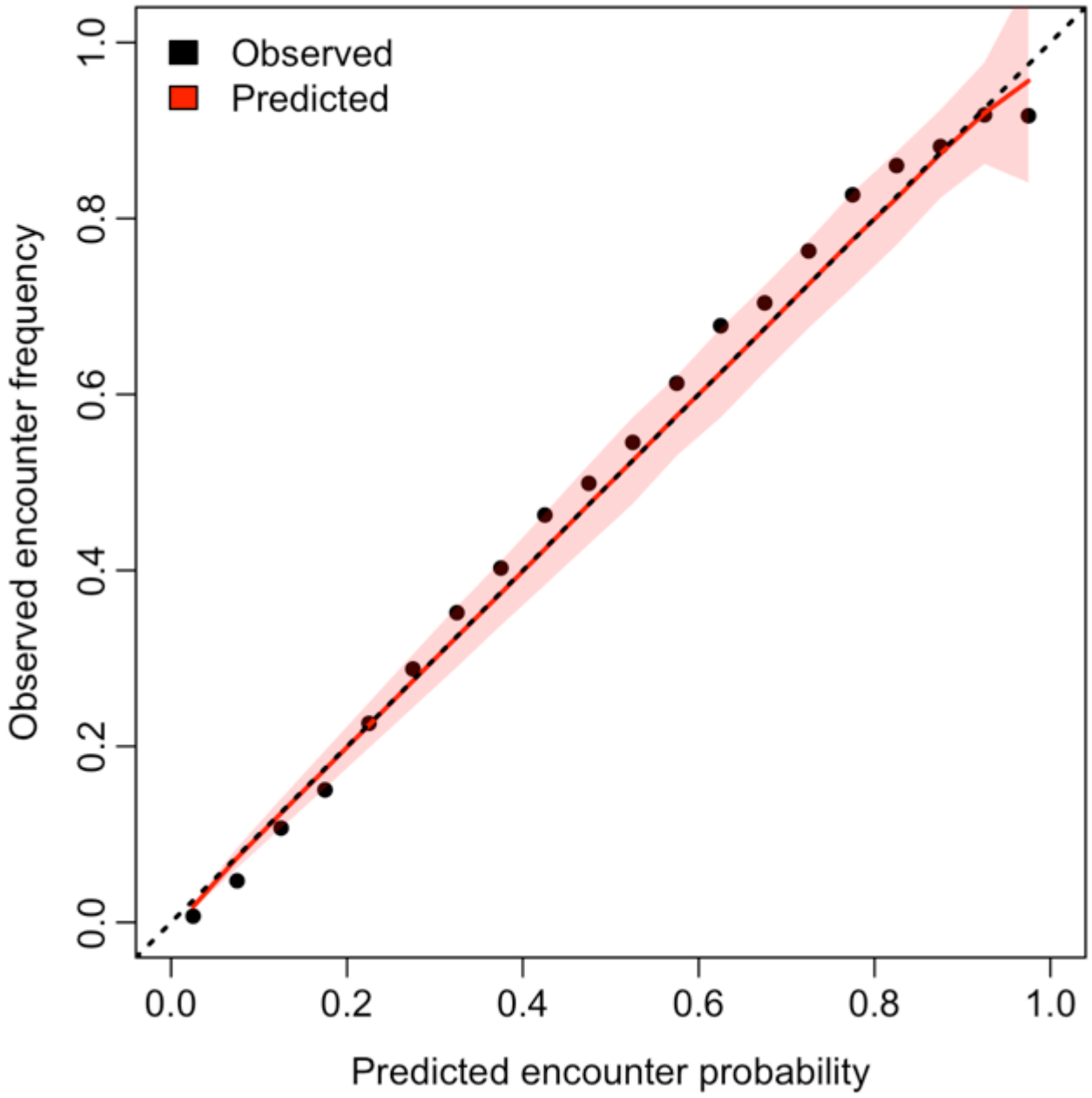

Fig. S7

Expected probability and observed frequency of encounter for “encounter probability” component.

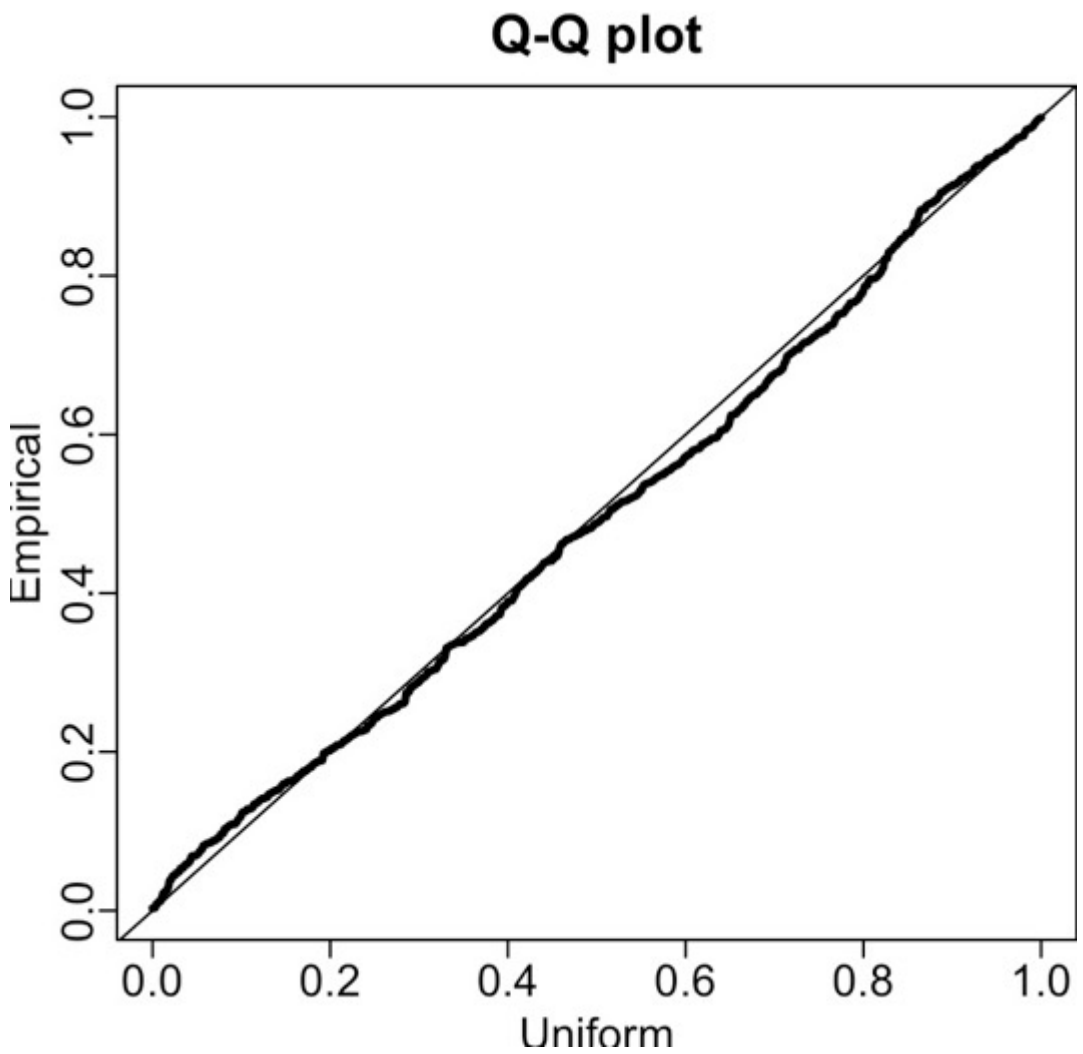

Fig. S8

Quantile-quantile plot indicating residuals for positive catch rate component in March.

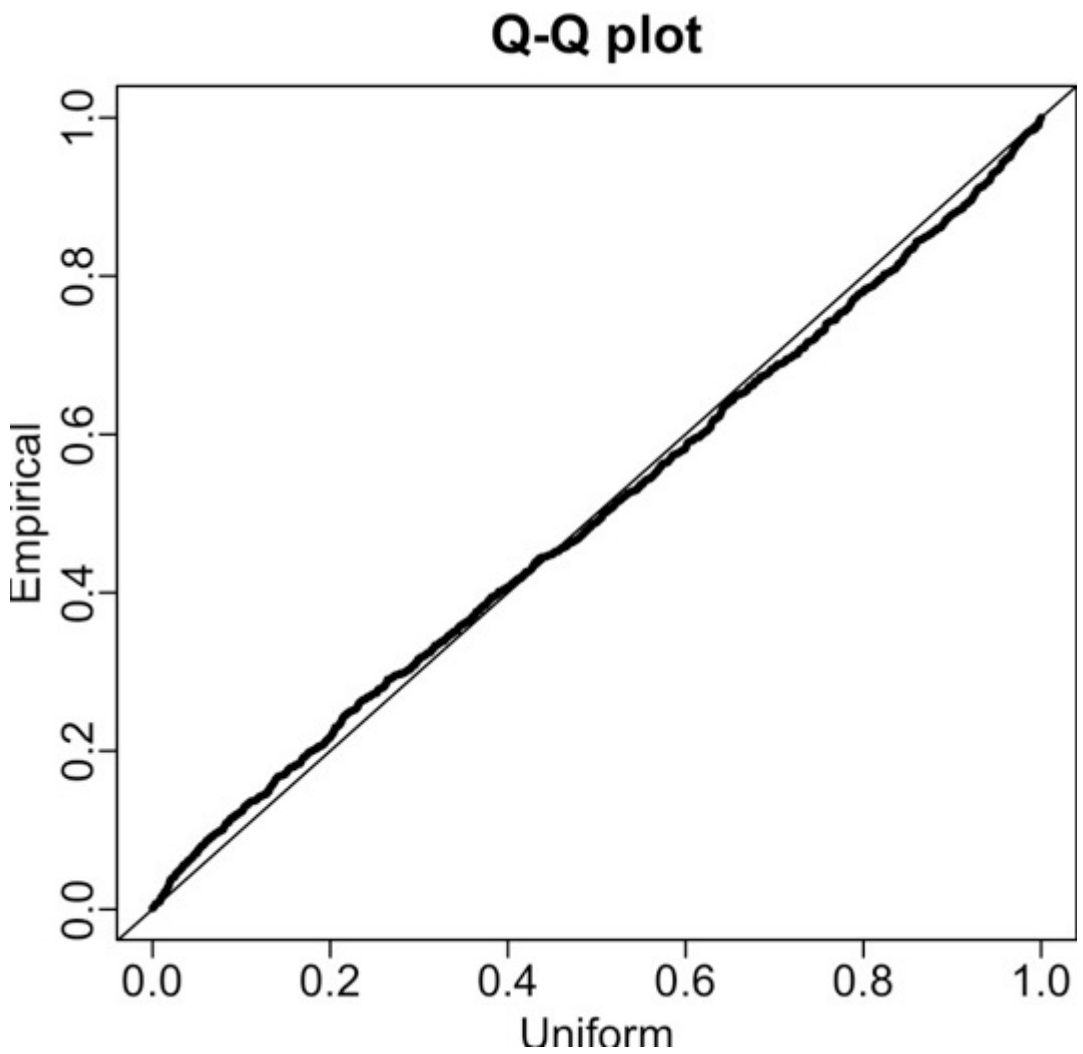

Fig. S9

Quantile-quantile plot indicating residuals for positive catch rate component in April.

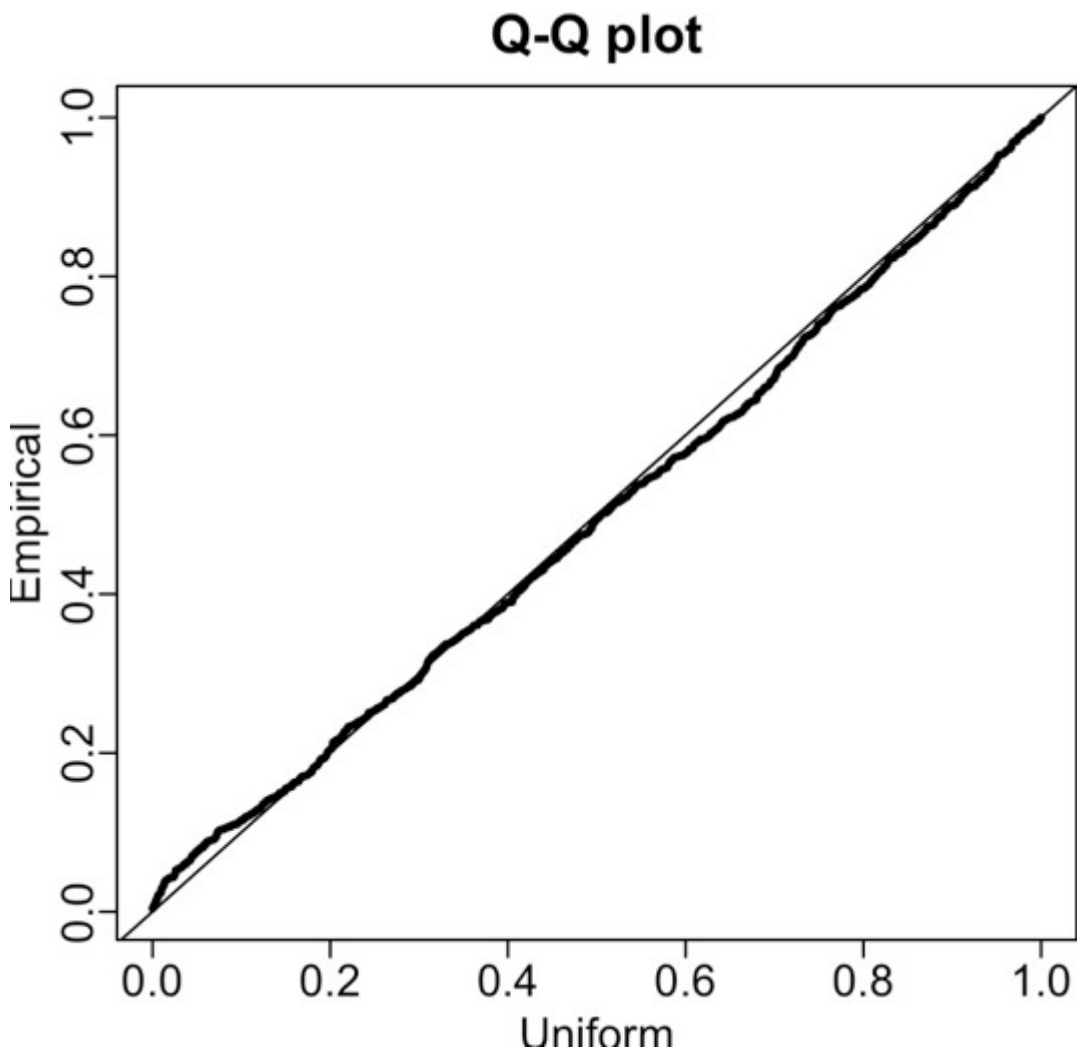

Fig. S10

Quantile-quantile plot indicating residuals for positive catch rate component in May.

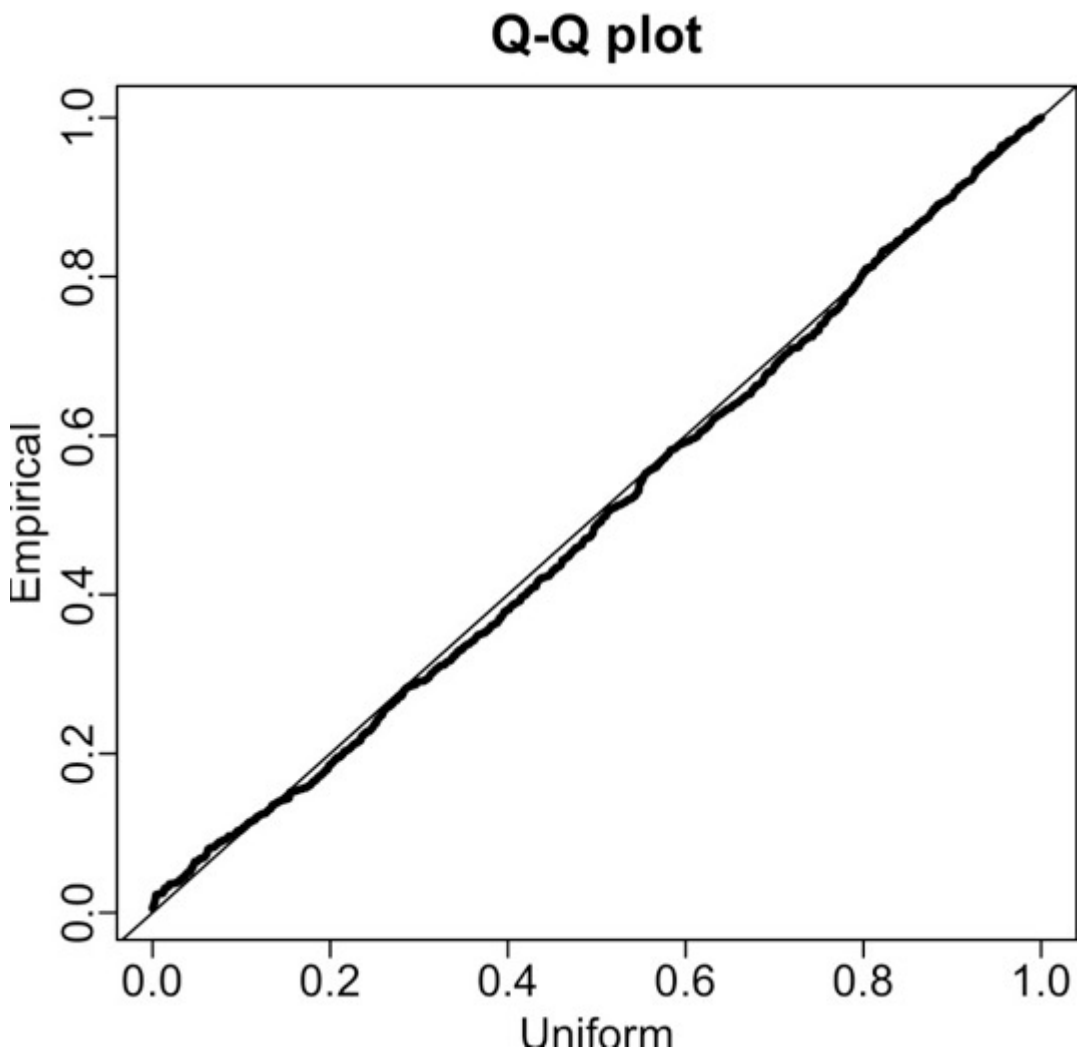

Fig. S11

Quantile-quantile plot indicating residuals for positive catch rate component in June.

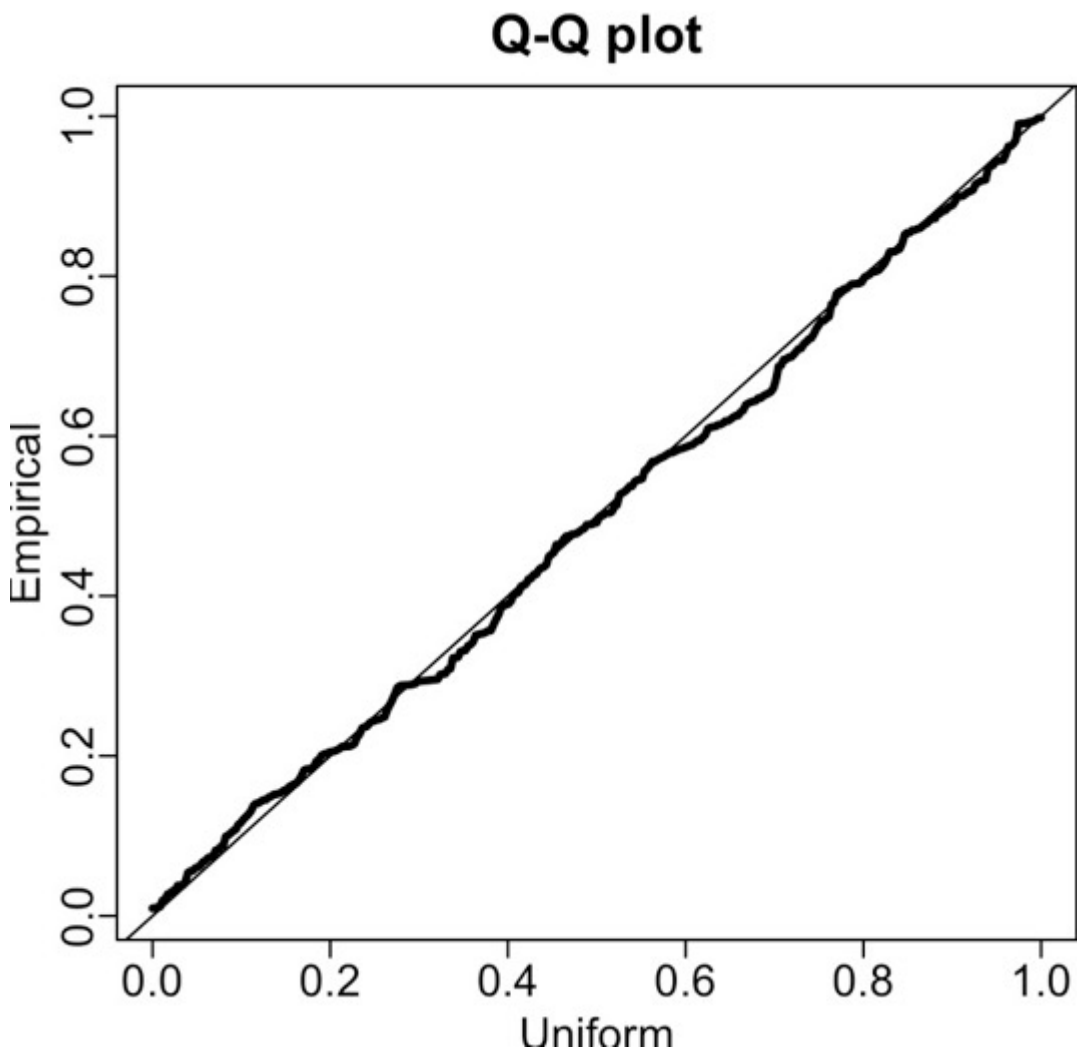

Fig. S12

Quantile-quantile plot indicating residuals for positive catch rate component in July.

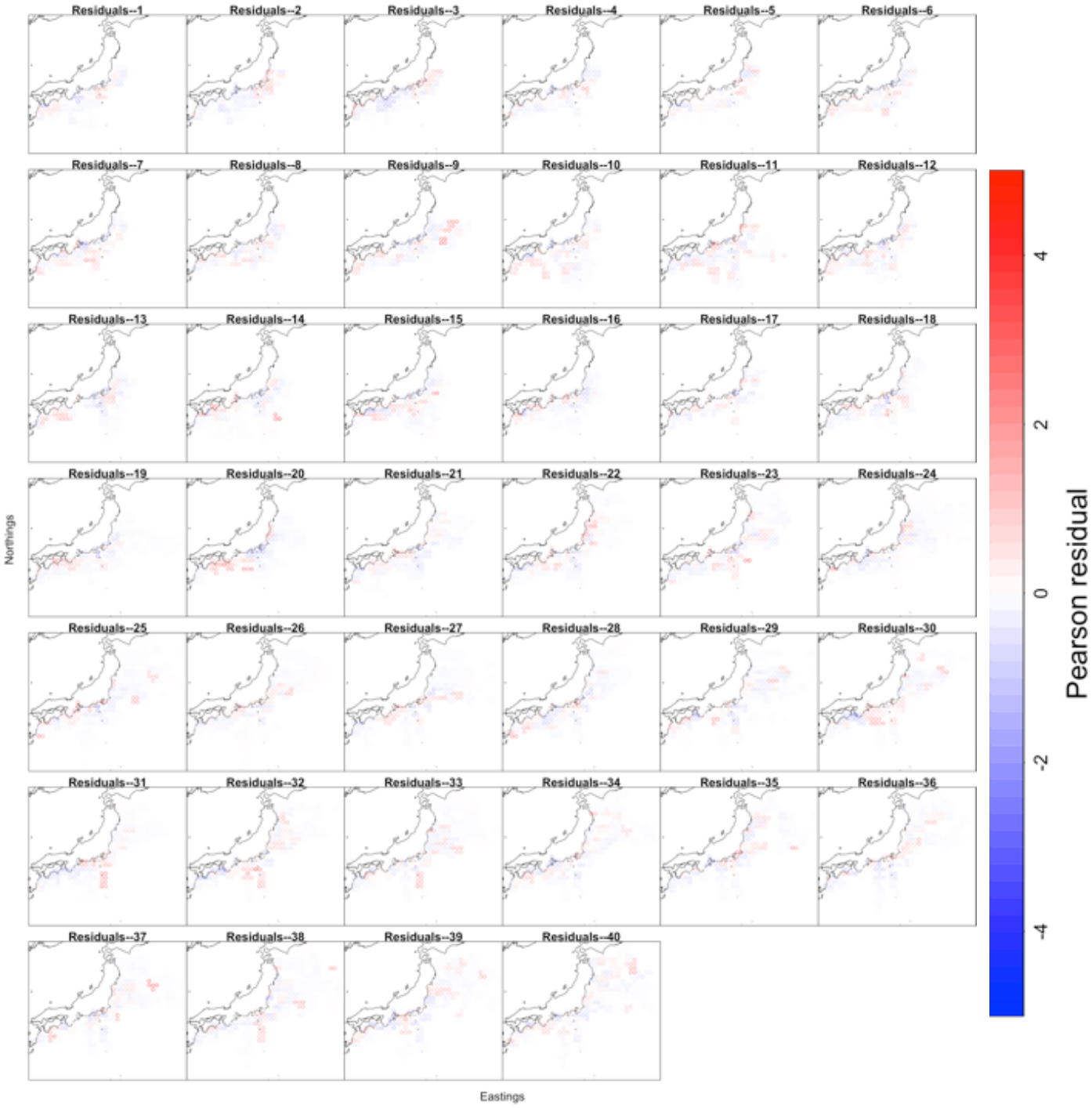

Fig. S13

Pearson residuals for encounter probability by knot.

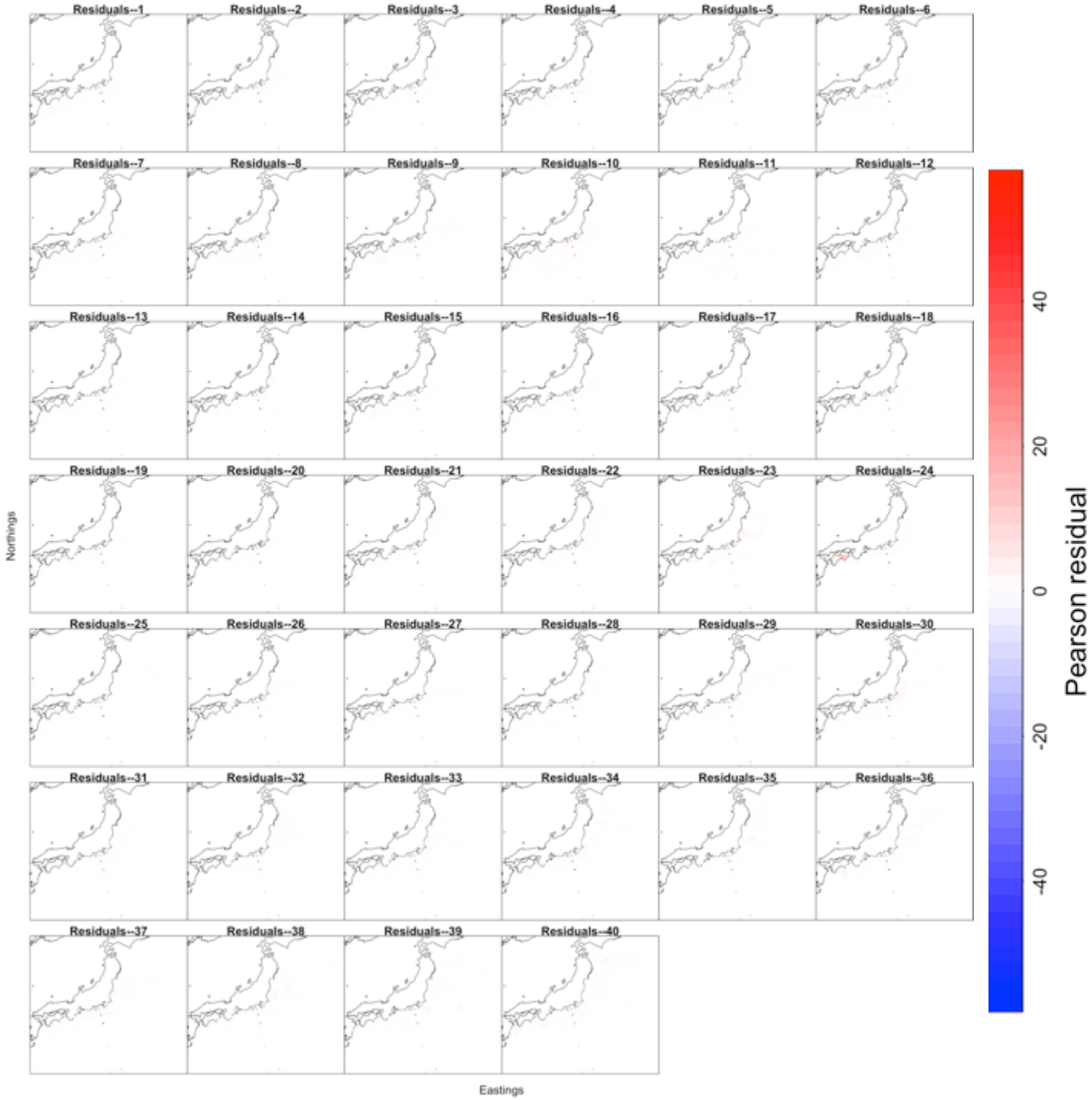

Fig. S14

Pearson residuals for positive catch rates by knot.

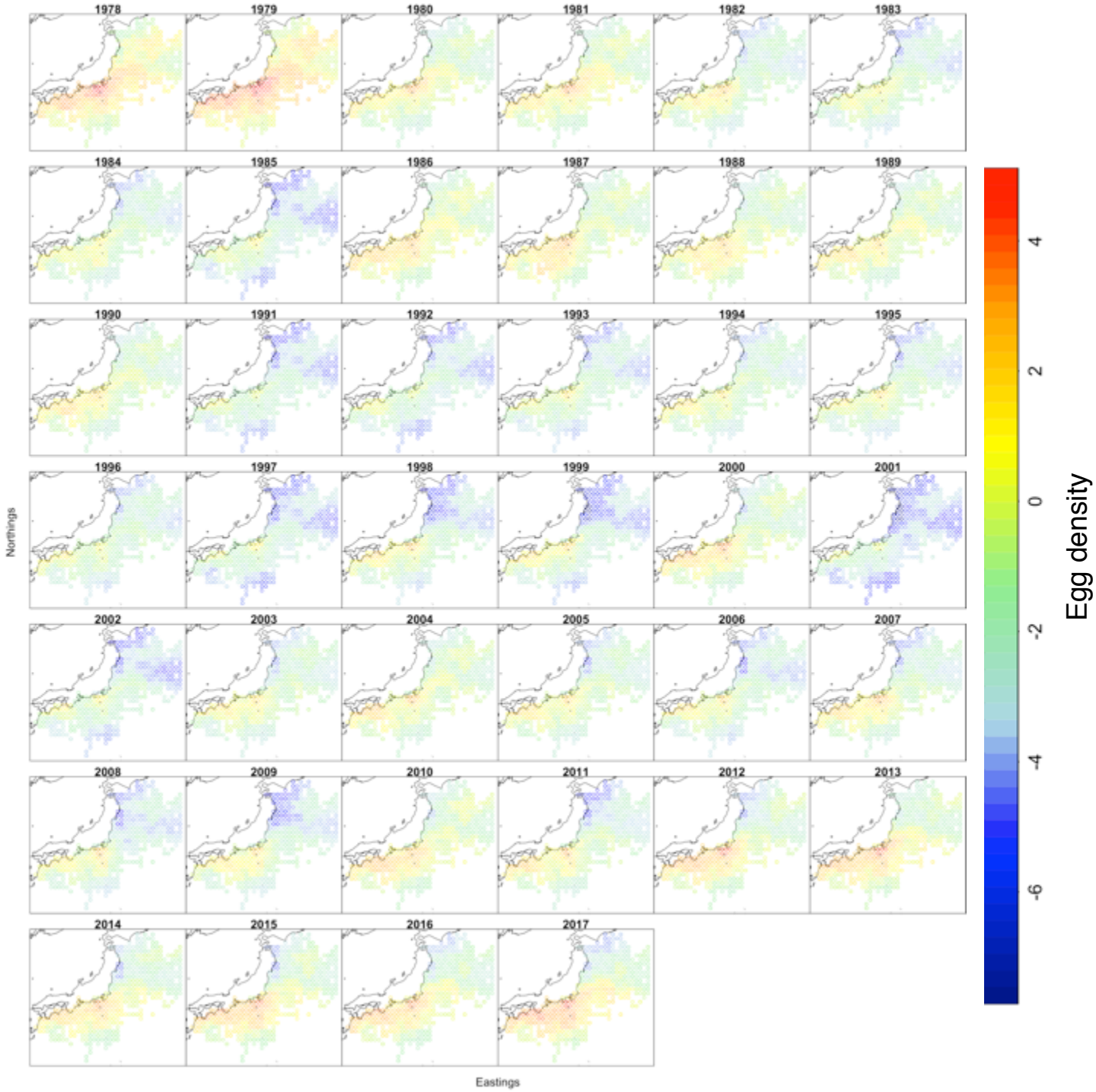

Fig. S15

Long-term changes in the spatial pattern of index of abundance $\hat{d}$ in March of chub mackerel *S. japonicus* in the western North Pacific.

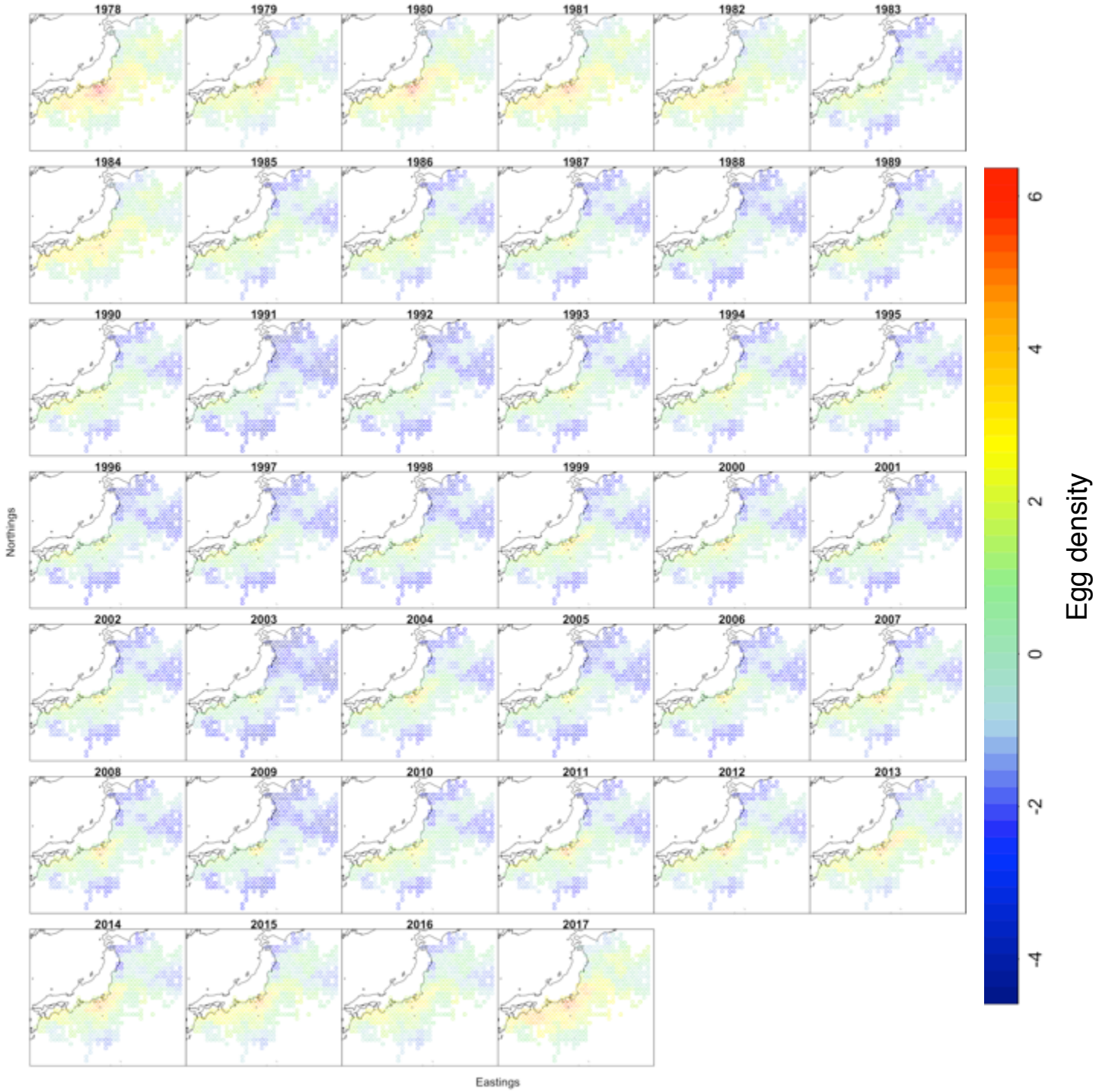

Fig. S16

Long-term changes in the spatial pattern of index of abundance $\hat{d}$ in April of chub mackerel *S. japonicus* in the western North Pacific.

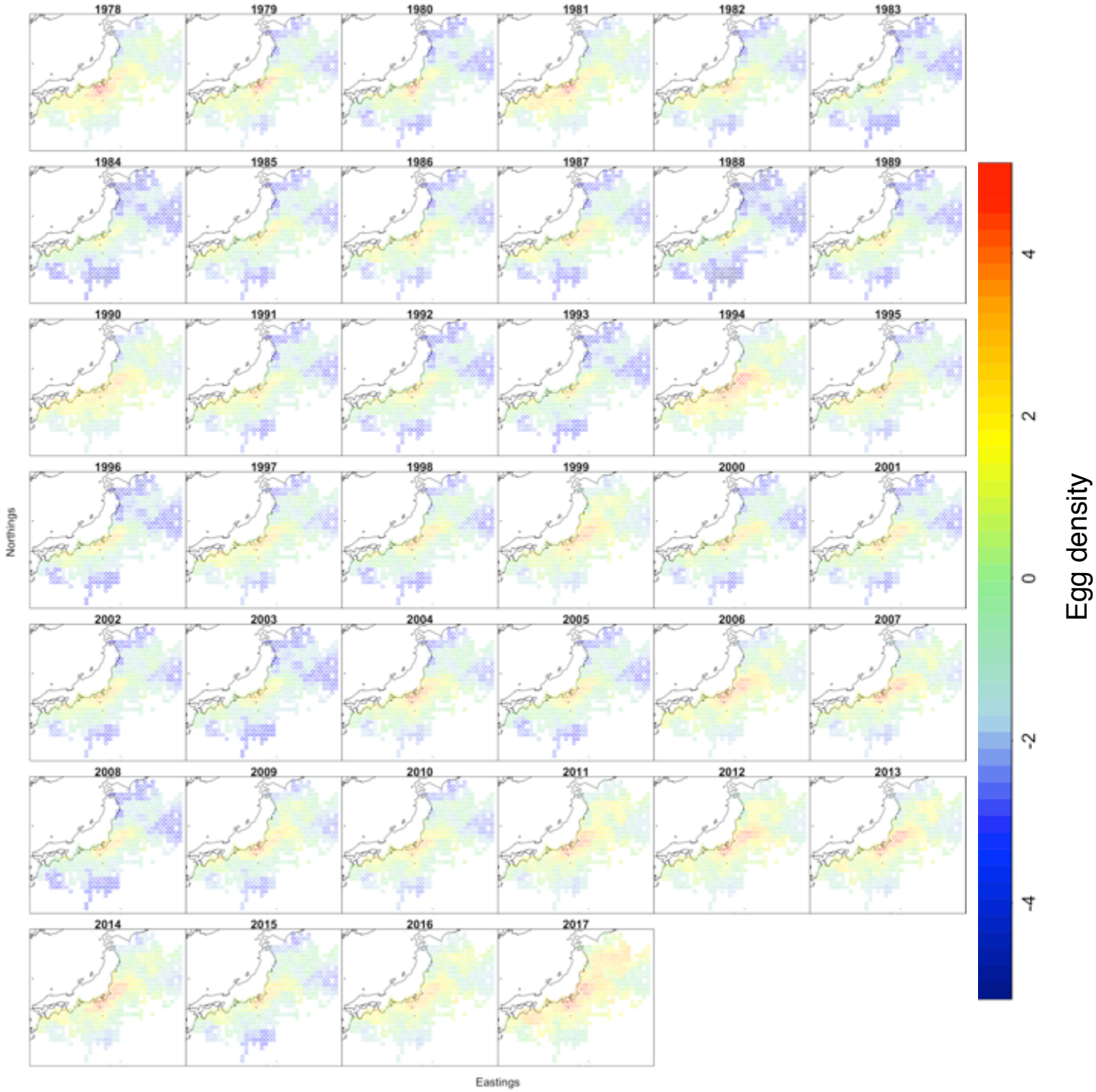

Fig. S17

Long-term changes in the spatial pattern of index of abundance $\hat{d}$ in May of chub mackerel *S. japonicus* in the western North Pacific.

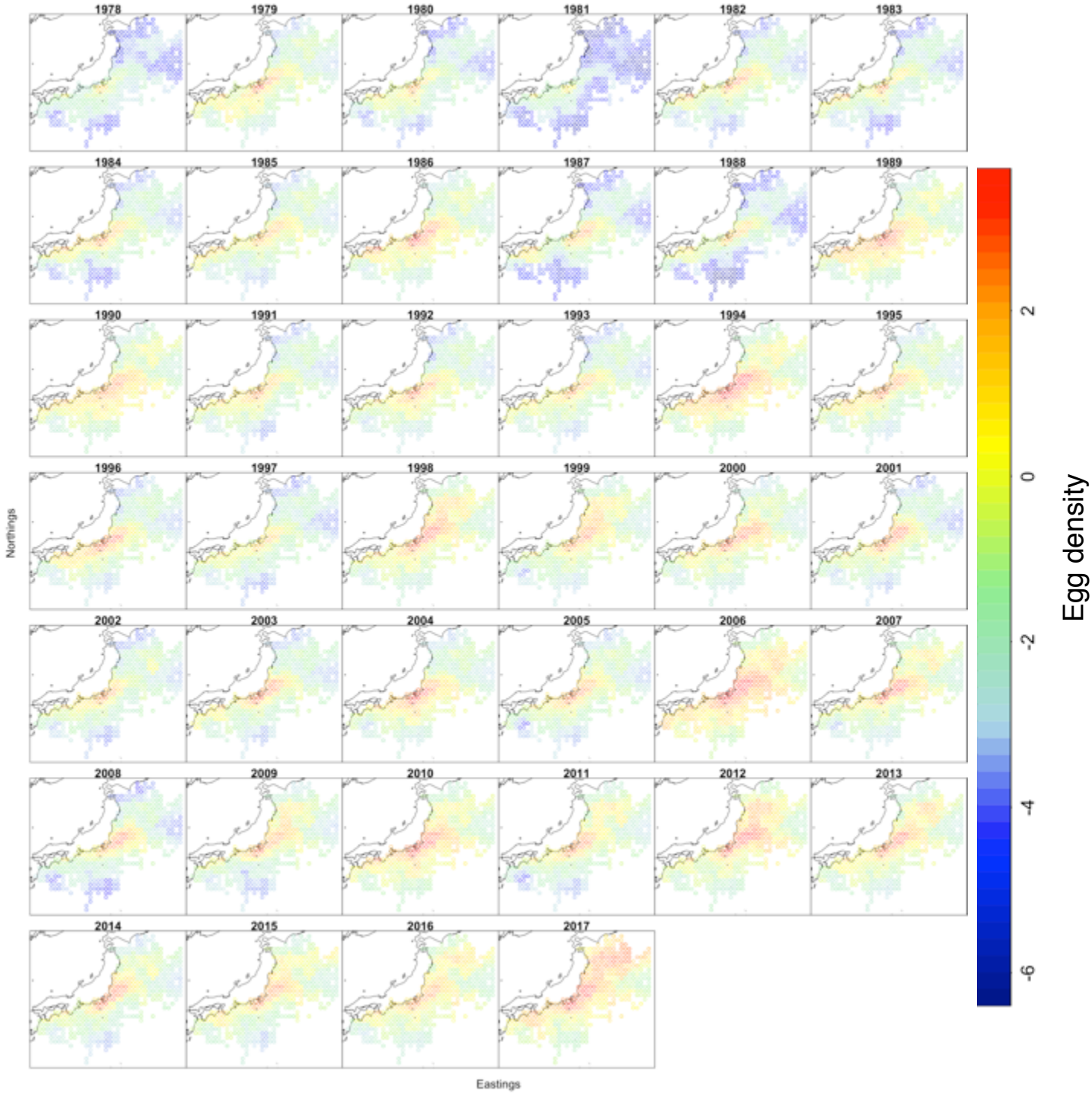

Fig. S18

Long-term changes in the spatial pattern of index of abundance $\hat{d}$ in June of chub mackerel *S. japonicus* in the western North Pacific.

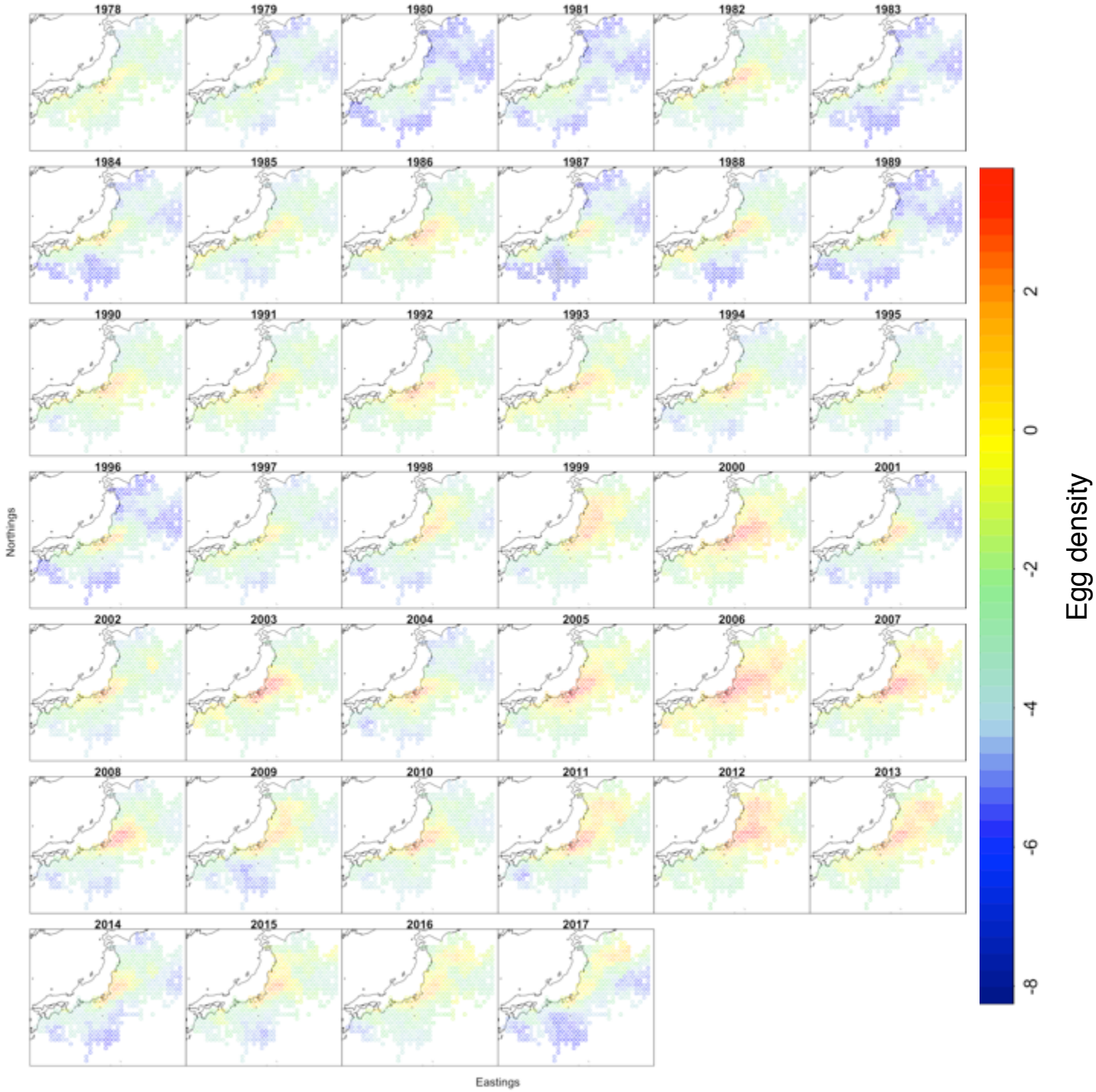

Fig. S19

Long-term changes in the spatial pattern of index of abundance $\hat{d}$ in July of chub mackerel *S. japonicus* in the western North Pacific.

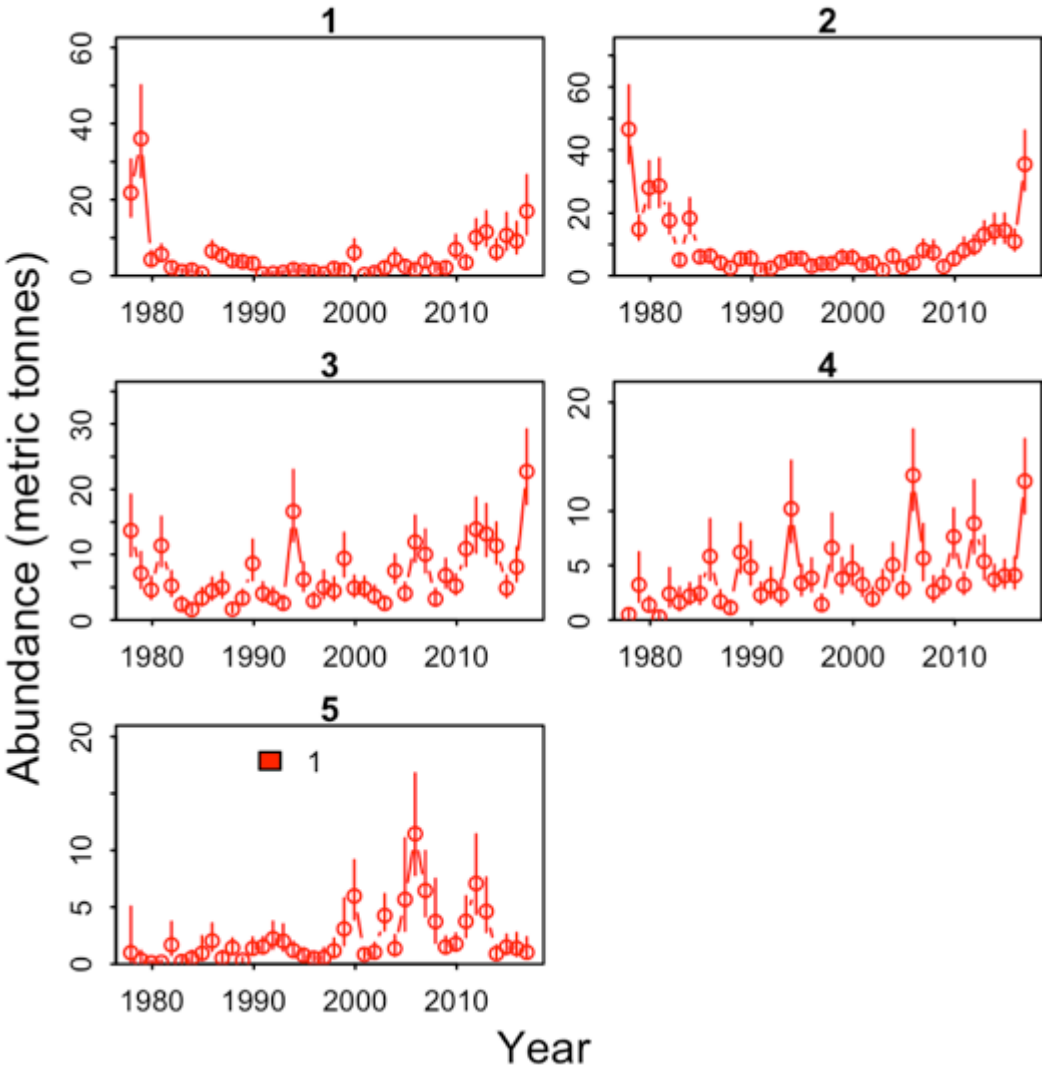

Fig. S20

Long-term changes in the index of abundance $\widehat{D}$ in from March (No. 1) to July (No. 5) of chub mackerel *S. japonicus* in the western North Pacific. The x-axis is year and the y-axis is the index of abundance.

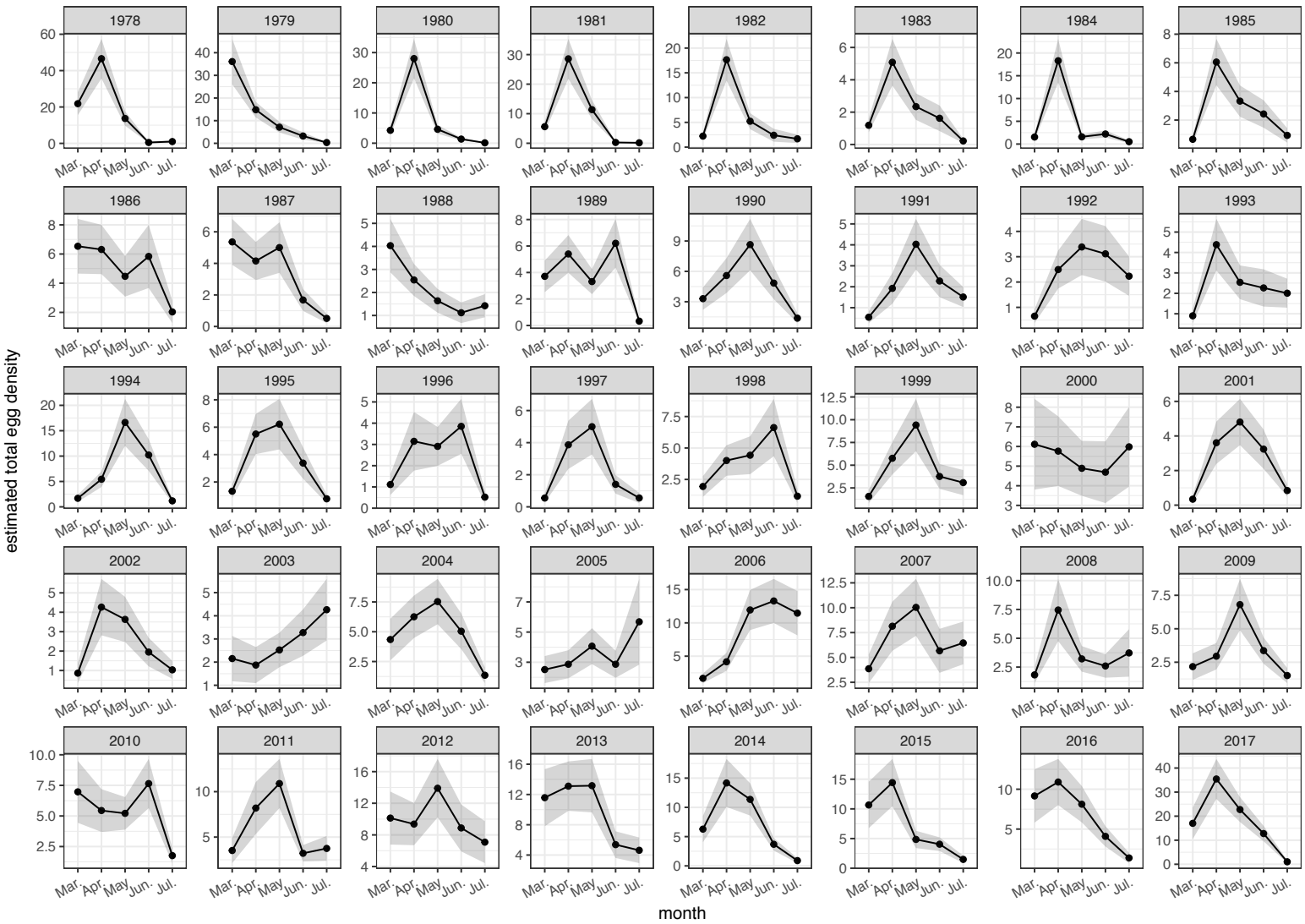

Fig. S21

Annual pattern of the index of abundance $\widehat{D}$ from March to July of chub mackerel *S. japonicus* in the western North Pacific. The x-axis is month and the y-axis is estimated density.

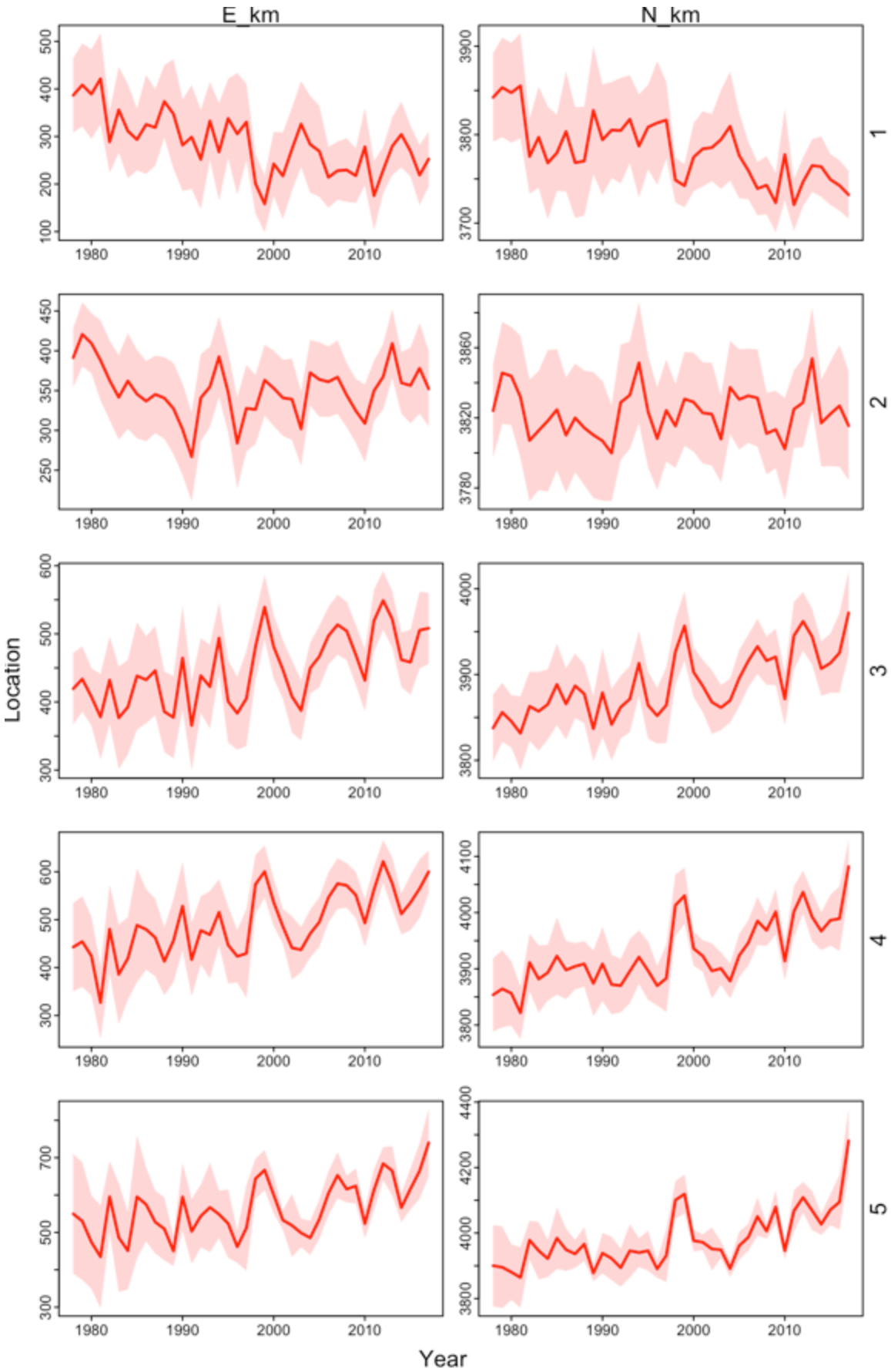

Fig. S22

Long-term changes in the geographical location of COG from March (No. 1) to July (No. 5) of chub mackerel *S. japonicus* in the western North Pacific. The x-axis is year and the y-axis is location.

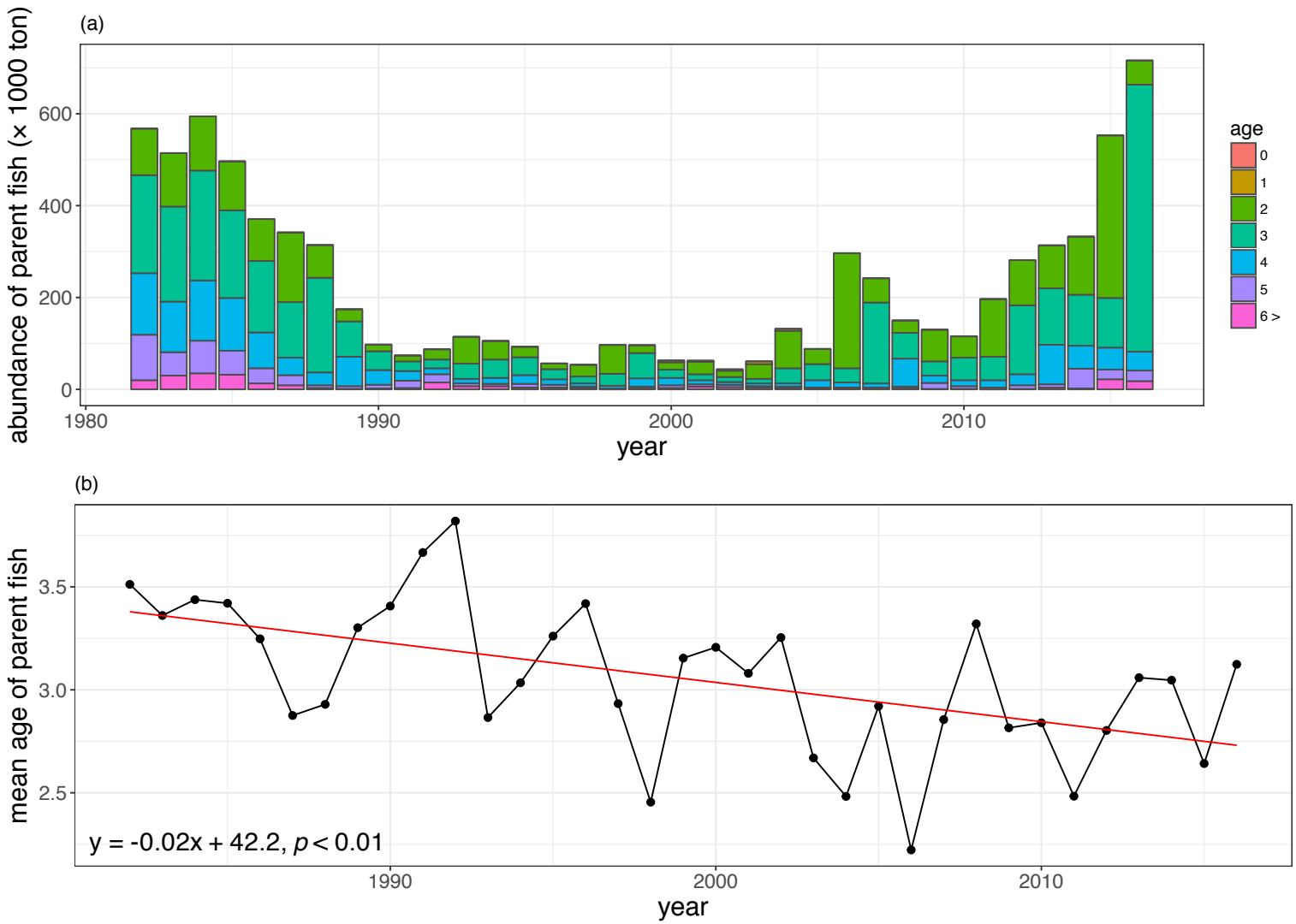

Fig. S23
Temporal changes in (a) age structure and (b) mean age of parental fish of chub mackerel during 1982 to 2017. The x-axis is year and the y-axis is (a) abundance of parental fish and (b) mean age of parental fish, respectively.

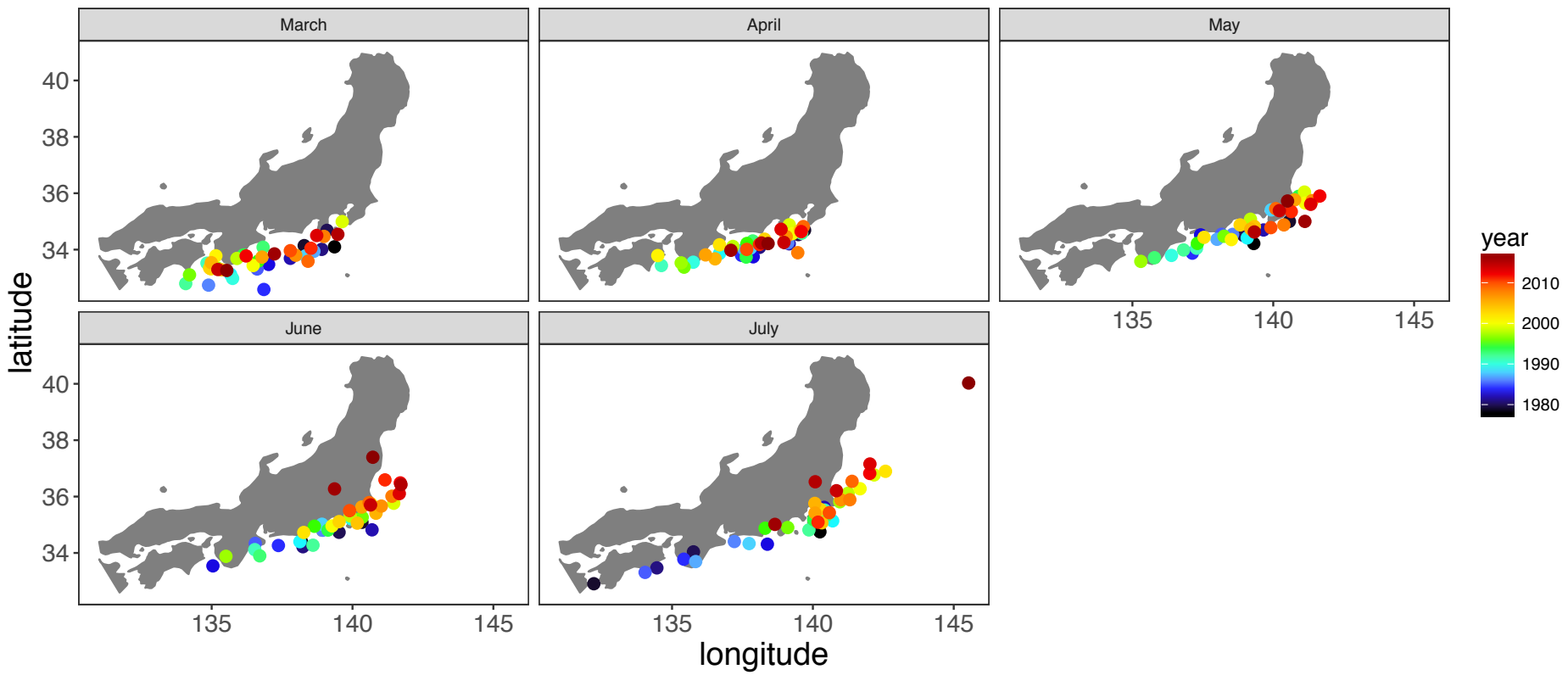

Fig. S24
Long-term changes in the Centre of Gravity (COG) of the raw egg density in each month, which was calculated from eq. (1) and eq. (2). The x-axis is the longitude and the y-axis is the latitude.

Table S1: Long-term trend of SST in each location by linear regression analysis. Locations correspond to Fig. A5a.

	Loc. 1		Loc. 3		Loc. 5		Loc. 7		Loc. 9		Loc. 11	
Month and variables	slope	*p*	slope	*p*	slope	*p*	slope	*p*	slope	*p*	slope	*p*
March												
year	0.025	0.02	0.023	0.07	0.020	0.10	0.013	0.38	0.015	0.28	0.010	0.50
April												
year	0.020	0.16	0.16	0.20	0.016	0.22	0.014	0.38	0.015	0.32	0.010	0.50
May												
year	0.028	0.06	0.06	< 0.05	0.044	< 0.01	0.038	< 0.05	0.036	< 0.05	0.029	0.05
June												
year	0.032	< 0.05	0.03	< 0.01	0.052	< 0.01	0.050	< 0.01	0.051	< 0.01	0.058	< 0.01
July												
year	0.033	< 0.05	0.01	< 0.05	0.035	< 0.01	0.041	< 0.01	0.044	< 0.01	0.051	< 0.01