NPFC-2025-SSC PS16-IP02 (Rev. 1)

Seasonal variation in maturity ogive of Pacific saury

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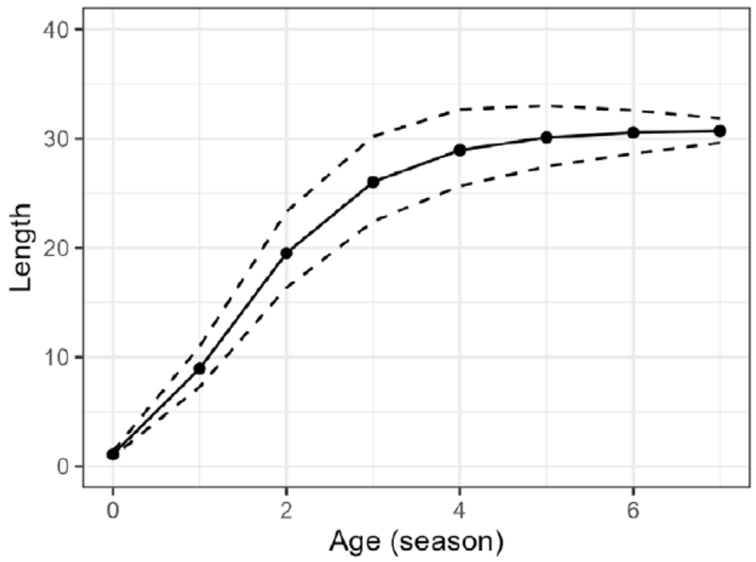
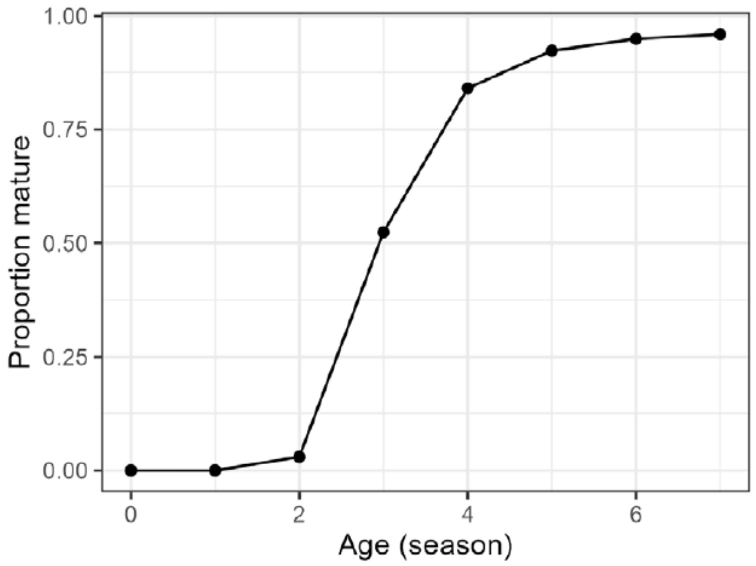
Seasonal model

Lifespan of cohorts (Step 18)

	Year 1				Year 2				Year 3			
	Season 1	Season 2	Season 3	Season 4	Season 1	Season 2	Season 3	Season 4	Season 1	Season 2	Season 3	Season 4
Season 1 cohort	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 7 (plus group)	Age 7 (plus group)	Age 7 (plus group)	Age 7 (plus group)
Season 2 cohort		Age 0	Age 1	Age 2	...	...						
Season 3 cohort												
Season 4 cohort				Age 0	Age 1	Age 2	...	...				

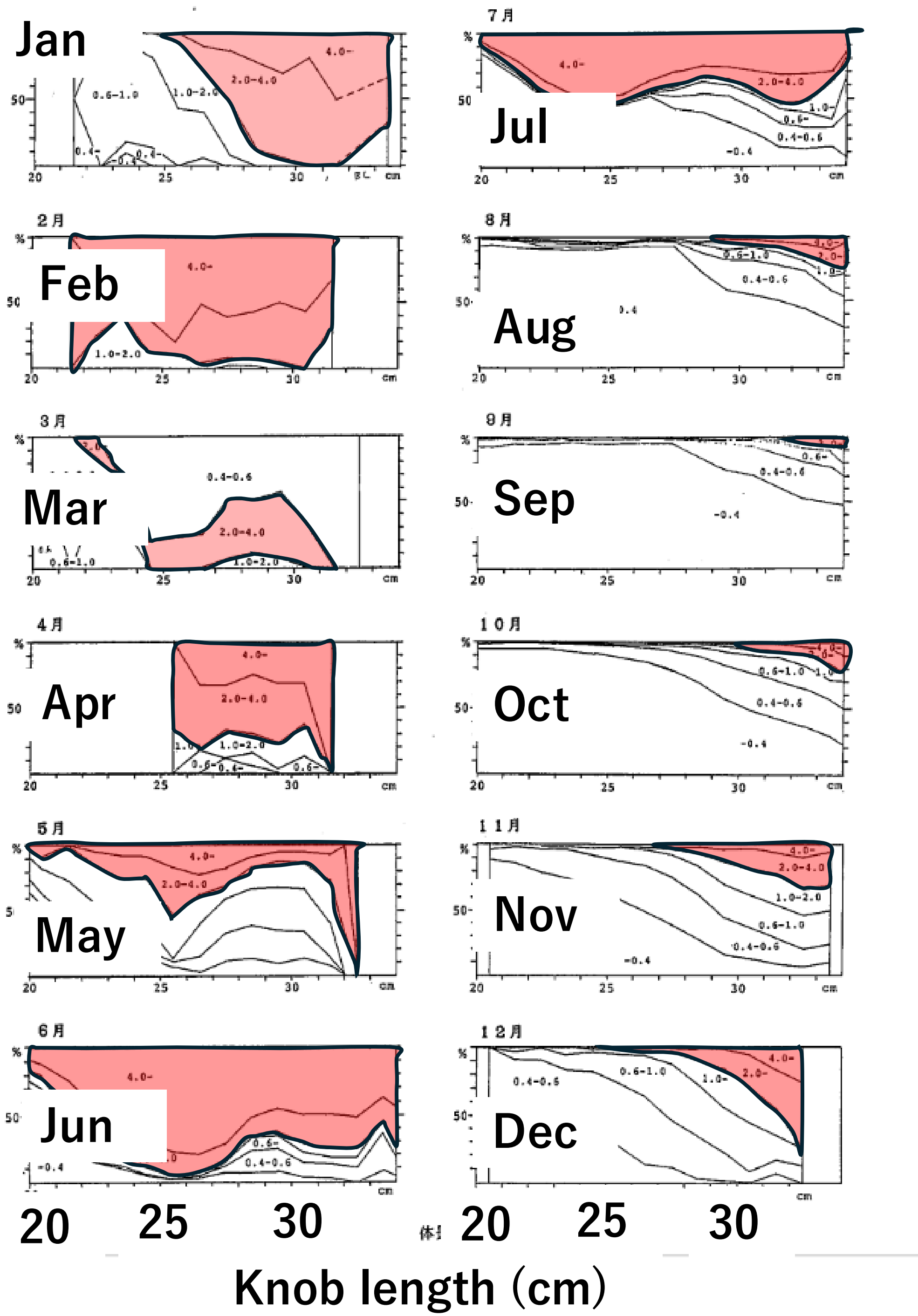




- Currently, in SS3, the seasonal structure is incorporated, and the maturation curve (the change in maturation probability with body length) is assumed to be the same across all seasons.
- However, it is known that the relationship between body length and maturation in Pacific saury (PS) varies greatly by season.

- Kosaka (2000) showed monthly change in relationships between knob length and gonad somatic index (GSI)
- Both large and small fish showed high GSI (>2) especially in winter
- Only a part of large fish showed GSI > 2 in other months.

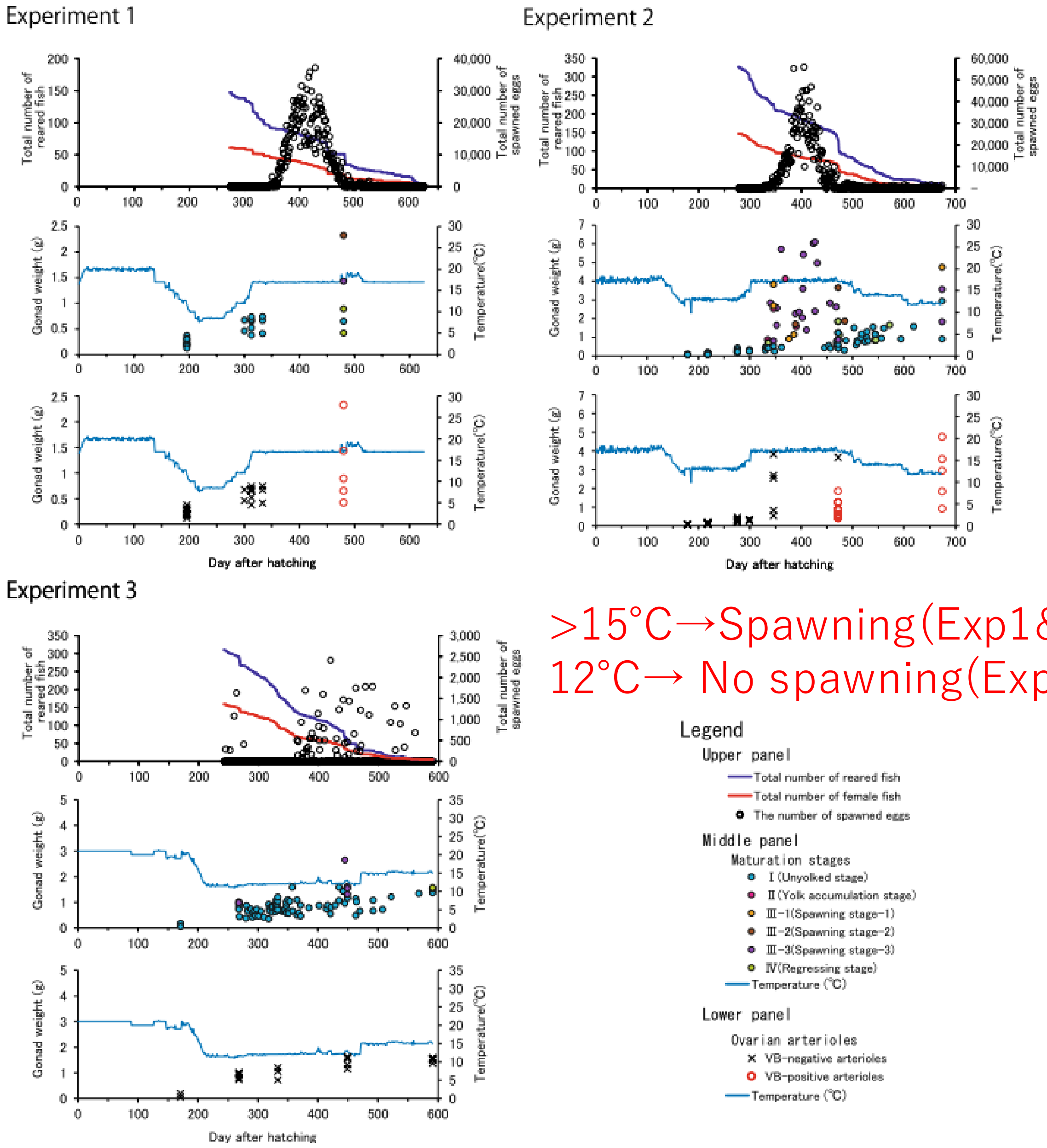
- However, information on the sampling areas and other details in Kosaka (2000) is insufficient, and it is unclear whether the samples are representative of the population.



Temperature affects maturation

Suyama et al. (2016)

- Pacific saury are distributed across a wide range of water temperatures.
- In rearing experiments (Suyama et al. 2016), it has been suggested that high water temperatures play a role in the progression of maturation.
- Therefore, it is expected that the relationship between body length and maturation varies with water temperature. This poses a significant challenge in deriving a maturation curve that accurately represents the population.
- In this study, we conducted an analysis focusing on how the relationship between body length and maturation changes with water temperature in each season.



>15°C→Spawning(Exp1&2)
12°C→ No spawning(Exp3)

Data

- Data1: Knob length (KnL, cm) and gonad weight (GW, g) of PS with ovarian tissue sections stained with hematoxylin and eosin in each season except for S3 (n=6893) in 1996-2024.

- Data2: KnL and GW of PS female (n=60852) caught by survey and fishery in each season in 1996-2019.

- GI=GW/KnL^3*100000

- Season:S1(Jan-Mar),S2(Apr-Jul), S3(Aug-Sep),S4(Oct-Dec)

Data

- D
  F nd
  e

Mature (1) or Immature (0)
GI
No data for S3

- Data2: KnL and GW of PS female (n=60852) caught by survey and fishery in each season in 1996-2019.

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Data

- D Mature (1) or Immature (0)
  F GI nd
  e No data for S3

- D GI
  s SST
  KnL
  Location

- GI=GW/KnL^3*100000

- Season:S1(Jan-Mar),S2(Apr-Jul), S3(Aug-Sep),S4(Oct-Dec)

Analysis

Following analysis was conducted for each season

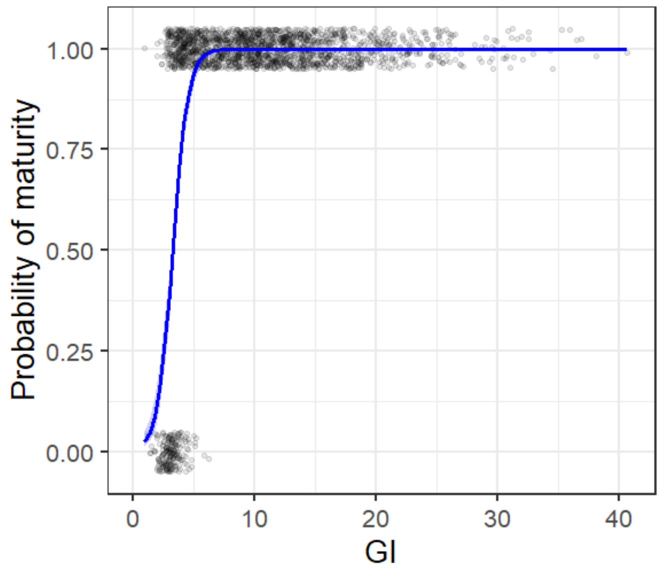
- Based on observations of ovarian tissue sections (Data1), individuals showing yolk accumulation were defined as “mature”, ovaries with more than half of the yolked oocytes in the atretic stages was defined as “ceased spawning”, and all others were defined as “immature”.

- In Data1, “mature” and “ceased spawning” individuals were coded as 1 and “immature” as 0, and a logistic regression of maturation on GI was performed using a GLM. Using the estimated models, the maturation probability for each individual in Data2 was predicted based on their GI.

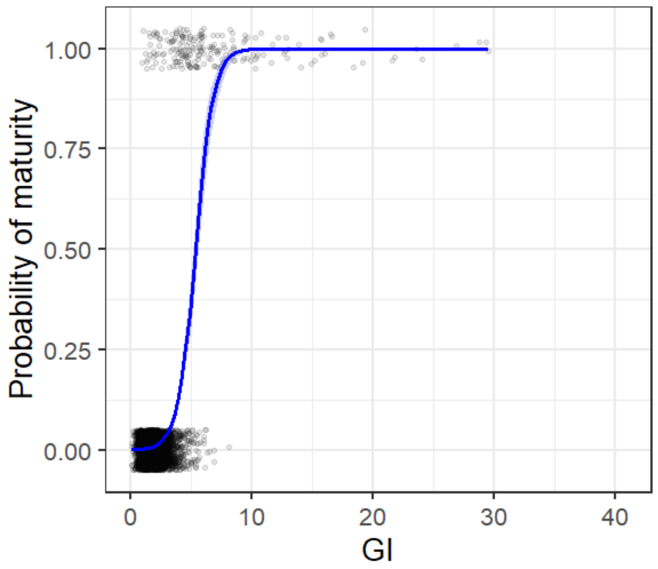
- Data1 contained no data in S3, therefore, we applied GLM analysis using all data from Data1 and applied to Data2 of S3.

Results (Relationships between GI and maturation)

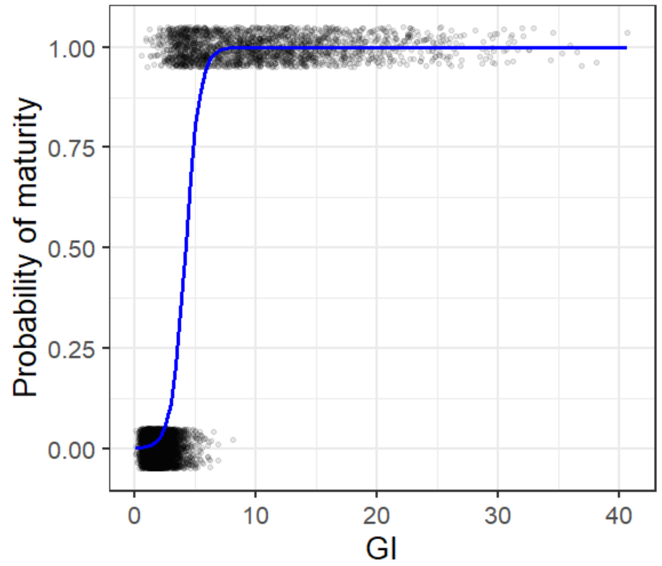
S1



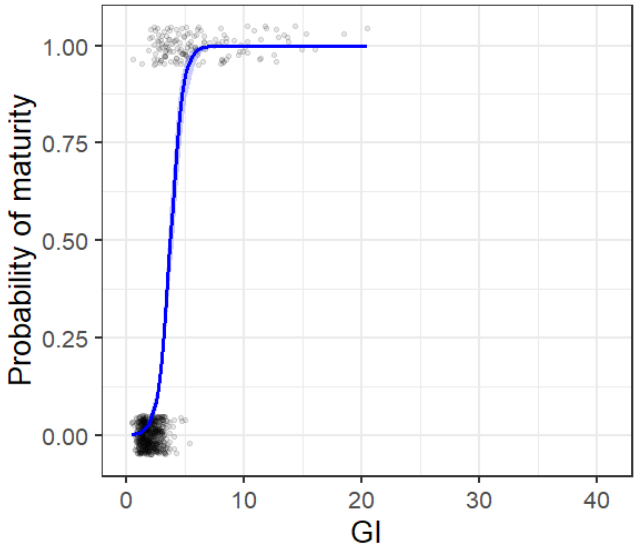
S2



S3(All seasons)



S4



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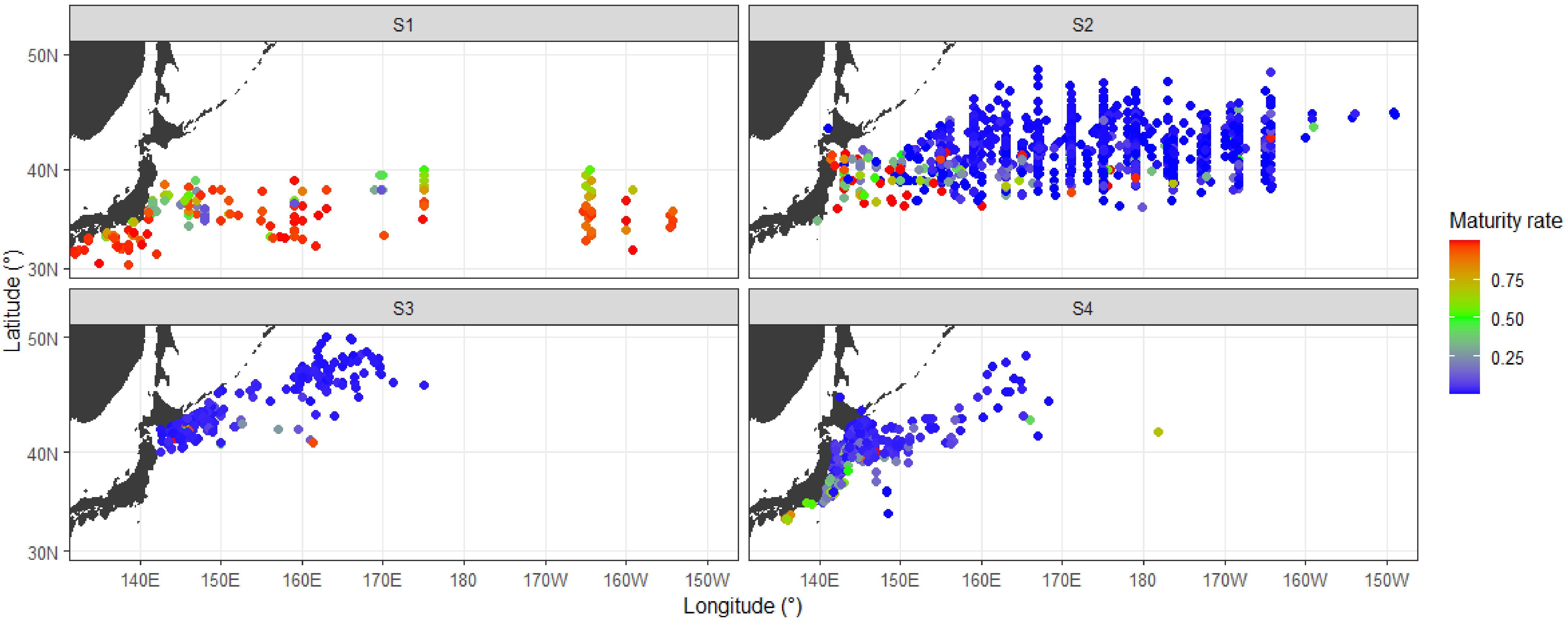
Results: spatial distribution of samples (Data2)



Analysis

- A generalized additive model (GAM) was fitted to the probit-transformed maturation probability, assuming Gaussian errors as follows.

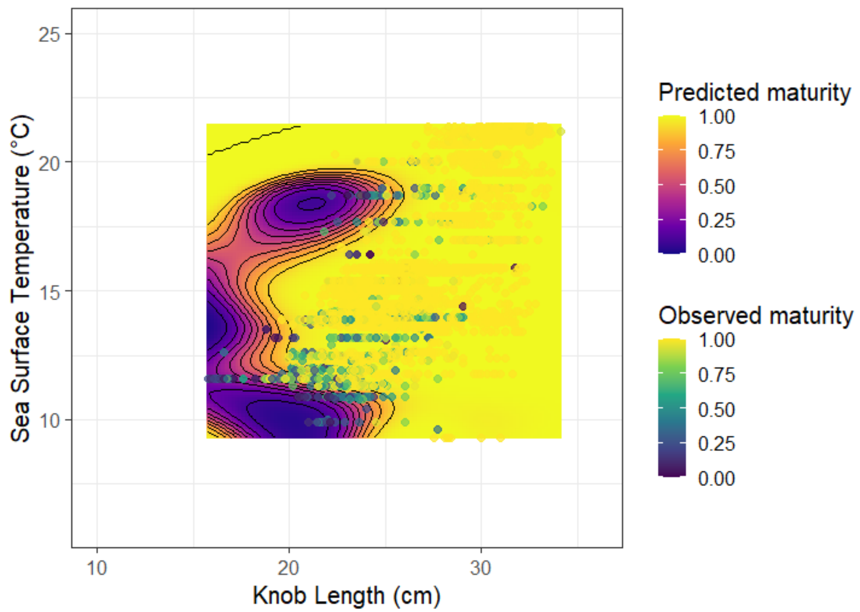
Maturation probability＝s(KnL)　＋s(SST)　＋ti(KnL,SST)

- Maturity ogive in each season was estimated by GAM with same manner as follows.

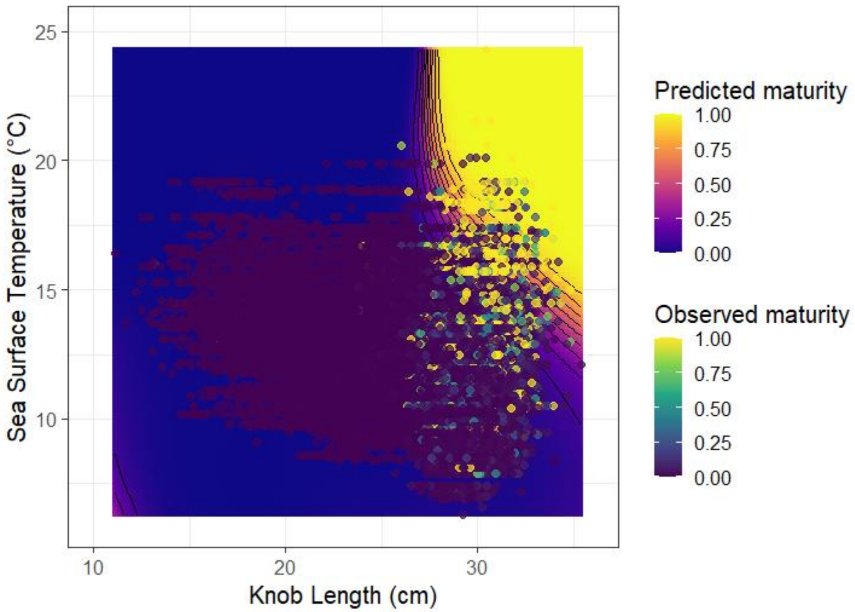
Maturation probability＝s(KnL)

Results: maturation probability against KnL and SST in each season

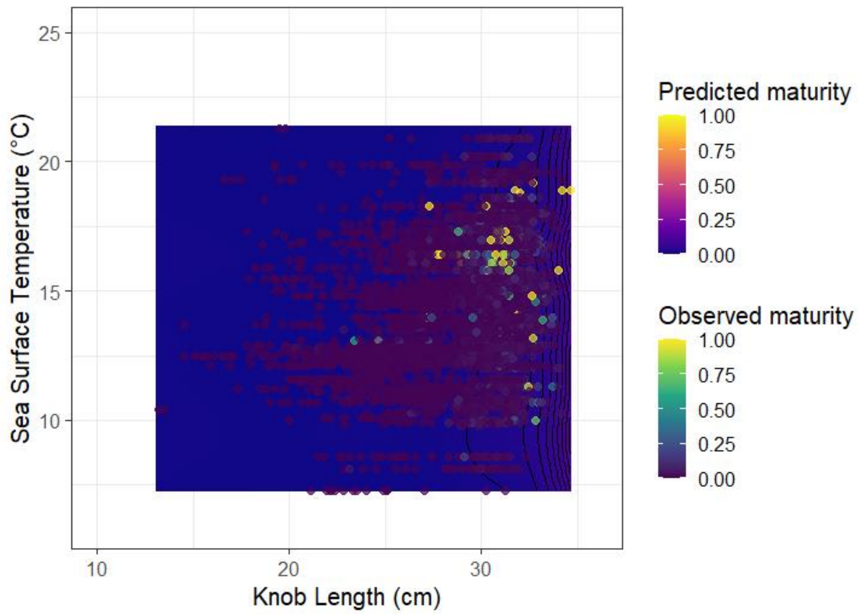
S1



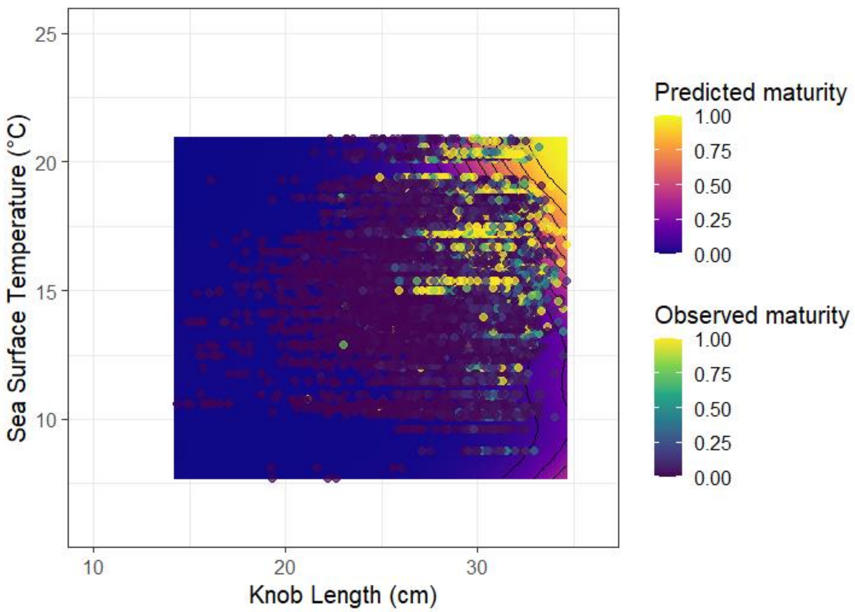
S2



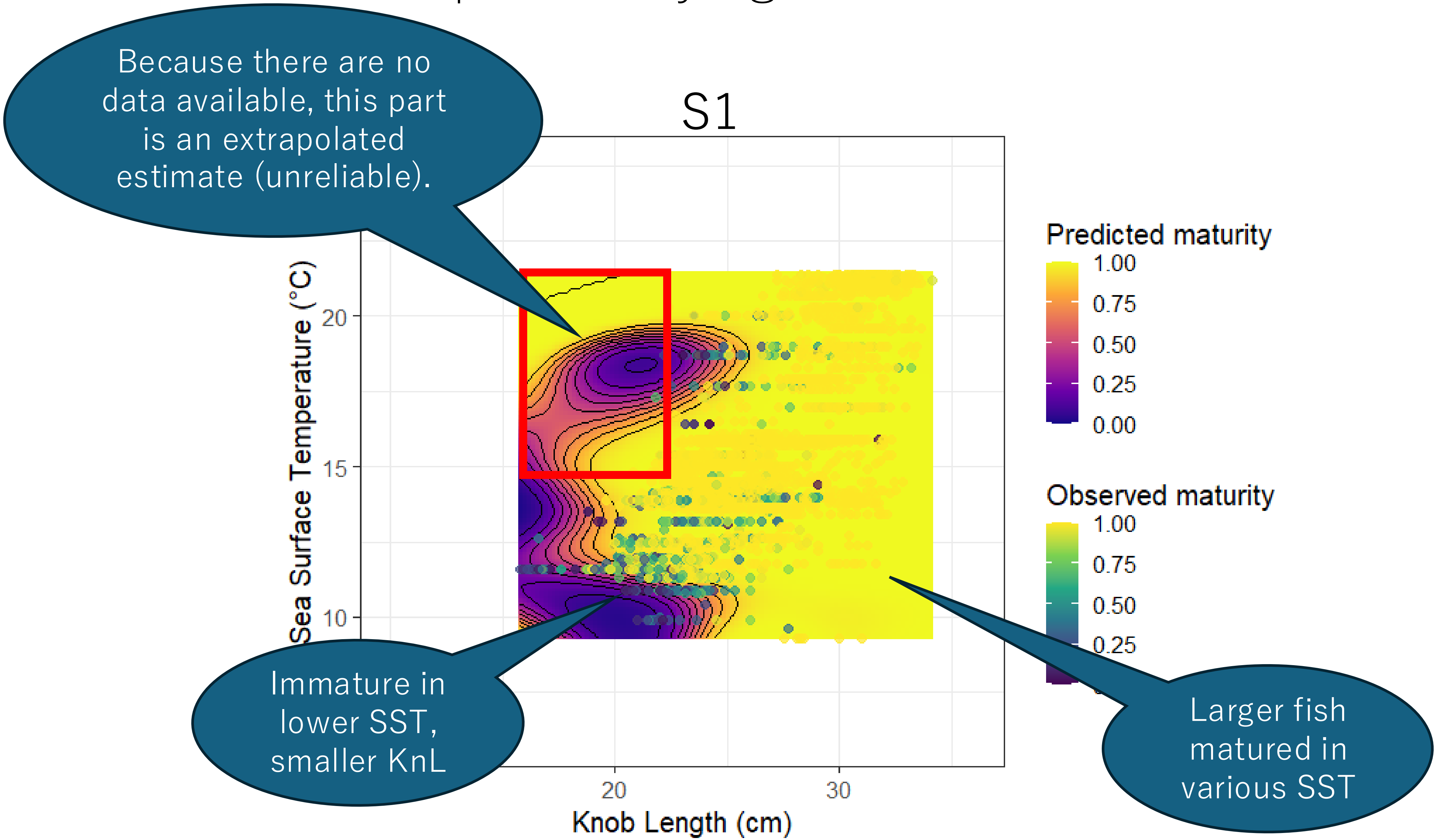
S3



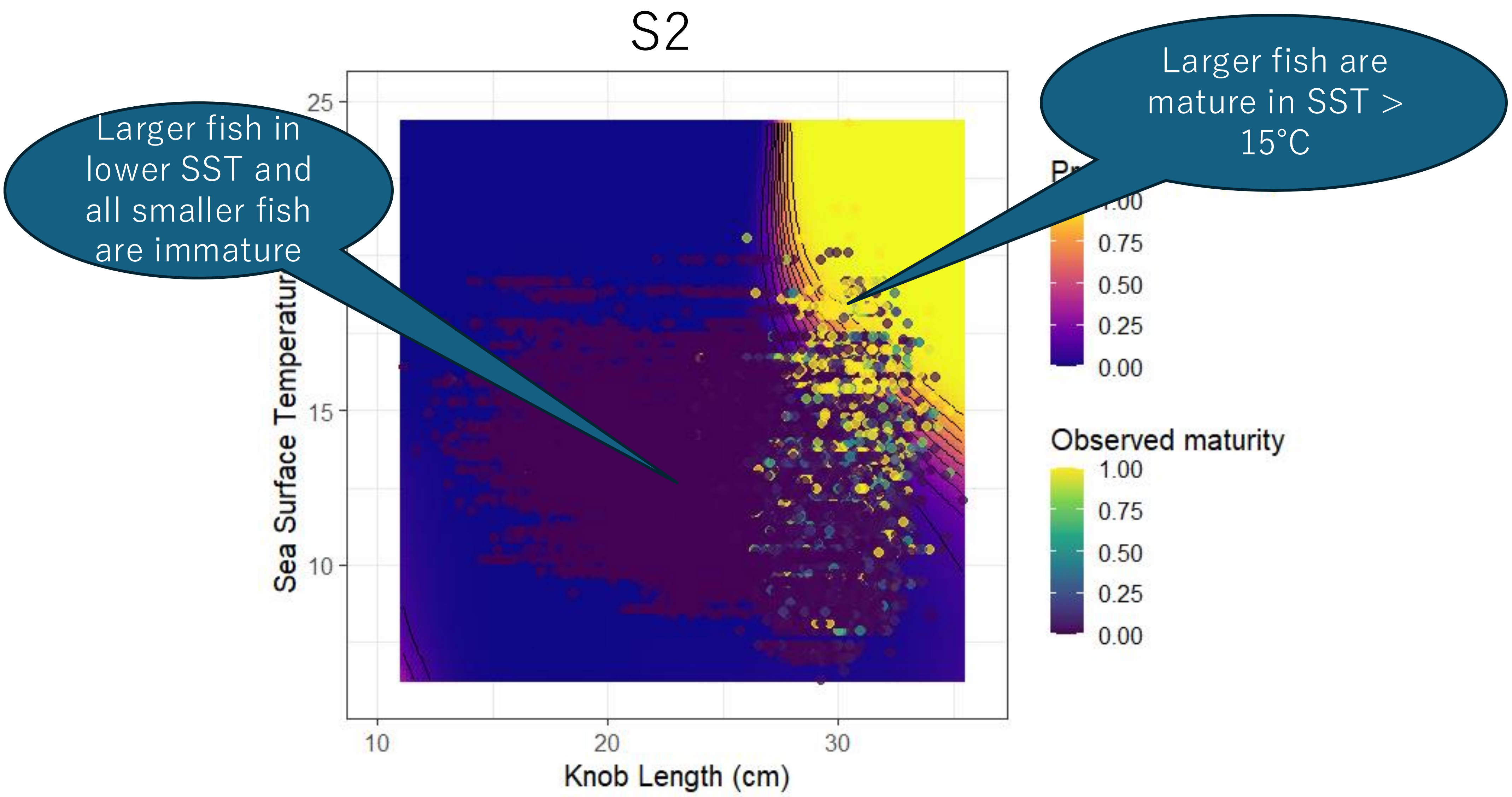
S4



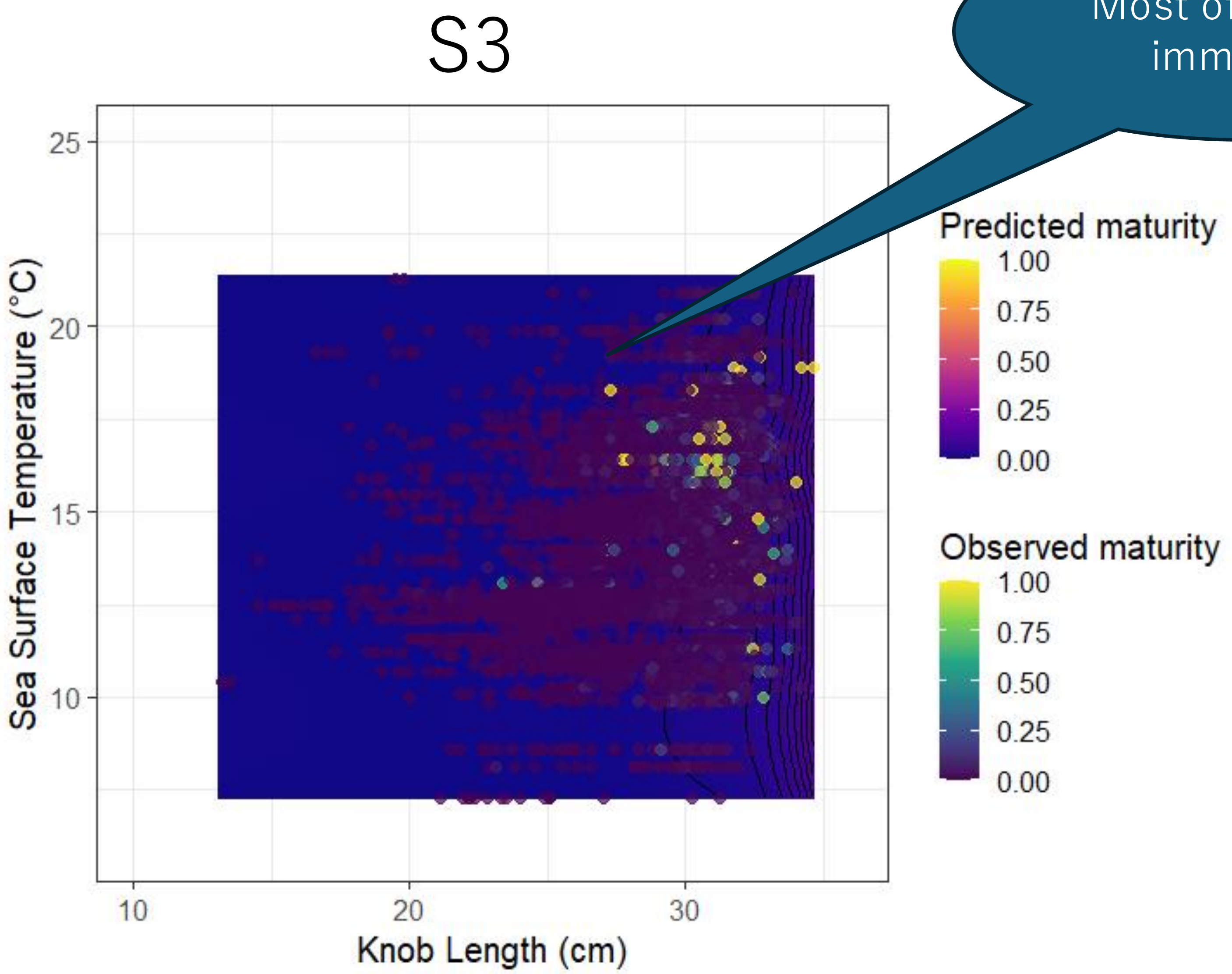
Results: maturation probability against KnL and SST in each season



Results: maturation probability against KnL and SST in each season

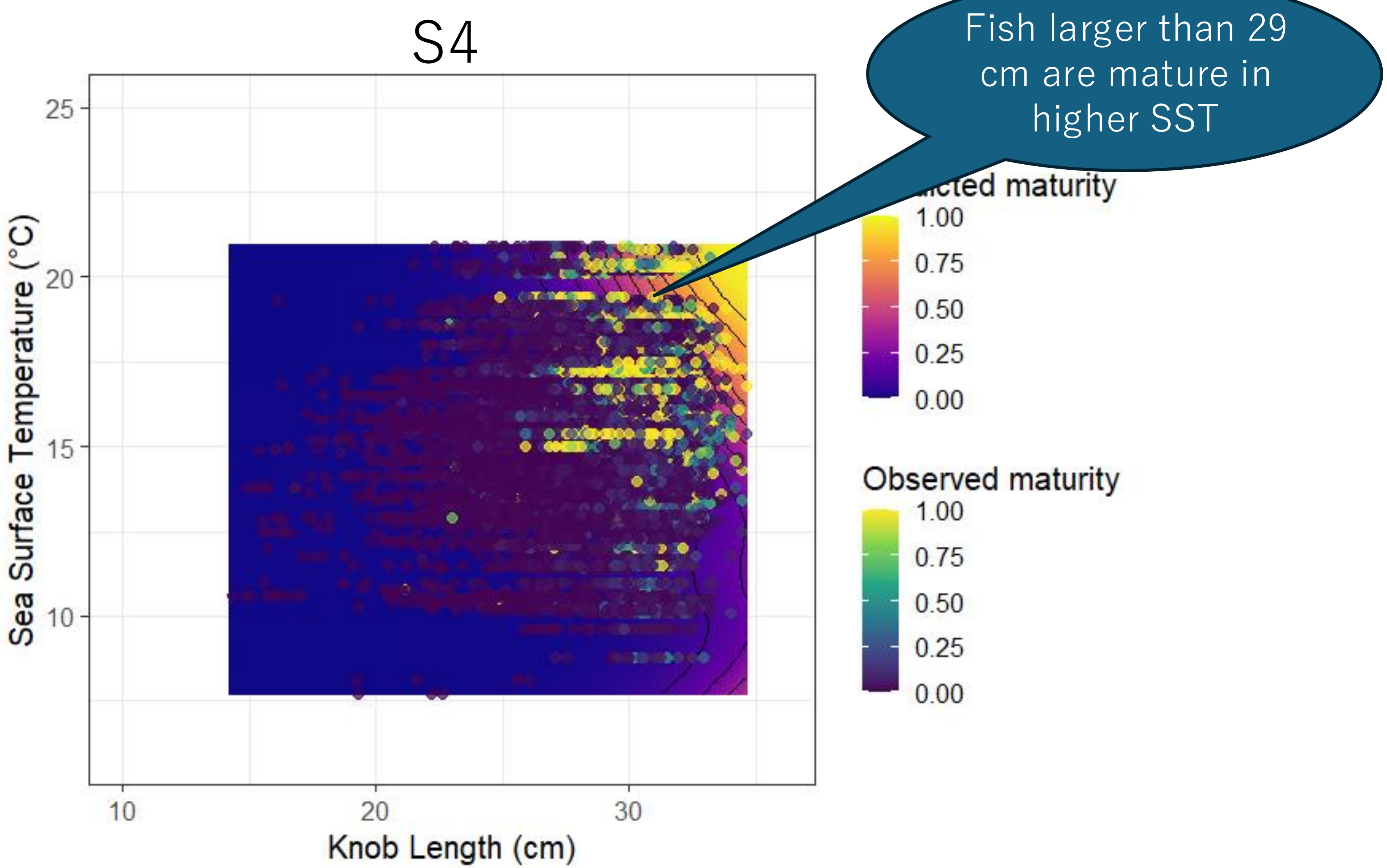


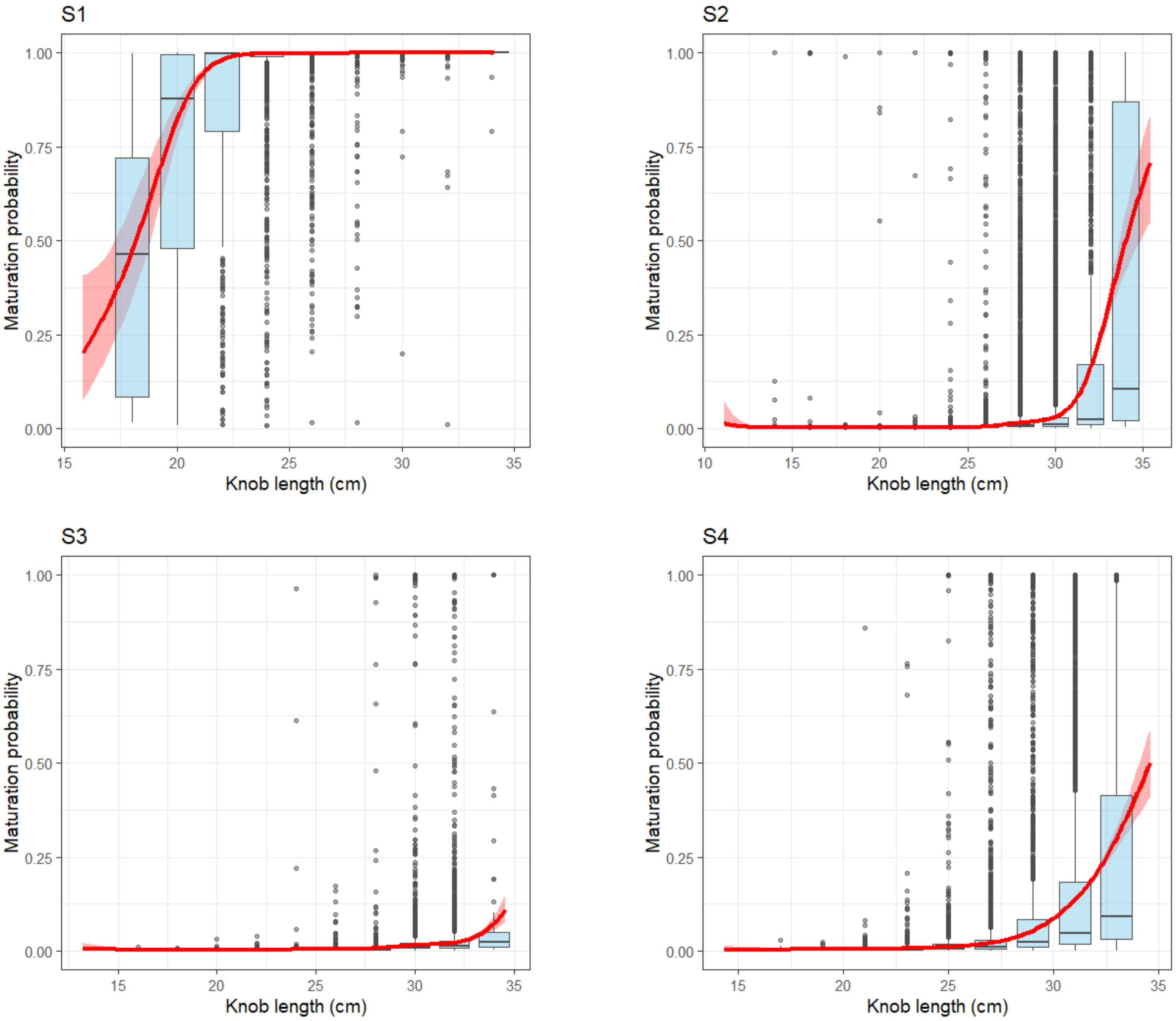
Results: maturation probability against KnL and SST in each season



Most of fish are immature

Results: maturation probability against KnL and SST in each season




S1
S2
S3
S4
Maturation probability
Knob length (cm)
0.00
0.25
0.50
0.75
1.00
10
15
20
25
30
35

Seasonal model

Lifespan of cohorts (Step 18)

	Year 1				Year 2				Year 3			
	Season 1	Season 2	Season 3	Season 4	Season 1	Season 2	Season 3	Season 4	Season 1	Season 2	Season 3	Season 4
Season 1 cohort	Age 0	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 7 (plus group)	Age 7 (plus group)	Age 7 (plus group)	Age 7 (plus group)
Season 2 cohort		Age 0	Age 1	Age 2	...	...						
Season 3 cohort												
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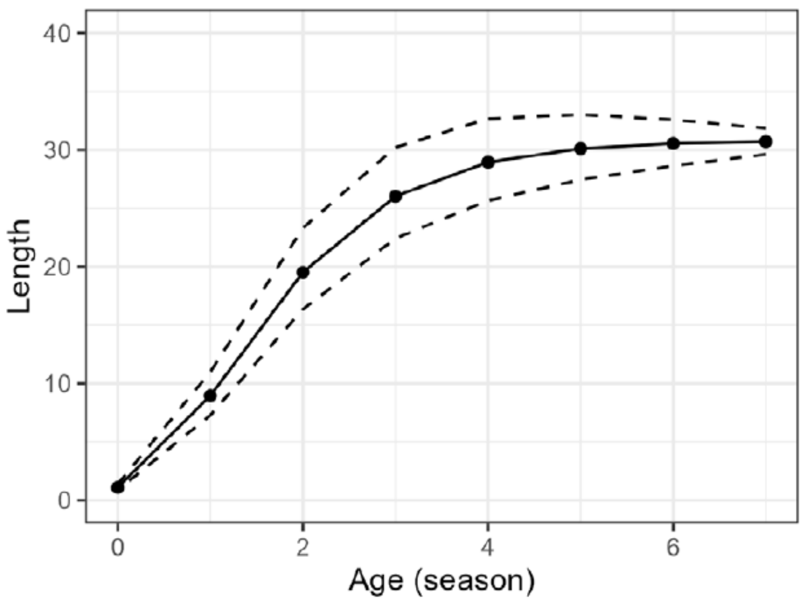
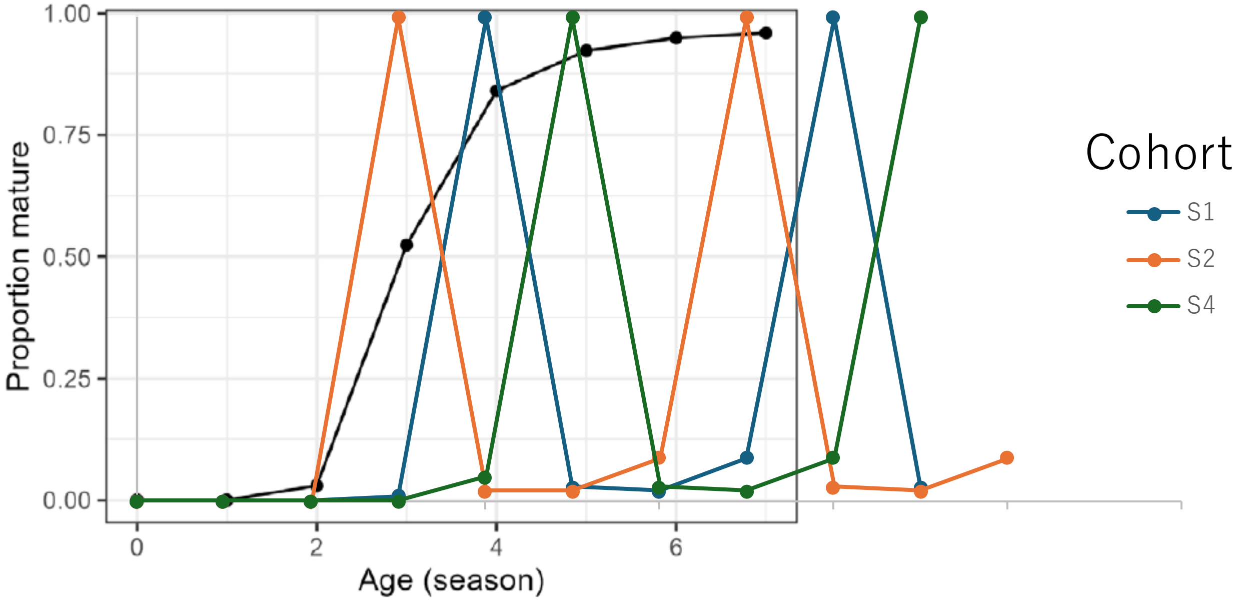
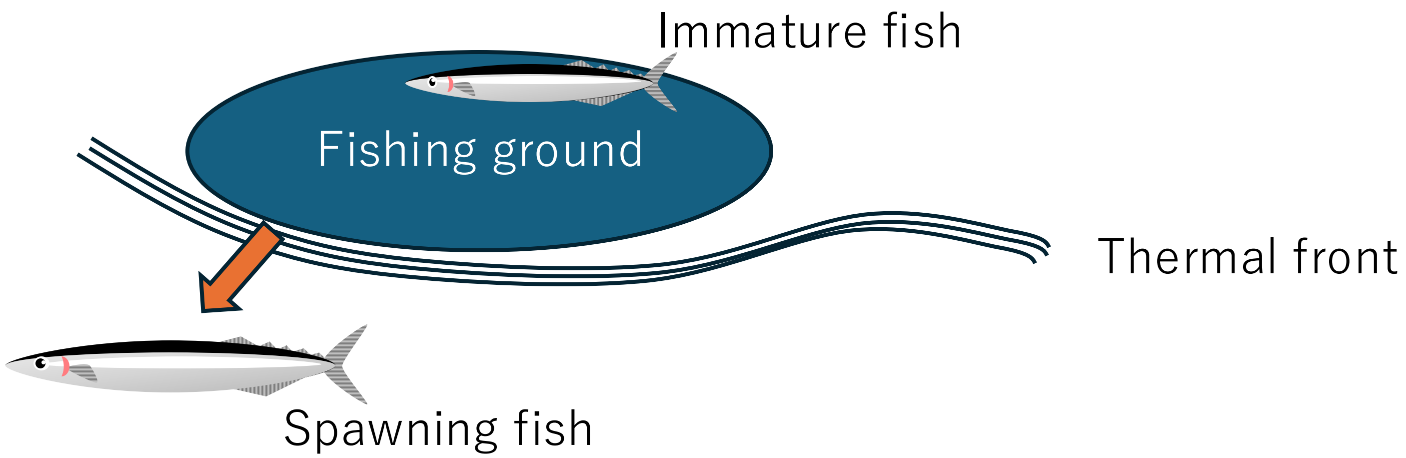




- In S2, S3, and S4, a non-negligible proportion of individuals remain immature regardless of body length. Therefore, the maturation schedule shows a pulse-like peak in S1.

Notation

- In S3 and S4, most of samples were collected by fisheries.
- Many of the mature fish are considered to move southward from the fishing grounds to spawn (Kimura et al. 1961).
- We do not have any information on the abundance of fish schools outside the fishing grounds.
- Therefore, it is difficult to estimate maturity ogive with weighting by area, at least in S4.



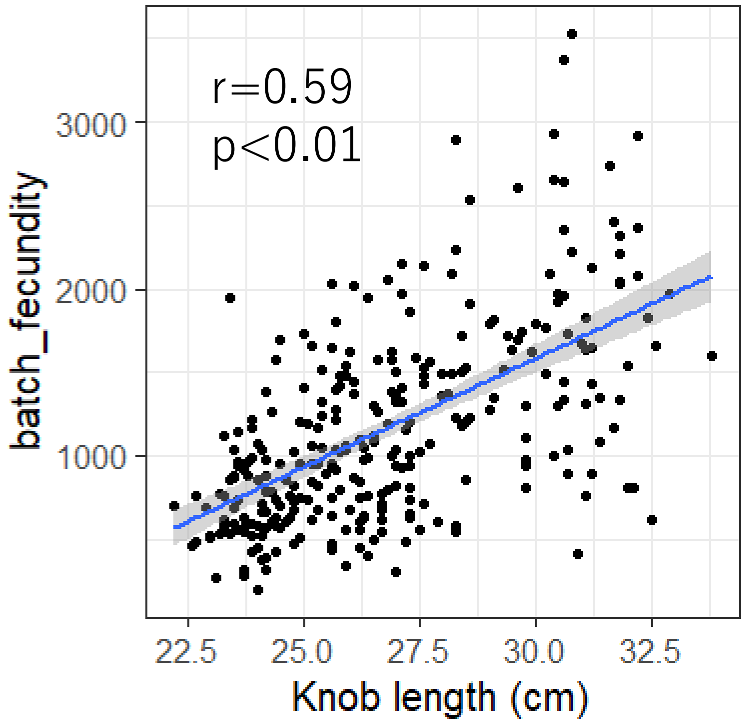
Other points

NPFC-2023-SSC PS11-WP08

Table 1 Summary of age-specific spawning parameters of Pacific saury

	Age 0					Age 1				
Year	2015	2020	2021	2022		1996	1998	1996	1997	1997
Season	W	W	W	W		W	W	S	S	A
Total number of ovary samples	77	123	81	284		83	342	221	150	331
Spawning frequency in days	3.3	6.7	4.2	8.6		2.9	3.7	3.9	3.6	3.7
Batch fecundity in thousands (sample number)	1.5 (38)	0.9 (27)	0.9 (27)	0.7 (73)		2.4 (20)	2.4 (20)	2.8 (141)	3.5 (15)	2.2 (34)
Nubmber of eggs spawned per day per fish in hundreds	**4.6**	**1.3**	**2.1**	**0.8**	**1.5, 3.9**	**8.3**	**6.5**	**7.2**	**9.7**	**5.9**
Note	Field sampling				Tank rearing	Field sampling				
Reference	This study				Suyama (2013)	Kurita (2001)				

W:winter (Jan-Mar), S:spring (May), A:autumn (Oct)



- Not only the proportion of mature individuals but also the size-dependent differences in spawning capacity (e.g., spawning frequency and batch fecundity) would be important.

Conclusions

1. The effects of water temperature and body length on maturation differ among seasons.

2. Individuals smaller than 25 cm mature mainly in warmer condition in S1.

3. Individuals larger than 29 cm mature mainly in warmer condition in S2 and S4, and in various temperature condition in S1.

4. There is at least a problem with assuming a common maturation curve for all seasons and the SSB calculated using it.

5. It should be noted that estimating the seasonal maturation curve requires weighting by area. However, due to sampling bias in the current data especially in S4, overcoming this issue is not easy.