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Domestic Stock Assessment of Japanese Sardine in Japan

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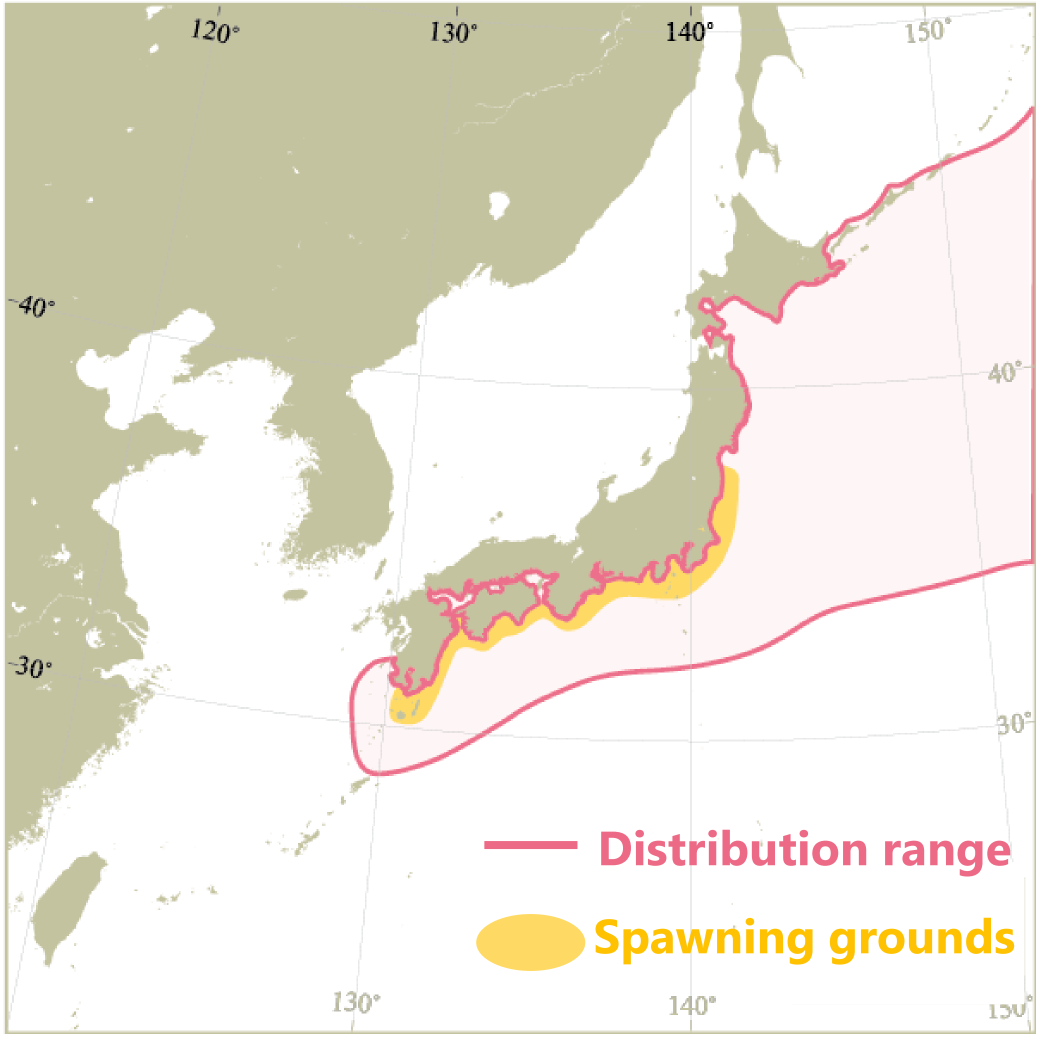
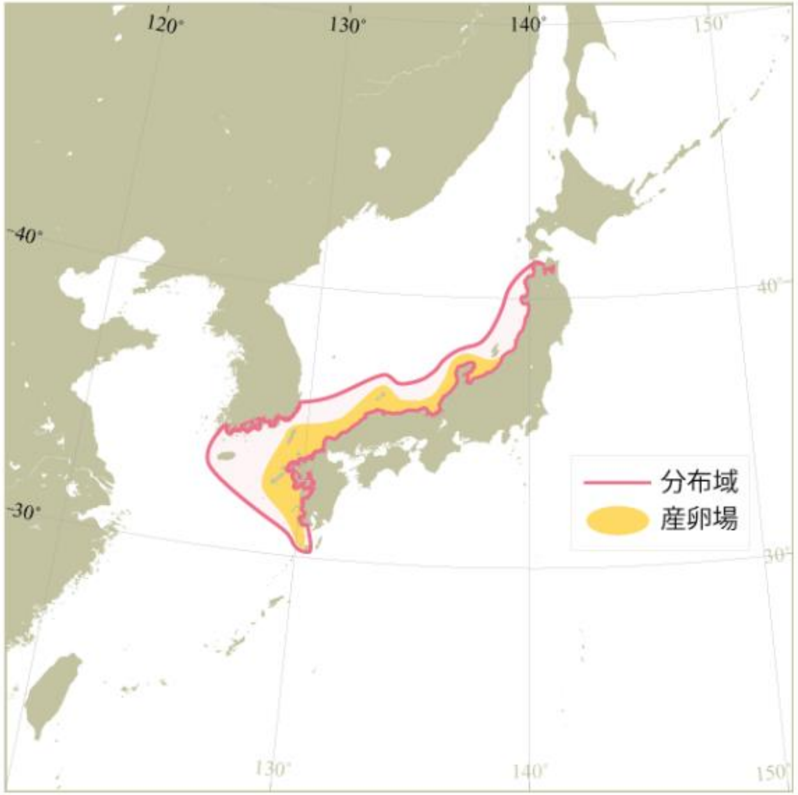
Spatial Structure of JS Stocks

Pacific stock



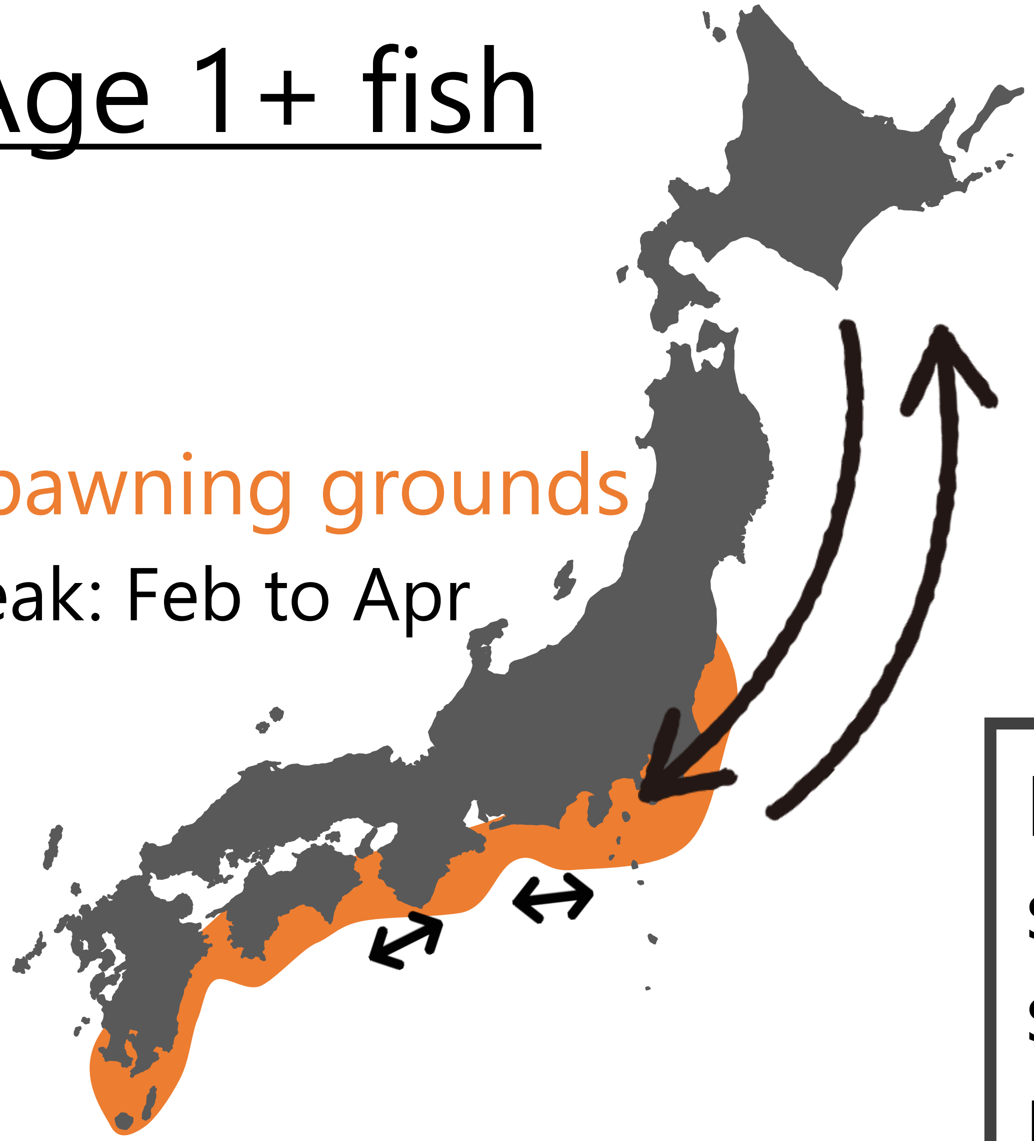
Tsushima Warm Current stock



- There are two stocks depending on distributions and biology
- Only the Pacific stock is distributed in the NPFC Convention Area

Distribution and Migration

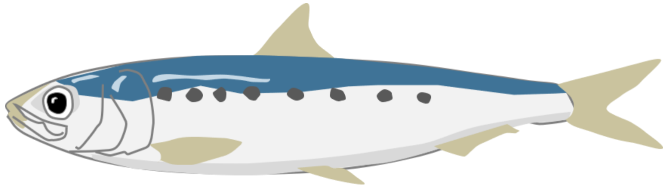
Age 1+ fish



Fished by large-scale purse seine, mid-scale purse seine, set net, and other fisheries on many coastal areas

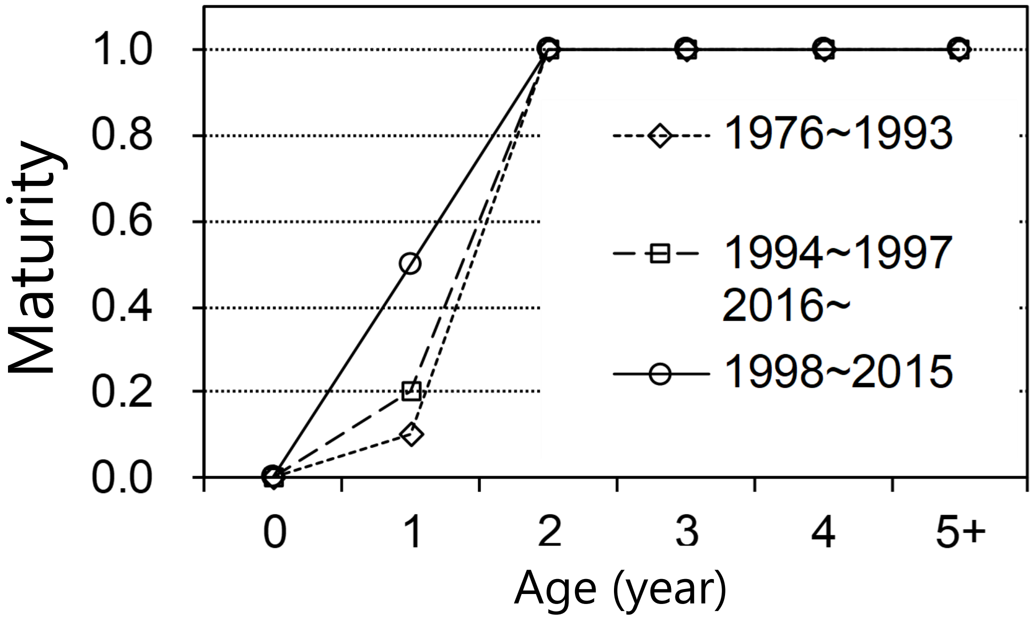
Biological Characteristics

Sardinops melanostictus



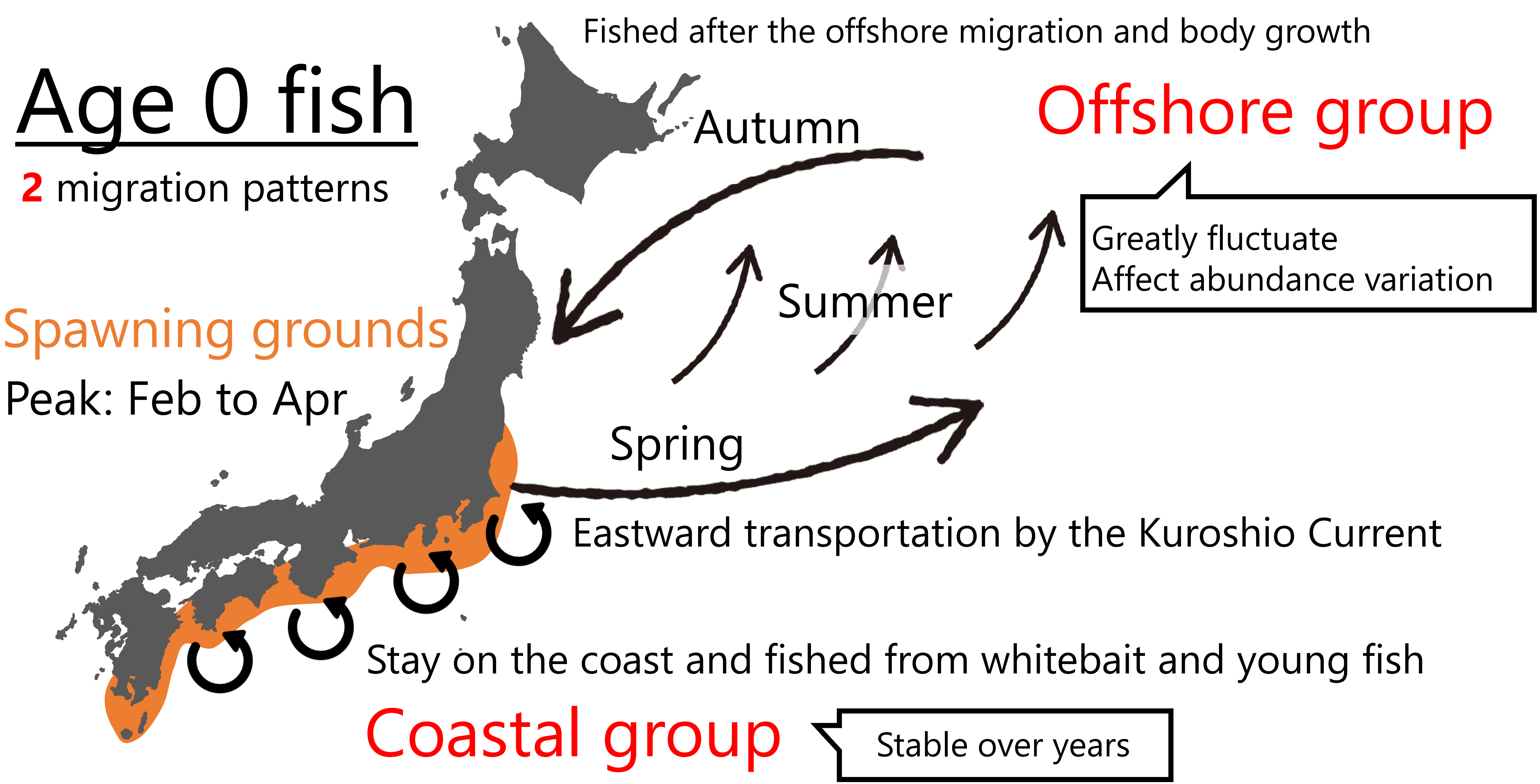
- The Longevity is about 7 YO
- The maximum body length is 22-24 cm

Maturity by age



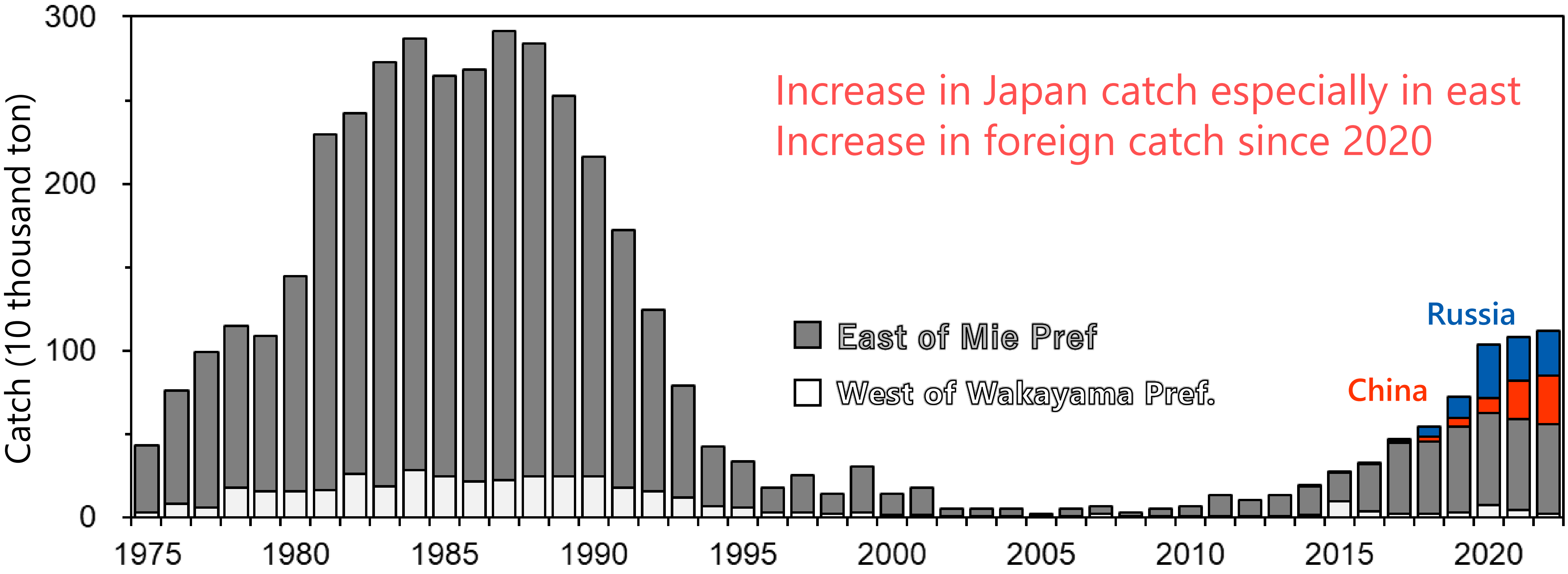
- Begin to mature from age 1
- The maturity rate at age 1 depends on the abundance level
- Almost all fish at age 2 mature

Distribution and Migration



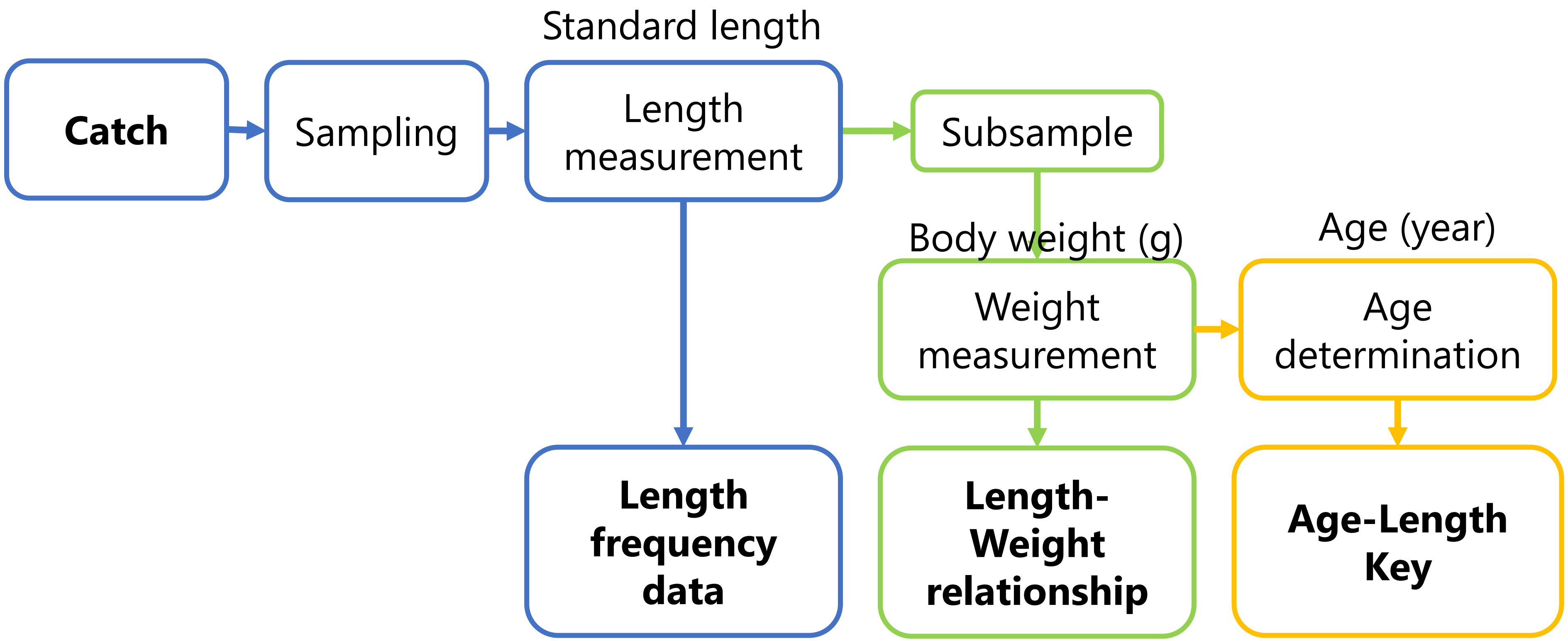
Catch Statistic

- Catch weights by Japan were taken from the national official statistic
- Data in Japan were originally collected from 18 coastal prefectures by month by gear
- Catch weights by China and Russia were taken from the NPFC statistics



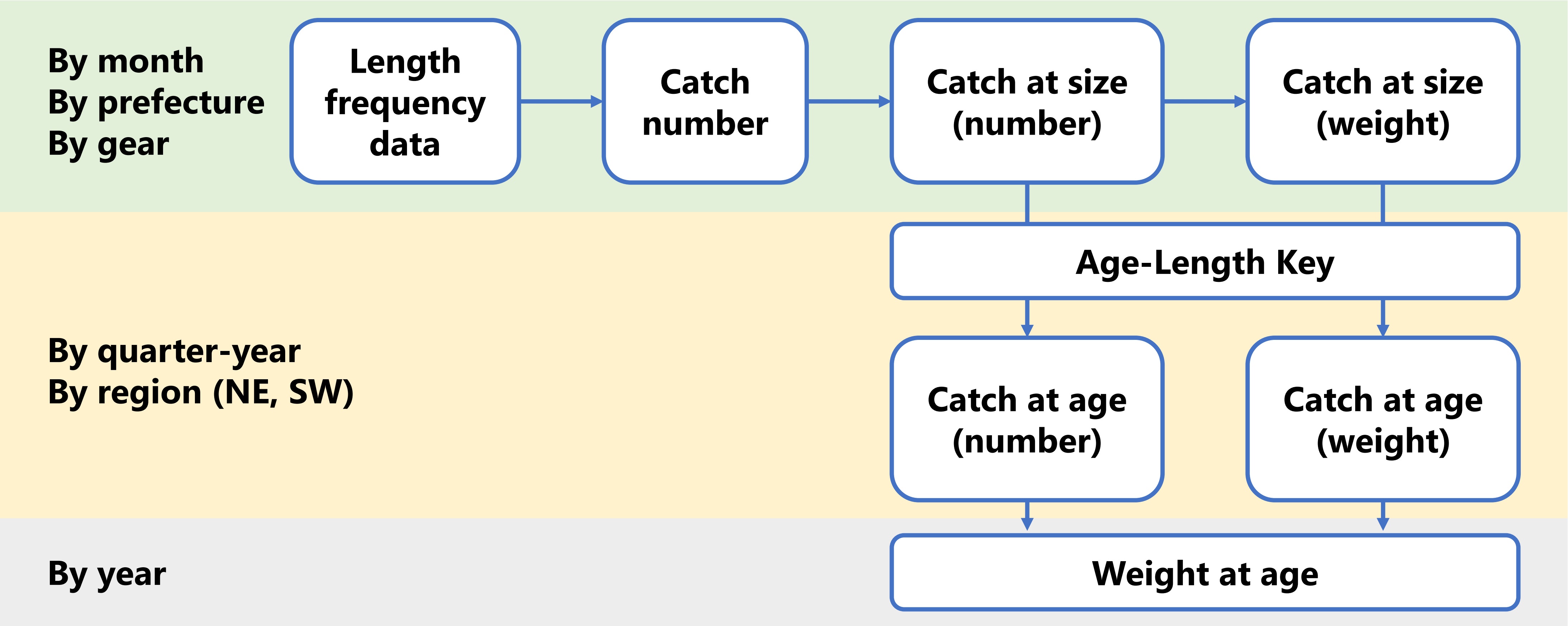
Length, Weight and Age Data

- Measurement data are collected from all 18 prefectures
- Data are treated by month and by fishing gear
- Age is estimated by otolith or scale reading



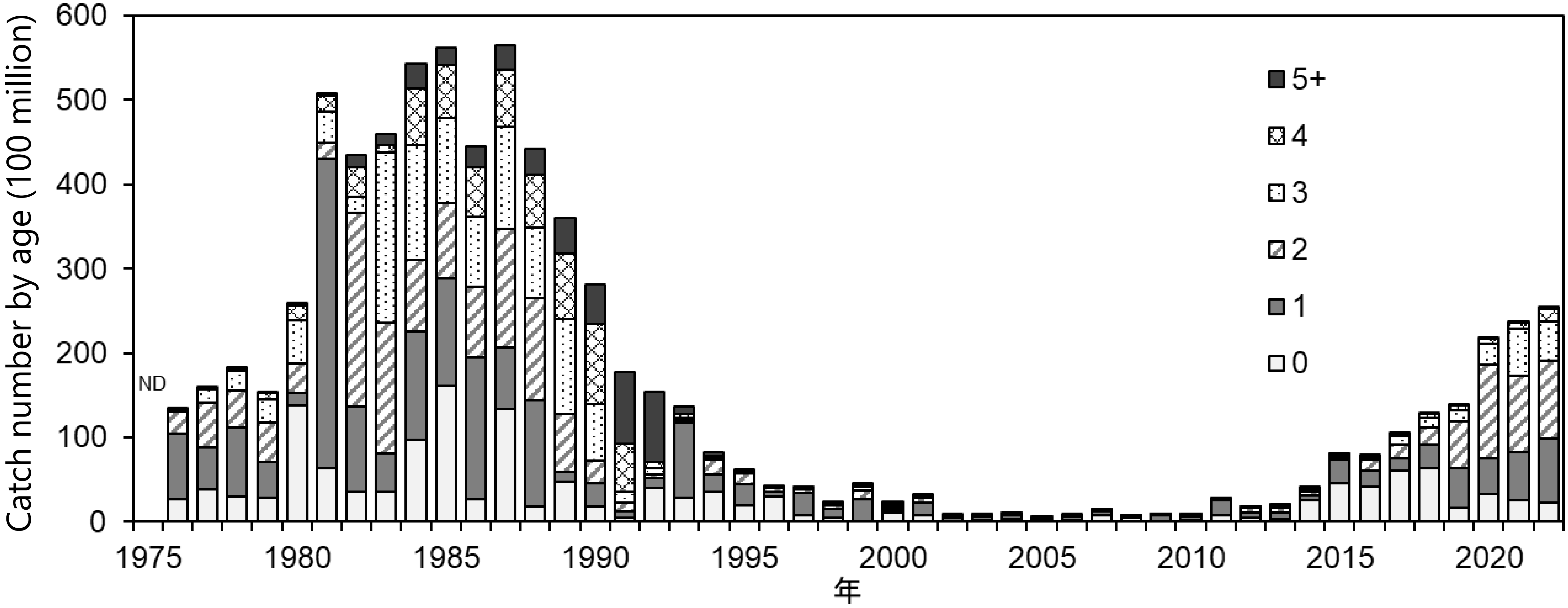
Catch at Age and Weight at Age in Japan

- Catch at size is derived from length frequency and L-W relationship
- ALK is applied to derive catch at age
- Weight at age is estimated from catch at age (weight)/catch at age (num)



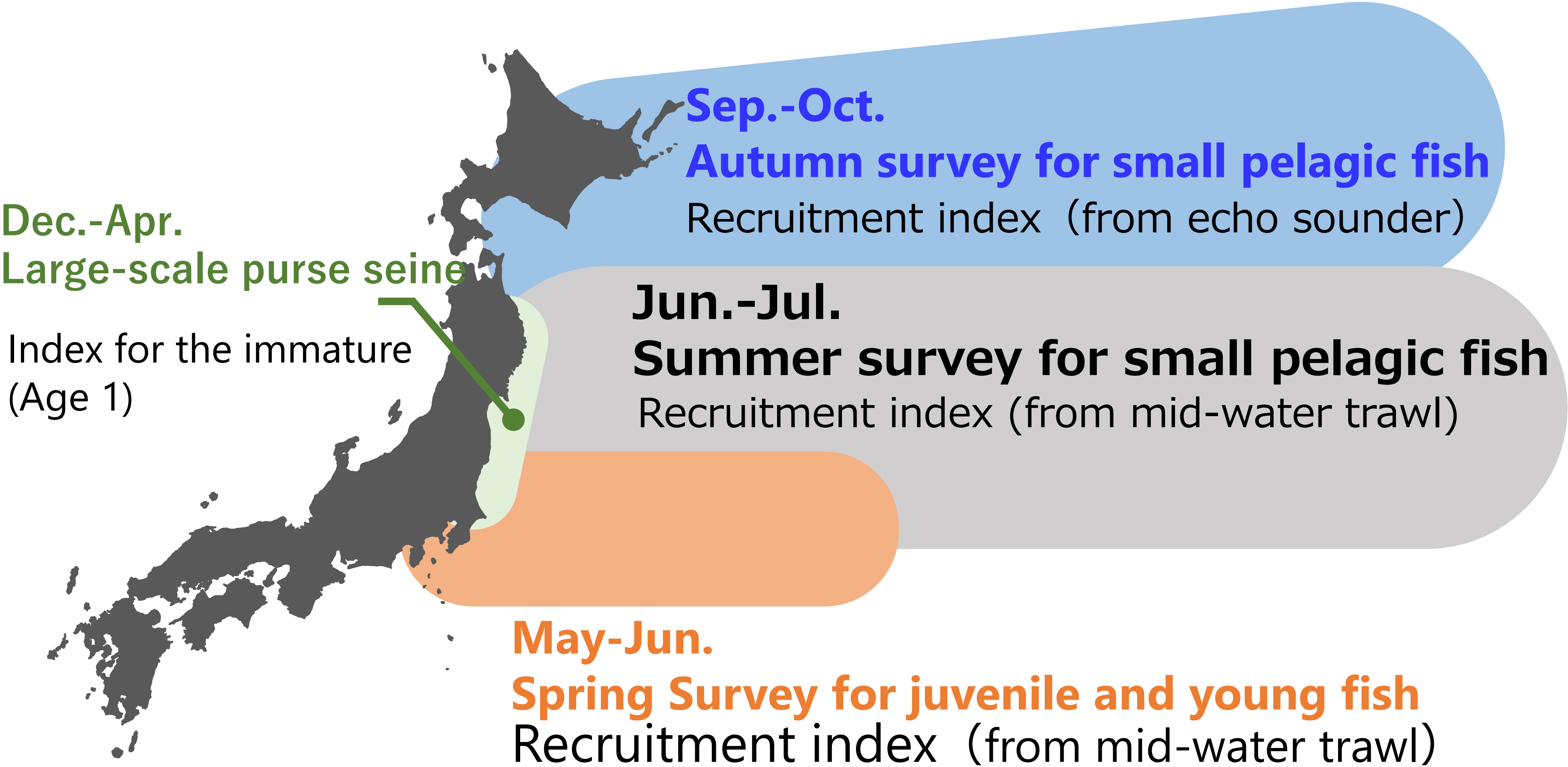
Age composition for foreign catch was assumed to be identical to that of the purse seine fishery in north of Miyagi pref. from Jul. to Dec.

Catch at age

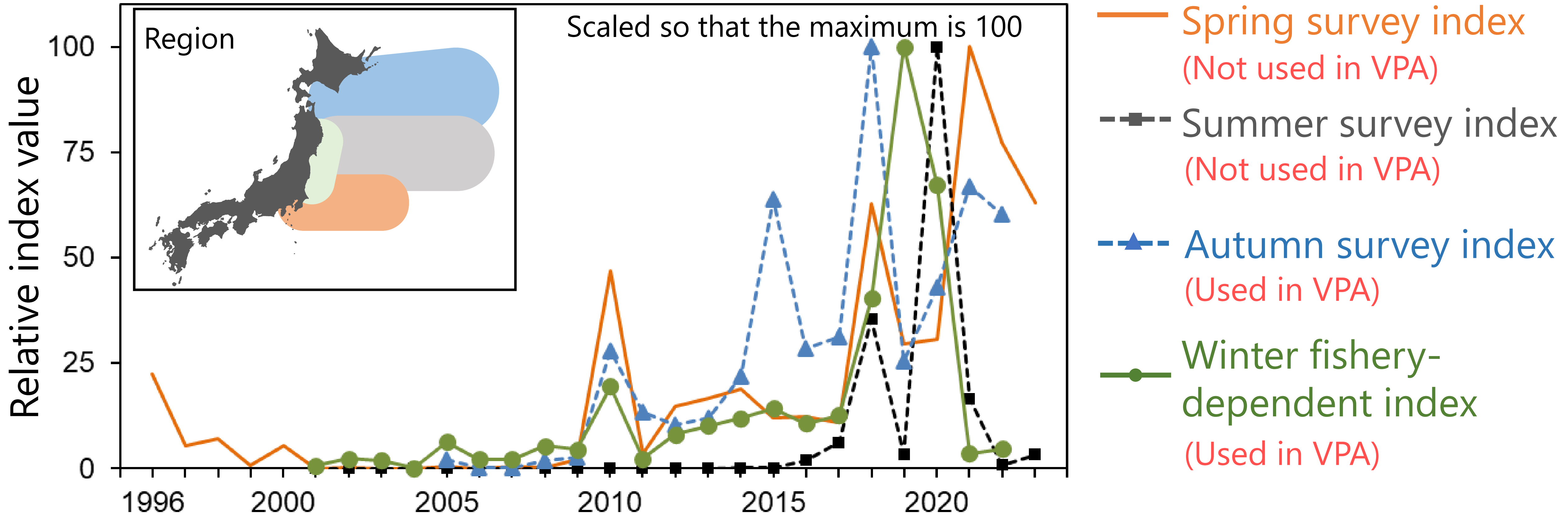


- Wide age classes were caught recently
- Catch of old fish has been increasing

Abundance indices for recruitment and age 1



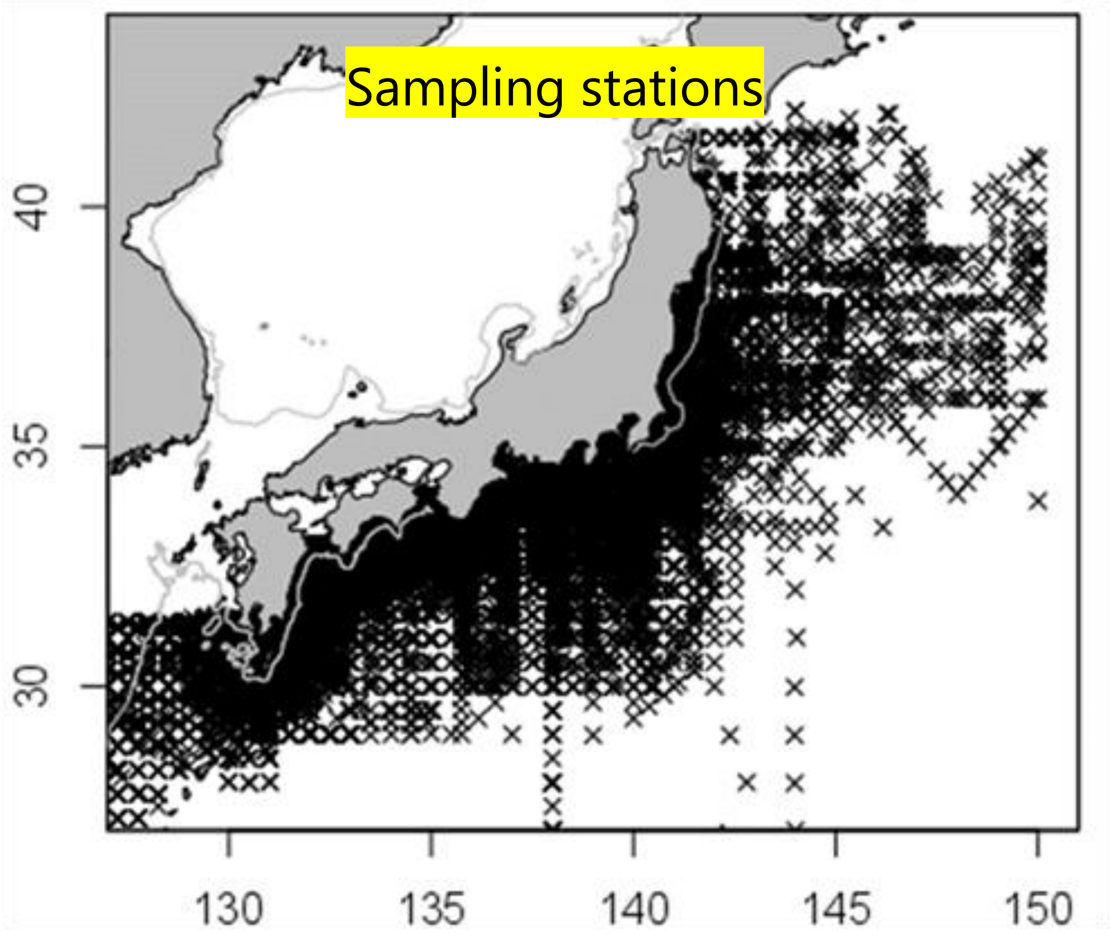
Trends of the Abundance indices

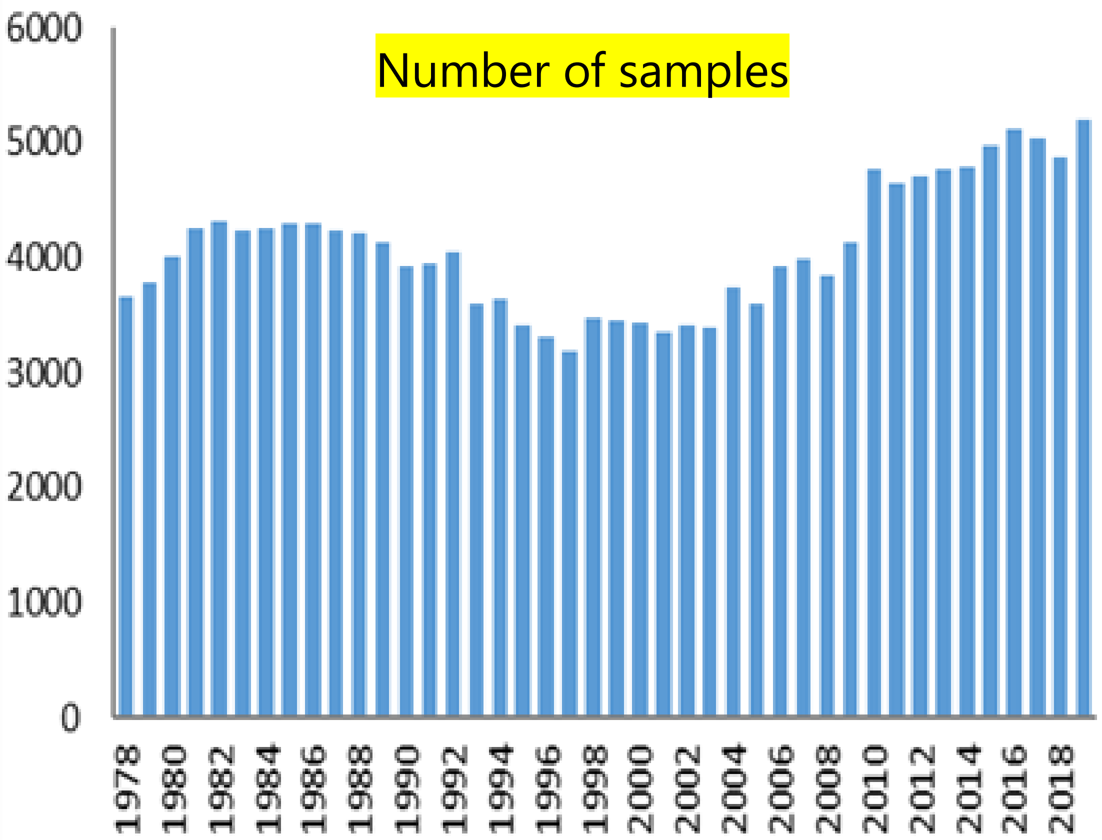


High values are frequently shown in recent years

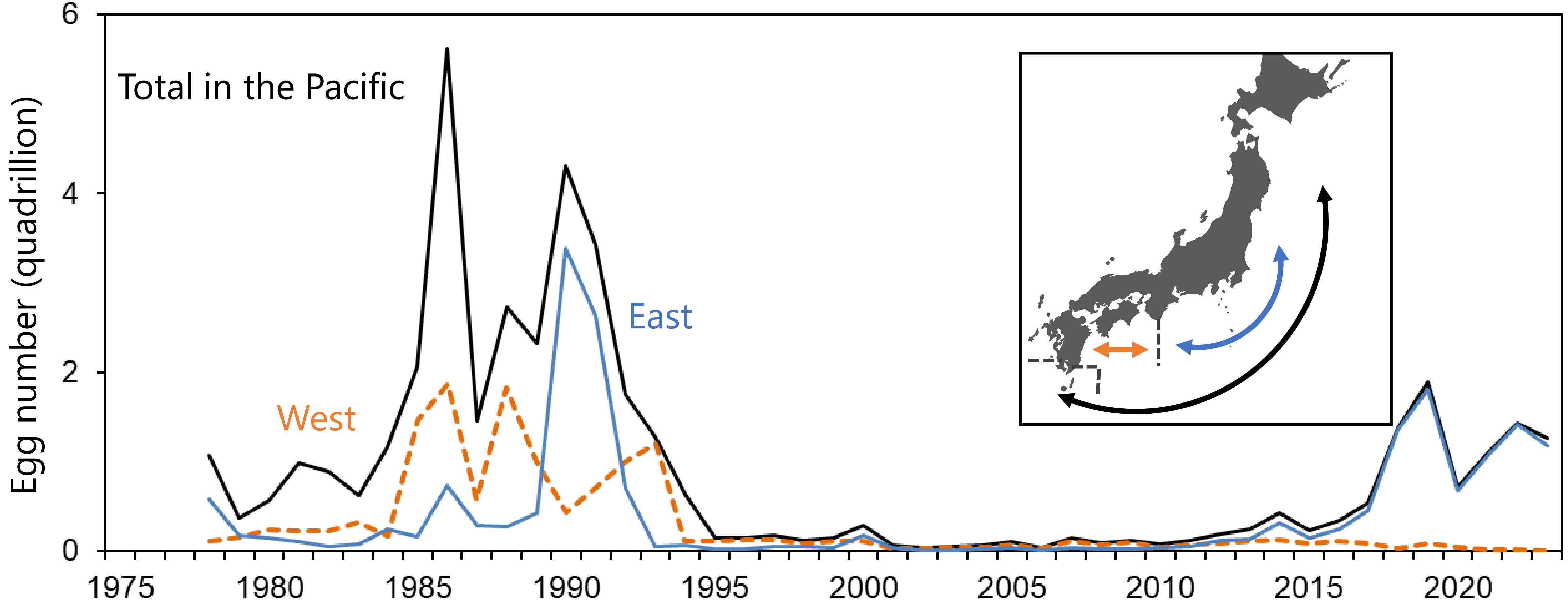
Egg and larval survey

- The Egg and Larval survey is conducted by 19 prefectural fisheries institutes and FRA in every month along the Pacific coast of Japan using NORPAC net
- Number of samples per year is c.a. 5 thousands





Egg abundance as an SSB index



High values in recent years especially in the eastern area

Tuned VPA

Age classes: 0 ~ 5+

Natural mortality: M = 0.4
from Tanaka's equation: M = 2.5/maximum age (Tanaka 1960)
2.5/7 = 0.357 ≈ 0.4

Use the Pope's approximation

Assume $F_{4,y} = F_{5+,y}$

Estimate nonlinear coefficients for the recruitment and age 1 indices

Ridge VPA (Okamura et al. 2017, ICES JMS)

Residual sum of square

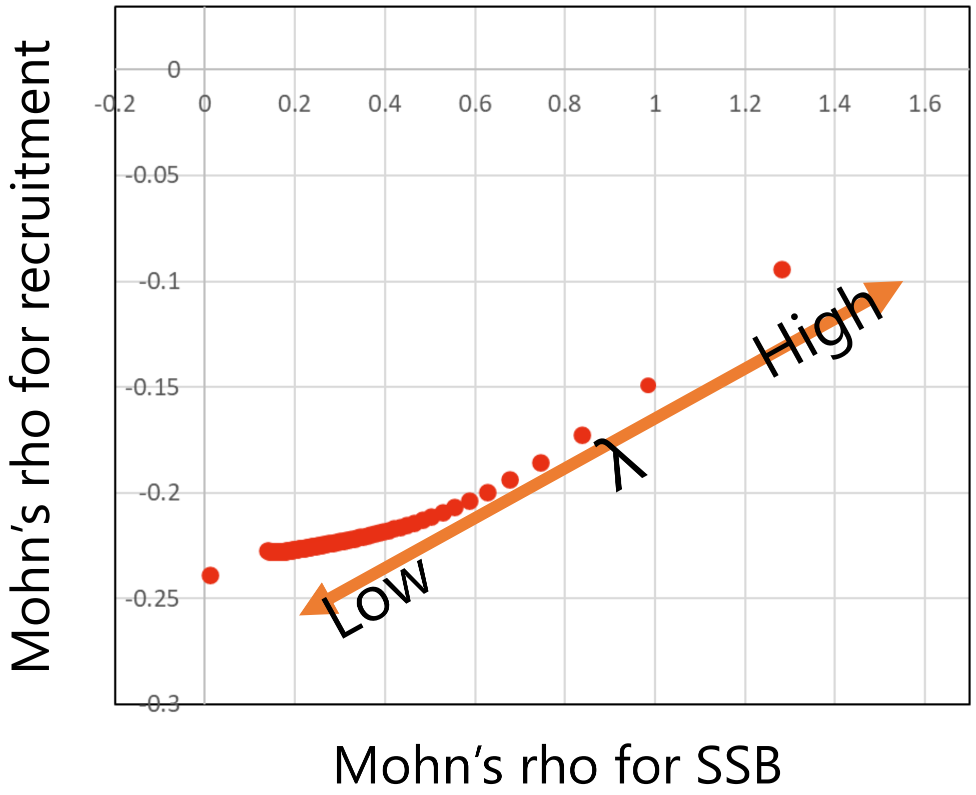
$$(1-\lambda)\sum_{k=1}^{3}\sum_{y}\left[\ln(I_{k,y})-\ln\left(q_k X_{k,y}^{b_k}\right)\right]^2+\lambda\sum_{a=0}^{4}F_{a,2022}^2$$

Select λ so that a retrospective bias is minimized

Pose a penalty for squared F to avoid divergence of F

$I_{k,y}$: Index values
$X_{k,y}$: Corresponding abundance estimate (SSB, N at age 0, or N at age 1)
q_k: Proportional constant
b_k: Nonlinear coefficient

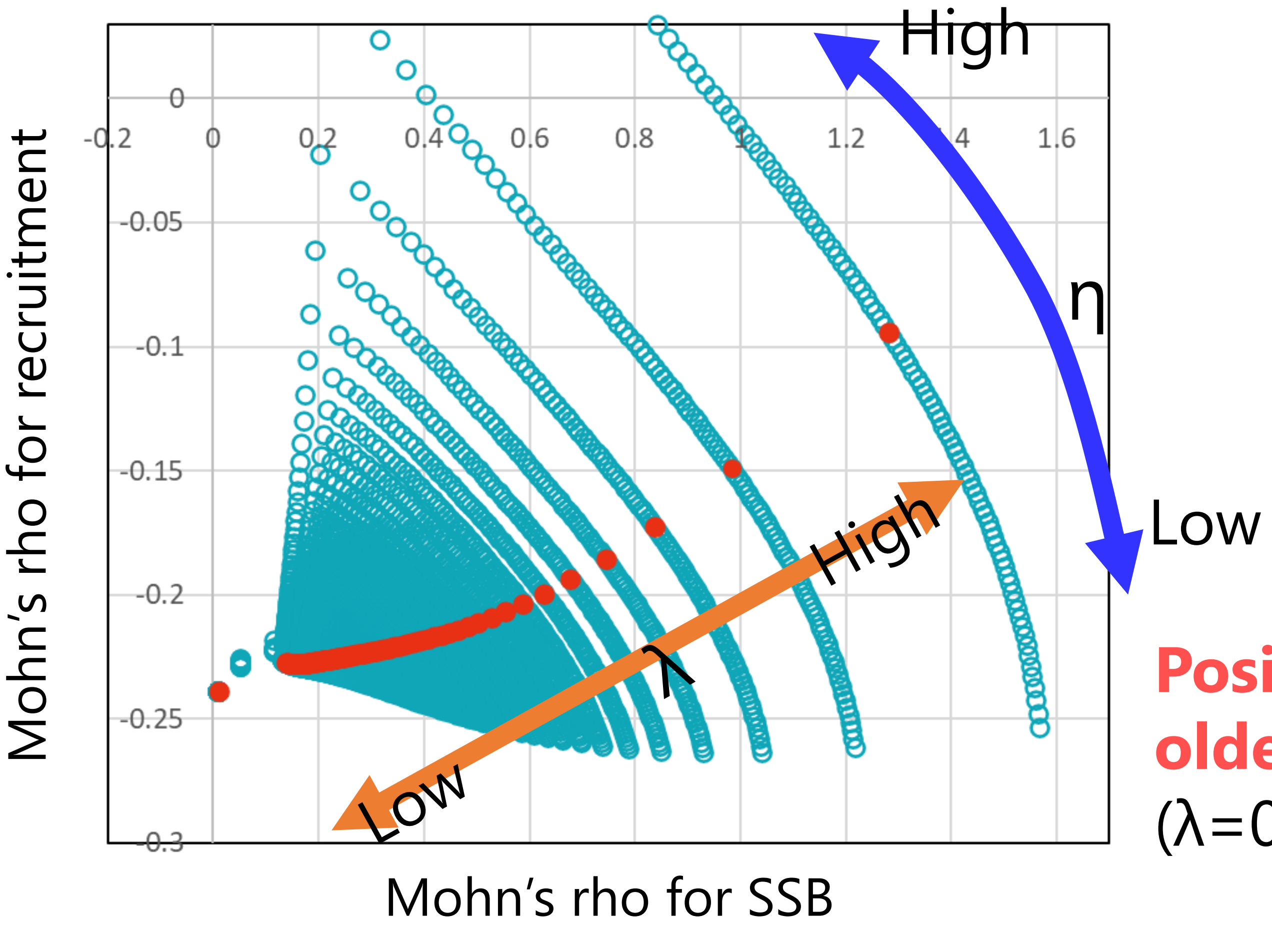
Impossible to reduced retrospective bias for both R and SSB (trade-off)



Extended Ridge VPA

Residual sum of square

$$(1-\lambda)\sum_{k=1}^{3}\sum_{y}\left[\ln\left(I_{k,y}\right)-\ln\left(q_k X_{k,y}^{b_k}\right)\right]^2+\lambda\left[(1-\eta)\sum_{a=1}^{4}F_{a,2022}^2+\eta F_{0,2022}^2\right]$$



Pose different penalties between age 0 and older

F at age 0 was estimated at a small value

The 'usual' penalty in the ridge VPA did not work on age 0

Posing a heavier weight on age 0 than on older ages mitigated the trade-off

(λ=0.72 and η=0.99 were selected)

Relationships between index and abundance

Autumn survey for age 0

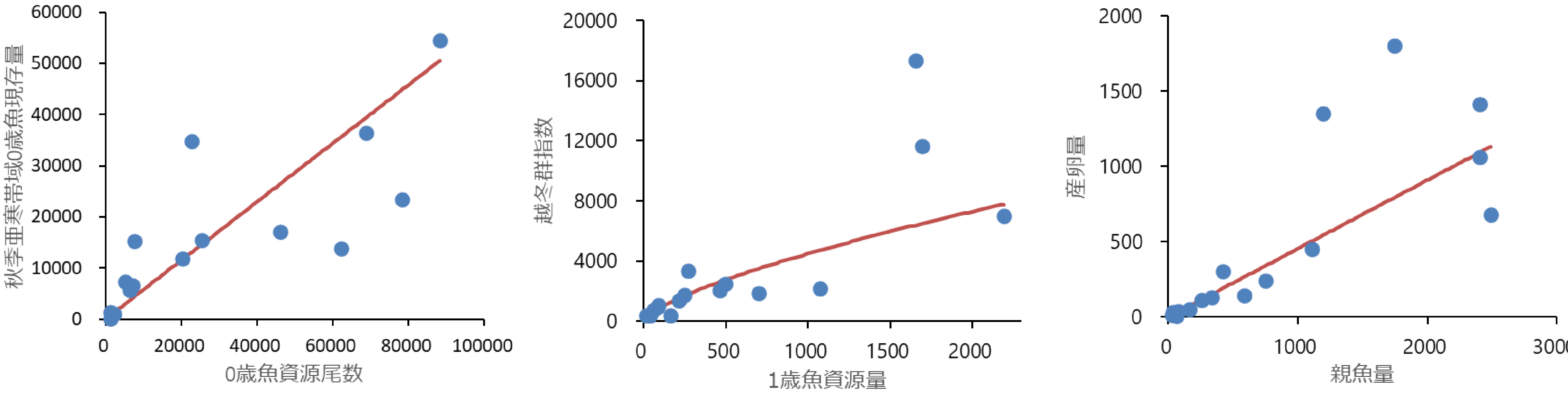
q=0.59　b=1.00

Fishery-dependent index for age 1

q=35.8　b=0.70

Egg abundance for SSB

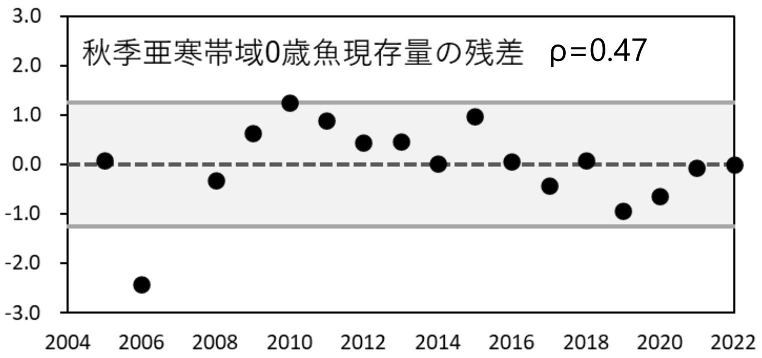
q=0.46　b=1.00 (fixed)



Showed the tendency of hyperstability
maybe because of fishery-dependent index

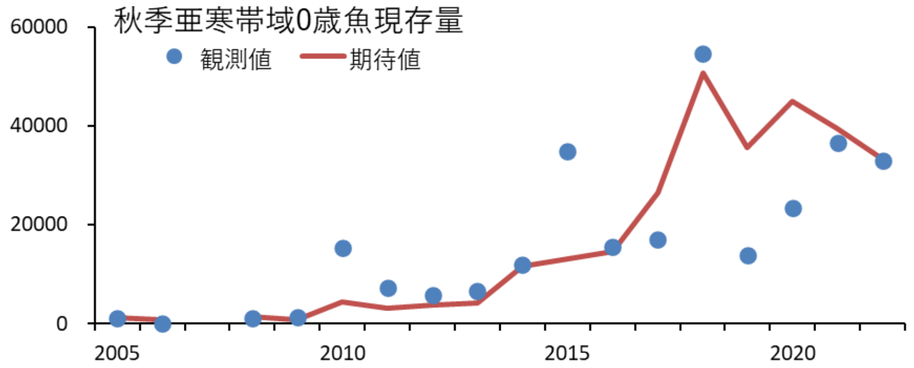
Residual plot as a model diagnostic

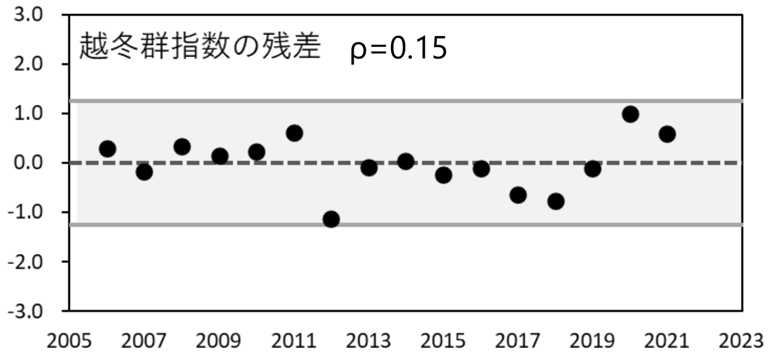
Residual



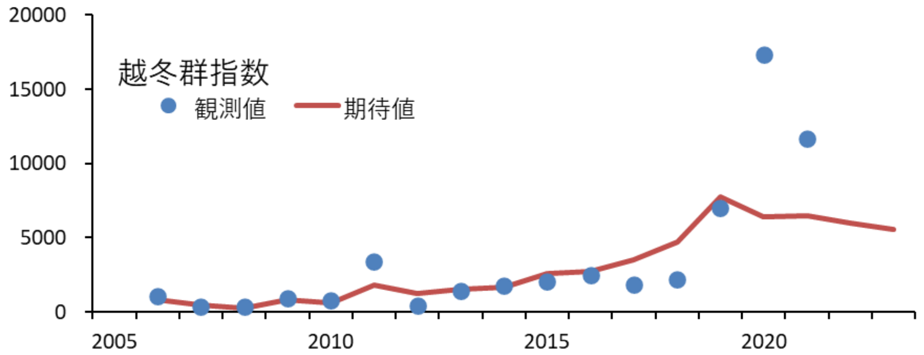
Autumn survey for age 0

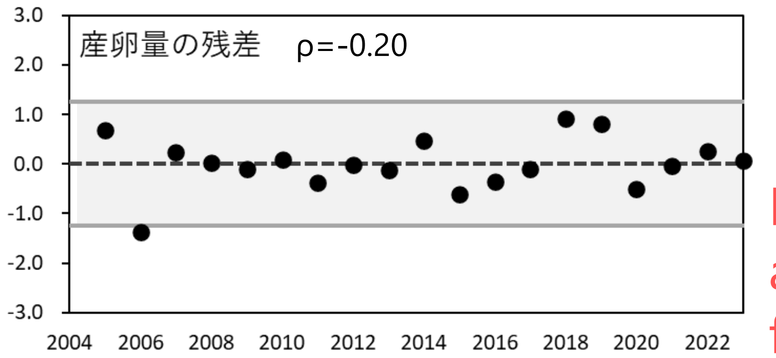
Shadow area: 95%CI





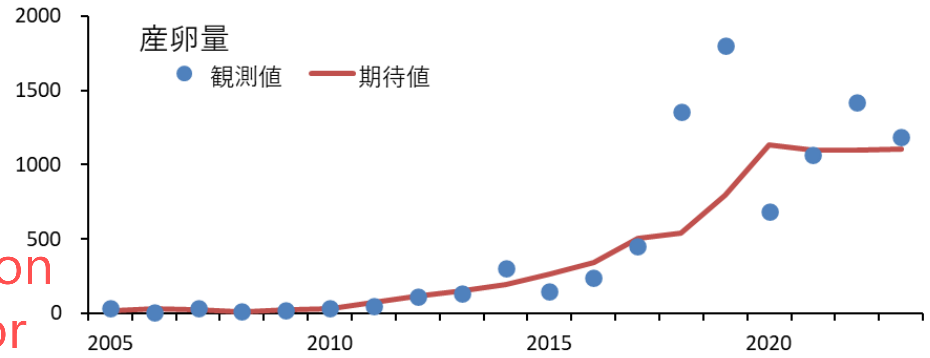
Fishery-dependent index for age 1



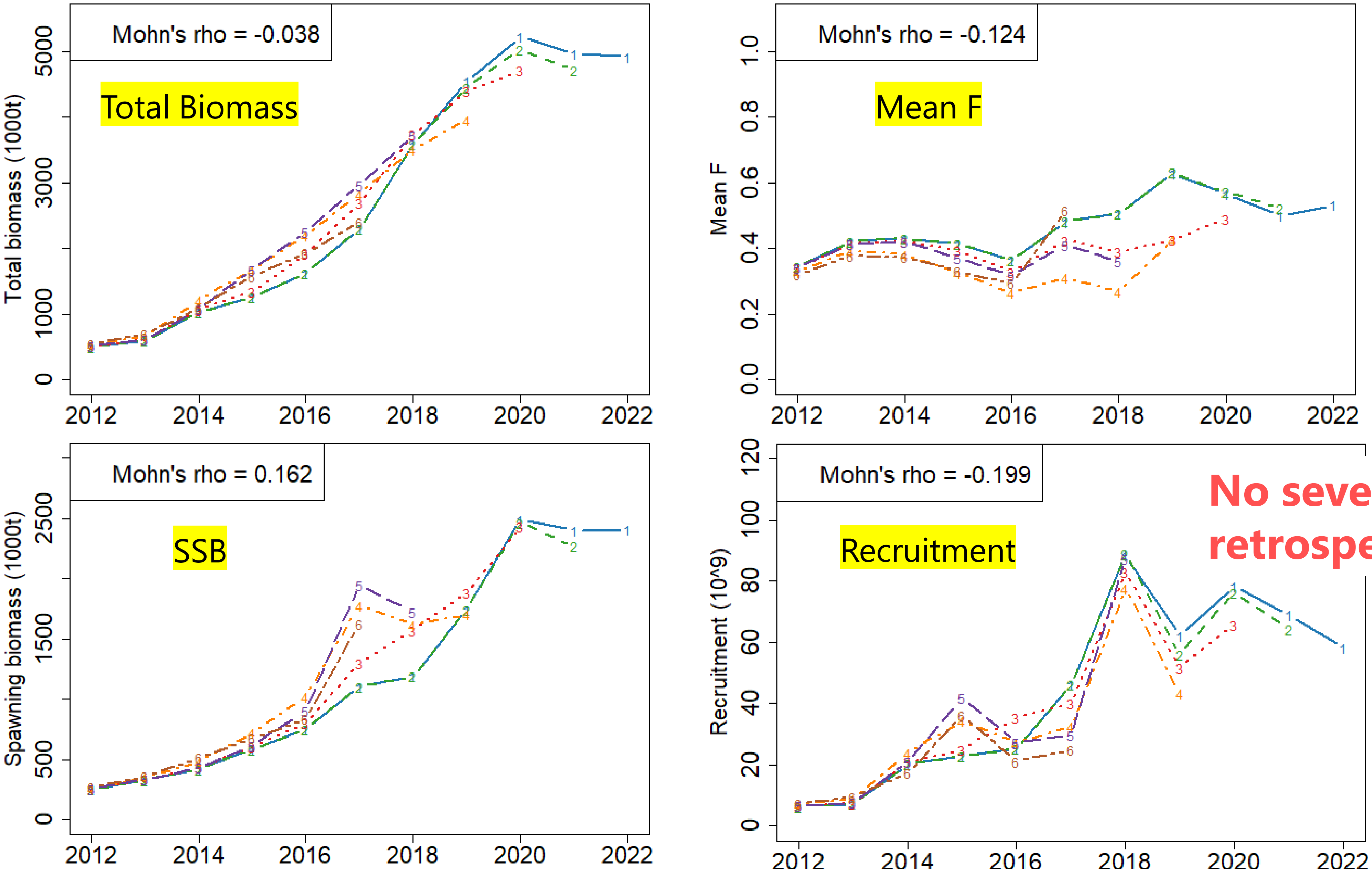


Egg abundance for SSB

Neither significant autocorrelation nor deviation from normal distribution for all the indices

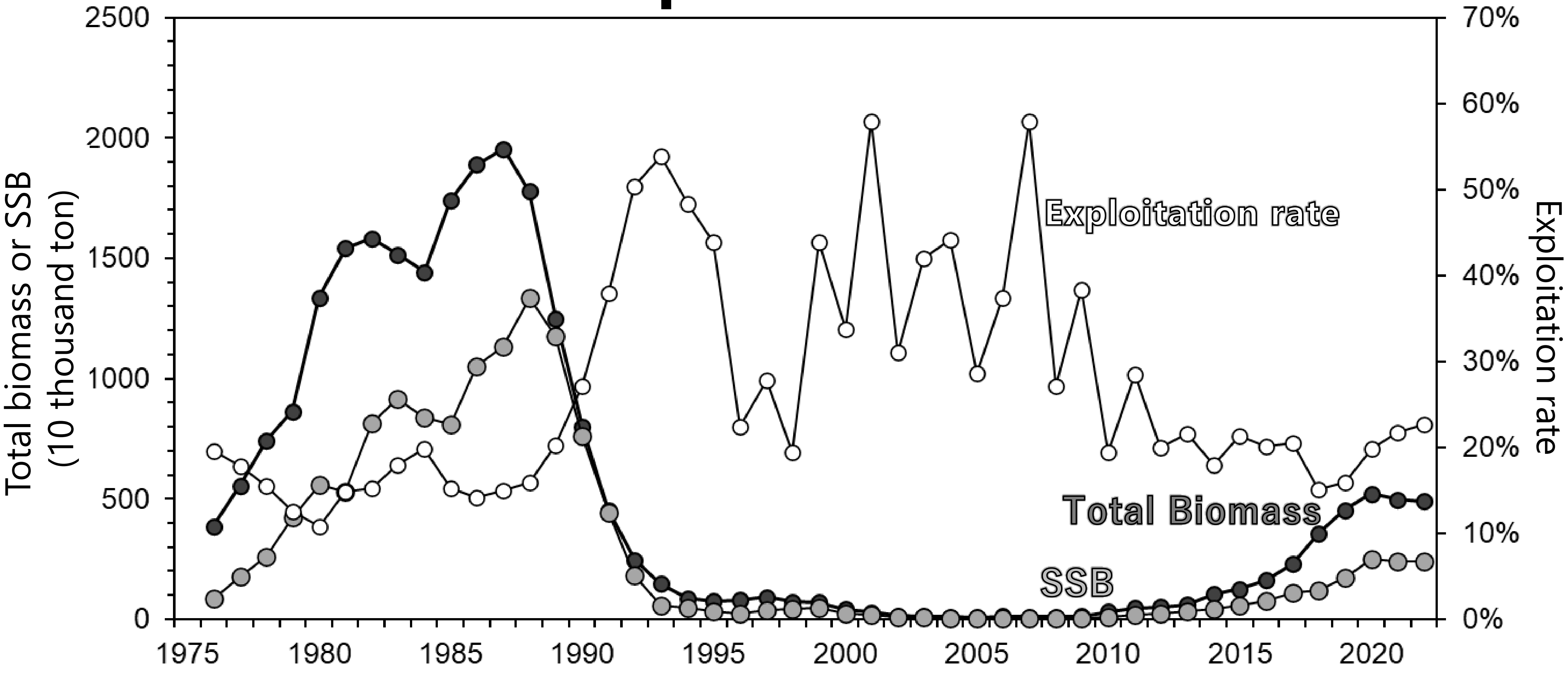


Retrospective analysis as a model diagnosti



No severe retrospective biases

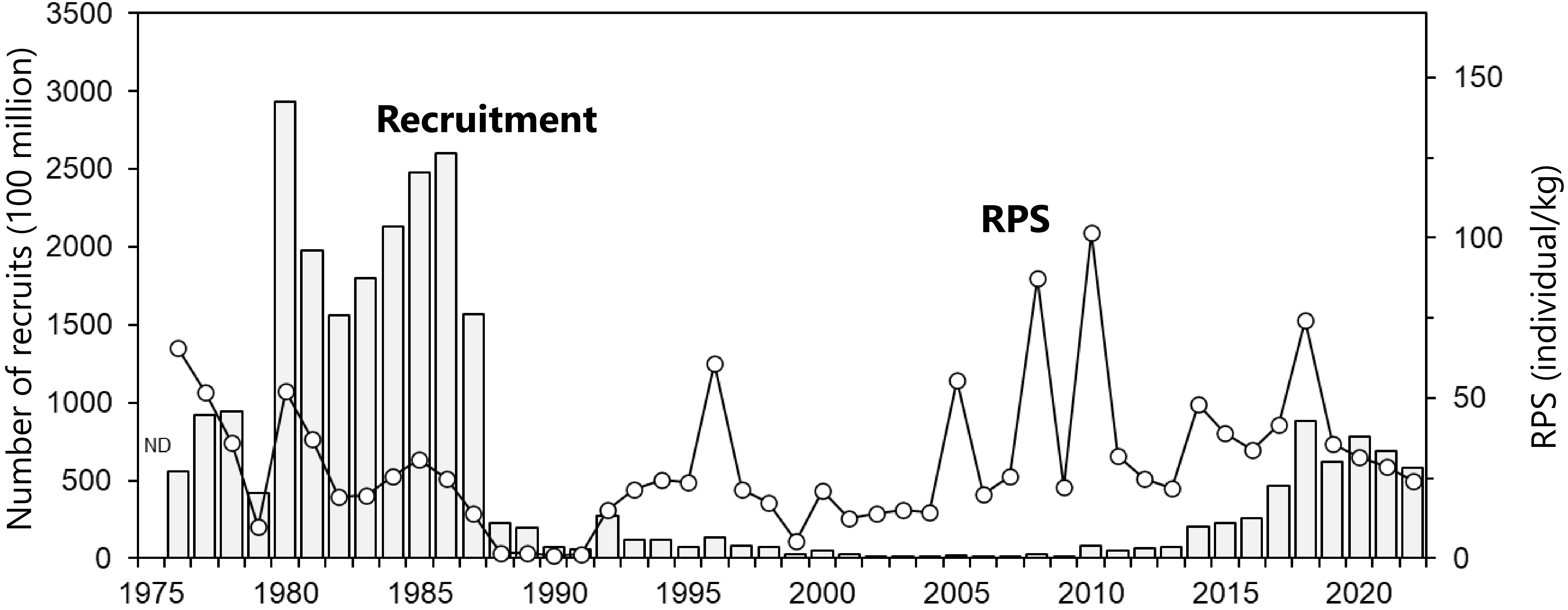
Biomass and Exploitation Rate



Total biomass increased since 2010 and SSB increased since 2022
Remained flat since 2020 (Biomass in 2022: 4910,000 mt, SSB in 2022: 2410,000 mt)

Catch rate declined in the late 2000s and remained low in the 2010s
However, it has increased from 2020 to 2022

Recruitment and RPS

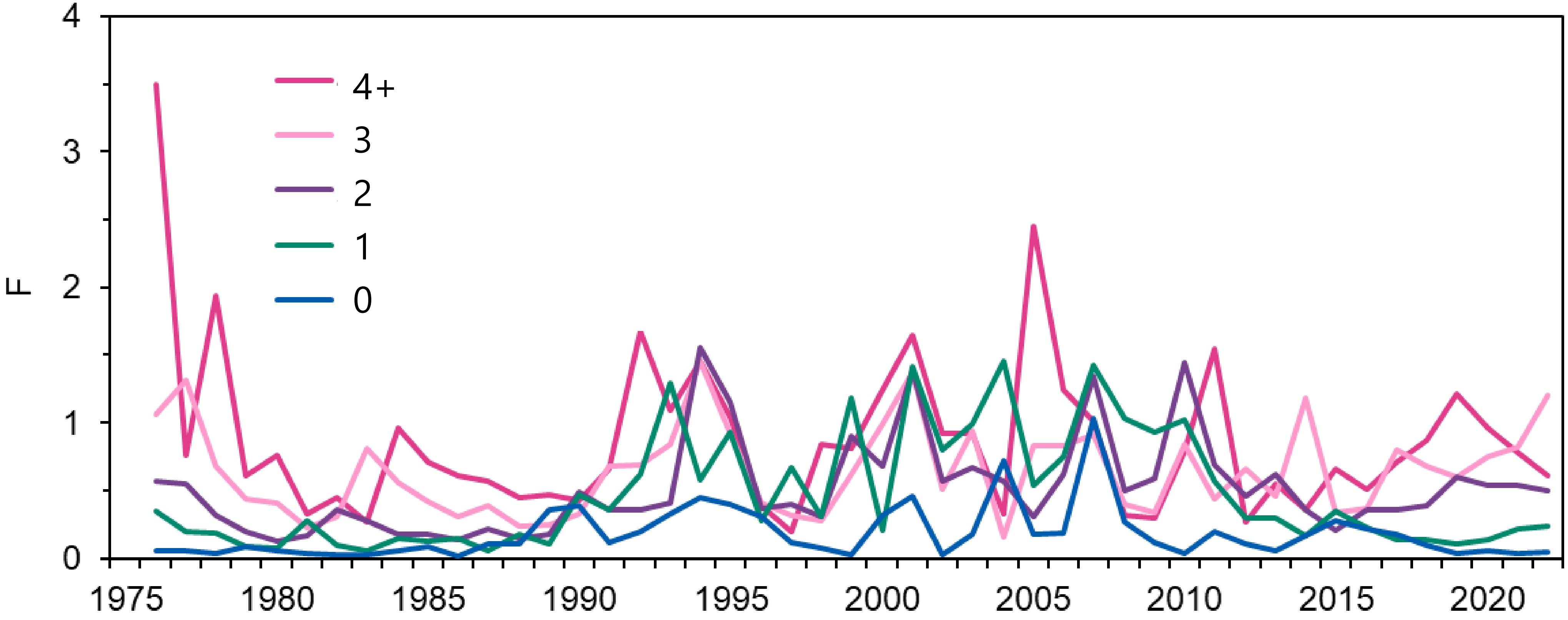


A high value of RPS increased recruitment in 2010

The increase in SSB and moderate RPS caused high recruitments since 2011

Especially high recruitments since 2018

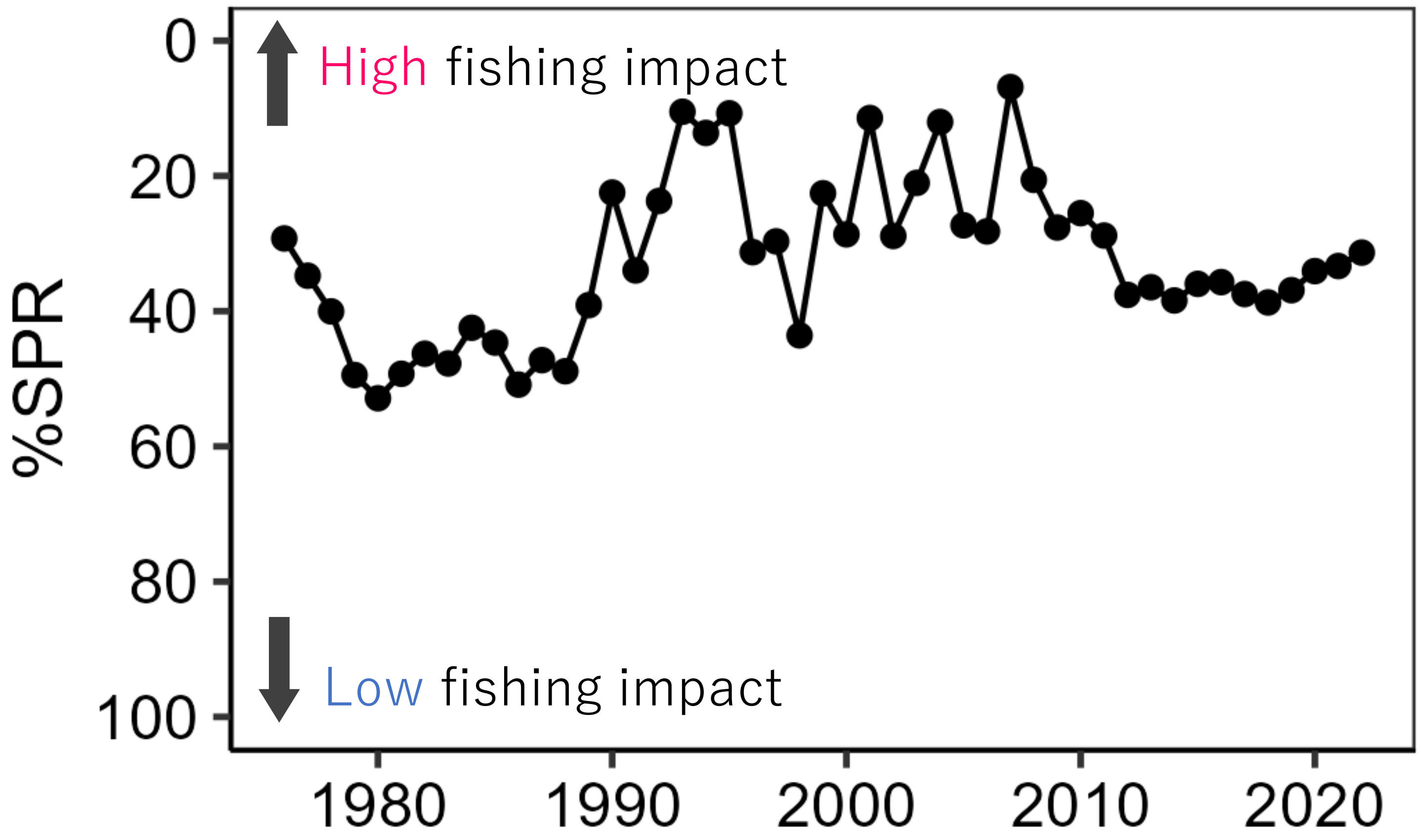
Fishing Mortality by Age



F at age 0 has been stable in recent years
F at old ages has been increasing

Fishing Mortality (%SPR)

%SPR：Ratio of SPR (SSB/R) without fishing to SPR with fishing

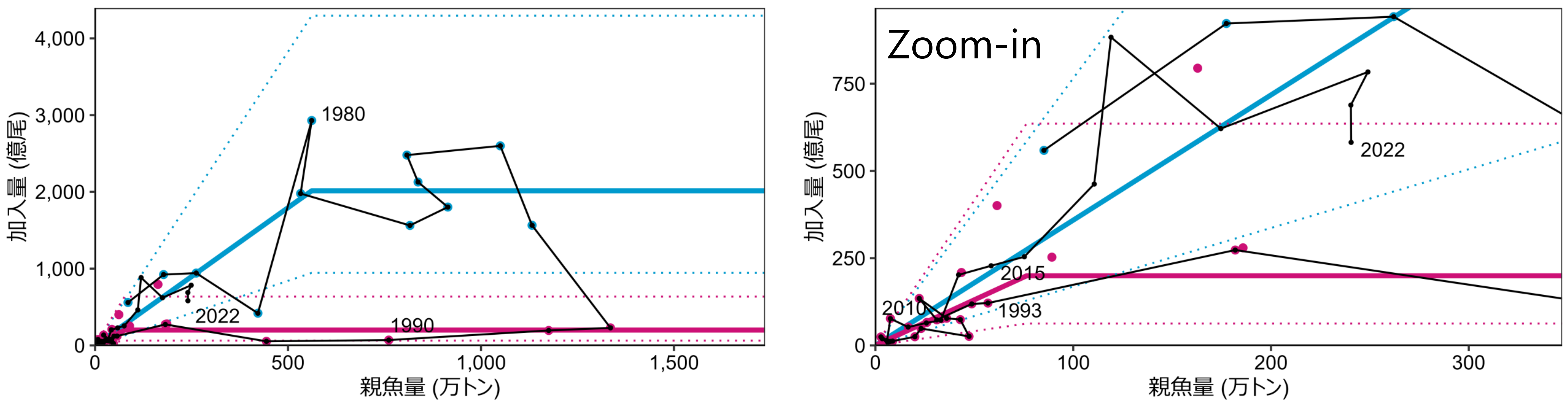


Fishing pressure increased along with the decline in abundance in early 1990s and early 2000s

Fishing pressure in 2020-2022 is maintained at low levels (≈ 30%SPR)

Stock-Recruitment Relationship

- Post-hoc estimation of the hockey-stick (HS) relationship from VPA outputs
- Separate regimes between 1987 and 1988



Estimate in 2023 stock assessment

Estimate at the benchmark stock assessment (2020)

High recruitment in recent years

But slow increase in SSB (probably due to decline in weights)

Why using the regime-based HS relationship?

Sardine is well known to exhibit large resource fluctuations in synchronization with multi-decadal global climatic oscillation

The pacific stock of JS shifted from high-recruitment to normal-recruitment regime in 1988 (Yatsu et al. 2005; Takahashi et al. 2009; Kurota et al. 2020)

No-regime model

Function	Optimization	Auto-correlation	a	b	S.D.	ρ	AICc	BIC
Hockey-stick	Least square	Yes	0.034	1,629,150	0.76	0.60	108.3	114.3
Ricker	Least square	Yes	0.032	1.52e-07	0.78	0.55	109.5	115.5
Beverton-Holt	Least square	Yes	0.040	5.00e-07	0.77	0.60	109.1	115.1

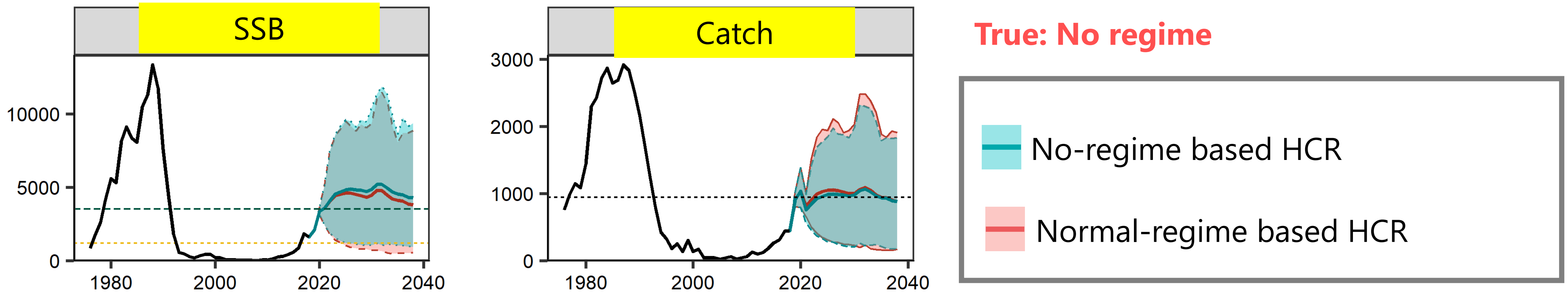
With-regime model

Function	Optimization	Regime	a	b	S.D.	ρ	AICc	BIC
Hockey-Stick	Least square	Normal	0.026	764,253	0.71	0	96.0	104.3
		High	0.036	5,612,630	0.46	0		
Ricker	Least square	Normal	0.027	2.73e-07	0.76	0	99.0	107.3
		High	0.052	9.68e-08	0.44	0		
Beverton-Holt	Least square	Normal	0.036	1.54e-06	0.73	0	96.9	105.1
		High	0.064	2.23e-07	0.43	0		

Minimum AIC & BIC

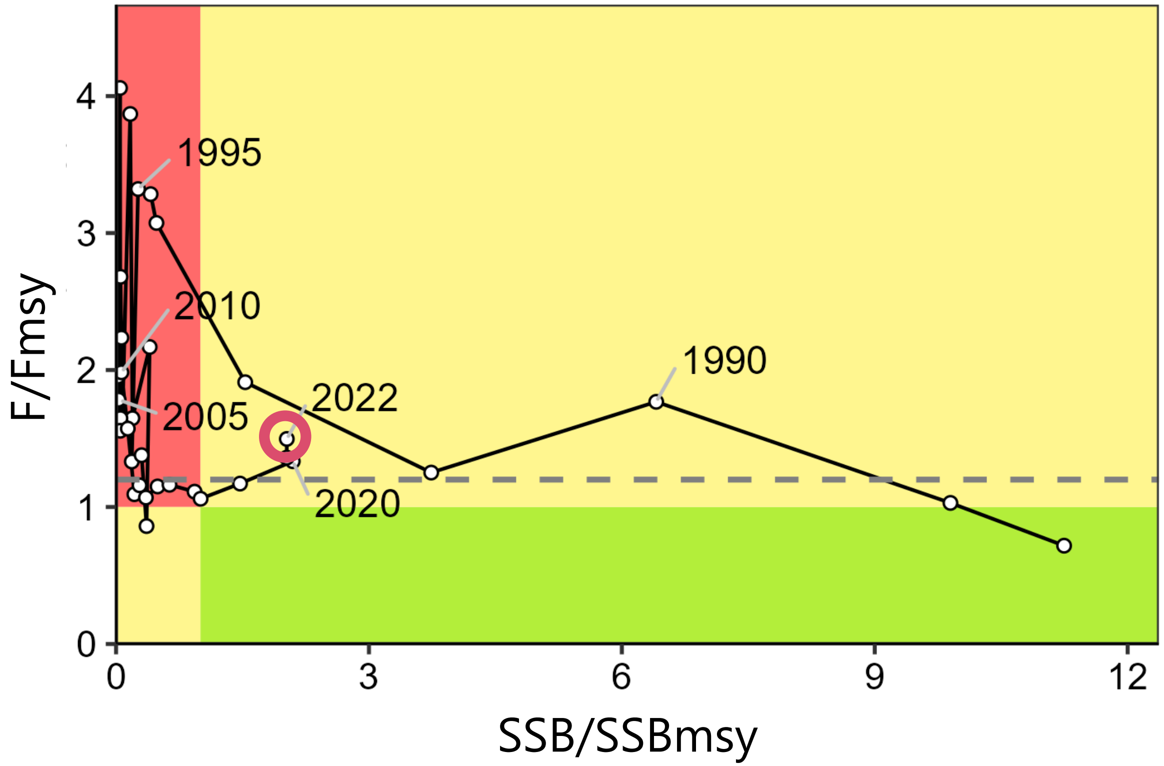
Why assuming the normal regime for recent years despite high recruitment?

- Recent estimates in recruitment are highly uncertain
- By a simple management strategy evaluation (MSE), it was confirmed that a normal-regime based harvest control rule (HCR) showed similar performance of no-regime based HCR when regimes were assumed not to exist

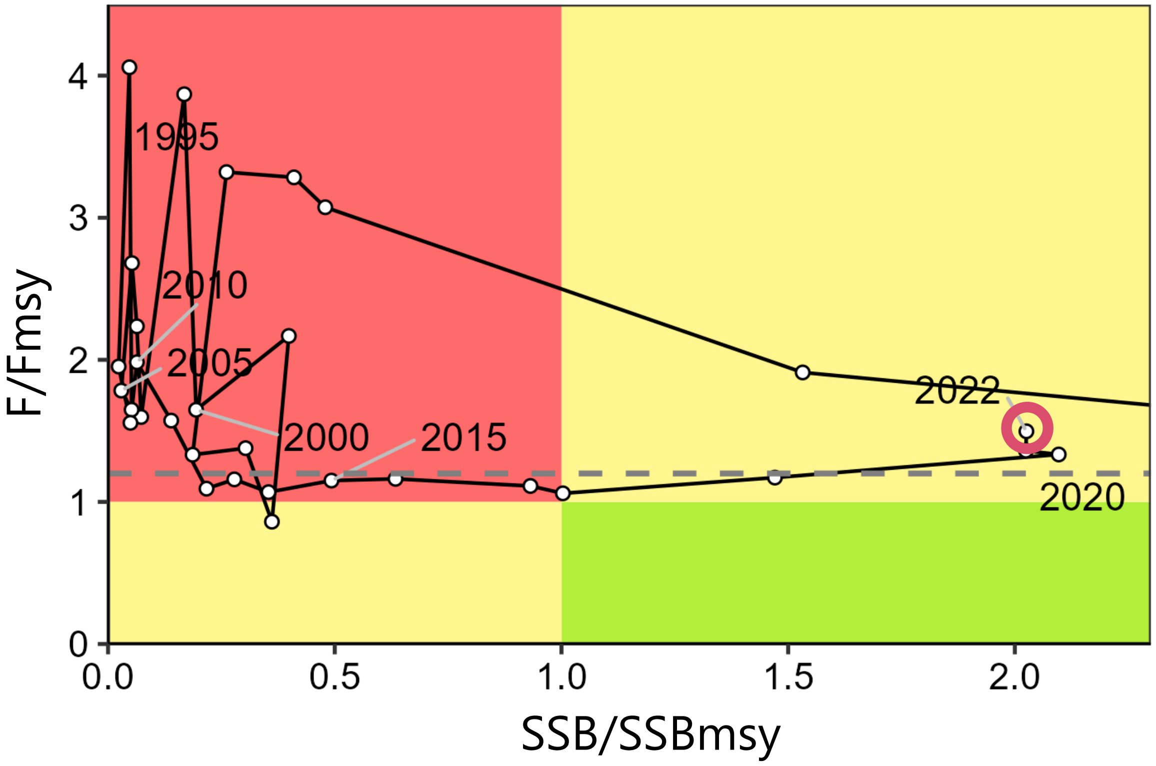


- By the simple MSE, it was also confirmed that when the current regime was assumed to be actually high, the normal-regime HCR would be able to catch JS sufficiently

Kobe plot



Zoom-in



- MSY reference points were estimated by a stochastic simulation with a random recruitment variability from the normal-regime SR relationship (see Ichinokawa et al. 2017, ICES JMS, for details)
- SSB in 2022 exceeded SSBmsy
- F in 2022 exceeded Fmsy

Summary

- Japan conducts the JS stock assessment by the tuned VPA with ridge penalty
- The MSY-based reference points were estimated from the stochastic simulation from the normal-regime SR relationship of the hockey stick function
- In 2022, estimated total biomass was 4.91 million ton and SSB was 2.41 million ton
- It exceeded SSBmsy (1.19 million ton)
- The current F (F2020-2022) exceeded Fmsy

Future Issues

- It is necessary to reflect actual age composition in the outside of Japanese EEZ
- Should consider more how to treat regimes for future projection and BRP
- Should conduct CPUE standardization