Winter-spawning stock (WS) Japanese flying squid

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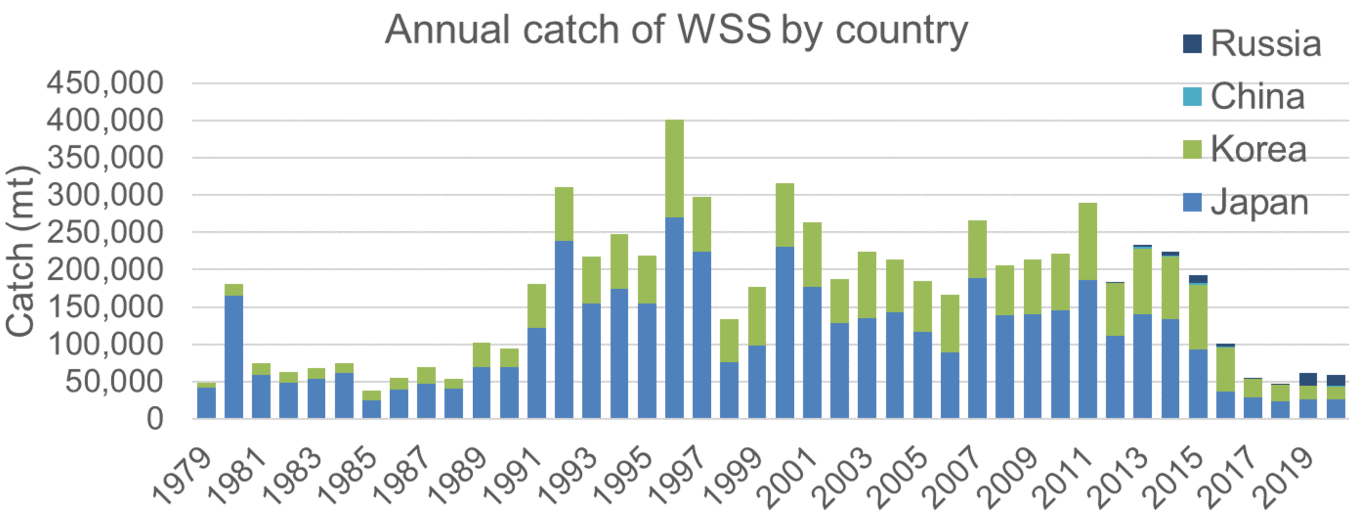
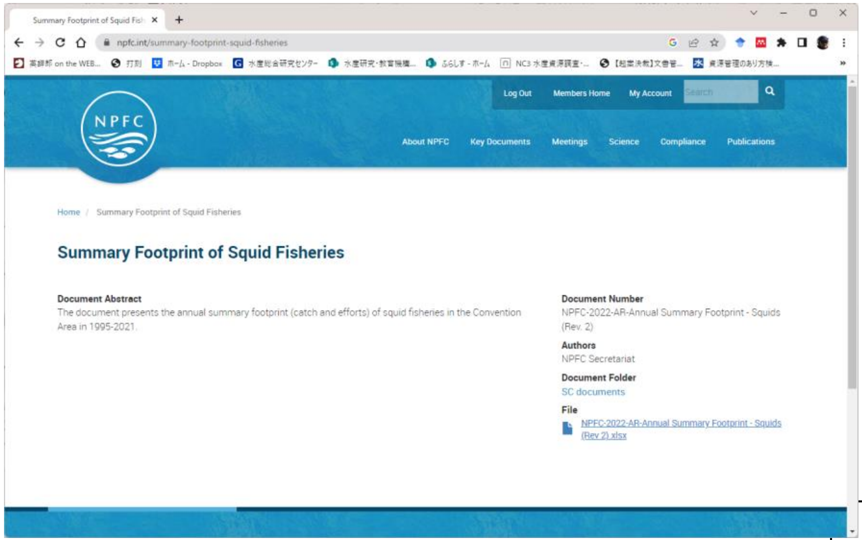
1. Catch data

Annual catch by country



Catch statistics by country

- Japan: Official statistics published by the Japanese government
- Korea: Official statistics published by the South Korean government
- China & Russia: Annual Summary Footprint by Member in the NPFC website



Reviewers' question

Question

Catches by China and Russia are not reported prior to 2012 in Table 3-1. Are catches by these countries likely to be a small fraction of the total catch over this time period? If not, how sensitive is the model to alternative assumptions about foreign catch?

Response

- Chinese and Russian JFS catch are taken from the NPFC statistics.
- China fleet operated in the NPFC Convention Area (High sea) does not target JFS, which do not form large school in offshore area.
- Russian trawlers targeting JFS in their national water have been started since 2012.
- The JFS catches from China and Russia are likely to have limited impact on the stock assessment result.

1. Catch data
Reviewers' question

<u>Question</u>

It was stated in the assessment report that "Catch was estimated from summary table of squid landing all over Japan (All fisheries Federation) and Research data of FRA (FRA).". Please provide detailed explanation on how this was done.

<u>Response</u>

- This sentence mentioned Japanese total catch for the terminal year (2021) from April to September.
  - The annual catch for the terminal year is calculated using Fcurrent.
- As prompt information on the latest fishery status, this total catch was reported in the stock assessment report.
  - Sales slip
  - Sample fishing vessel

2022年　8月分　全国イカ水揚げ集計表（全漁連）−1

スルメイカ（単月）　　（数量：トン、単価：円／KG）

地区	2022年8月						2021年8月						2020年8月					
	生		冷凍		計		生		冷凍		計		生		冷凍		計	
	数量	単価	数量	単価	数量	単価	数量	単価	数量	単価	数量	単価	数量	単価	数量	単価	数量	単価
北海道	411	762	108	905	520	792	702	557	98	673	800	571	353	733	78	683	431	724
大畑	12	802	–		12	802	15	906	–		15	906	10	887	–		10	887
八戸	343	663	13	1,295	356	687	195	643	8	752	203	647	1,427	506	–		1,427	506
久慈・宮古・山田	54	636	–		54	636	5	628	–		5	628	201	518	–		201	518
大槌・釜石	14	574	–		14	574	5	477	–		5	477	4	712	–		4	712
大船渡・気仙沼	38	611	–		38	611	27	775	–		27	775	31	616	–		31	616
石巻・女川	9	487	–		9	487	10	483	–		10	483	12	180	–		12	180
塩釜	–		–		–		–		–		–		–		–		–	
小名浜・大津・銚子	–		–		–		–		–		–		–		–		–	
(三陸地区計)	470	654	13	1,295	483	671	255	663	8	753	263	665	1,685	510	–		1,685	510
秋田	85	650	–		85	650	36	836	–		36	836	142	611	–		142	611
山形	57	640	90	977	148	846	21	872	120	705	141	729	122	624	209	732	331	692
新潟	67	626	–		67	626	54	805	–		54	805	128	645	–		128	645
石川	450	814	191	1,165	641	919	151	885	160	638	311	757	471	715	486	660	957	687
福井	38	696	–		38	696	14	815	–		14	815	40	471	–		40	471
京都	–		–		–		–		–		–		–		–		–	
兵庫	4	804	–		4	804	52	653	39	611	91	635	29	645	–		29	645
鳥取	22	602	–		22	602	36	717	–		36	717	50	530	–		50	530
境港	–		–		–		27	337	–		27	337	–		–		–	
浜田	3	624	–		3	624	4	466	–		4	466	3	511	–		3	511
下関	1	426	–		1	426	–		–		–		2	367	–		2	367
(日本海地区計)	726	750	281	1,105	1,007	849	393	779	320	660	712	725	987	657	695	681	1,681	667
福岡・唐津	34	557	1	1,901	35	597	6	484	1	1,035	7	578	17	399	1	1,284	18	430
佐世保・長崎	13	483	–		13	483	9	302	–		9	302	10	457	–		10	457
(九州地区計)	48	536	1	1,901	49	565	15	374	1	1,035	17	424	27	420	1	1,284	27	440
総合計	1,655	719	404	1,059	2,059	786	1,366	639	427	666	1,793	645	3,051	583	773	682	3,824	603

2. Biological information

Reviewers' question

Question

What is the evidence to support the assumption that M = 1.2 /yr?

Response

- M values based on Tanaka (1960) and Paury (1980) were calculated as 0.21 /mn and 0.26 /mn, respectively.
- Z value estimated with daily decrease rate of survey CPUE in the Sea of Japan was 0.174 per month, smaller than the empirical estimates.
  - Details on estimation of Z will be explained in the presentation on autumn-spawning stock
- As a result, 0.1 /mn of M was employed.
  - Spawning immediately prior to end of life
  - Highly exploited species

M for other squids

- 3.12 /yr for Argentine shortfin squid based on Paury (1980).

Reviewers' question

Question

What is a reasonable range of M and the evidence to support that this range is reasonable?

Response

- M of 1.2 /yr was used for the base case.
- Ms of 0.6 /yr and 1.8 /yr was applied for the sensitivity cases.
- This range of M (0.6 to 1.8 /yr) is conventional one.

3. Estimation of abundance

Estimation of recruitment

Questions

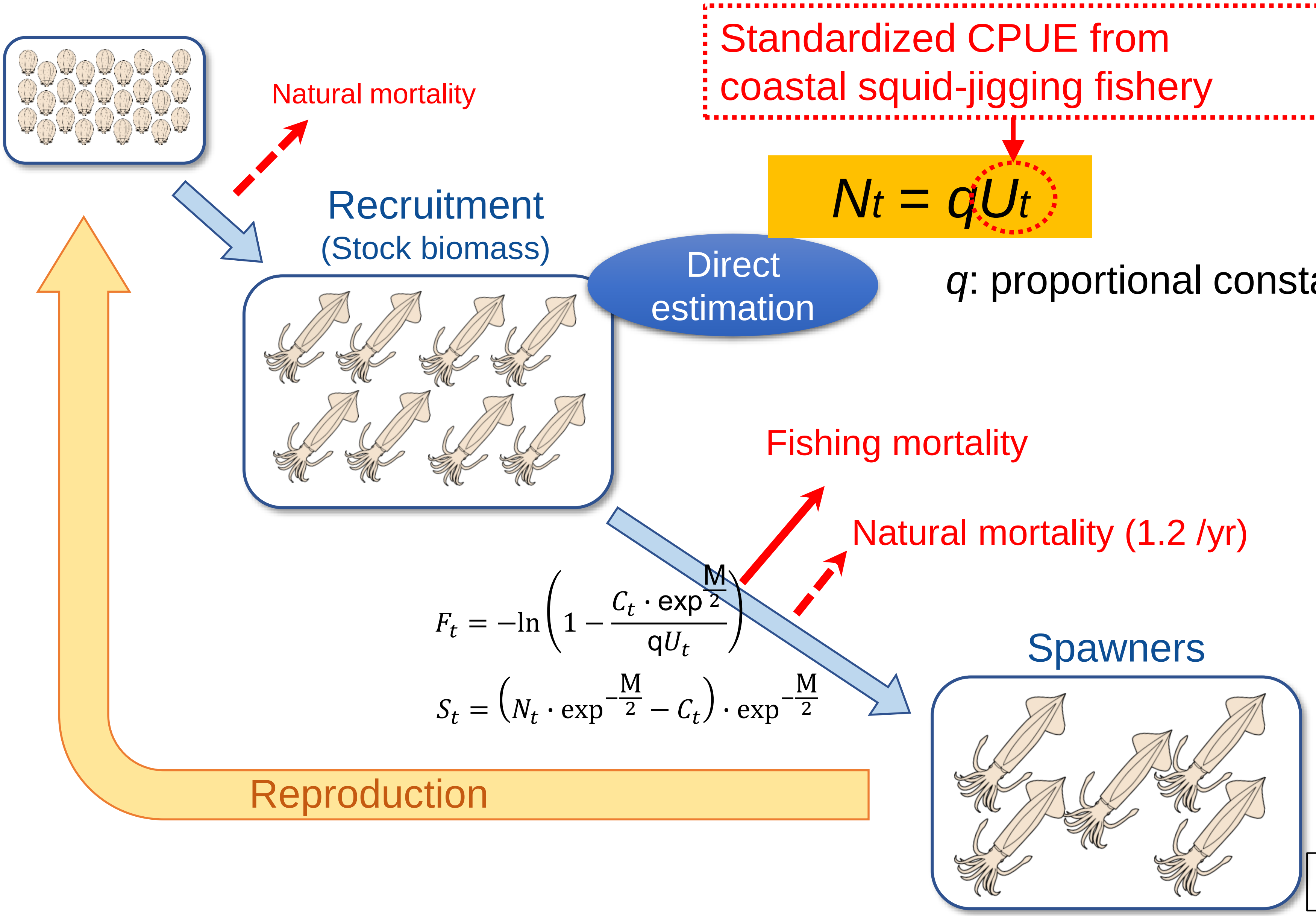
- Abundance estimation for squid species is generally thought to be very difficult. It is therefore important to examine the processes used to do so here.
- The index is very important because **the recruitment** is assumed to be scaled up from this index. Please explain the index in more detail.

Recruitment is the key estimate in abundance estimation in the stock assessment on JFS. <- See next slide

Definition of recruitment

- defined as number of squid entering the fishing ground in the nursery grounds of WS in Pacific.

How important is recruitment abundance index?



$$N_t = qU_t$$

q: proportional constant

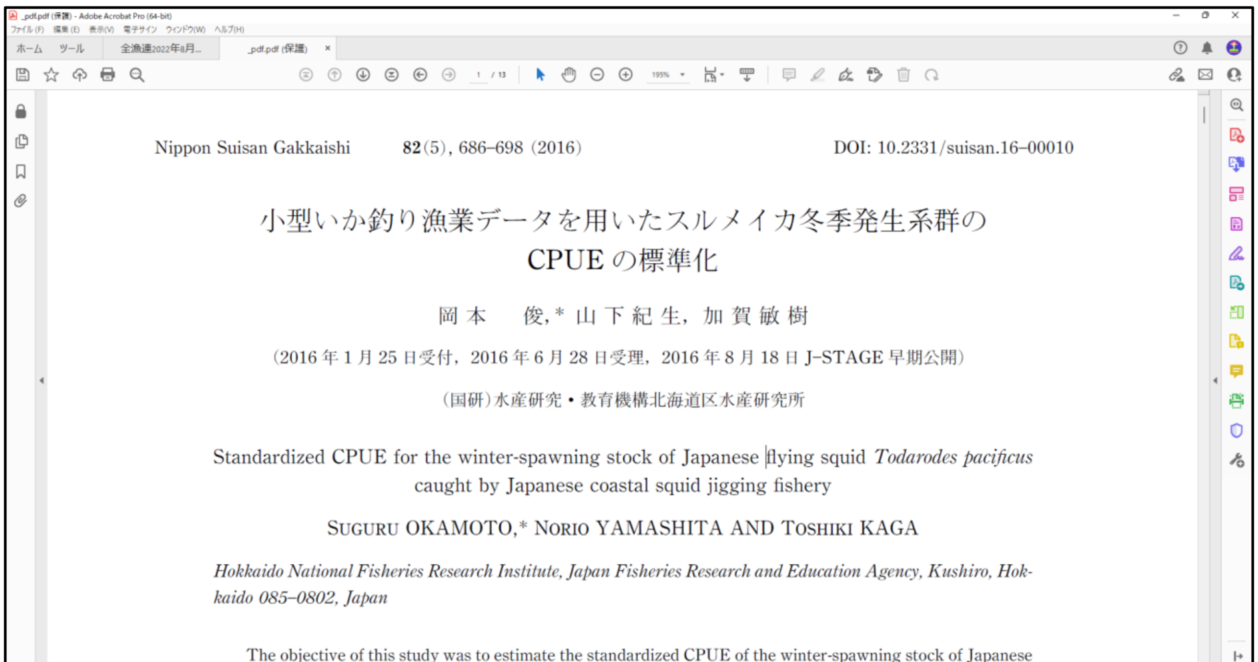
$$F_t = -\ln\left(1 - \frac{C_t \cdot \exp^{\frac{M}{2}}}{qU_t}\right)$$

$$S_t = \left(N_t \cdot \exp^{-\frac{M}{2}} - C_t\right) \cdot \exp^{-\frac{M}{2}}$$

3. Estimation of abundance

Recruitment abundance index

- Okamoto-san published a paper on standardized CPUE from coastal squid-jigging fishery
- Time series of the CPUE are used to estimate recruitment


Nippon Suisan Gakkaishi 82(5), 686–698 (2016) DOI: 10.2331/suisan.16–00010

小型いか釣り漁業データを用いたスルメイカ冬季発生系群の
CPUE の標準化

岡本 俊,* 山下紀生, 加賀敏樹

(2016 年 1 月 25 日受付, 2016 年 6 月 28 日受理, 2016 年 8 月 18 日 J-STAGE 早期公開)

(国研)水産研究・教育機構北海道区水産研究所

Standardized CPUE for the winter-spawning stock of Japanese flying squid *Todarodes pacificus* caught by Japanese coastal squid jigging fishery

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Hokkaido National Fisheries Research Institute, Japan Fisheries Research and Education Agency, Kushiro, Hokkaido 085–0802, Japan

The objective of this study was to estimate the standardized CPUE of the winter-spawning stock of Japanese

Okamoto et al. 2016

Coastal squid-jigging fishery

- Fishing ground

  Coastal waters off the northeastern part of Japan on the Pacific side

- Fishing season

  July to December

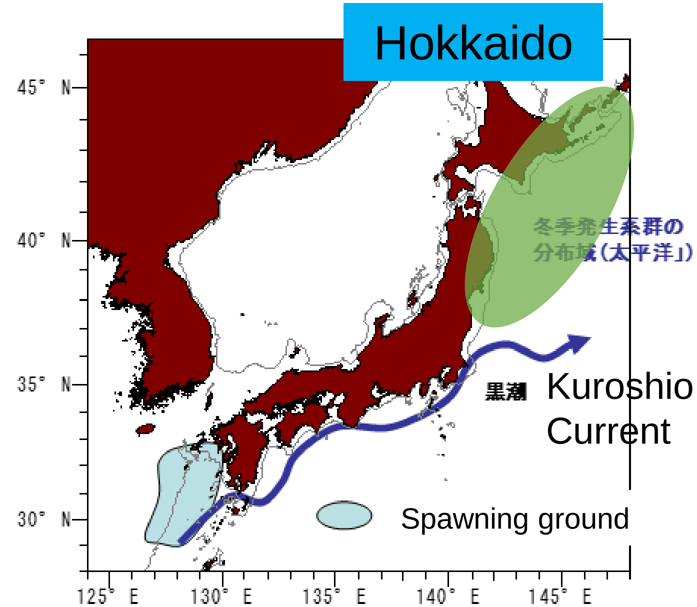
- Vessel size

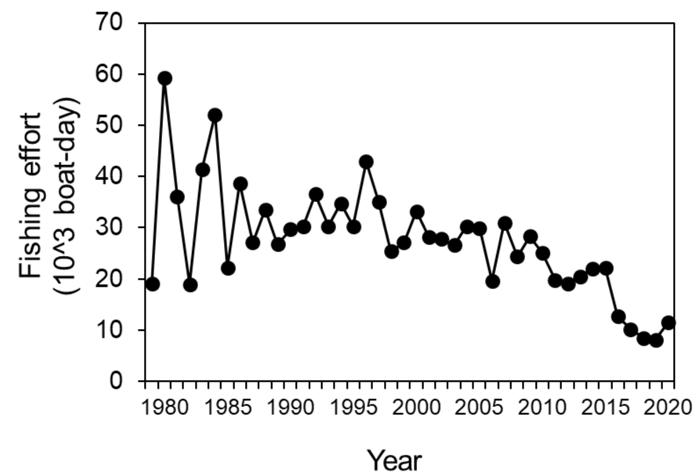
  19 GRT and smaller

- Fishing effort

  10 to 20 thousand boat-day per year in last five years

<u>Coastal squid-jigging fishery is major fleet for fishing of WS.</u>





Materials and methods in Okamoto et al (2016)

- Sales slip data collected from 17 ports of 7 regions
  - Monthly catch and number of boats with landing
  - 1979 to 2013
    - Terminal year is updated annually
  - July to December
  - 17 ports were integrated into 7 regions, which was used as a variable of port
- Statistical model: GLMM

$$\log(CPUE + \delta) = Intercept + Year + Month + Port + Year * Month + Year * Port + Month * Port$$

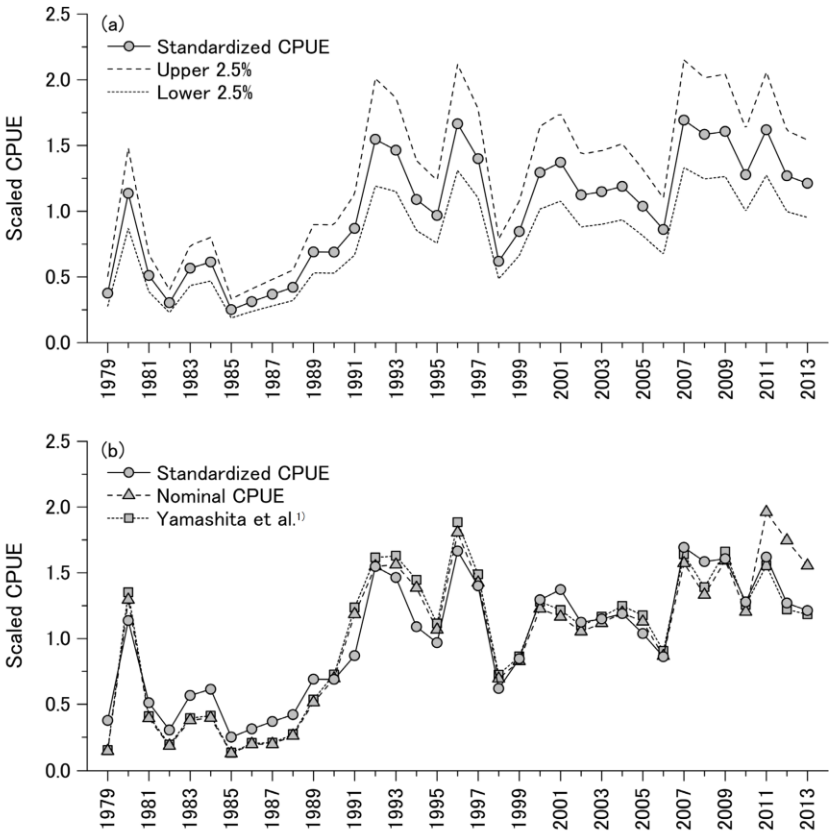
  - δ is constant.
  - All explanatory variables were categorical ones.
  - Interactions with *Port* worked as mixed effect.
- AIC and BIC were used to select model.

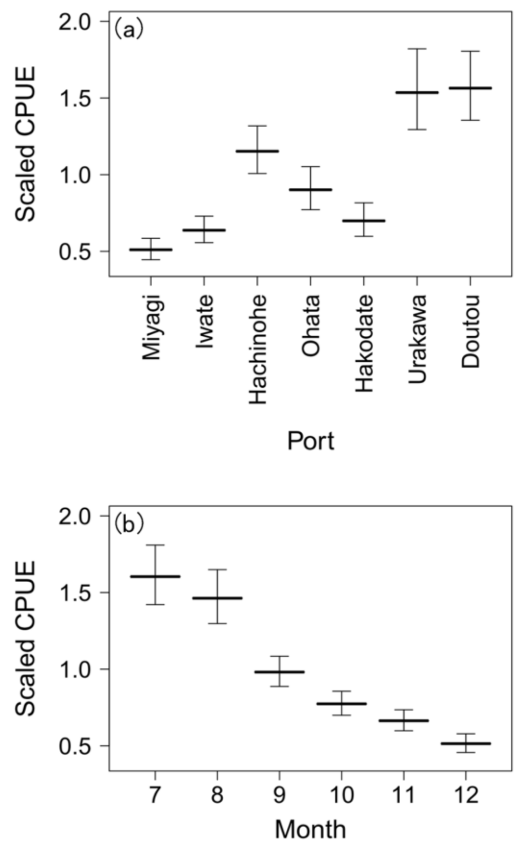
Standardized CPUE from Okamoto et al (2016)

Selected variables

- AIC: All variables
- BIC: Variables without Year*Month

Standardized CPUE from the AIC-selected model





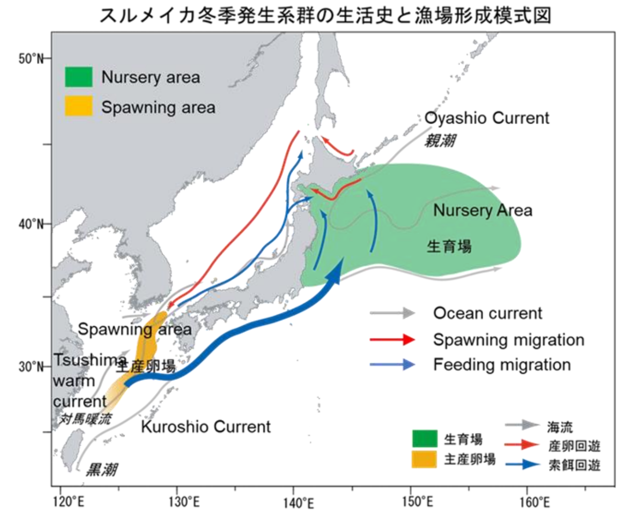
Reviewers' question about the index

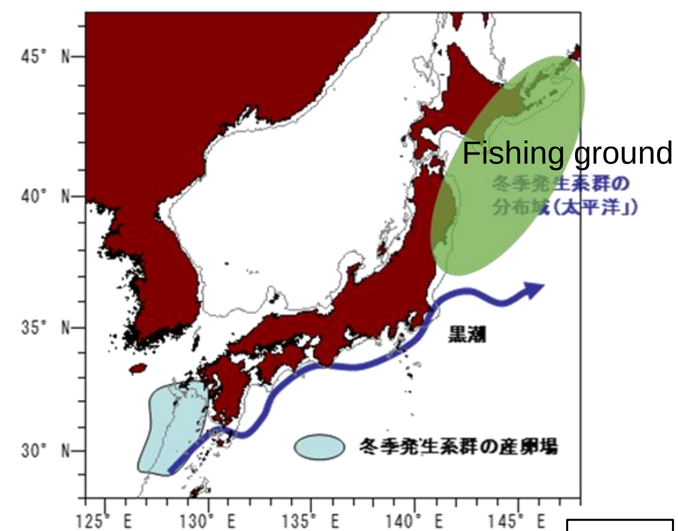
<u>Question</u>

Please explain why this index is thought to be representative of the entire stock.

<u>Response</u>

- Squid of WS are distributed mainly in coastal waters off the Pacific side of the northeastern part of Japan.
- The fishing grounds of the coastal squid-jigging fishery are formed in those waters.
- The standardized CPUE from the coastal squid-jigging fishery can be thought to include abundance information on WS.





Reviewers' question about the index

Question

What is the uncertainty in the index?

Response

- Standard errors can be calculated for the index via CPUE standardization.
- At this moment, no consideration of any those errors.
- In future, those errors could be in the stock assessment process.

Proportional constant *q*

- Each recruitment index value was scaled up with the proportional constant *q*.

$$N_t = qU_t$$

- This constant *q*
  - is critical to determine annual recruitment.
  - has been traditionally used in the stock assessment of WS.

<u>Question</u>

The critical assumptions for the abundance estimates are that $N_t=qU_t$ and q is fixed at 18.32. It seems like the average exploitation rate was assumed to be 0.3 and thus a q of18.32 was assumed. I am not sure this makes sense to me. Please explain the assumptions made and where they come from.

How to calculate *q*

<u>Assumption</u>

□ Mean exploitation rate (1979-2001) = 0.3

<u>Rationale</u>

- The exploitation rates of AS were estimated to be ranged between 0.2 to 0.4 (JSNFRI 1997; 1998)
- Kidokoro et al (2006) estimated this rate to be approx. 0.3 for 1979-2001.
- The exploitation rates for WS were estimated to be at the same level (0.3) for 1979-2001 (Mori 2006).

<u>Calculation</u>

- $Nt = qUt$
- Mean Ct / Nt for 1979-2001 is 0.3.
- q was calculated with (C / U) / 0.3
  - C / U corresponds to a mean value for 1979-2001
  - U is standardized CPUE

□ <u>q = 18.32</u>

Reviewers' question about *q*

<u>Question</u>

The estimate of q for this stock assumes an average exploitation rate of 0.3 from 1997 to 2000, which is smaller than the average exploitation rate assumed for the autumn-spawning stock (0.447). What is the basis for the difference in average exploitation rates between the two stocks? Also, what is the estimated value of q for this stock? For the 2021 projection, the reported value is 18.32, which is difficult to interpret in this context.

<u>Response</u>

- Method to calculate *q* is different between two stocks.
- Assumption of *q* estimation is exploitation rate of 0.3 and fishing mortality of 0.447 for WS and AS, respectively.
- Calculation of *q* for AS will be explained later.

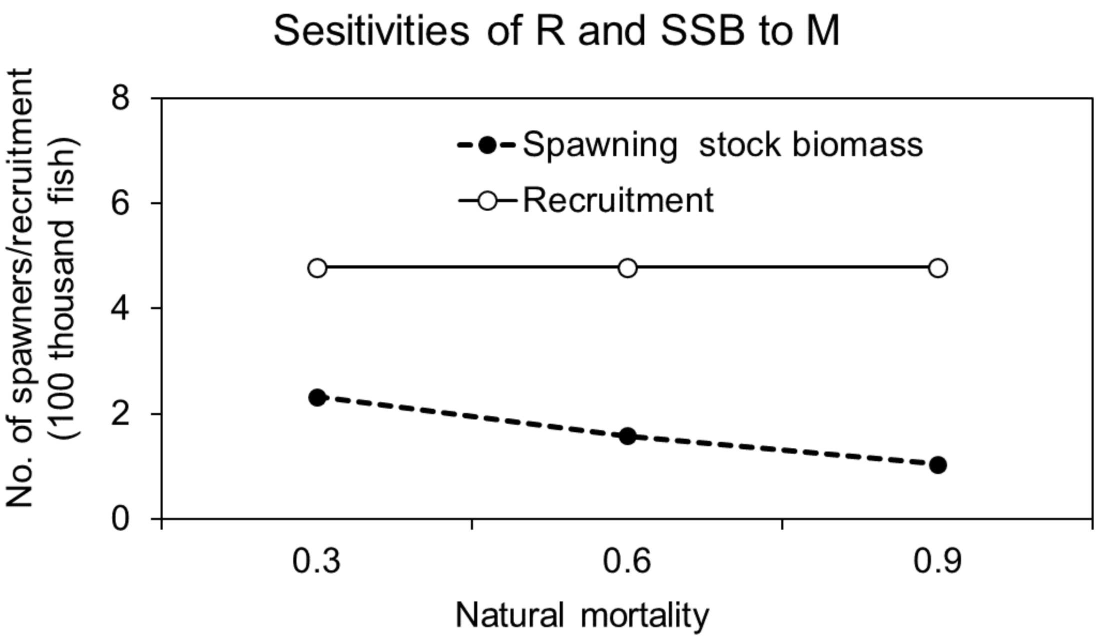
Reviewers' question

Question

How sensitive are the results to this range of M?

Response

- Setting of M, which has no effect of recruitment estimation, can affect estimation of spawning stock biomass.



Reviewers' question

Question

In the sensitivity test to alternative values of M (Fig. 4-4), can you describe why the 2021 biomass does not change, while the 2021 Spawning Stock Biomass (SSB) changes? Is this change in M applied to all steps in the assessment that rely on M? Looking at Equation 2, a change in M would affect the estimate of q, which would affect the biomass estimate in Equation 1.

Response

- Direct estimation of the 2021 biomass (recruitment) with the index.
- SSB estimates can be changed according to assumption on M.

$$S_t = \left(N_t \cdot \exp^{-\frac{\mathrm{M}}{2}} - C_t\right) \cdot \exp^{-\frac{\mathrm{M}}{2}} \qquad \text{(eq. 3)}$$

- M value also does not affect *q*.

4. Stock-recruitment and management quantities

4. Stock-recruitment and management quantities

Reviewers' question

Question

Is calculation of MSY necessary for management? Or can you use some other proxy?

Response

- Small examples of MSY-based management for squids
    - Jumbo flying squid is managed based on MSY estimated via surplus production model in SPRFMO.
    - In US, fishing mortality achieving 30% egg-escapement is set as Fmsy proxy for market squid.
    - In US, Bmsy proxy derived from survey results is set to longfin squid.
- Target escapement rate is employed in some cases, eg: Argentine shortfin squid.
    - Fmsy set for WS corresponds to 37% escapement rate.

5. Others

Reviewers' question

Question
- How is uncertainty propagated in the assessment?
- What is the role of uncertainty in the management of this stock?

Response
- Recruitment deviation is used to estimate target reference point, SBmsy.
- No consideration though abundance estimation.

Reviewers' question

Question

On the title page of the report, it is noted that reference points in the report were proposed in July 2020, and were to be finalized in December 2020. Do the reported reference points in the report represent the final values, or did a change occur after publication?

Response

- The reference points proposed in December 2020 was adopted at the stakeholder meeting in December 2021.

Reviewers' question

Question

What fraction of the potential suitable area for spawning (Appendix Figure 4-7) is sampled by the larval survey each year? If the survey covers a significant fraction of the area, and average estimates of fecundity are available, it could be possible to estimate spawning stock using the above-mentioned egg production methods.

Response

- Sampling survey in the spawning ground has been covered approximately 40-50% of the potential suitable spawning area.
- Egg production model could be one of the future candidate procedure to estimate SSB.
  - To do so, information of fecundity should be collected.

Reviewers' question

<u>Question</u>

Stocks such as these with annual life spans, and long time series of catch and effort (or CPUE) are prime candidates for application of the Empirical Dynamic Modeling framework (c.f. Munch et al. 2020). I encourage you to explore this approach for Japanese flying squid, and would be happy to introduce you to Dr. Steven Munch at the NMFS SWFSC Fisheries Ecology Division for more information. Dr. Munch has found that the predictive skill of this model improves upon parametric and nonparametric stock recruitment relationships when applied to short-lived species such as squid.

<u>Response</u>

We appreciate your suggestion about application of the EDM framework.

Reviewers' question

Question

Reporting uncertainty in standardized CPUE, q, z* (daily total mortality), stock-recruitment parameters, and development of a prior for M would allow propagation of uncertainty into management quantities such as spawning biomass.

Response

- We appreciate your advice to future development of the JFS stock assessment.
- Future task of the JFS stock assessment is to incorporate uncertainties in estimation of abundance.

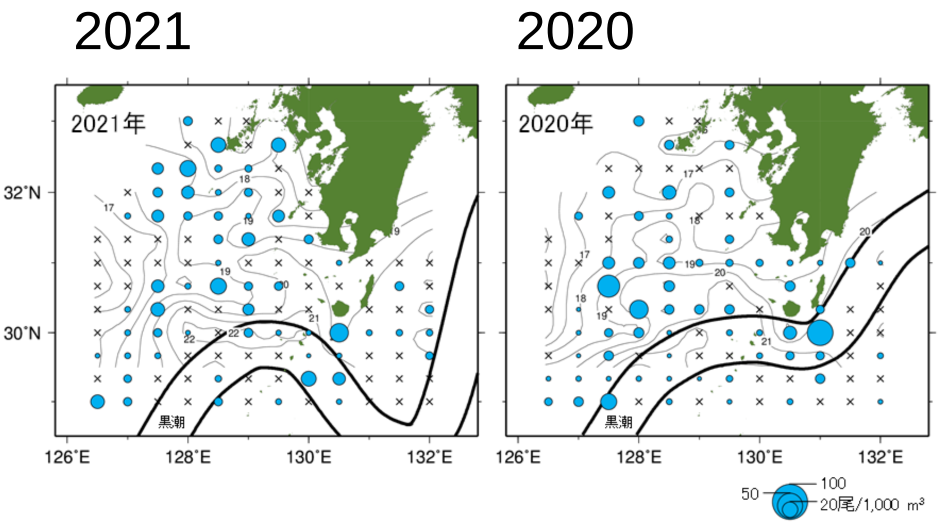
Reviewers' question

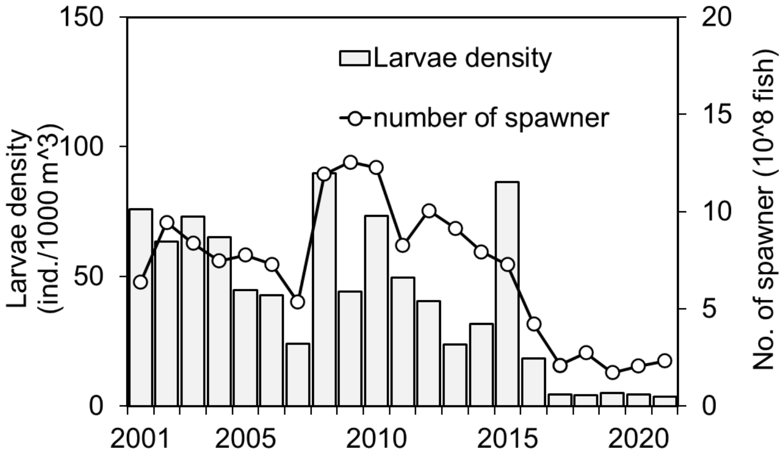
Question

An independent estimate of spawning stock size could be obtained from larval survey data via an egg production method (Lasker 1985). If average fecundity of females is known, then estimation of the parental stock size could be based on observed densities of larvae.

Response

- Surveys on larvae are conducted annually for both AS and WS.





6. Revisit to discussion on estimation of recruitment

6. Revisit to discussion on estimation of recruitment

Assumption in constancy of *q*

Questions

- Is the scaling up using a constant 18.32 reasonable? Typically, when I standardize a CPUE, the goal is to try to make q constant over the time series but as the time series change, the value for the constant q changes.
- Please explain why this index is thought to have a constant catchability and can be scaled up to represent absolute recruitment?

Response

- As pointed out, assumption of constant *q* is critical in the stock assessment of JFS.
- Difficult to conduct direct validation of this assumption.

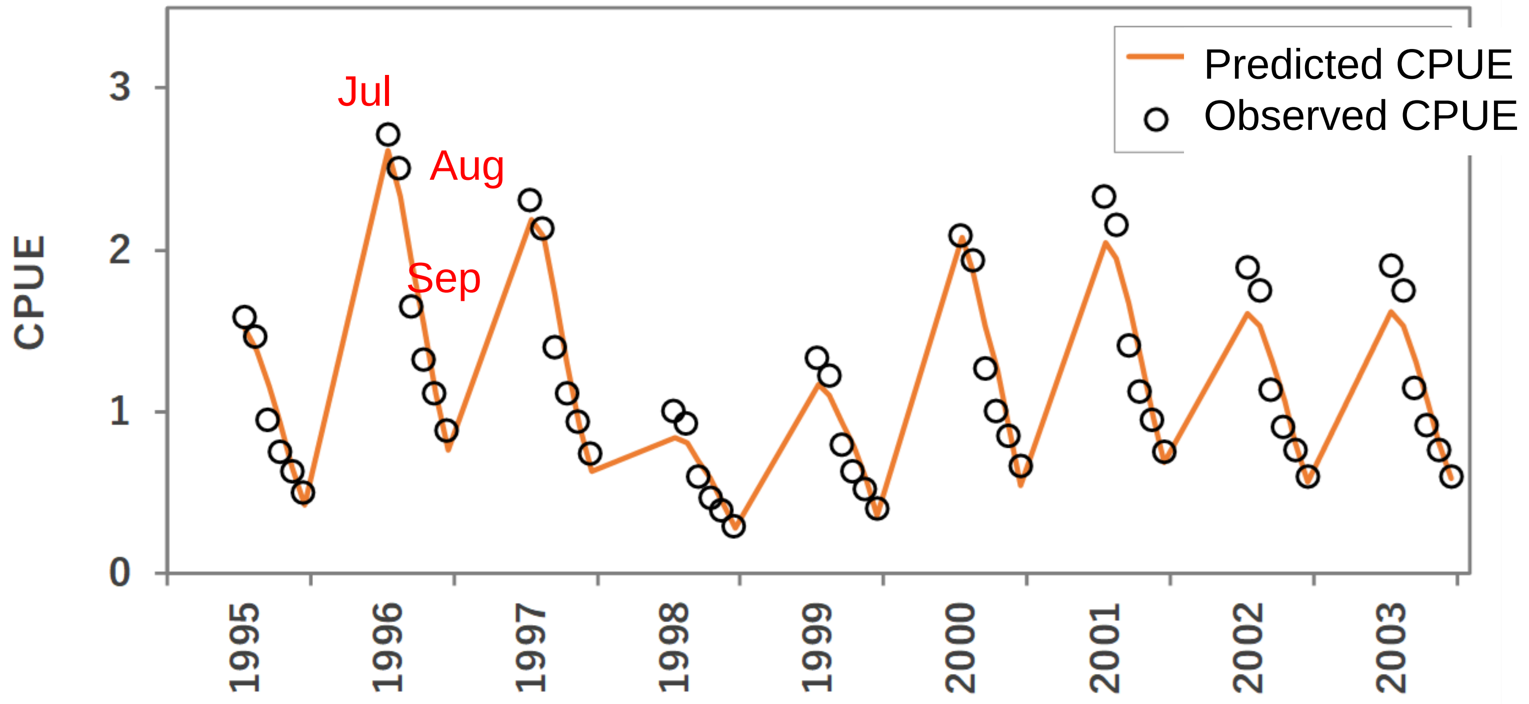
□ Comparison with estimates from alternative methods.

  - SS3
  - Depletion model
  - SAM

Trial of application of SS3

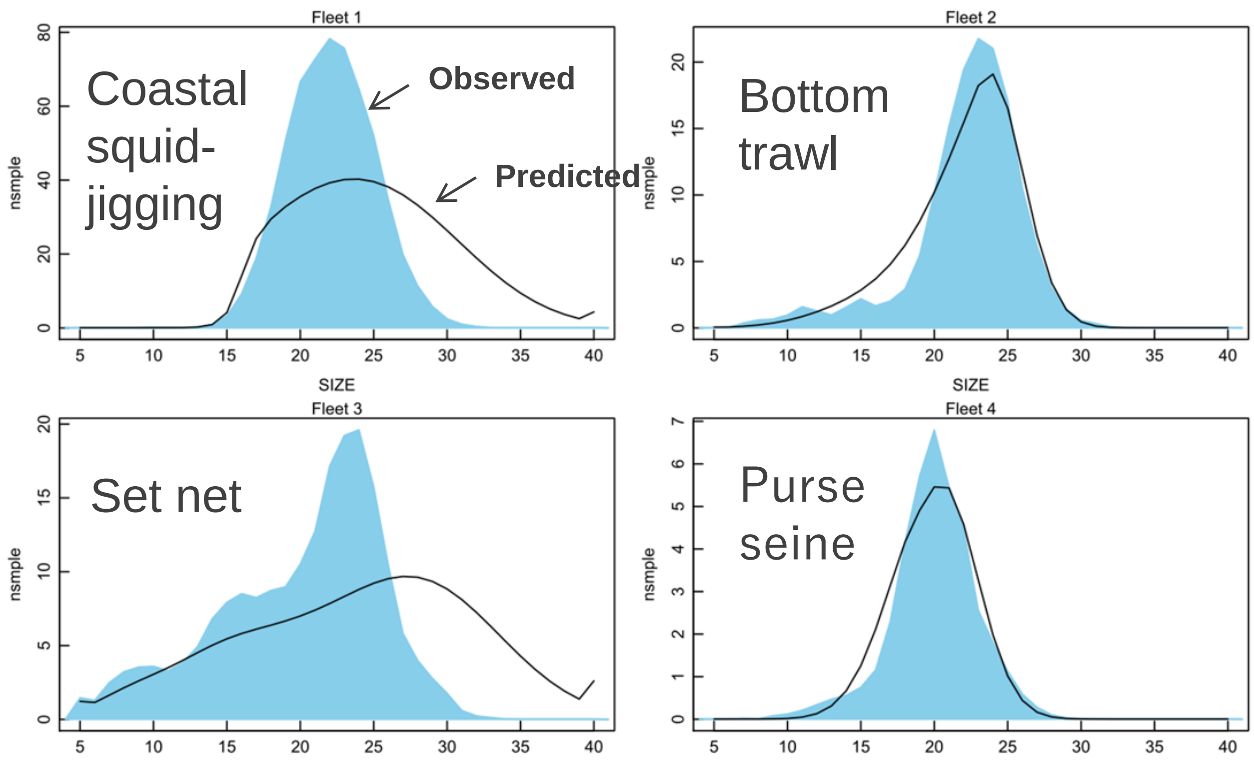
- Okamoto-san and Fukuda-san tried to apply SS3 to JFS WS data.
- Purpose of the application
    - To validate average exploitation rate of 30% for 1979-2001
        - An assumption to calculate *q*
    - To consider uncertainty
- Duration of data: 1995 to 2016
- CPUE: coastal squid-jigging CPUE
- Constant *q* was assumed.
- Down-weight treatment to size data

Results of SS3 – Fitting to CPUE



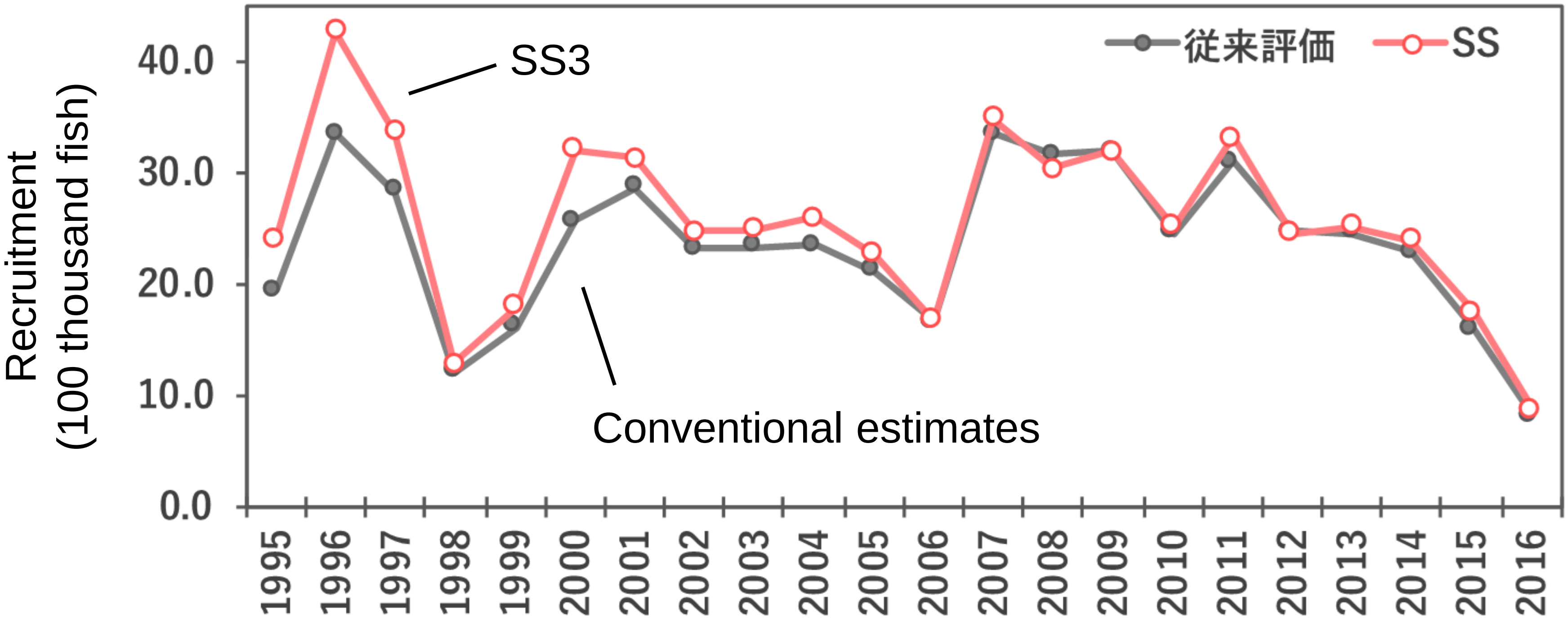
- Generally, good fit.
- Underprediction for Jul-Aug CPUE.

Results of SS3 – Fitting to size data



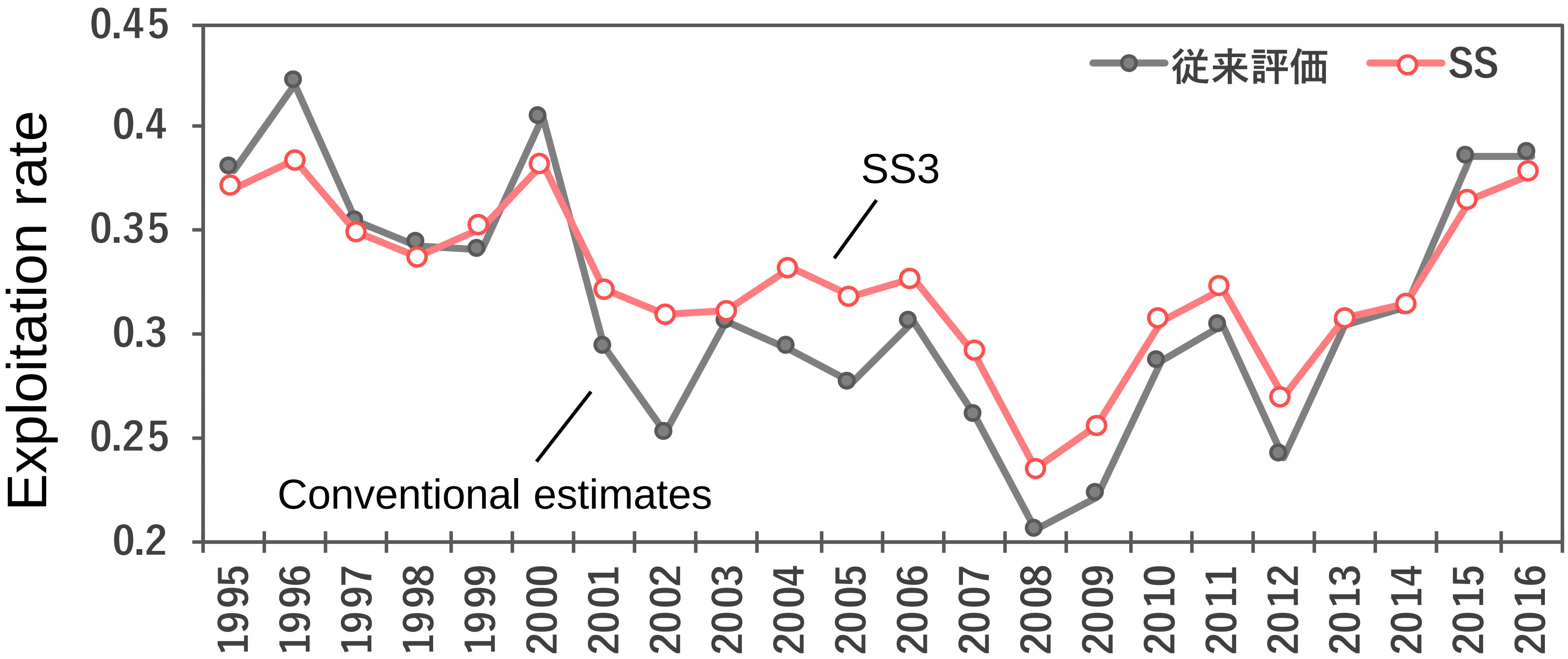
- Good fit to bottom trawl and purse seine.
- Poor fit to coastal squid-jigging and set net.

Results of SS3 – Recruitment



- Mean recruitment over the year from SS3 was 9% larger than that of conventional estimate.

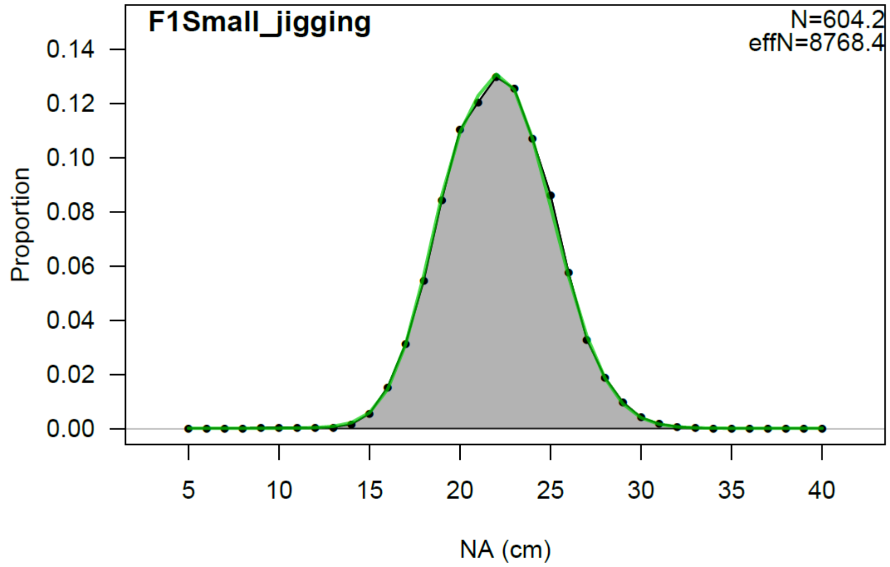
Results of SS3 – Exploitation rate

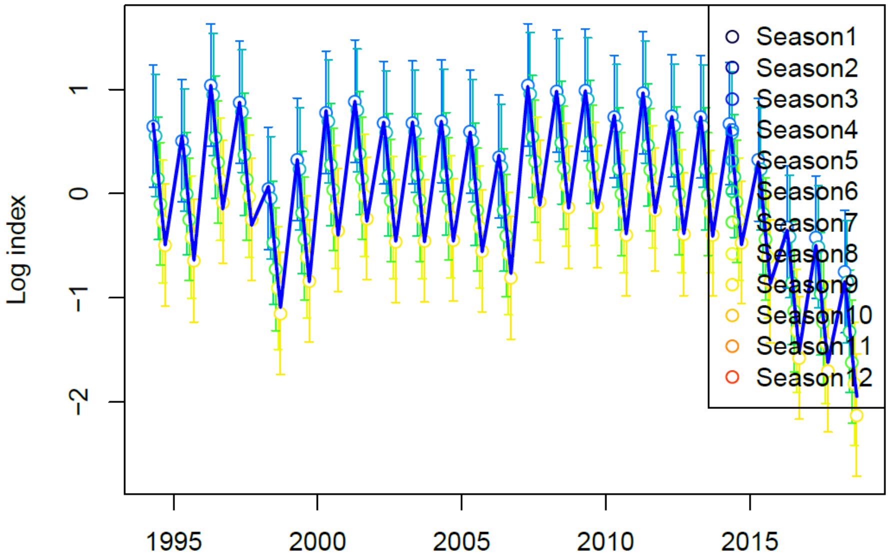


- Mean exploitation rate over the year from SS3 was 4% larger than that of conventional estimate.

6. Revisit to discussion on estimation of recruitment

SS3 – Improvement of fit

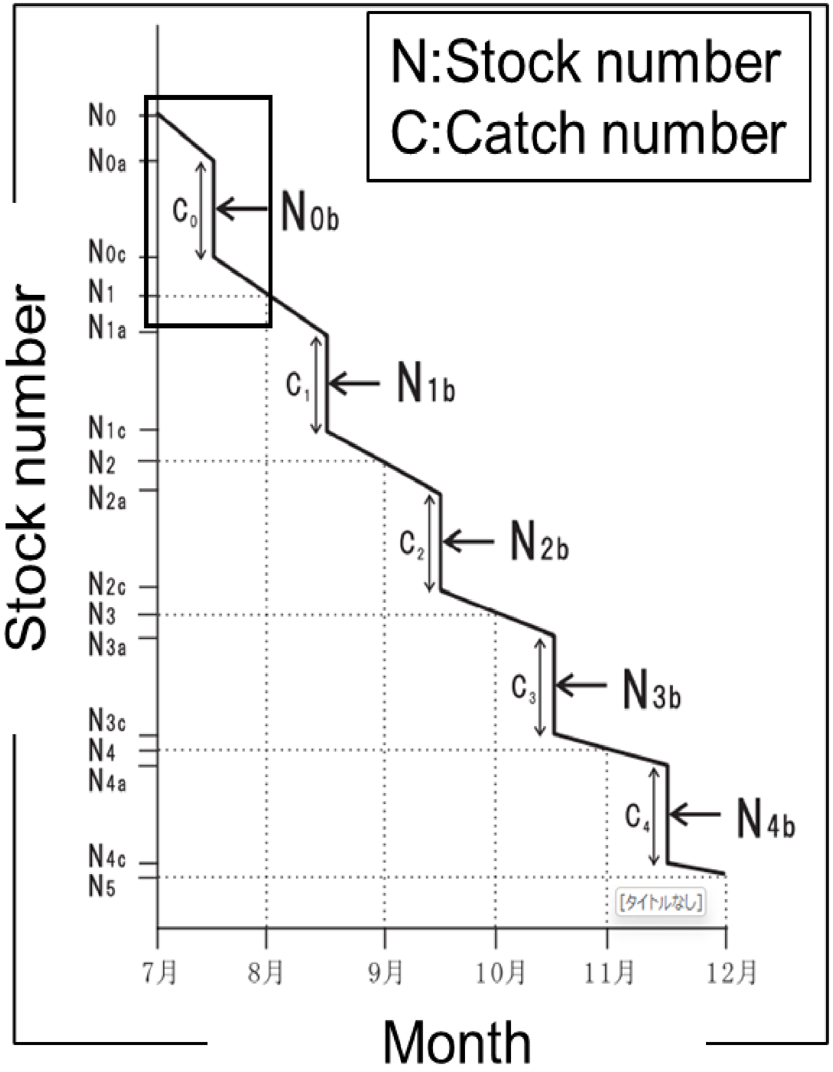




Application of depletion model

- Moriyama-san tried to apply depletion model to JFS WS data in 2022.
- Purpose of the application
  - To validate average exploitation rate of 30% for 1979-2001
    - An assumption to calculate *q*
- Modified DeLury method proposed by Mori (2006)
  - Inclusion of M in depletion process
- Duration of data: 1979 to 2021
- CPUE: coastal squid-jigging CPUE

Depletion model: Method



(Mori, 2006)

__Modeling__

Depletion process in month *i*

- Phase 1 (natural mortality)

  $N_{ia} = N_i e^{-M/2}$

  (M = 0.1 per month)
- Phase 2 (natural and fishing mortalities)

  $N_{ib} = N_{ia} - C_i/2$
- Phase 3 (natural and fishing mortalities)

  $N_{ic} = N_{ib} - C_i/2$
- Phase 4 (natural mortality)

  $N_{i+1} = N_{ic} - C_i/2$

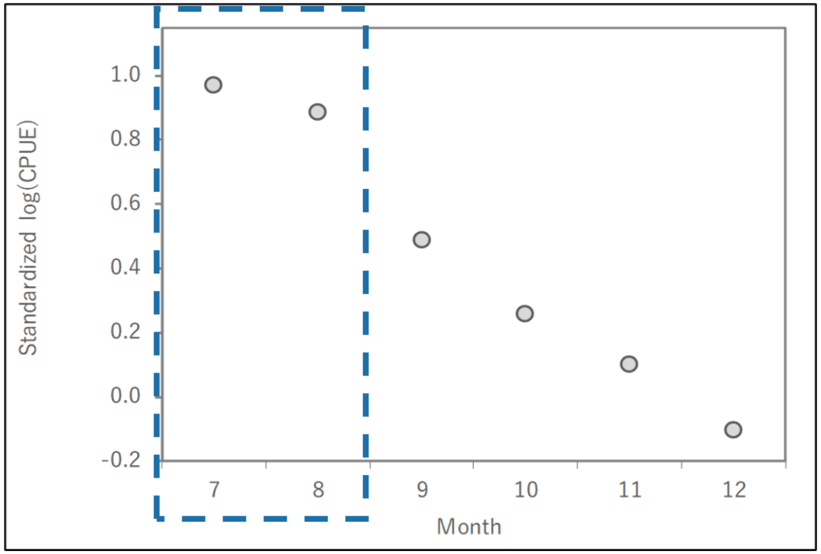
Depletion model – Parameter estimation

- To estimate parameters, stock number at phase 2 in each month was used to fit to observed monthly CPUE

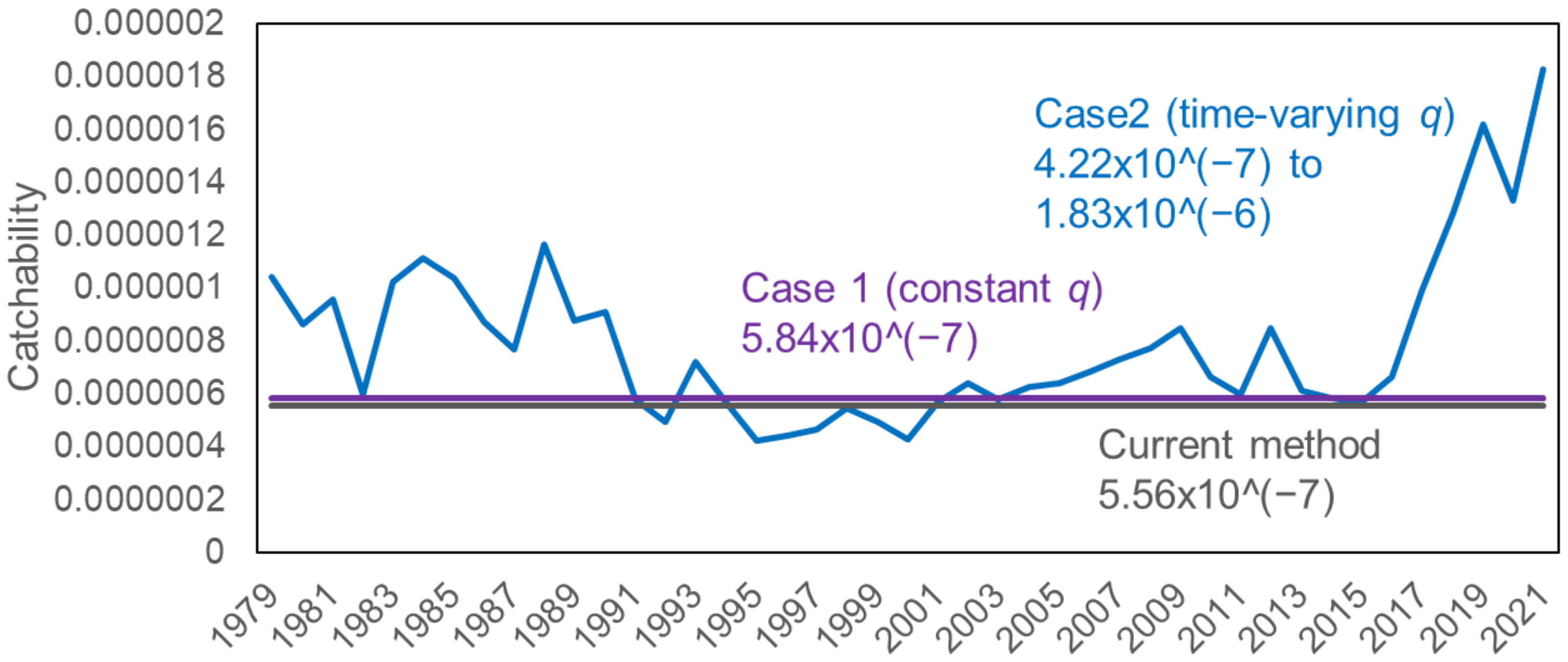
  Predicted CPUE = qN_{ib} (q: catchability)

- In Moriyama-san's study, two cases regarding assumption of q were established.
  - Constant q as case 1
  - Time-varying q as case 2
- During July and August, squids continuously enter fishing ground.

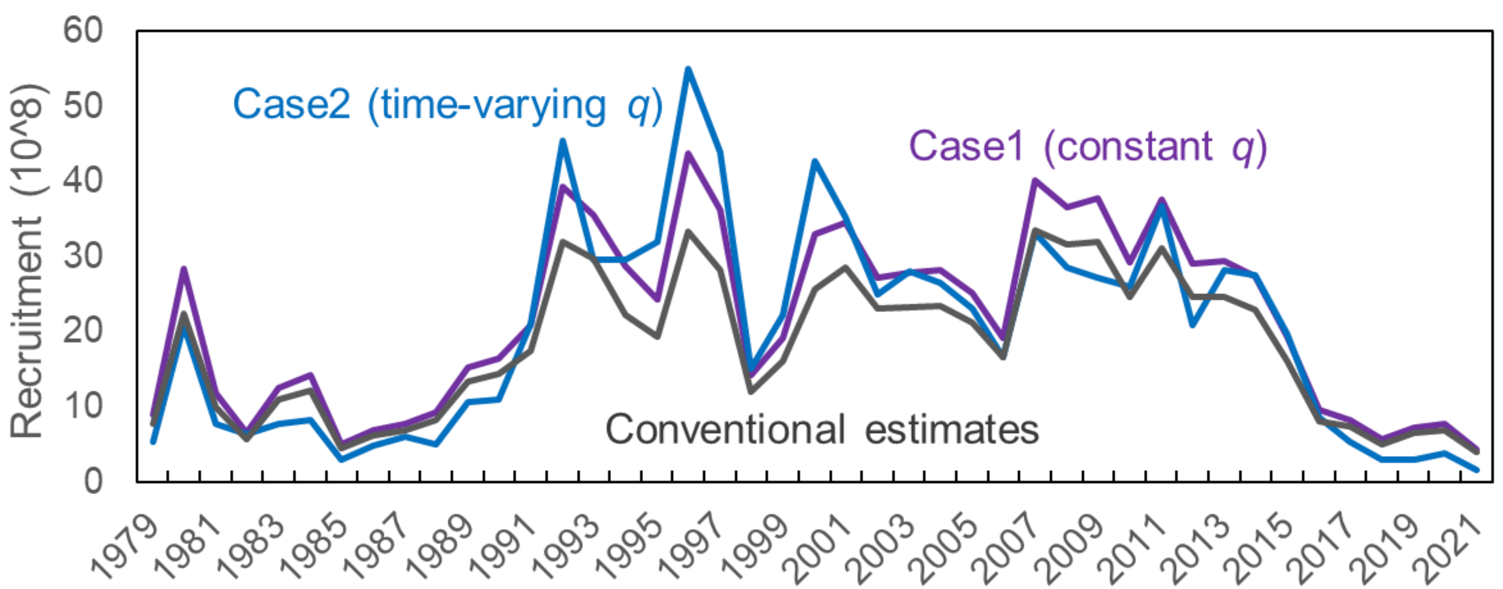
  -> Monthly CPUE for those two months were excluded in fitting.



Results of depletion model – Estimated *q*

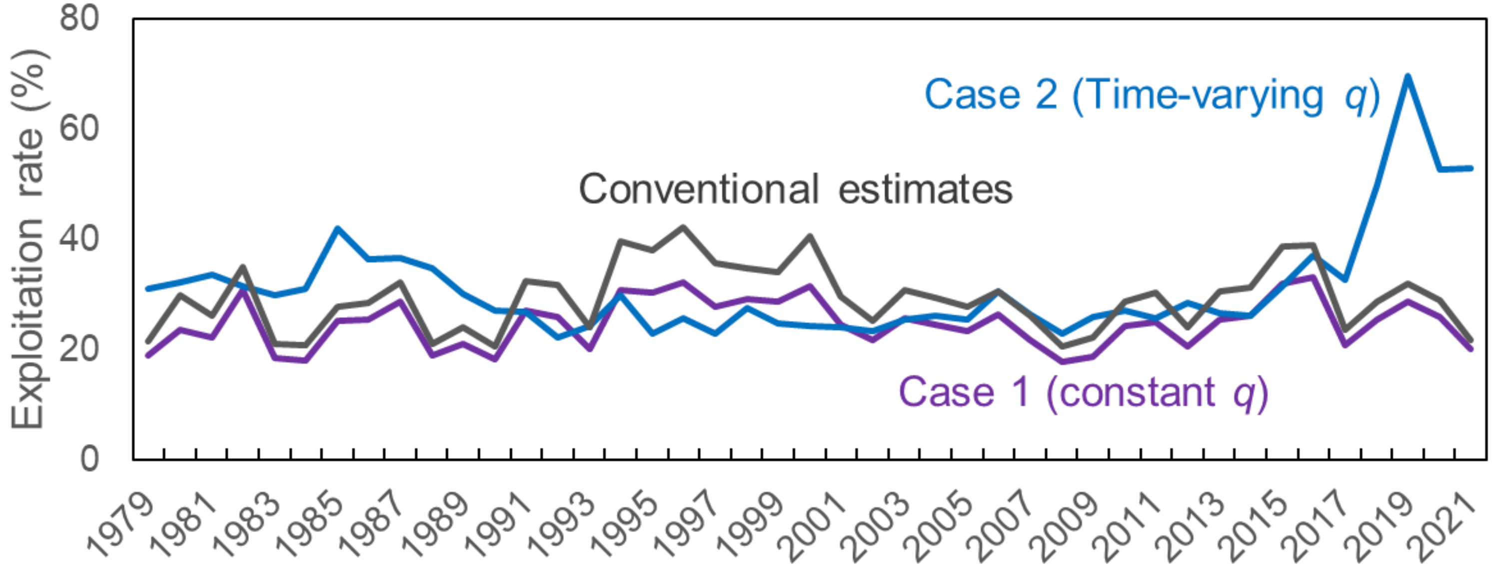


Results of depletion model – Recruitment



- Mean recruitment over the year from case 1 was 20% larger than that of conventional estimate.
- Mean recruitment over the year from case 2 was 11% larger than that of conventional estimate.

Results of depletion model – Exploitation rate



- Mean exploitation rate over the year from case 1 was 16% larger than that of conventional estimate.
- Mean exploitation rate over the year from case 2 was 5% smaller than that of conventional estimate.

6. Revisit to discussion on estimation of recruitment

Application of SAM

- Nishijima-sam published a paper of stock assessment of JFS with SAM.
  - SAMUIKA (State-space Assessment Model Used for IKA).
- SAM is a prime candidate of the future stock assessment models to apply to JFS.
- <u>*q* was estimated and worked as a constant catchability.</u>

SPECIAL FEATURE (ORIGINAL ARTICLE)

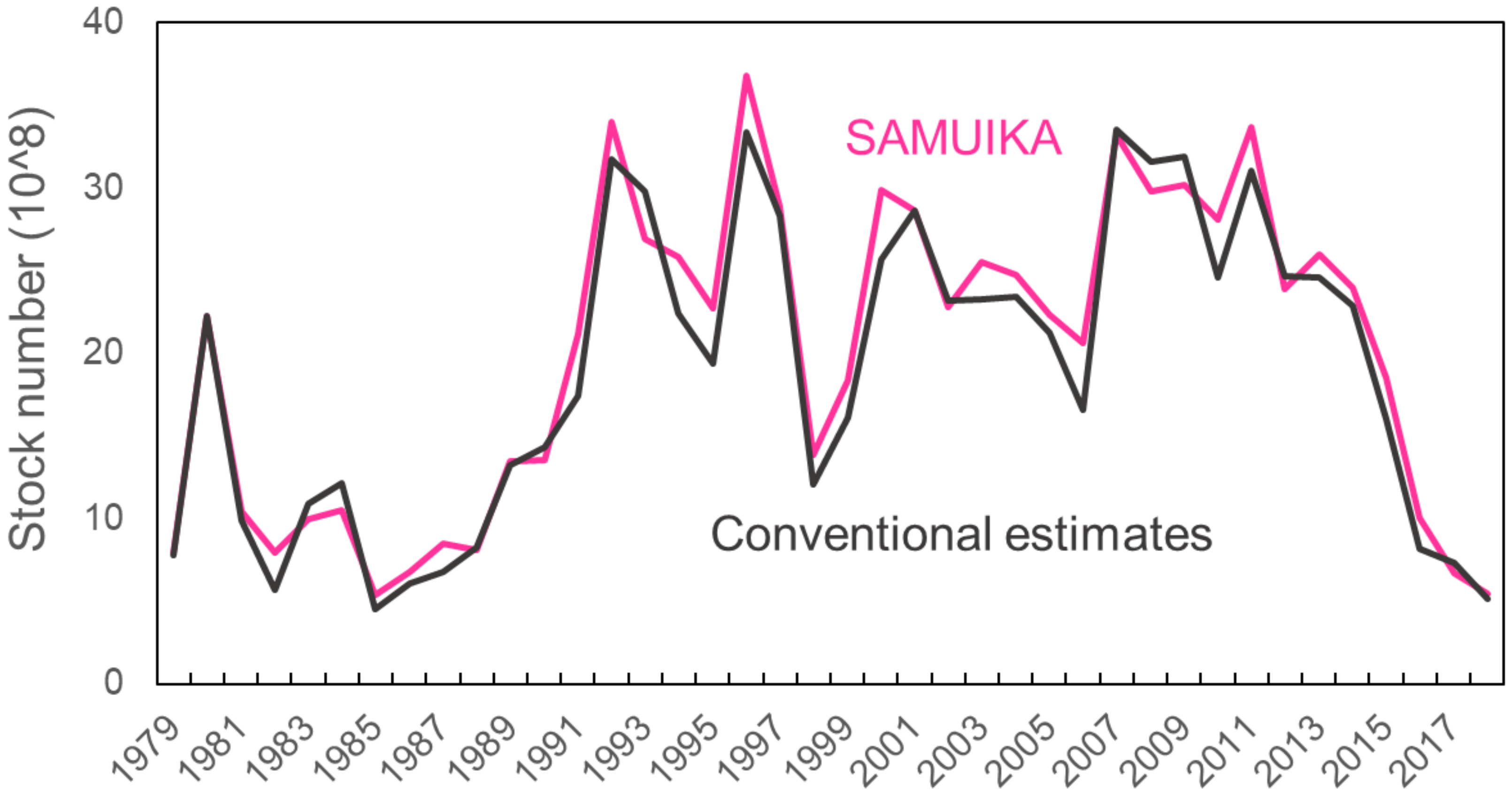
Population Ecology WILEY

Marine ecosystem services: Ecological, socioeconomic and cultural sustainability

State-space modeling clarifies productivity regime shifts of Japanese flying squid

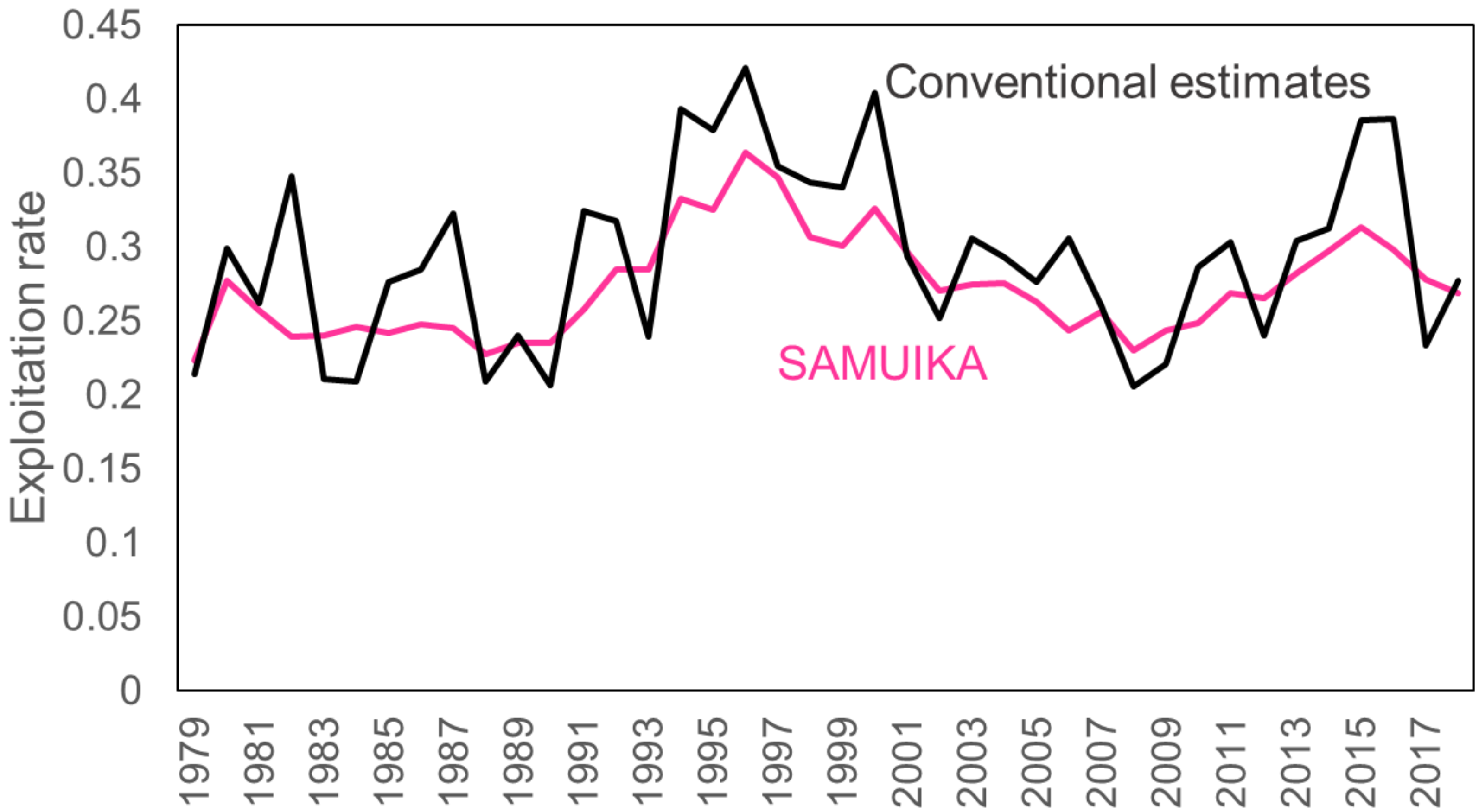
Shota Nishijima[1] | Hiroshi Kubota[2] | Toshiki Kaga[1] | Suguru Okamoto[1] | Hisae Miyahara[2] | Hiroshi Okamura[1]

SAM − Comparison of recruitments estimates



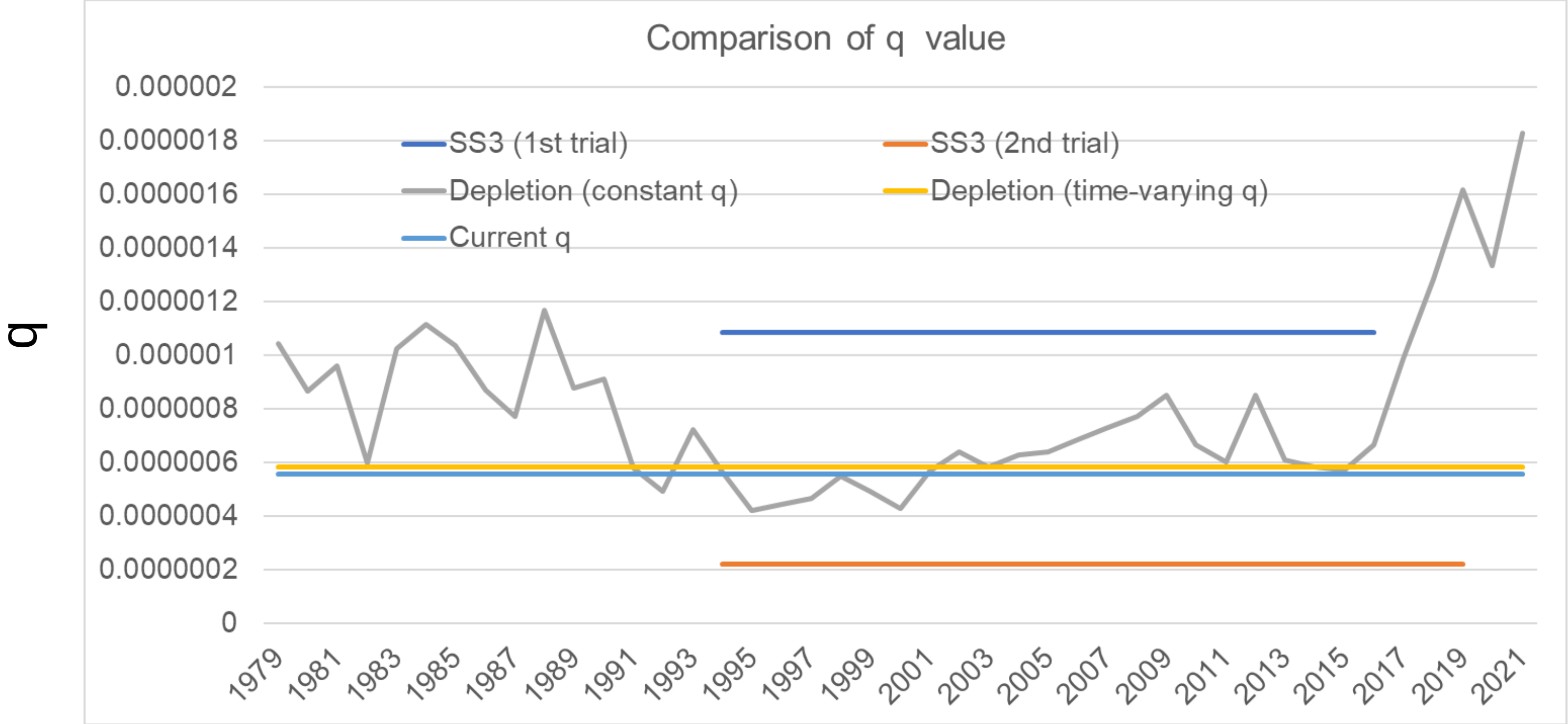
- Mean recruitment over the year from SAMUIKA was 5% larger than that of conventional estimate.

Comparison of exploitation rate



- Mean exploitation rate over the year from SAMUIKA was 7% smaller than that of conventional estimate.

Homework of WS: Comparison of q value



Method	q
SS3 (1st trial)	1.09E-06
SS3 (2nd trial)	2.22E-07
Depletion (constant q)	5.84E-07
Depletion (time-varying q)	7.93E-07 (4.22E-7 to 1.83E-6)
Current q	5.56E-07