

Extending Joint CPUE Standardization for Neon Flying Squid

Updated Data and Flexible Covariate Effects in jointCPUE

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Brief Recap and What Is New

➤ Brief recap

- Multiple fleets observe a shared population process but have different catchability
- The joint model separates the shared abundance signal from fleet-specific effects influencing catchability

➤ New in this update

- This update uses revised data through 2025
- Flexible formulas now allow covariates in either the population or catchability component
- Linear, smooth, fixed-factor, and random-factor effects
- SST case study and comparison of resulting CPUE indices

What the Updated Analysis Compares

- Separate analyses are conducted west and east of 170°E.
- Both yearly and monthly standardized indices are estimated.
- No-SST joint models are compared with no-SST single-fleet models.
- Three joint scenarios are compared: no SST, SST in catchability, and SST in population; trajectories and CVs use a common model structure.

Covariates Extend the CPUE Decomposition

Observed CPUE is decomposed into a shared population component, fleet-specific catchability, and observation error.

$$\text{CPUE}_{f,s,t} = \text{Biomass}_{s,t} \times q_{f,s,t}$$

$$\log(\text{CPUE}_{f,s,t}) = y_t + \omega_s + \varepsilon_{s,t} + X_{s,t}^{\text{pop}} + q_{f,s,t} + X_{f,s,t}^q$$

- y_t : fixed time effect
- ω_s : time-constant spatial field
- $\varepsilon_{s,t}$: spatiotemporal field
- $q_{f,s,t}$: fleet-specific catchability
- $X_{s,t}^{\text{pop}}$: covariate effects that describe population density
- $X_{f,s,t}^q$: covariate effects that influence catchability
- The standardized index integrates the population component over the projection grid
- A log-normal observation model is used for the aggregated positive-CPUE data

Availability and Selectivity Shape Fleet-Specific CPUE

Different fleets can encounter and capture different portions of the same squid population.

$$\text{CPUE}_{f,s,t} = q_{f,s,t}^{\text{eff}} \sum_l B_{s,t,l} \times A_{f,s,t,l} \times S_{f,l}$$

- $B_{s,t,l}$: population biomass in length class l
- $A_{f,s,t,l}$: availability — proportion of biomass available to fleet f
- $S_{f,l}$: relative selectivity at length l for fleet f
- $q_{f,s,t}^{\text{eff}}$: catchability coefficient
- Aggregated CPUE identifies their combined influence, not each component separately
- Explicit selectivity requires fleet-specific length compositions and a length-structured model

Covariates Can Enter Two Model Components

- **Population component:** formula_population specifies effects on the latent population distribution.
- Population covariates must also be supplied on the projection grid.
- These effects contribute directly to the standardized population index.
- **Catchability component:** formula_catchability specifies effects that influence catchability.
- Catchability effects are observation-level adjustments and are removed when estimating the population index.

Supported Covariate Effects

The formula interface distinguishes effect shape from covariate data type. Numeric variables remain numeric unless wrapped in `s()`; factors remain factors.

Catchability smooth

`formula_catchability = ~ s(sst)`

Population smooth

`formula_population = ~
s(sst_season)`

Linear numeric

`~ sst + chl`

Fixed factor

`~ season`

Random factor

`~ f(season)`

Combined

`~ s(depth, by = fleet) + season`

Updated jointCPUE Code

Yearly index:

```
fit <- jointCPUE(  
  data_utm = data_utm,  
  mesh = mesh,  
  formula_catchability = NULL,  
  formula_population = ~s(sst_fishingseason),  
  projection_data = sst_inputs,  
  index = "yearly",  
  month_diffs = "off",  
  obs_sd = "fleet",  
  pop_spatial = "on",  
  pop_spatiotemporal = "on",  
  pop_spatiotemporal_type = "iid",  
  q_diffs_system = "on",  
  q_diffs_time = "off",  
  q_diffs_spatial = "on",  
  ncores = ncores )
```

Monthly index:

```
fit <- jointCPUE(  
  data_utm = data_utm,  
  mesh = mesh,  
  formula_catchability = NULL,  
  formula_population = ~s(sst),  
  projection_data = sst_inputs,  
  index = "monthly",  
  obs_sd = "fleet",  
  pop_spatial = "on",  
  pop_spatiotemporal = "on",  
  pop_spatiotemporal_type = "iid",  
  q_diffs_system = "on",  
  q_diffs_time = "off",  
  q_diffs_spatial = "off",  
  ncores = ncores )
```

SST Must Match the Model Time Scale

Yearly index

- Catchability: monthly observation SST, $s(sst)$
- Population: fixed fishing-season SST, $s(sst_season)$

West: May-November

East: May-July

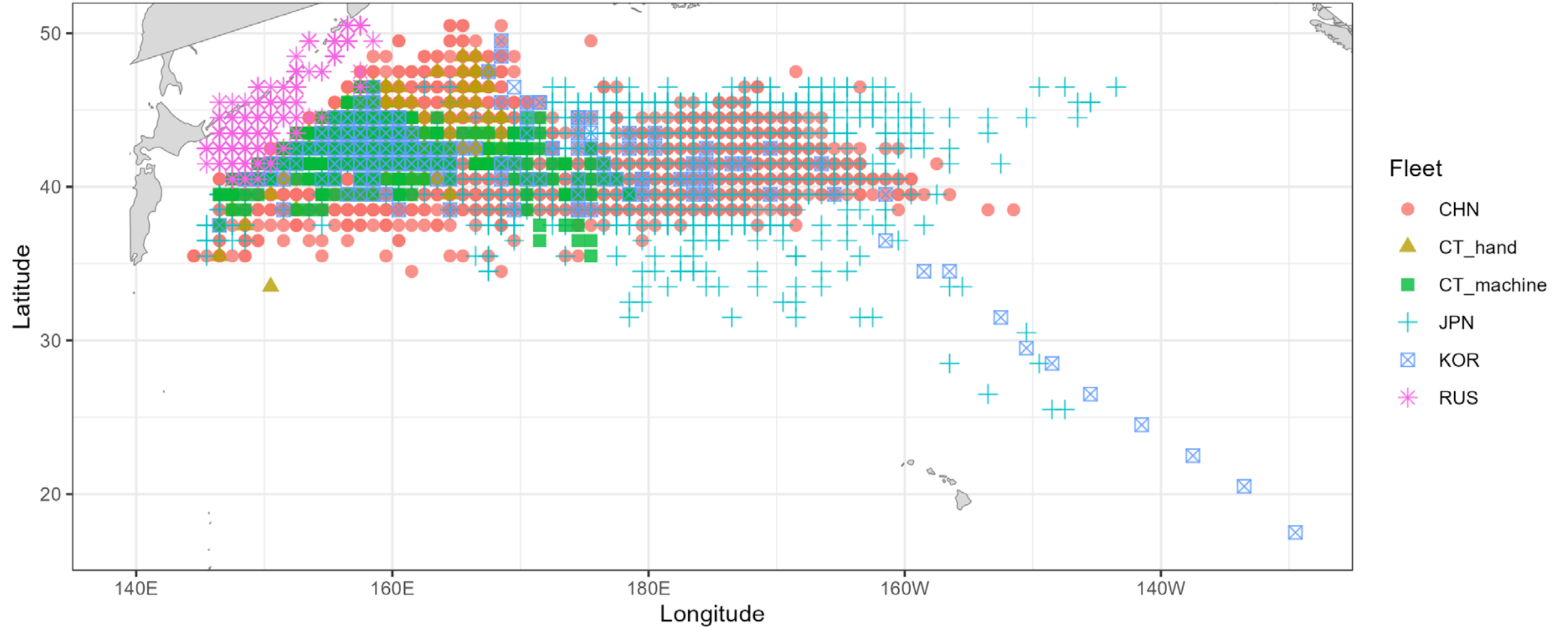
Monthly index

- Catchability: monthly SST, $s(sst)$
 - Population: monthly SST, $s(sst)$
- Projection grids receive SST for each modeled month

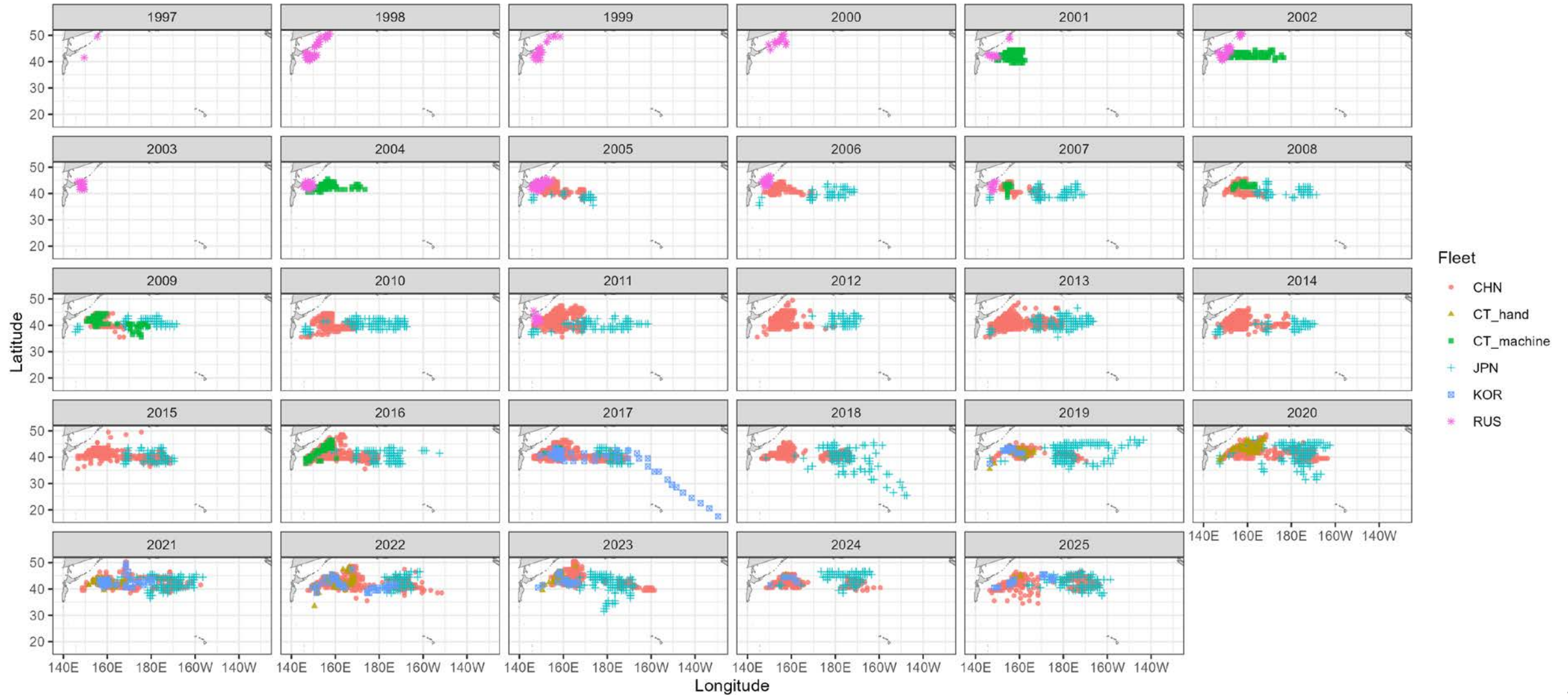
NFS Data Update to 2025

Member	Gear type	Records	Temporal coverage	Effort	Note
China	Jigging	4,424	2005-2025; May-November	Operational days	
Chinese Taipei	Handline , machine and mixed	1,034	2001-2009, 2011, 2016-2025; April-December	Machine-days, handline-days	Keep only handline or only machine (88 records with mixed gear types, 340 records without any gear or zero effort)
Japan	Jigging	1,933 (1,555 170E_East, 378 170E_West)	2005-2025	Machine-days	Remove NW records with missing coordinates (59 records)
Korea	Jigging	180	2017, 2019, 2021-2025; June-November	Machine-days (impossible to distinguish whether handline or machine)	
Russia	Drift-net	266	1997-2007, 2011; April-December	Vessel-days	

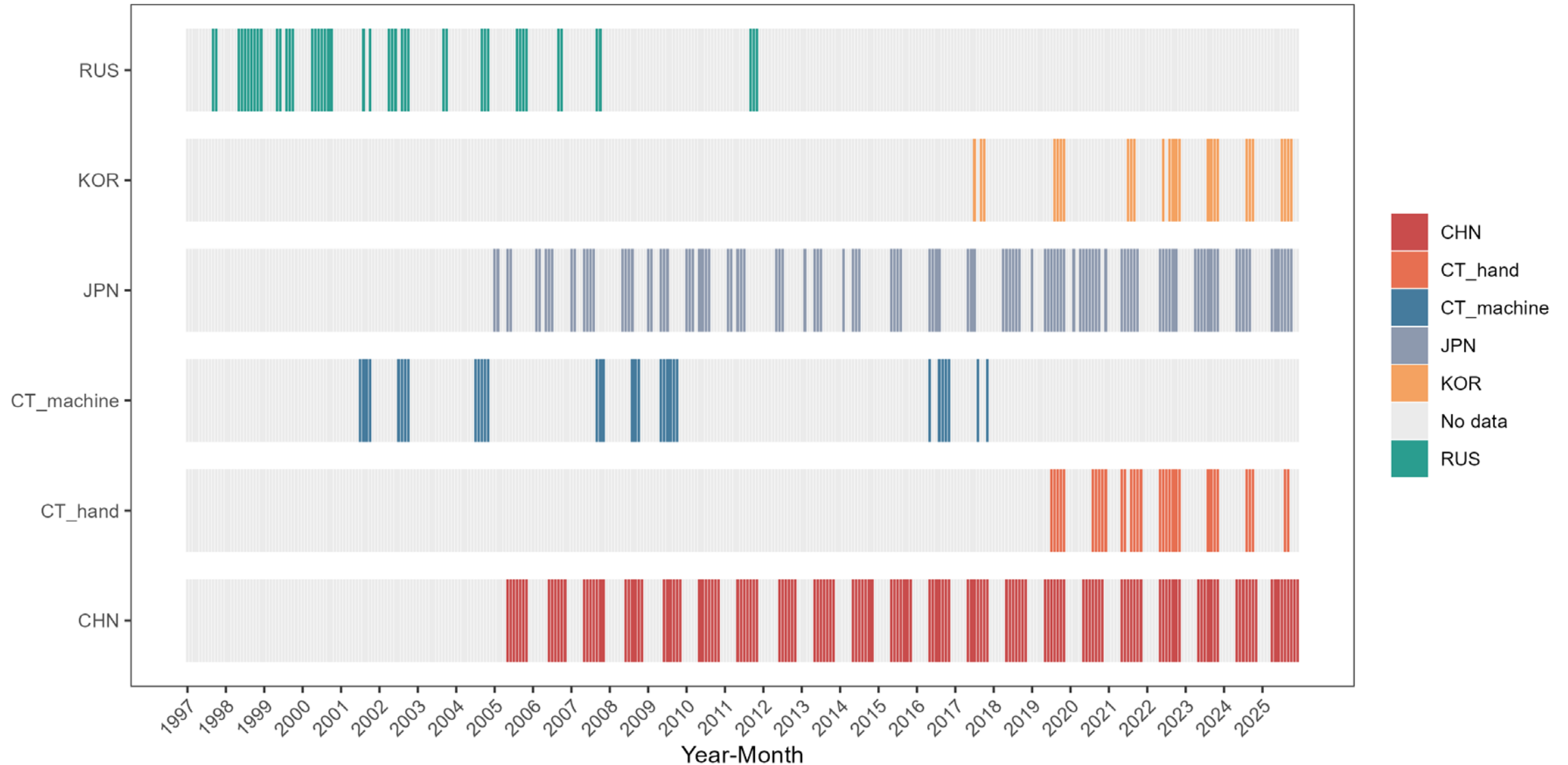
NFS Data Overview – spatial distribution



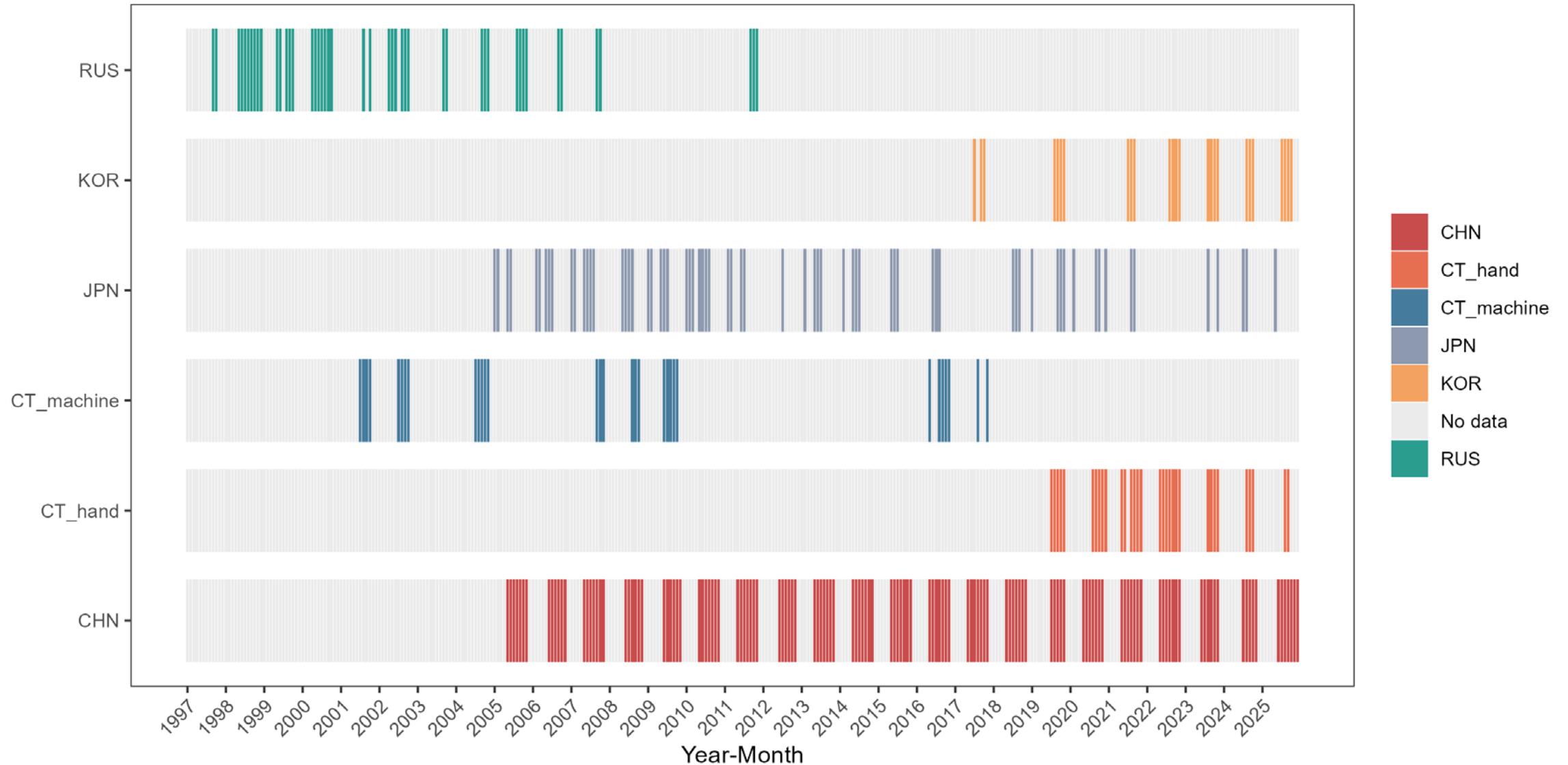
NFS Data Overview – yearly spatial distribution



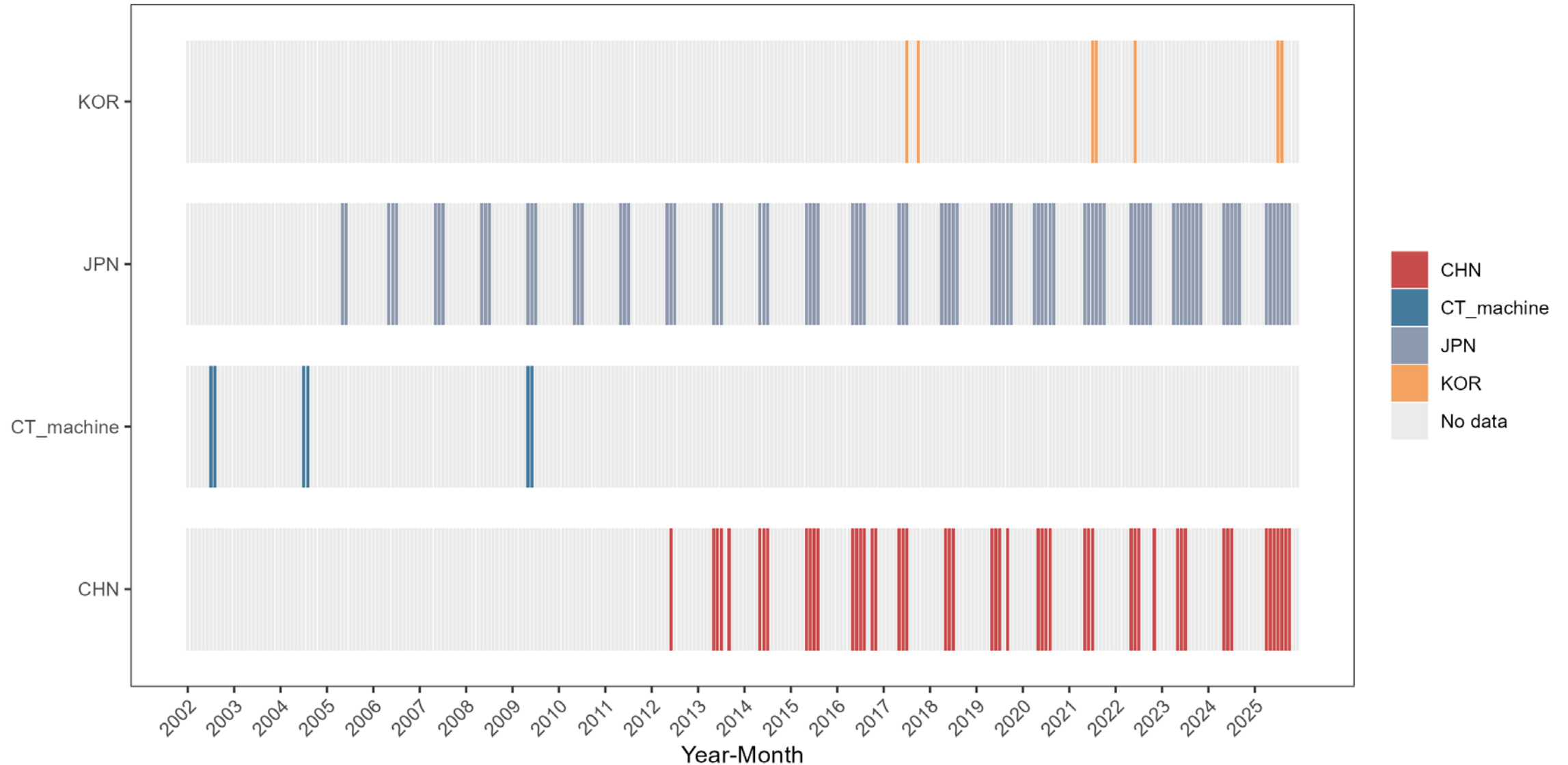
NFS Data Overview – temporal coverage



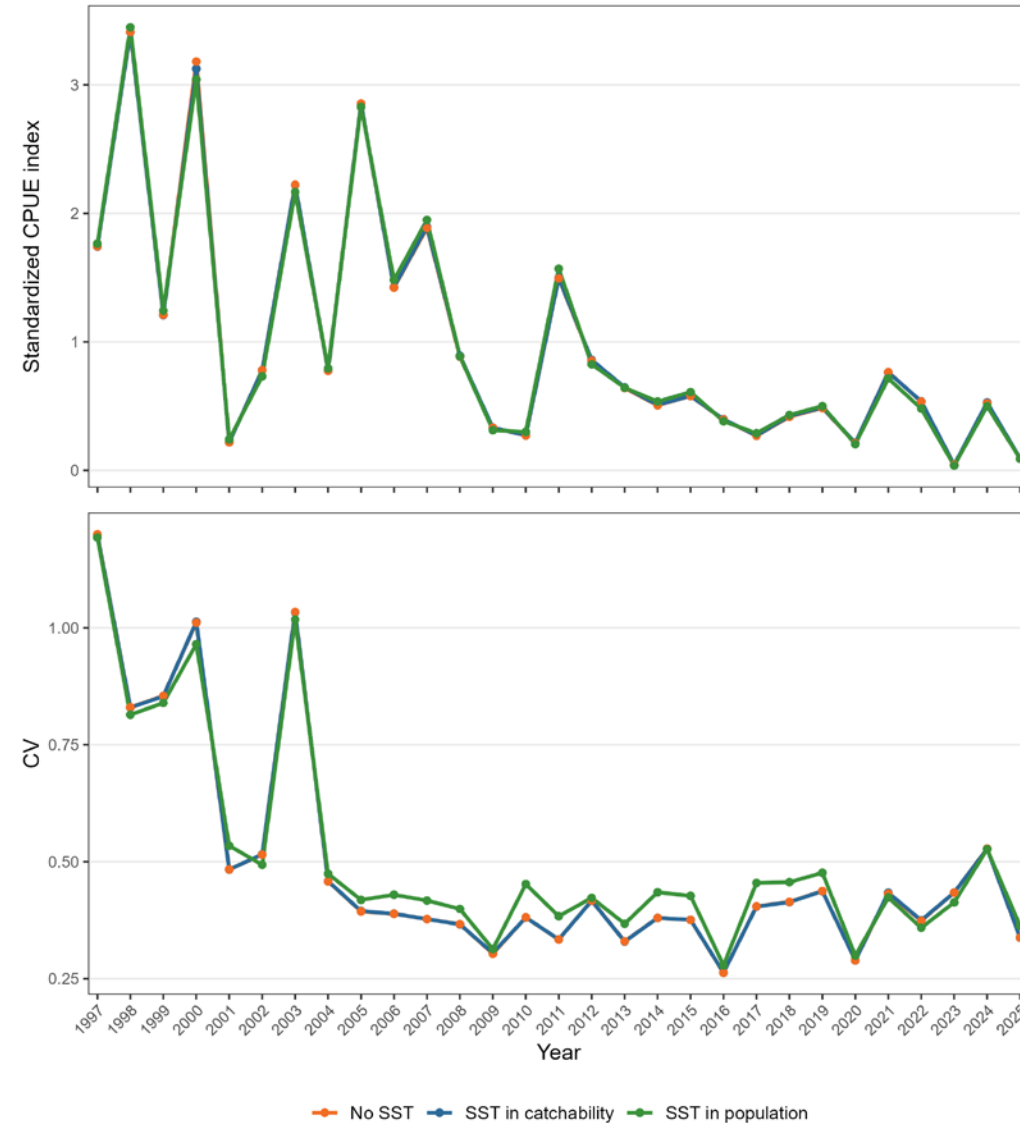
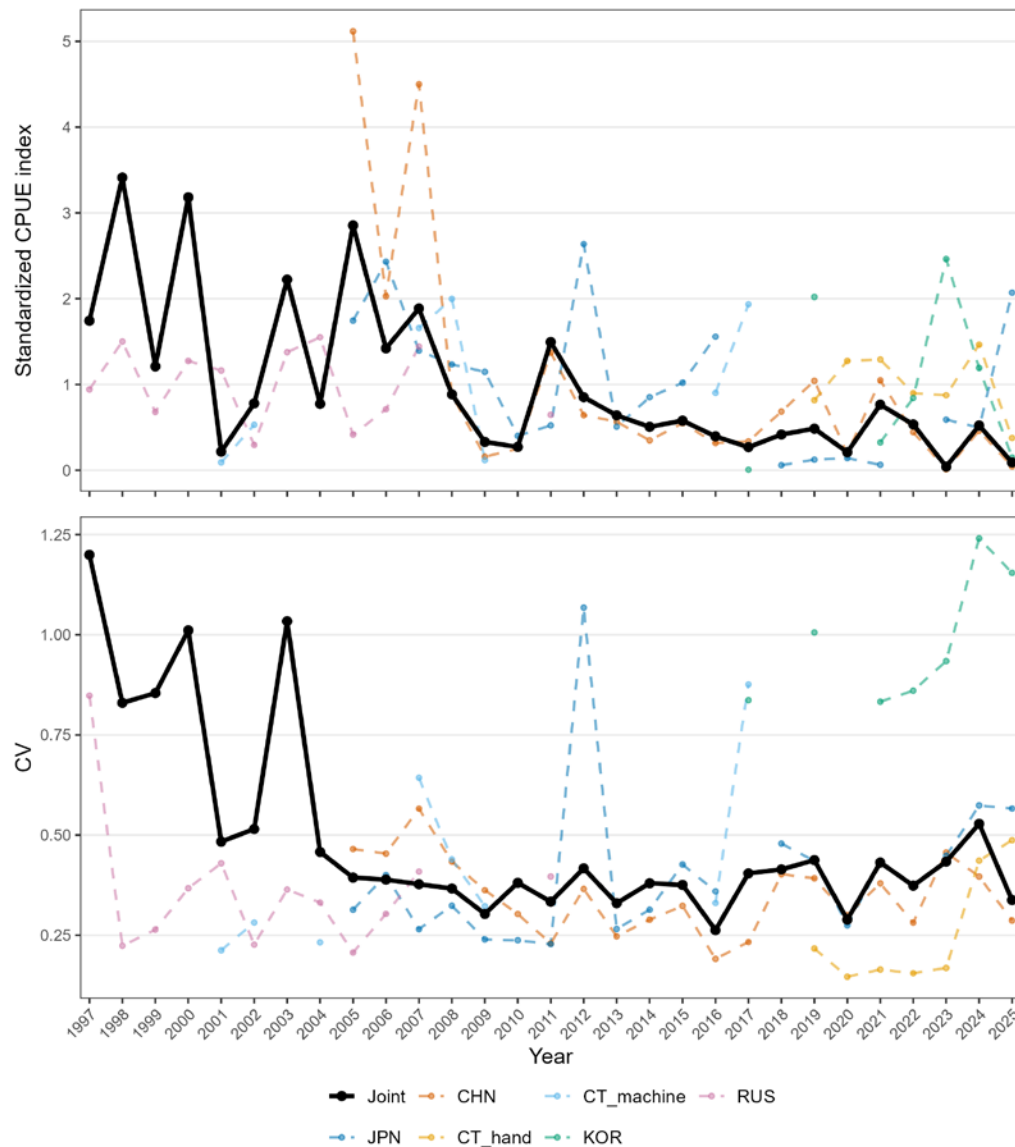
NFS Data Overview – 170° E west temporal coverage



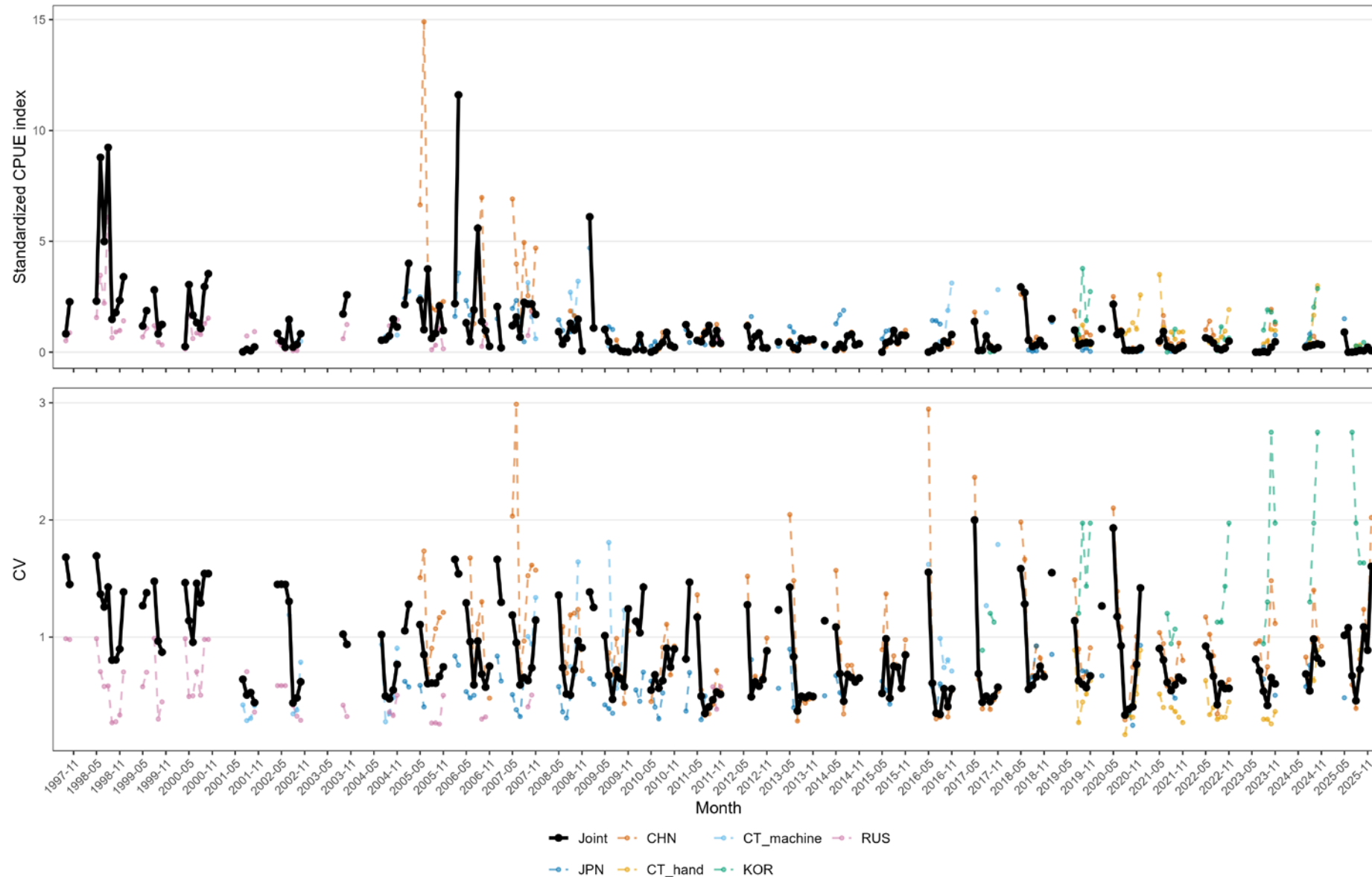
NFS Data Overview – 170° E east temporal coverage



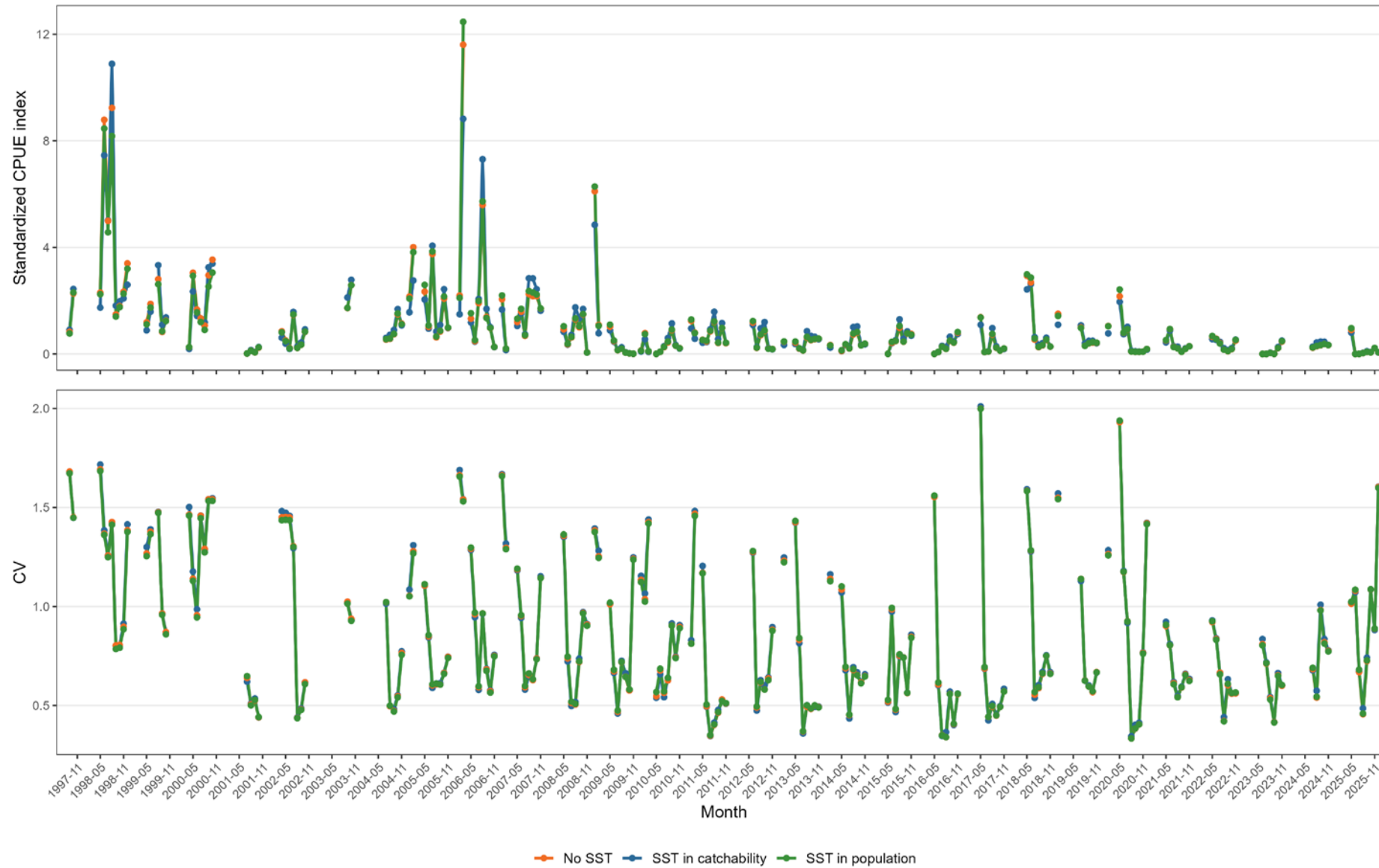
170° E West Yearly Standardized Index (JPN as Reference)



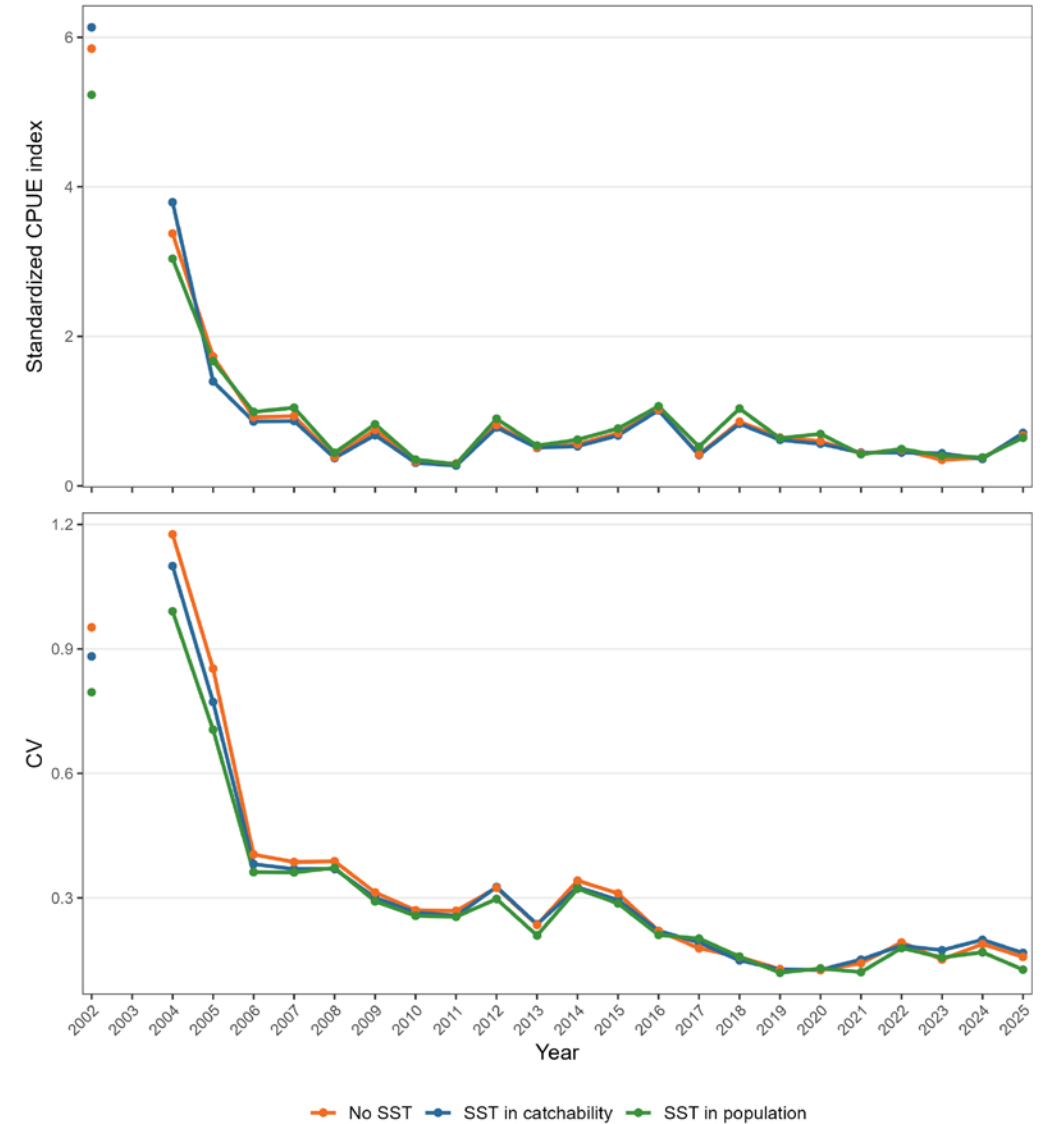
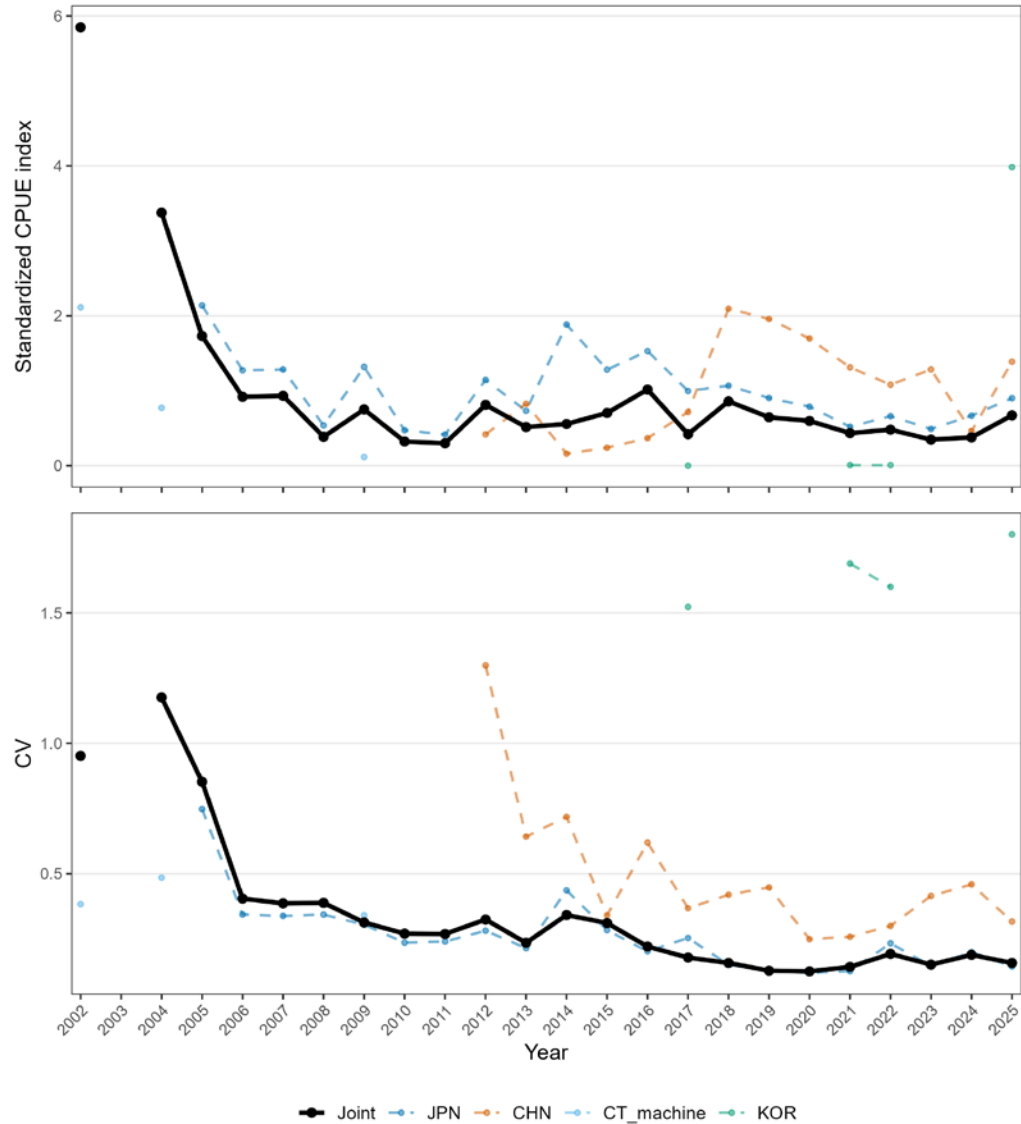
170° E West Monthly Standardized Index (JPN as Reference)



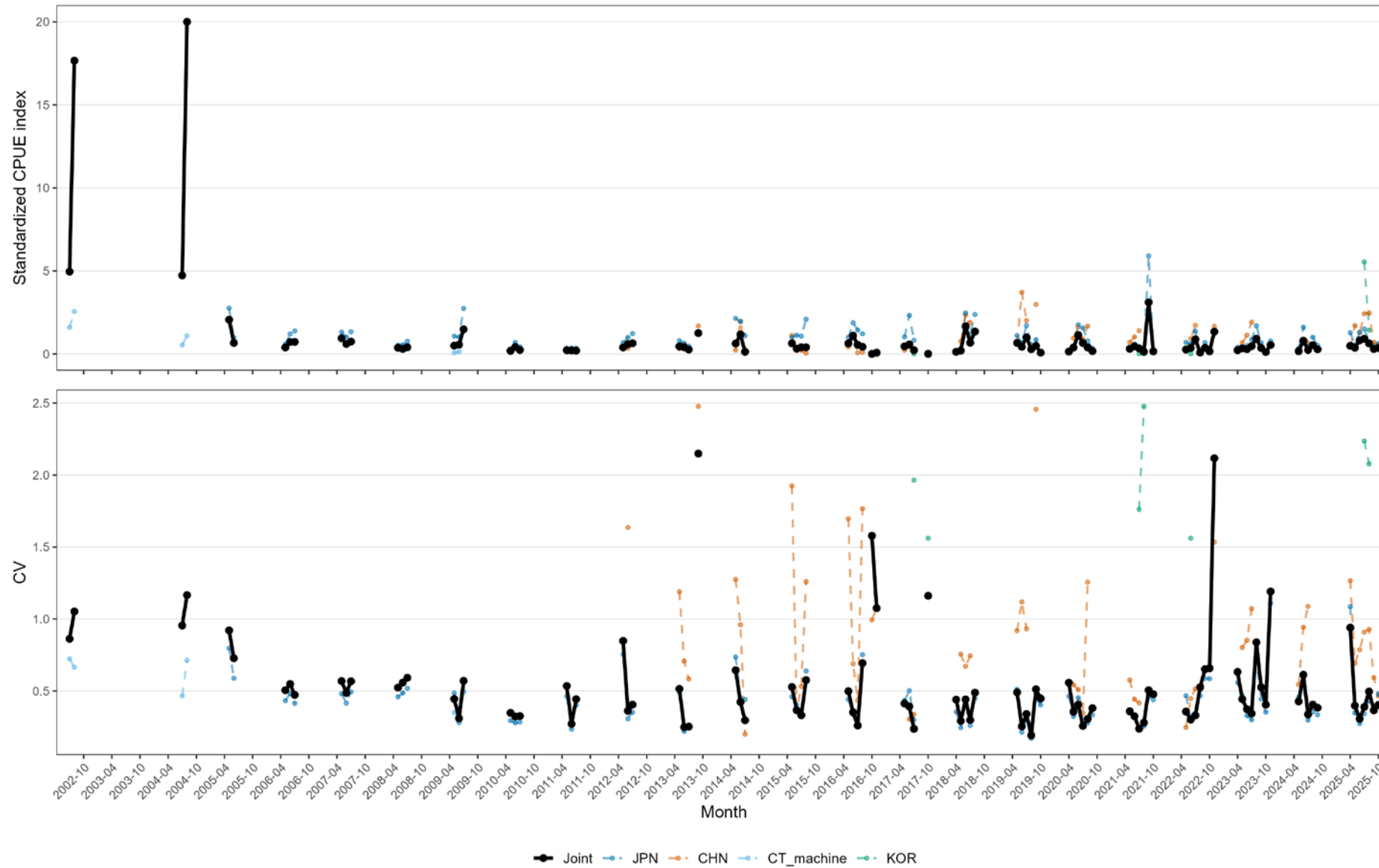
170° E West Monthly Standardized Index (JPN as Reference)



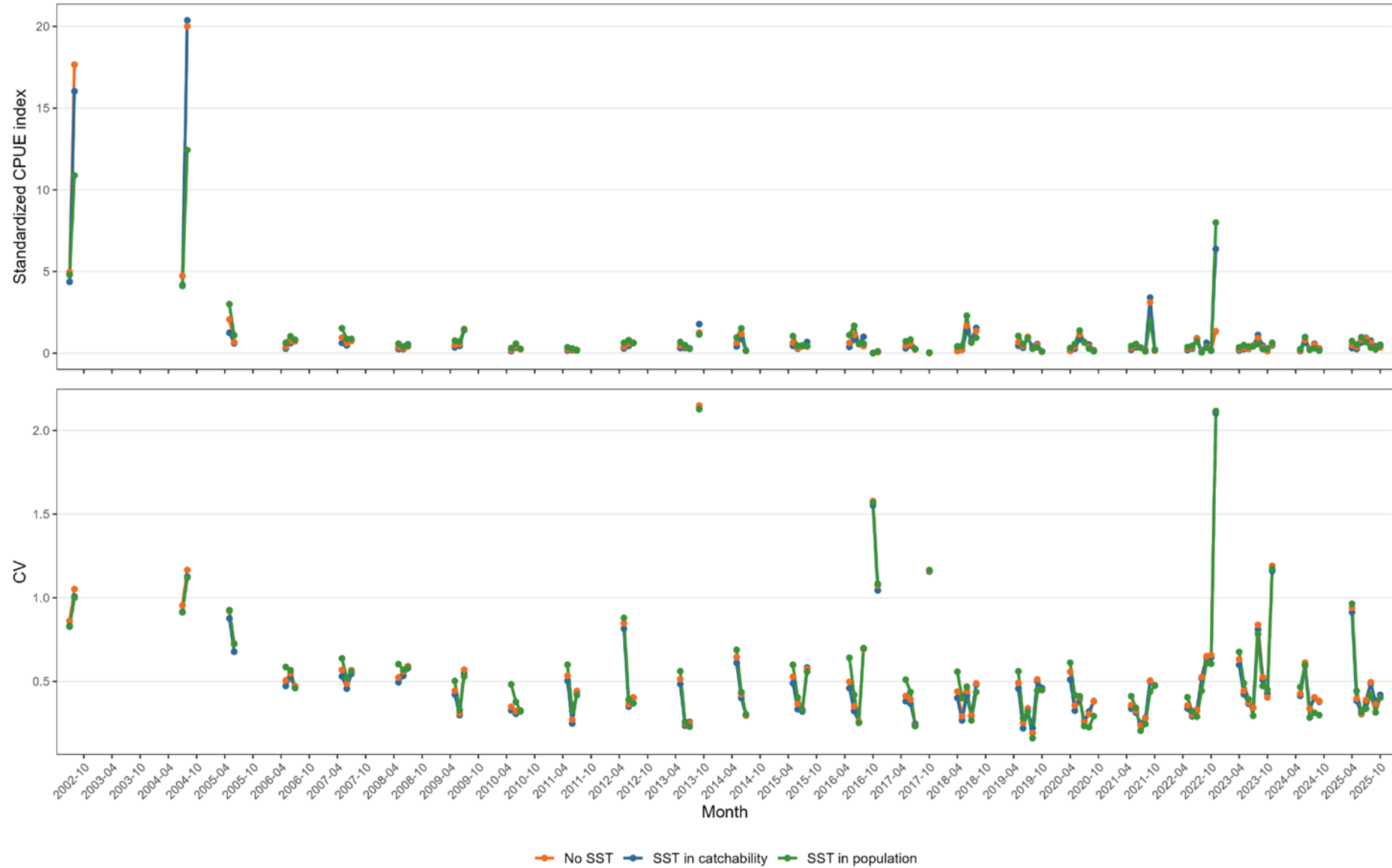
170° E East Yearly Standardized Index (JPN as Reference)



170° E East Monthly Standardized Index (JPN as Reference)



170° E East Monthly Standardized Index (JPN as Reference)



Key Takeaways

- Updated NFS data extend through 2025 and remain heterogeneous across fleets, regions, and seasons.
- jointCPUE now supports flexible covariates in both population and catchability components.
- Numeric effects can be linear or smooth; factors can be fixed or random.
- SST scenarios evaluate whether environmental effects are better represented through catchability or population distribution.
- Final interpretation should consider index behavior, CV, convergence, Hessian diagnostics, and biological plausibility.