An interpretable rule-based framework for defining species-gear management units in multispecies, multi-gear fisheries

Classifying species group–fishery relationships using Korea's long-term catch records

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1.1 Why fishery definitions and review scope matter

Stock assessment models

Changing fishery contributions

Changing fishery contributions warrant review of assessment models and selectivity.

In simulated gear transitions, biomass estimates were biased when selectivity was mis-specified or held fixed over time.

Cheng et al. (2024)

CPUE standardization

Defining comparable CPUE records

Consider fishery definitions, spatial and temporal scope and targeting when standardizing CPUE.

Standardization choices can substantially change the index, and with it assessment outcomes and management decisions.

Hoyle et al. (2024)

Which records should we review together?
Explicit criteria anyone can re-run, so tacit case-by-case choices become explicit

Cheng, M. L. H., Goethel, D. R., Hulson, P.-J. F., & Cunningham, C. J. (2024). Confronting transitions in fishery fleet structure and selectivity: Practical recommendations for integrated age-structured stock assessments based on simulation analysis. *Canadian Journal of Fisheries and Aquatic Sciences, 81*(12), 1676–1696. https://doi.org/10.1139/cjfas-2024-0129

Hoyle, S. D., Campbell, R. A., Ducharme-Barth, N. D., Grüss, A., Moore, B. R., Thorson, J. T., Tremblay-Boyer, L., Winker, H., Zhou, S., & Maunder, M. N. (2024). Catch per unit effort modelling for stock assessment: A summary of good practices. *Fisheries Research, 269*, Article 106860. https://doi.org/10.1016/j.fishres.2023.106860

Why

1.2 Mackerels illustrate the choice of review scope

Source: Ministry of Oceans and Fisheries TAC expansion plan and 2026/27 TAC plan (Notice 2026-71)

Korean management context

Plan to expand TAC (Total Allowable Catch) to most coastal and offshore fisheries by 2031

Mackerel TAC units 2026/27 fishing season

Managed by species TAC set on named mackerel species

Large purse seine — Chub + blue mackerel
Stage 3 · Full implementation

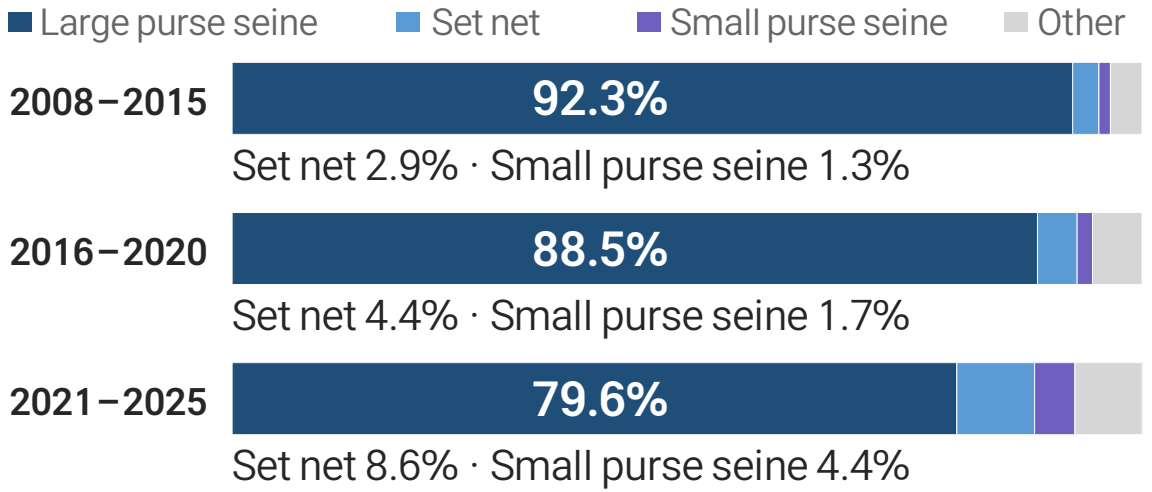
Small purse seine — Chub mackerel
Stage 2 · Vessel-level pilot

Managed by fishery One TAC on the whole set-net catch

Set net — All species combined
Stage 1 · Fishery-level pilot
Pilot excludes Gyeongnam and Jeju waters

All three fisheries land mackerels.
What differs is the unit the TAC is set on.

Chub mackerel: fishery shares by period



100% = each period's total chub mackerel catch

Species-level 90% lists, 2008–2025

Chub mackerel
Large purse seine + set net
2 fisheries · **92.53%** of catch

Blue mackerel
Large purse seine
1 fishery · **99.28%** of catch

Separate chub and blue mackerel records begin in 2008.

1.3 Two questions, one common basis

Q1 How can we classify species group–fishery relationships?

Q2 Which fisheries should we review together?

Comparable catch records	**A common basis across fisheries** Regular updates and comparable annual totals
Catch relationships and fishery lists	**Identify the fisheries catching each group** Describe relationship types and select fishery lists
Compare landing regions, sales channels and periods	**Find where the selected fisheries' share changes** Compare periods, landing regions and sales channels

Types and lists are computed side by side from the same table.

2.1 A long-term catch dataset, built and maintained

Historical tables
Not in current KOSIS releases

1990–2002
Annual regional tables

Year × source label × fishery × province × sales channel

2003–2005
Monthly national tables

Month × source label × fishery
National records

Current KOSIS data
Korean Statistical Information Service

2006–2025
Monthly regional data

Month × source label × fishery × province × sales channel

1969–1989 species category × fishery tables examined, not used: categories and totals differ from the current series.

Processing and ongoing maintenance

01 Clean & reshape → **02 Link categories** → **03 Validate & update** → **04 Report findings**

Historical tables into one common long format

Species and fisheries across sources and years

Regularly maintain the Catch Information Platform for TAC Stock Assessment

Send findings from checks back to the data provider

Long-term study dataset, 1990–2025

Year × species group × fishery; totals match published figures

Annual aggregates; no individual vessel or trip observations

Main analysis period
2006–2025

Long-term analyses span 1990–2025. Their results and the finer reporting detail available from 2006 motivate the focus on 2006–2025.

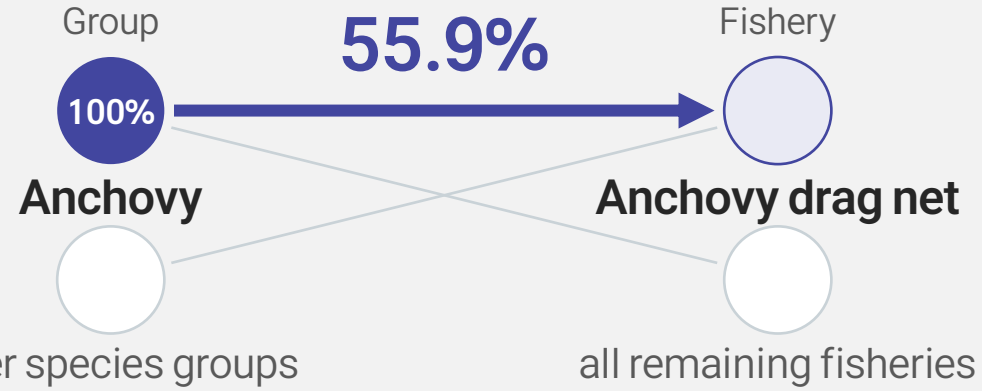
Rules

3.1 Share and composition have different denominators

Anchovy example · 2006–2025 totals · Max share and combined share: % of the anchovy group's total recorded catch

Starting from the species group

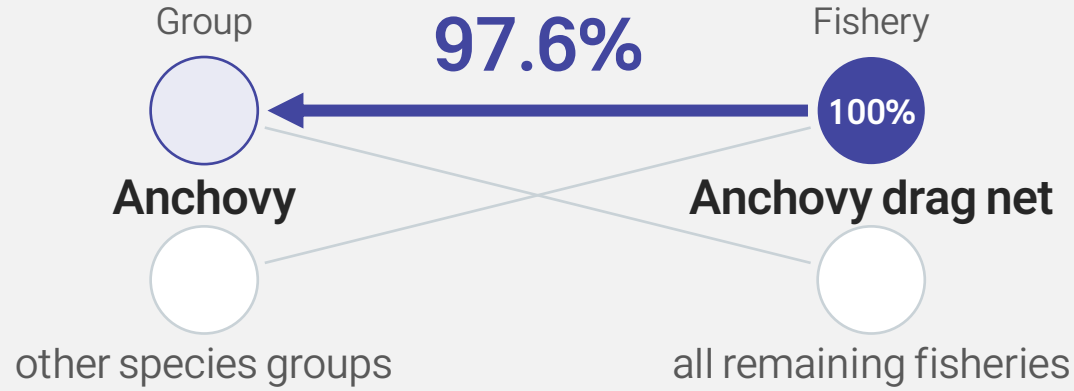
Share p(f | s): which fisheries take the anchovy catch, and how much?



100% = the anchovy group's total recorded catch
("Other fisheries" included)
Max and combined share use 38 candidate fisheries.

Starting from the fishery

Composition p(s | f): what makes up the anchovy drag net catch?



100% = the anchovy drag net's total recorded catch
(112 species groups)
Includes groups not classified.

Max share

55.9%

Largest single-fishery share (anchovy drag net)
Composition threshold not applied

Combined share

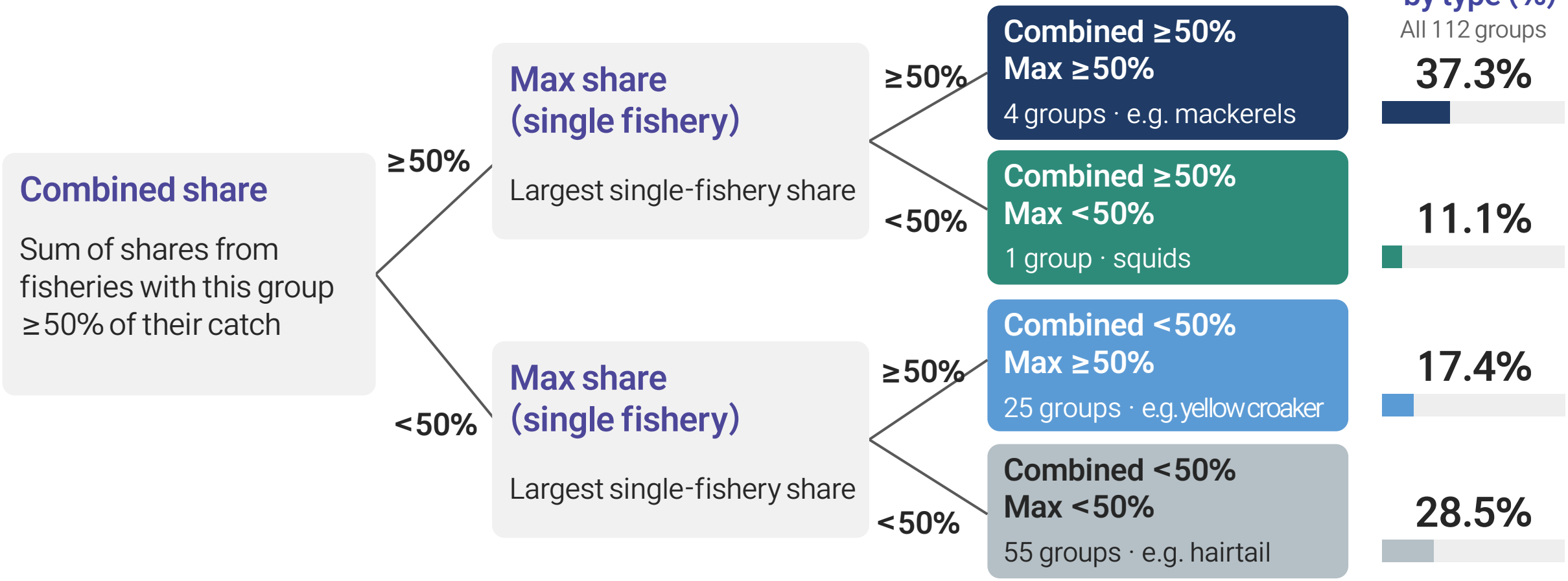
68.9%

Sum of shares where anchovy is ≥50% of the catch
4 fisheries: 55.9 + 5.4 + 3.8 + 3.7 (rounded) · 0 if none qualify

Rules

3.2 Four types summarize relationships across 85 species groups

87 species groups screened, 85 classified · 2006–2025 · Combined and max share: % of each group's total recorded catch
Two groups (walleye pollock, trouts) are deferred: below 100 t in candidate fisheries.
The other 25 of 112 groups account for 5.8% of recorded catch.

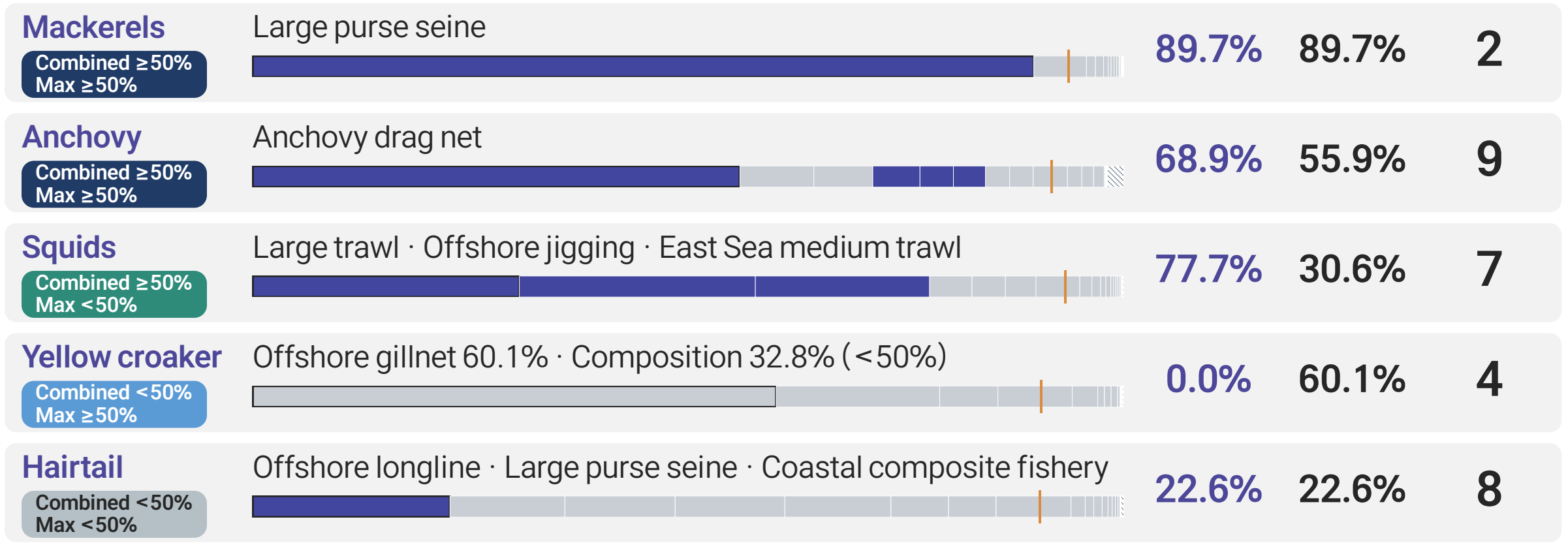


5 groups with combined share ≥50% account for 48.4% of all recorded catch.

Results

4.1 Same type, different fisheries and list sizes

2006–2025 · Full bar = each species group's total recorded catch
90% list: add candidate fisheries by decreasing share until their total first reaches 90%



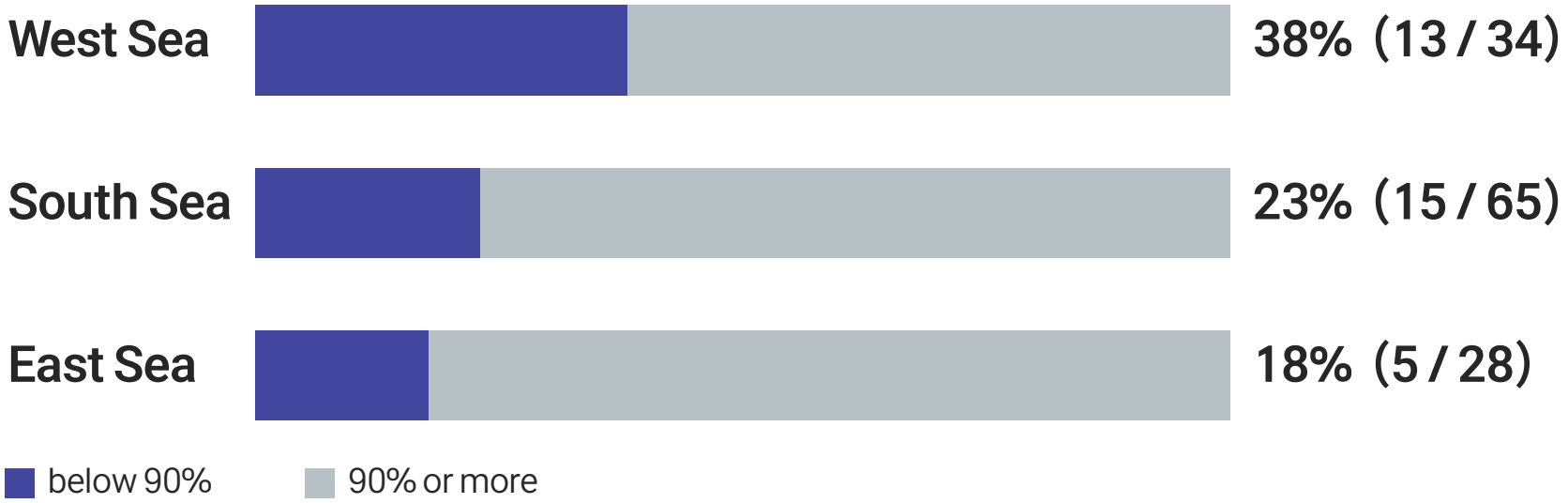
Candidate fisheries cover less than 90% of catch for the other 12 groups, all shellfish.

73/85 groups have a 90% list; median 6 fisheries, maximum 11

5.1 National lists need regional coverage checks

For 2006–2025, coverage is the share of a group's regional landings from fisheries on its national 90% list.

Share of eligible groups below 90% coverage, by landing region



The 33 shortfalls

Catch coverage	Count
85% to <90%	22
80% to <85%	2
Below 80%	9

Lowest coverage
Sardine in the East Sea, 62.9%

Squid coverage East Sea 95.5%, South Sea 93.2% (2006–2025 list). Section 5.4–5.5 hold the 2006–2015 list fixed.

127 eligible combinations: 85 groups × 3 seas = 255 → 151 where the sea lands ≥10% of the group's national catch
→ 150 with sufficient regional records → 127 whose group has a national 90% list (73 groups).
Regions indicate where the catch is landed. Fishing locations can differ.

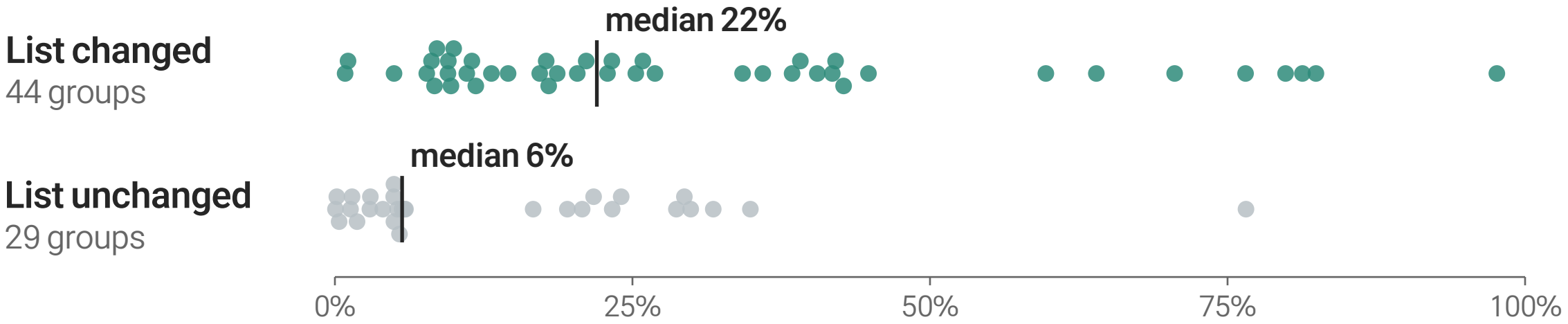
33 of 127 group–region combinations (26%) fall below 90% coverage.

5.2 Lists depend on the sales channels included

The main analysis uses both sales channels. Non-cooperative sales account for 16.9% of all recorded catch in 2006 – 2025.

With cooperative sales only, the 90% list changes for 44 of 84 groups

Horizontal position shows non-cooperative sales as a share of each group's recorded catch.



84 groups = 85 classified minus one whose records are insufficient with cooperative sales only (96% non-cooperative).
73 have a 90% list in at least one scope and appear as dots (72 in both); 11 have none in either.

What counts as a change?

List membership differs for 43 groups. Manila clam has a list only with cooperative sales. Rank changes alone do not count.

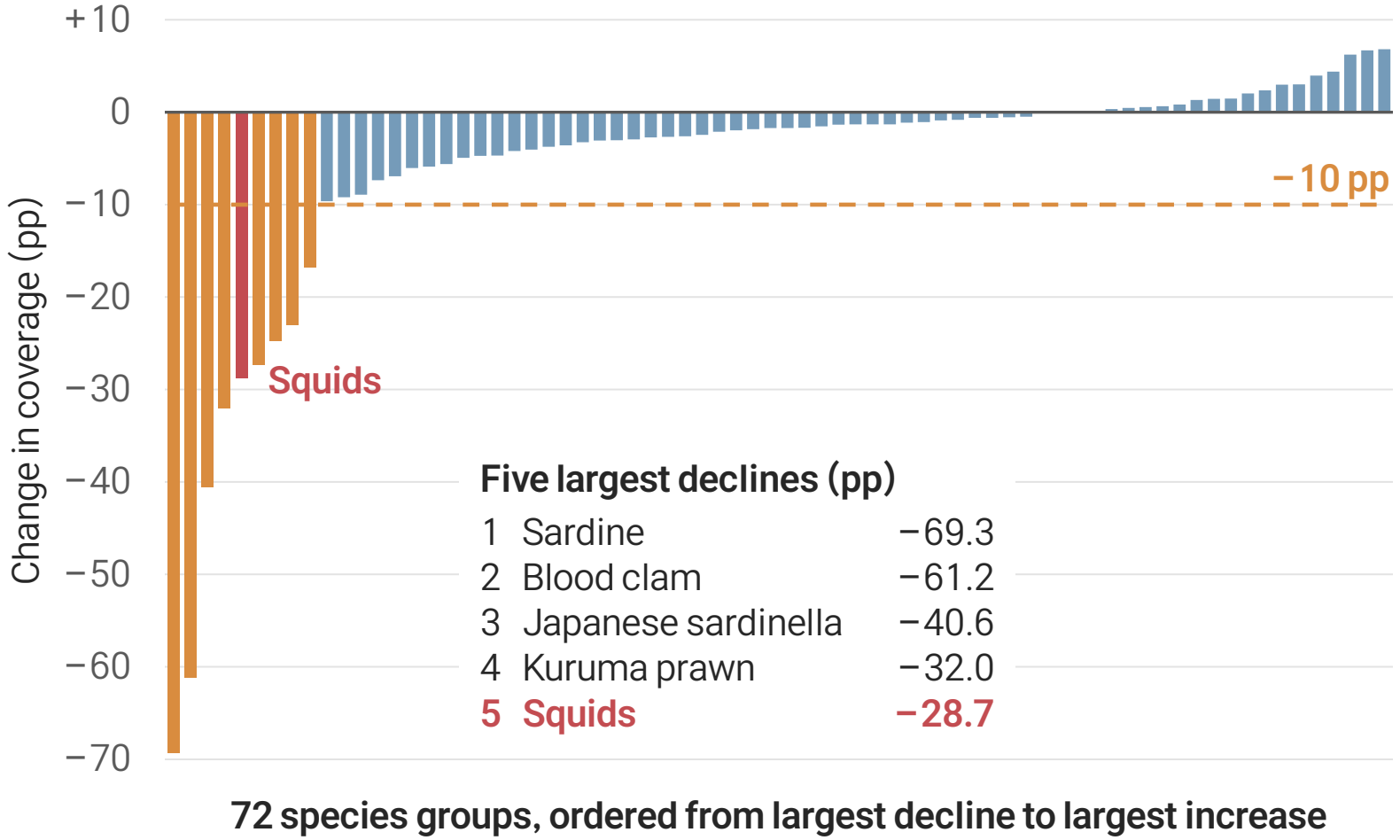
Largest-share fishery

In 69 of 84 groups, the same fishery ranks first under both sales scopes.

Groups whose lists change have a higher median non-cooperative share (22% vs 6%).

5.3 Fixed lists show where coverage changes

Earlier 90% lists held fixed: 2006–2015 compared with 2016–2025



Lost ≥ 10 pp

9 of 72

groups (orange and red bars)

Median change

−1.71 pp

across the 72 groups

Squids

−28.7 pp

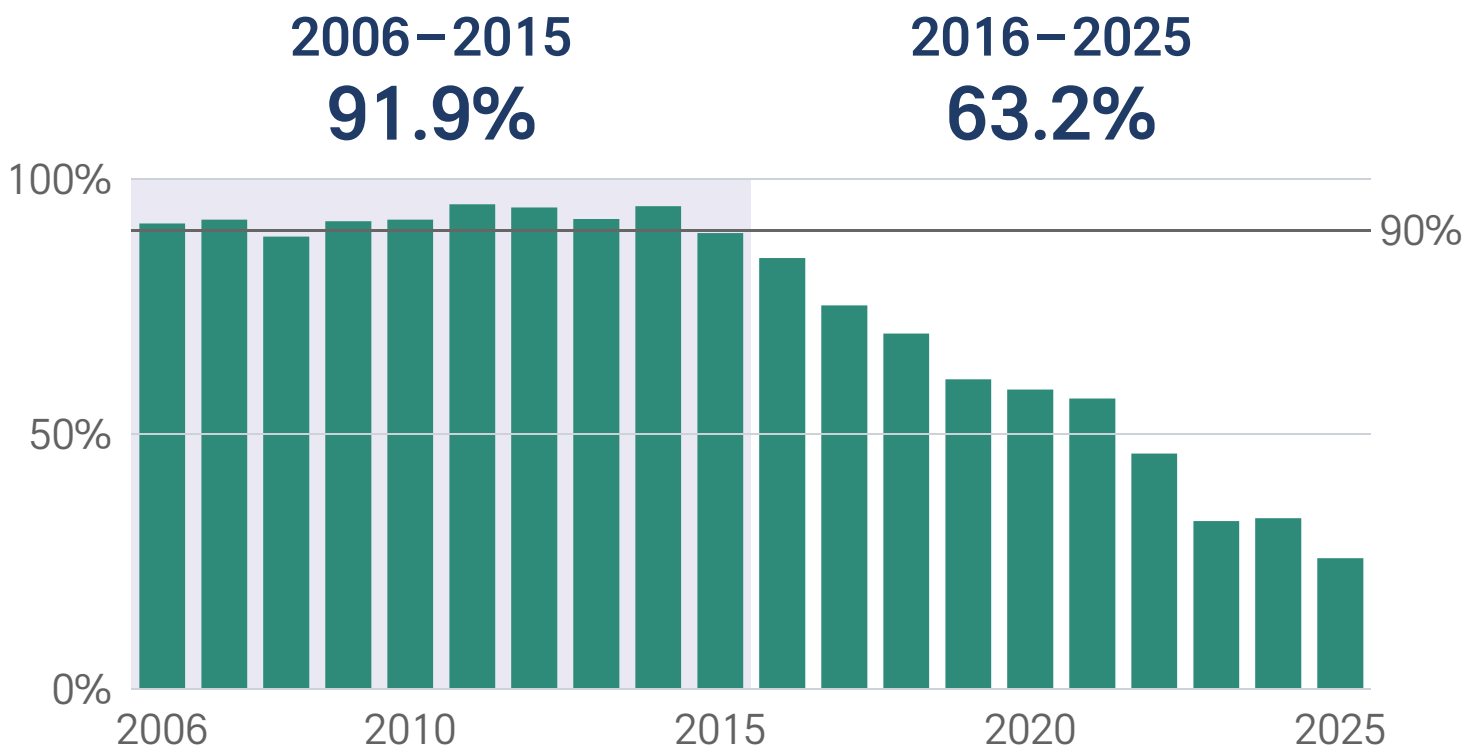
5th-largest decline

72 groups with sufficient records in both decades and an earlier list. Bar: later minus earlier coverage, in percentage points (pp). Blue: decline <10 pp or increase. Orange: decline ≥10 pp; red: squids. Descriptive comparison, not a test of causes.

5.4 Reading the squid coverage decline

The five fisheries selected in 2006–2015 form the fixed list through 2025.

Fixed-list coverage by year



Bars: annual coverage · Large values: pooled decade coverage
100% = each year's total recorded squid catch

Fixed 90% list

- Offshore jigging
- Large purse seine
- Large trawl
- East Sea medium trawl
- Coastal composite fishery

Annual mean catch (t) **Inside list: 160,000 → 35,000** **Outside list: 14,000 → 20,000**

5.5 Fixed-list coverage of squid catch varies by landing region

Fishery shares: 2006–2025 · Fixed national list: selected in 2006–2015 · Landing regions ≠ fishing locations

West Sea

3.3% of national



Fixed list · Earlier → later

86.5% → 27.0%

South Sea

46.8% of national



Fixed list · Earlier → later

92.8% → 55.8%



East Sea

49.9% of national



Fixed list · Earlier → later

91.4% → 79.6%

Earlier: 2006–2015
Later: 2016–2025

National: 91.9% → 63.2%

Denominator: each region's squid catch in each period

Offshore jigging · East Sea medium trawl · Large trawl · Large purse seine · Coastal composite fishery · Set net · Offshore gillnet · Large pair bottom trawl · Other

Offshore gillnets: year-round ban on Japanese flying squid in the East Sea and east of 128°30′E in the South Sea (since Dec 2021).
For gillnets licensed by Busan, Ulsan, Gyeongbuk or Gyeongnam, the line is 129°E. Source: Fisheries Act Enforcement Decree, Annex 7.

National list coverage can hide large differences among landing regions.

6.1 What the framework supports, and its limits

Checked

Rules vs clustering

Clustering on max share and share-weighted composition (6.2): k-means, Ward and GMM, raw or standardized, k = 2–4 (18 combinations)
Neither rules nor clusters were more stable in every comparison.

Prediction

Adding types to max share and list size does not improve prediction of fixed-list coverage loss here.

Fishery-size null model

The count of five groups with combined share ≥50% was not unusual.

Limits

Aggregated catch records

These records do not directly show which species fishers target (Liu et al. 2022). Nor do they show which species are caught together. Stock, effort, price, regulation and reporting effects are mixed.

Assessment and management

Stock identity, management effects and transfer to other reporting systems remain untested.

Information retained by the index

76 of 85 groups have combined share 0. Differences along this axis are compressed.

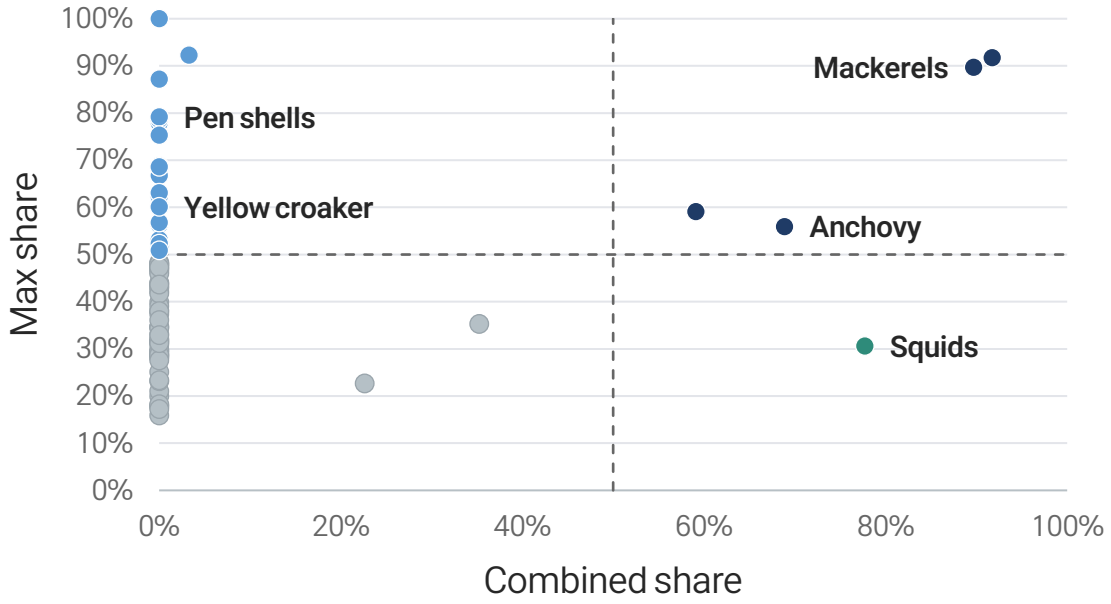
The framework classifies species groups, lists fisheries for review and checks coverage.

Liu, X., Hansen, C., Nedreaas, K., Stockhausen, H. H., & Heino, M. (2022). Gaussian mixture models reveal highly diverse targeting tactics in a coastal fishing fleet. ICES Journal of Marine Science, 79(10), 2709–2727. https://doi.org/10.1093/icesjms/fsac207

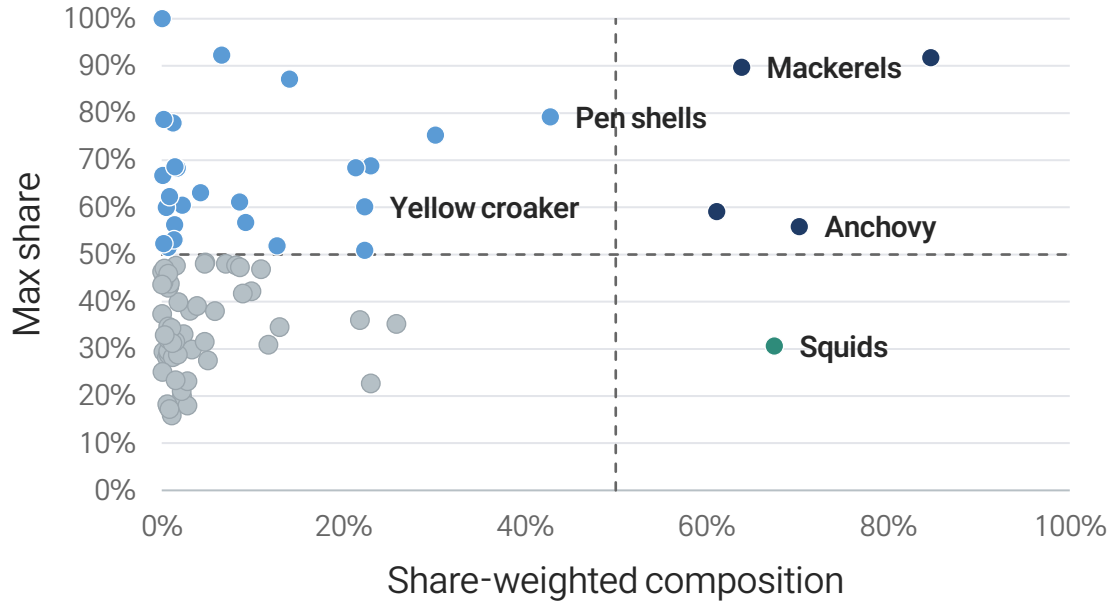
Future work

6.2 Share-weighted composition keeps continuous differences

Combined share (x) vs max share (y)



Share-weighted composition (x) vs max share (y)



● Combined ≥50% · Max ≥50% ● Combined ≥50% · Max <50% ● Combined <50% · Max ≥50% ● Both <50%

76 / 85 zero combined share
23 of them have max share ≥50%

No zeros
Σshare × composition, no 50% condition

Same types at 50%
All 85, as with combined share

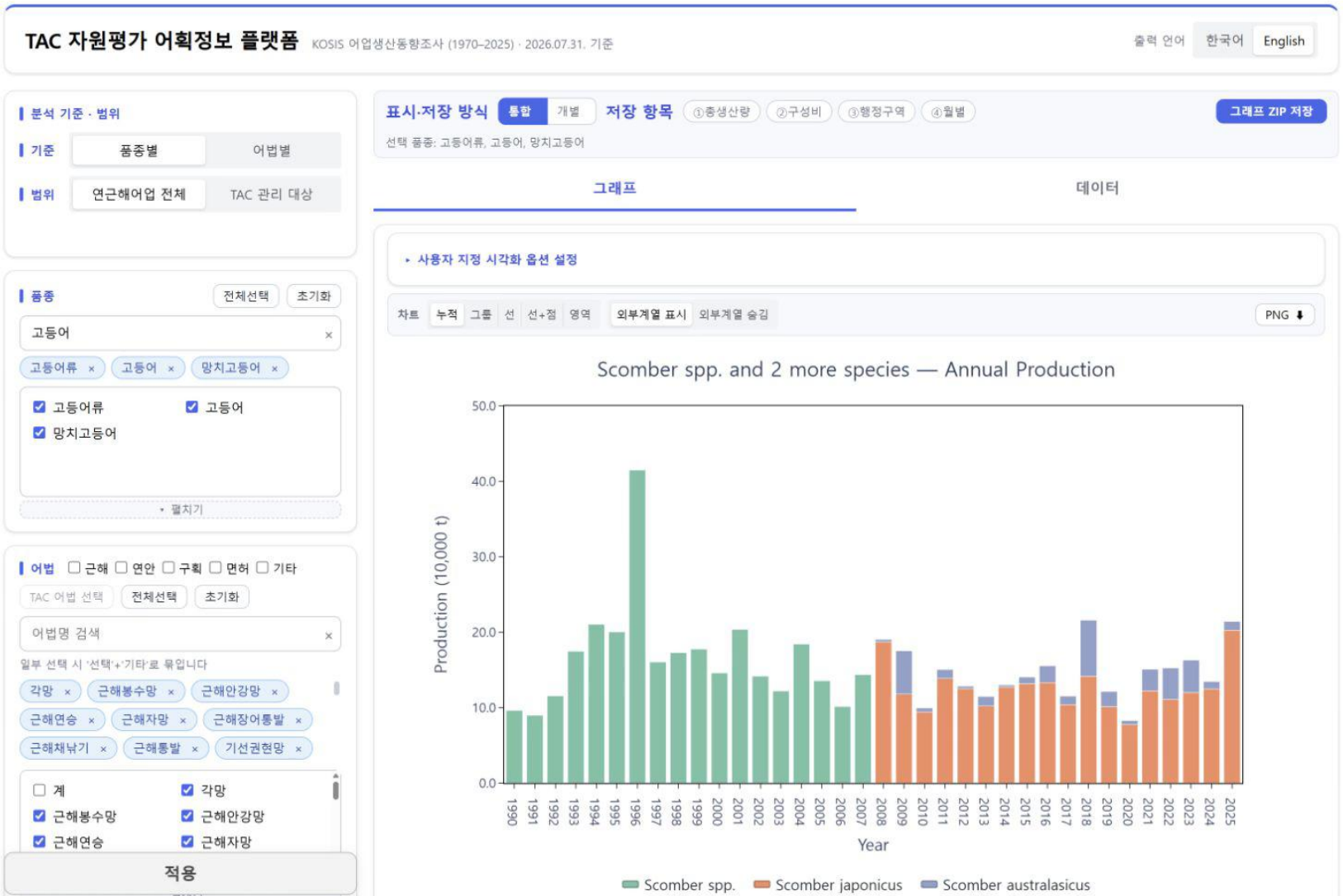
Already used in the 6.1 clustering. Before it can replace combined share, the rolling-window, null and prediction tests need rerunning.
Next: test sensitivity to catch size and production value, and usefulness for assessment review. It cannot recover trip-level information.

Same four types, more information: continuous values keep the differences within each type.

6.3 Linking results to the assessment platform after validation

Catch Information Platform for TAC Stock Assessment

Built by the presenter on the 2.1 dataset · current view: mackerel example



Planned additions

Relationship types

Share and composition for each group and fishery

90% lists

Fisheries to review together for each group

Coverage checks

Coverage by landing region, sales channel and period

Then link assessment data

Length, age and CPUE

For the fisheries on each group's list

Logbooks and habitat

Grid-level fishing locations and seasons

7.1 Conclusions

Q1. Rules classify 85 species groups

Input: one catch table, 87 groups × 38 fisheries
Measures: share and composition
Rules: two 50% thresholds, four types
Combined ≥50%: 5 groups, 48.4% of catch

Q2. 90% lists name fisheries to review

Lists: 73/85 groups, median 6 fisheries
Regions: 33/127 combinations below 90%
Sales channel: lists change for 44/84 groups
Fixed lists: 9/72 groups lose ≥10 pp

What this study adds

- A **reproducible** framework built from catch records alone, the most basic fishery data
- **Explicit rules** reproduce the same types and lists from the same catch table
- Lists and coverage can be **re-measured** whenever the records are updated, not fixed once
- A **starting point** for placing biological, effort and CPUE data by fishery, period and region

A building block for EBFM: catch shares are a first input to technical-interaction (mixed-fisheries) analysis.

Mixed-fisheries analysis also requires stock and fleet definitions, effort data and quota constraints.

Thank you

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