Navigating Changes in Small Pelagic Fish and Forage Communities: Climate, Ecosystems, and Sustainable Fisheries

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The importance of incorporating ontogenetic diet shifts in Ecopath models

Comparing single-stanza and multi-stanza representations for key forage fish and predators on the Portuguese continental shelf

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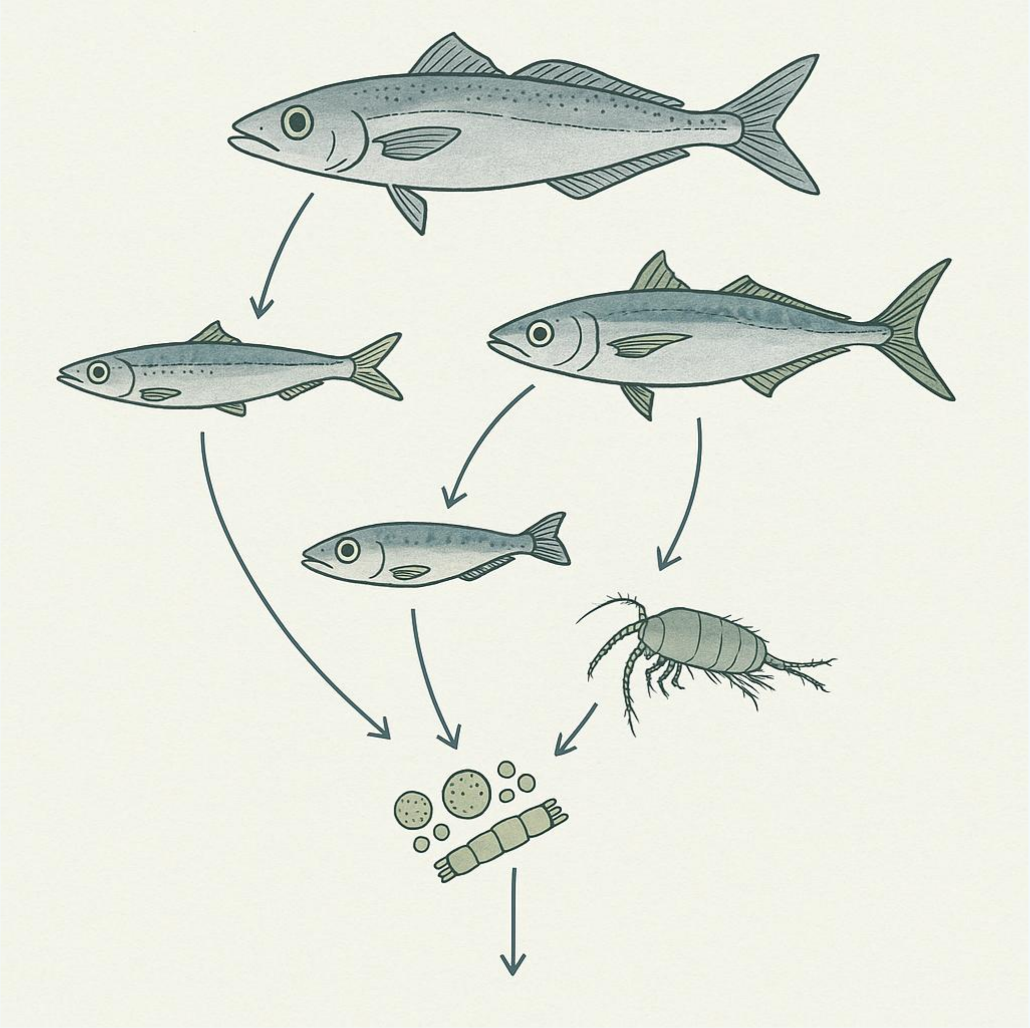
Why ontogenetic diet shifts matter



Forage fish connect plankton production to higher trophic levels

Ecological role
- Small pelagics channel energy from plankton to fish, seabirds and mammals.
- Changes in their predation pressure propagate through the food web.

Modelling challenge
- Food web models often aggregate life stages
- Aggregation may hide important differences in diet, mortality and prey vulnerability.

Scientific gap
- When juvenile and adult stages occupy different trophic niches, representing them as one group may hide important trophic differences and influence model results

Life-stage structure is not only a technical modelling choice: it can change ecological interpretation.

Refs: Pauly et al. 2000; Christensen & Walters 2004; Sánchez-Hernández et al. 2019

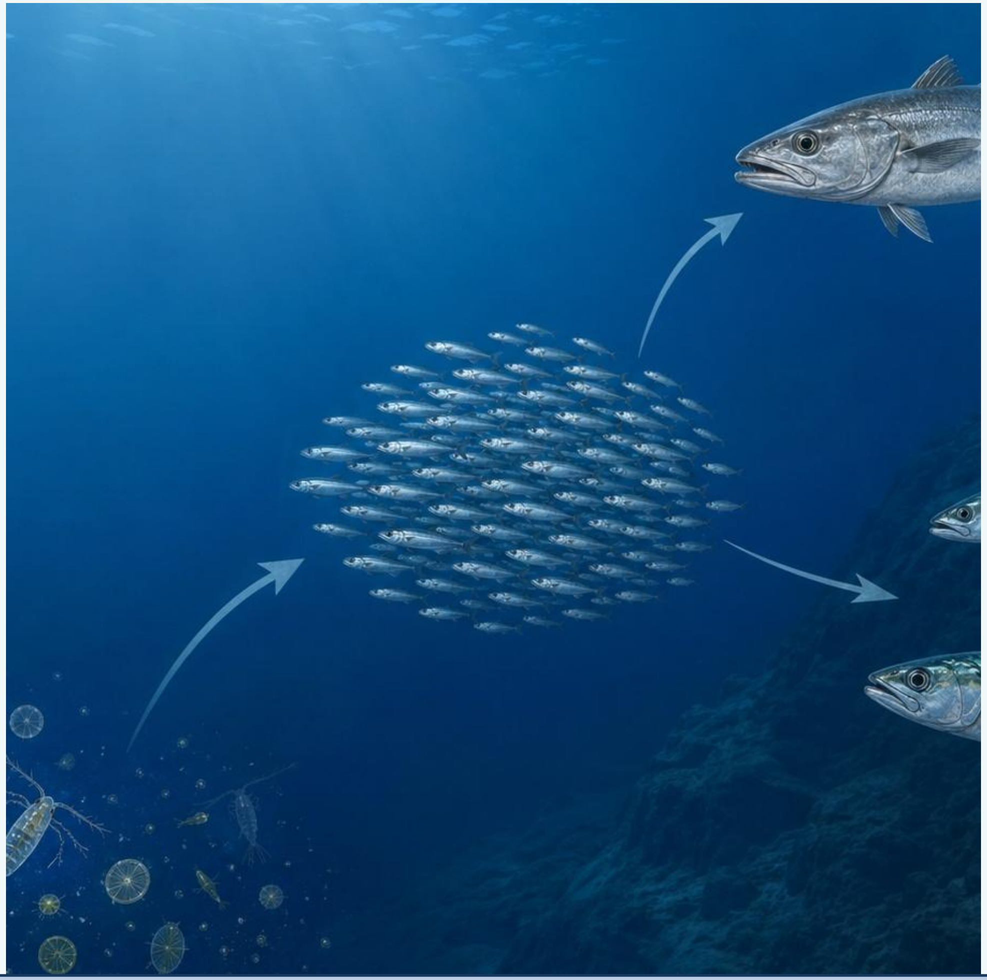
Same species, different trophic role

Concept

Juvenile stage
- lower body size
- higher predation exposure
- typically, stronger reliance on planktonic prey

Ontogenetic shift
- diet changes with growth
- trophic position increases
- vulnerability and mortality change

Adult stage
- greater piscivory in predators
- different prey spectrum
- different role in energy transfer



Question: Does explicitly splitting juvenile and adult stages change trophic structure and food-web interpretation?

Refs: Sánchez-Hernández et al. 2019; EwE multi-stanza guidance, Heymans et al. 2016

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Research objective

Main objective

Evaluate how representing key species as separate juvenile and adult stanzas, compared with a single aggregated group, affects Ecopath model balance, trophic structure, ecological realism and food-web interpretation.

1. Input structure
- P/B, Q/B, EE
- diet composition
- biomass partitioning

2. Balance
- EE diagnostics
- sensitivity to diet assumptions

3. Trophic structure
- trophic position
- predation mortality
- consumption flows

4. Interpretation
- hidden variability
- ecological realism

What changes when ontogeny is represented explicitly?

Two Ecopath configurations

Methods

Single-stanza model

- Juvenile and adult individuals combined into one functional group.
- One diet composition per species.
- Simpler parameterisation - fewer balancing constraints.

Multi-stanza model

- Juvenile and adult stanzas represented separately.
- Stage-specific diets and biomass allocation.
- Captures trophic ontogeny and stage-specific vulnerability to predators.

Six key species parameterized with updated diets and juvenile-adult logic

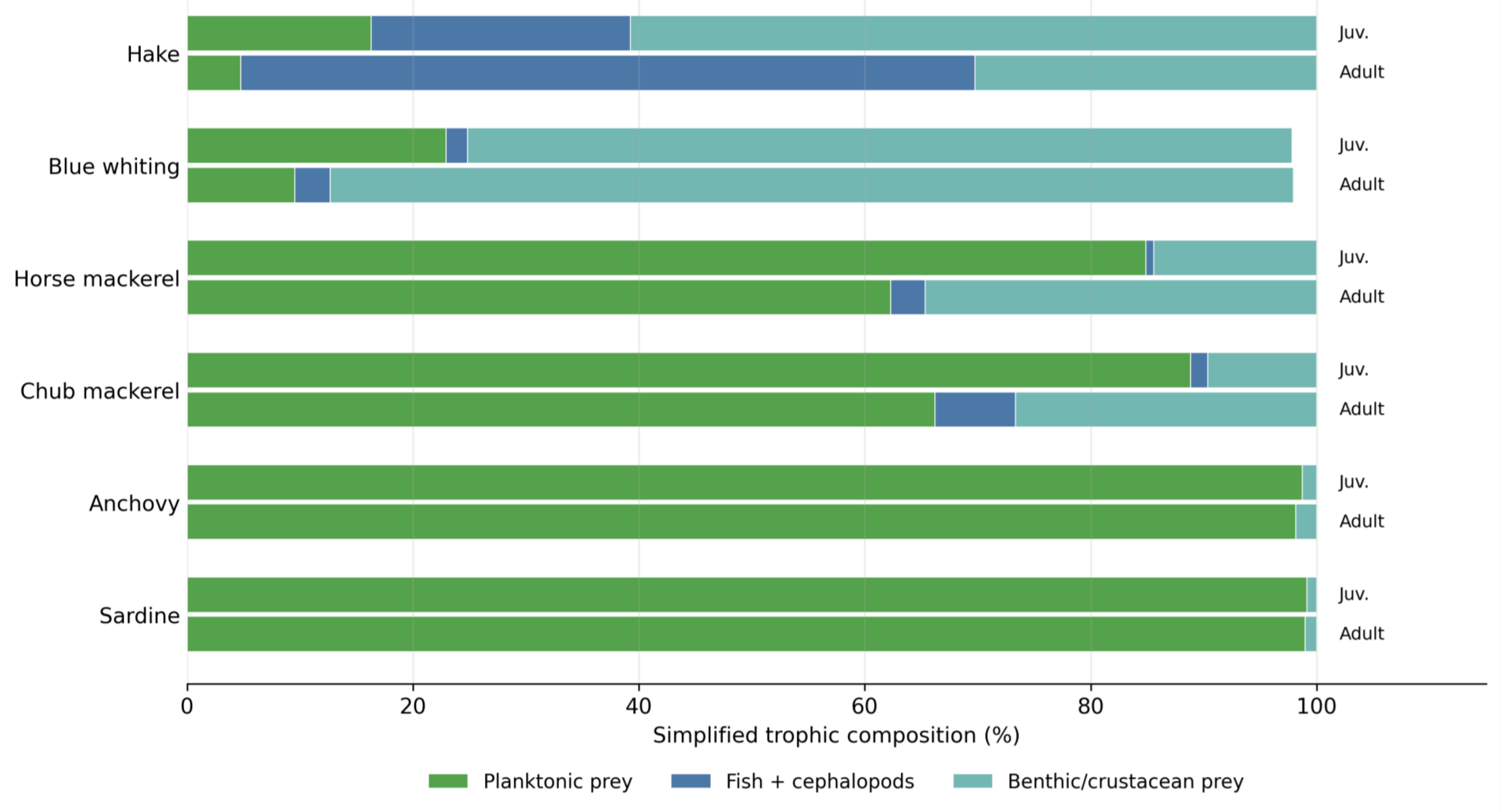
Hake	Blue whiting	Horse mackerel	Chub mackerel	Sardine	Anchovy
30 cm	19 cm	22.9 cm	21.3 cm	16 cm	10.1 cm

Separation points and diet matrices

Juvenile–adult separation was based on literature-informed length thresholds. Diet matrices were parameterised from stomach content analyses and adjusted during model balancing to satisfy Ecopath mass-balance constraints.

Refs: Christensen & Walters 2004; Heymans et al. 2016

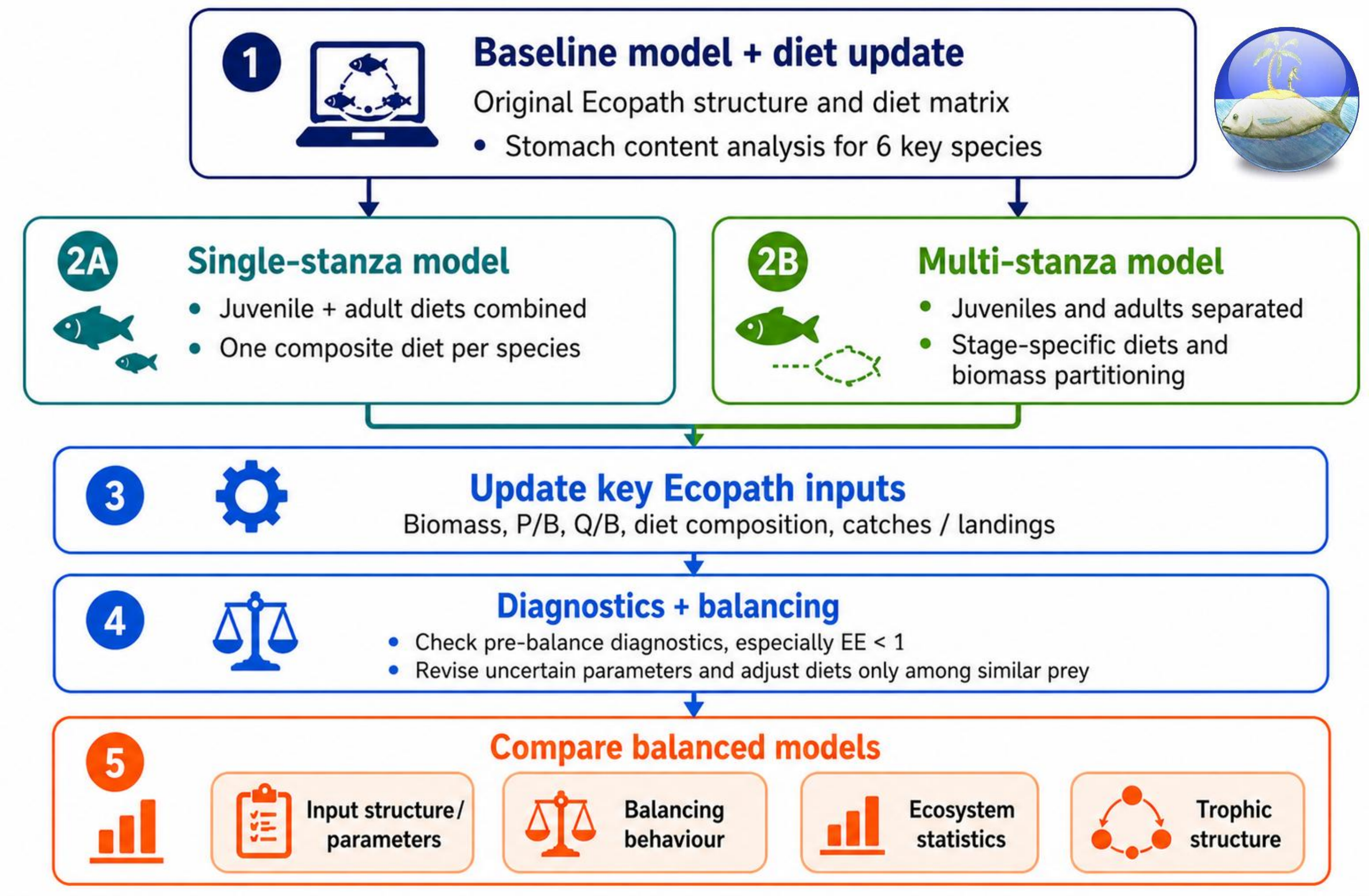
Juvenile and adult diets



Refs: Christensen & Walters 2004; Heymans et al. 2016

Workflow

Methods



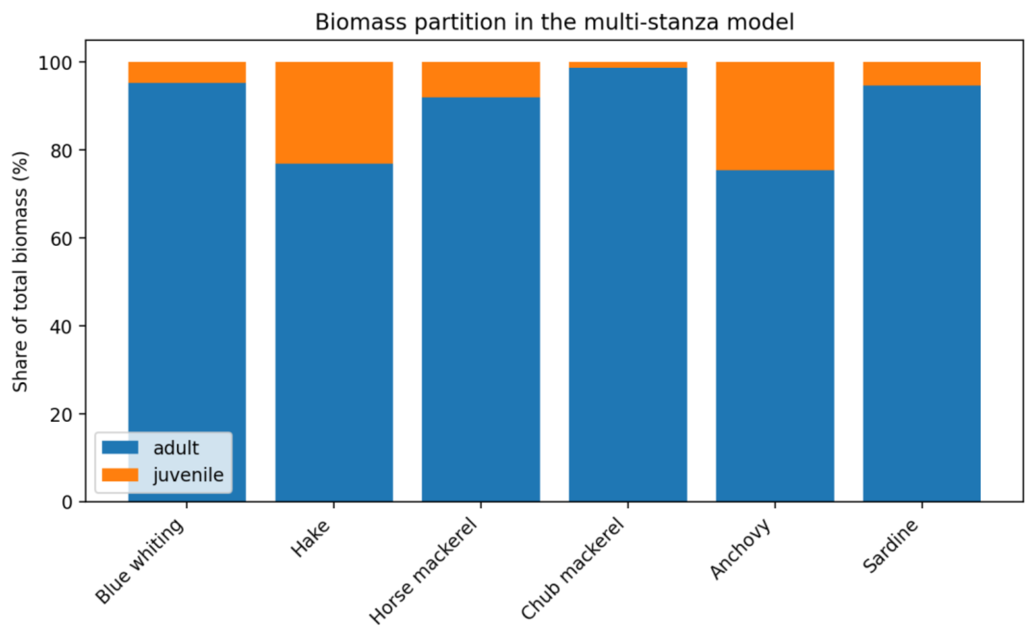
Refs: Heymans et al. 2016; Christensen & Walters 2004

Biomass, P/B, Q/B comparison

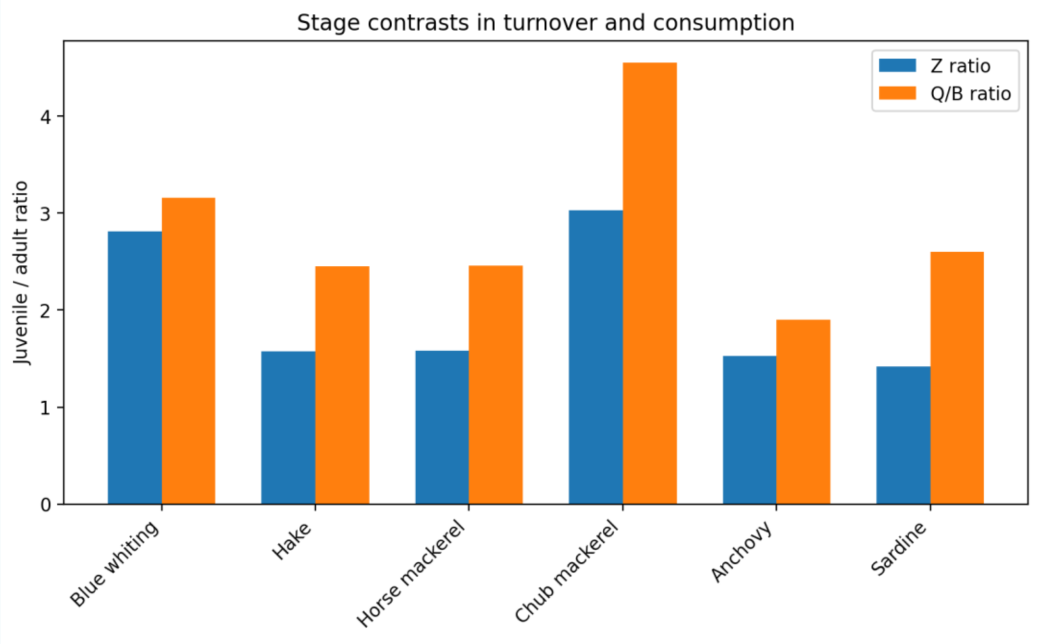
Model inputs

Ecopath input parameters varied for the both model configurations. The adult stage parameters are equal in both model, but multistazna model require some additional inputs that differ for juveniles when comparing to adult's stanza.

Biomass



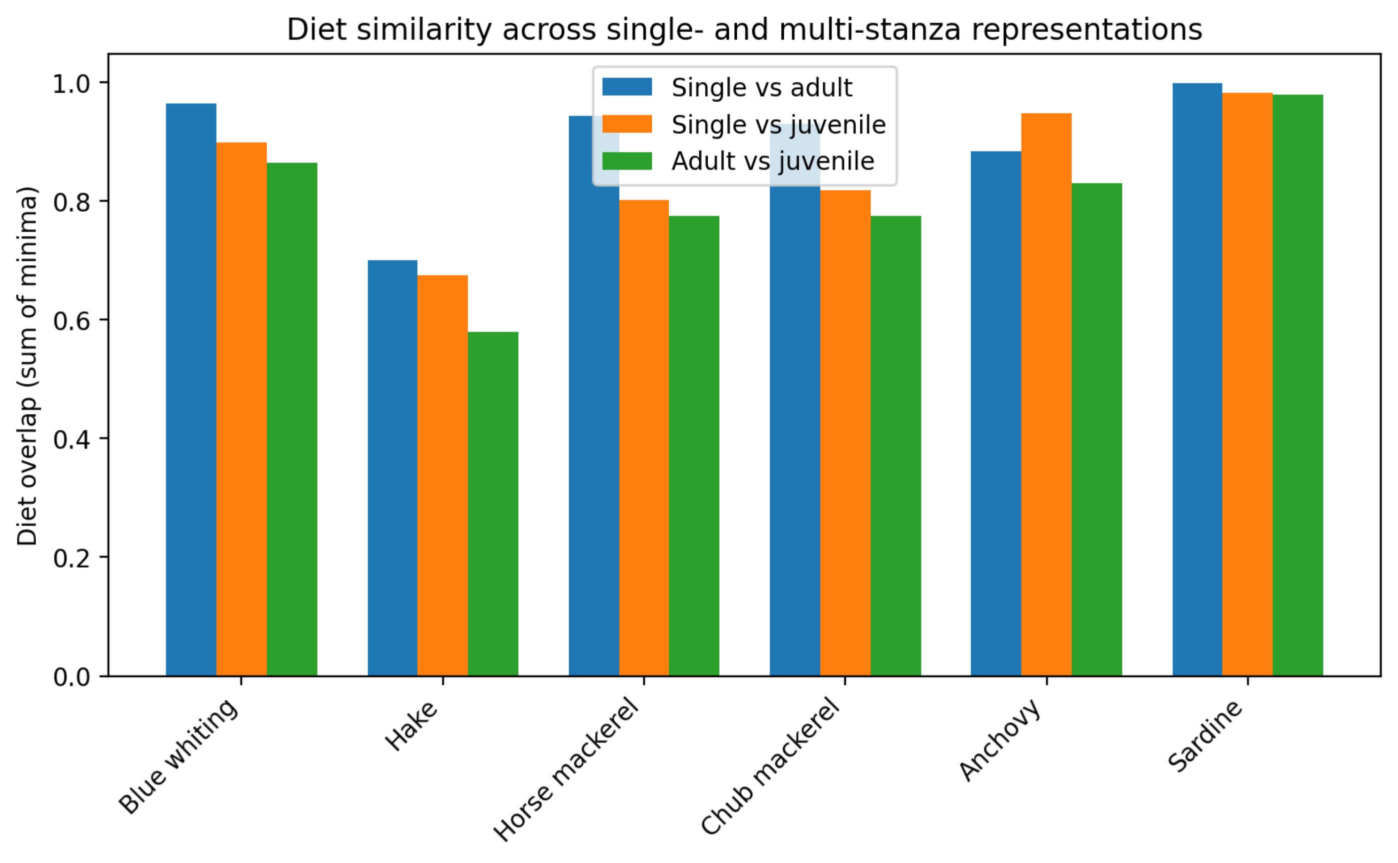
P/B and Q/B



Diet comparison

Model inputs

Diets



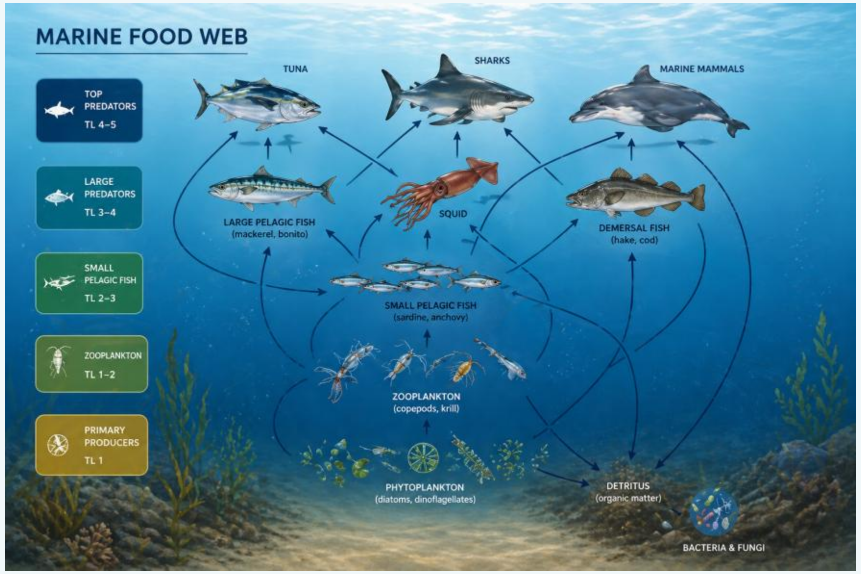
Balancing behaviour

Single-stanza
- easier to balance
- aggregation masks inconsistencies
-lower sensitivity to diet assumptions

Problems identified
- juvenile sardine EE >> 1
- adult sardine EE >> 1
- demersal and benthopelagic groups affected

Multi-stanza
- more difficult to balance
- juveniles: low biomass + high predation = EE > 1
-strong sensitivity to diet assumptions

Solution applied
- reduced excessive piscivory
- redistributed predation to similar prey
-maintained existing trophic links



Balance problems revealed where trophic demand was biologically unrealistic relative to available production.

EE = ecotrophic efficiency; Ecopath requires EE <= 1 for mass balance

Ecosystem-level comparison

Results

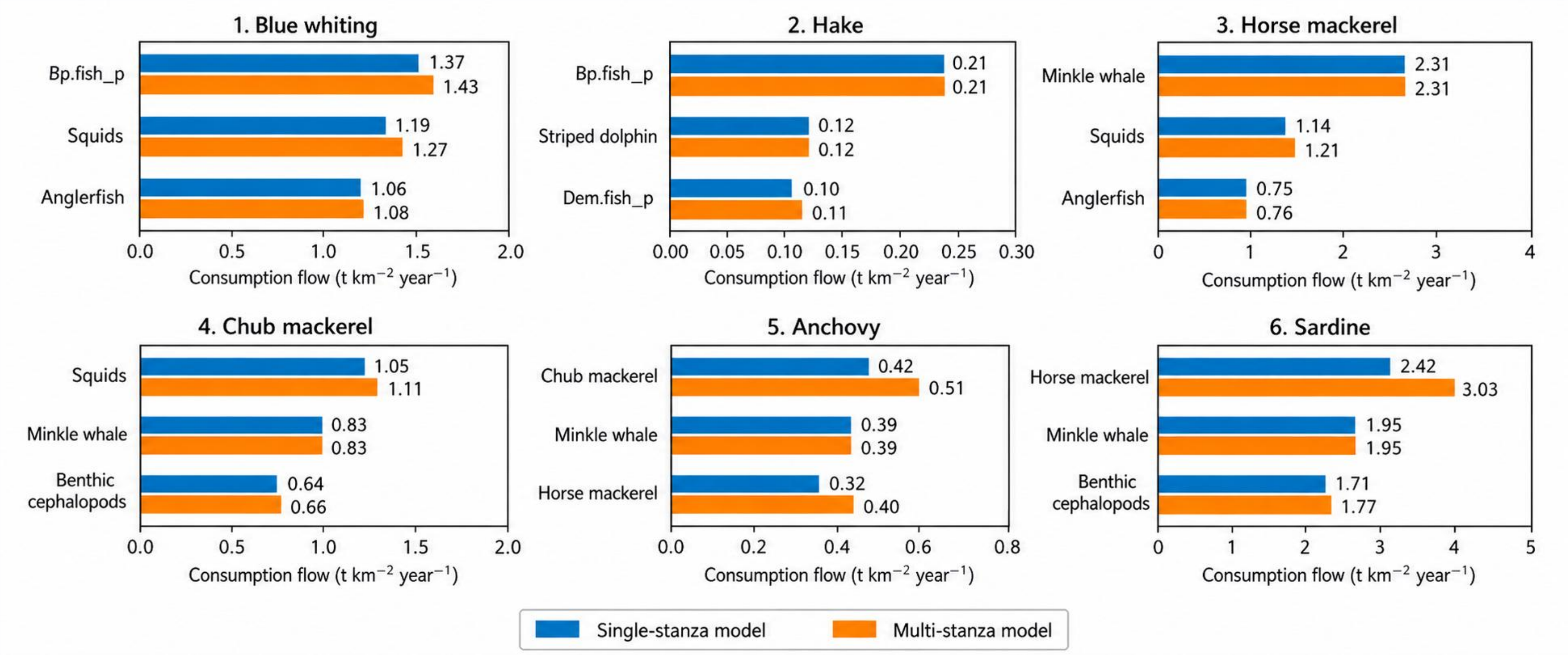
Key ecosystem statistics varied between model configurations.

System indicator	Single-stanza value	Multi-stanza value	% change (Multi vs Single)	Interpretation
Total biomass (excluding detritus)	266.496	287.911	+8.0% ↑	Biomass increased moderately in the multi-stanza model.
Total consumption	6604.258	6993.826	+5.9% ↑	Total consumption increased moderately.
Connectance index	0.303	0.317	+4.6% ↑	Connectance increased slightly, indicating more realised trophic links.
Total system throughput	13660.730	14098.870	+3.2% ↑	System throughput increased slightly.
Shannon diversity index	2.876	2.924	+1.7% ↑	Diversity changed only slightly.
Total catch	7.332	7.295	−0.5% ↓	Total catch is almost unchanged between models.
Pedigree	0.550	0.508	−7.6% ↓	Pedigree decreased, reflecting greater parameter uncertainty in the multi-stanza model.
System omnivory index	0.205	0.188	−8.3% ↓	Omnivory decreased slightly, suggesting more compartmentalised trophic pathways.

Predator–prey consumption flows

Results

Main predators are similar but flow strength changes.



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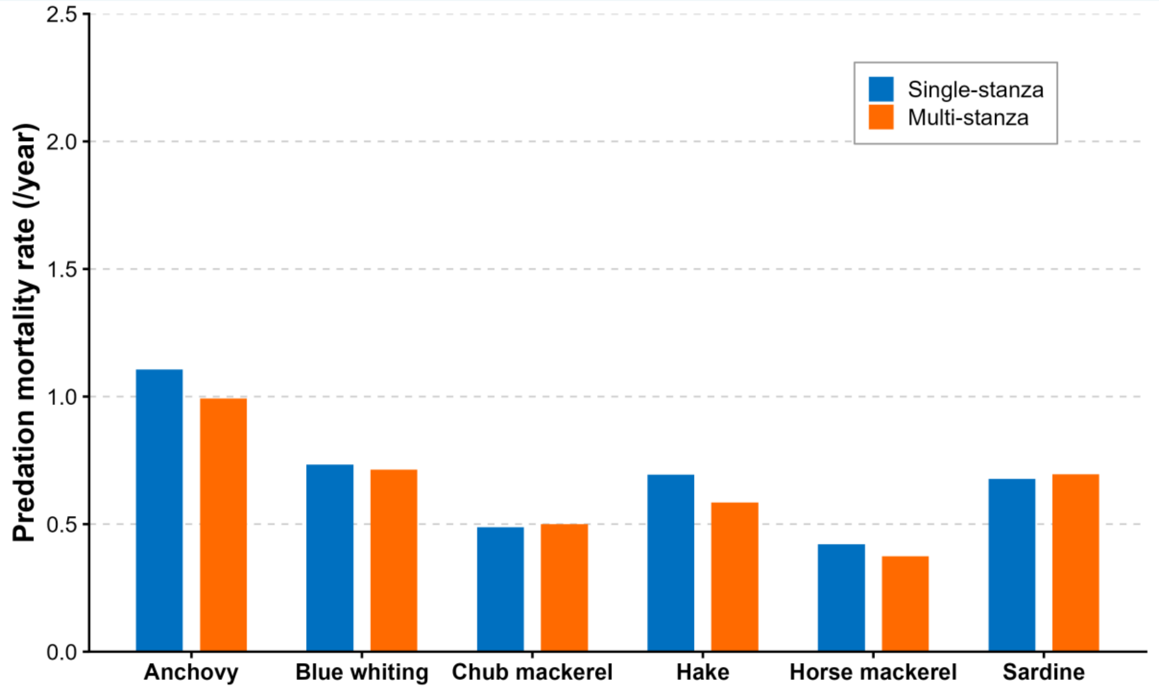
Predation mortality

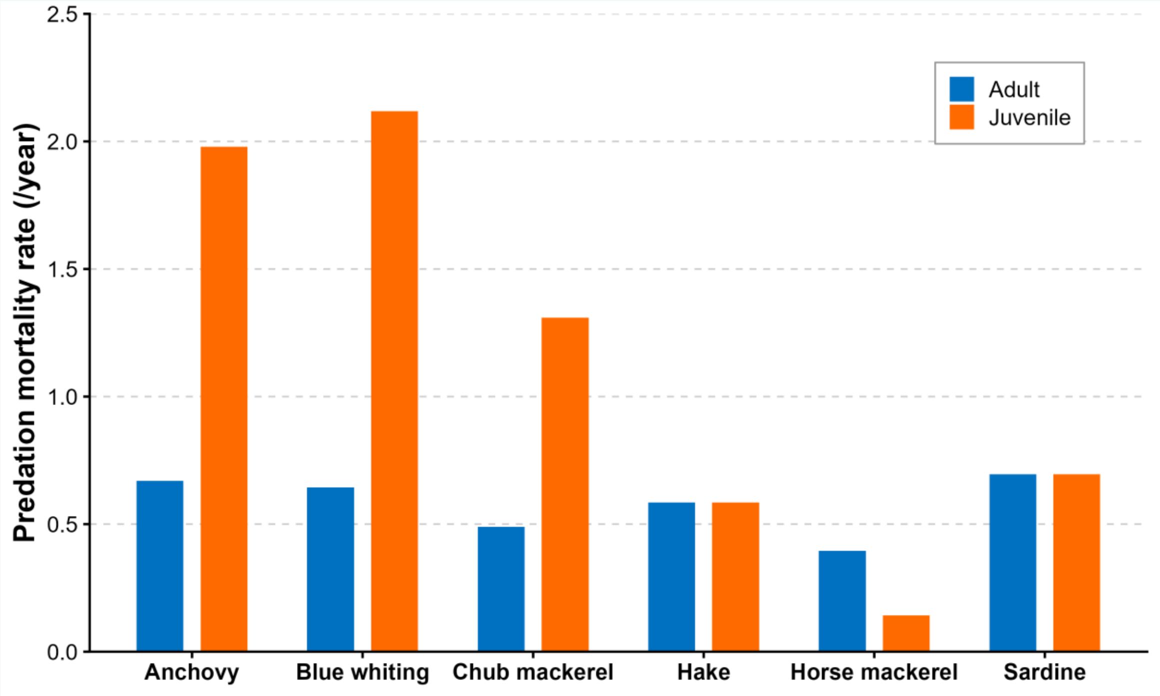
Results

The overall predation mortality is similar between models, but the multi-stanza model reveals important juvenile–adult differences that are hidden in the single-stanza model.

Single stanza vs Mutli-stanza



Adult vs Juvenile in Multi-stanza model



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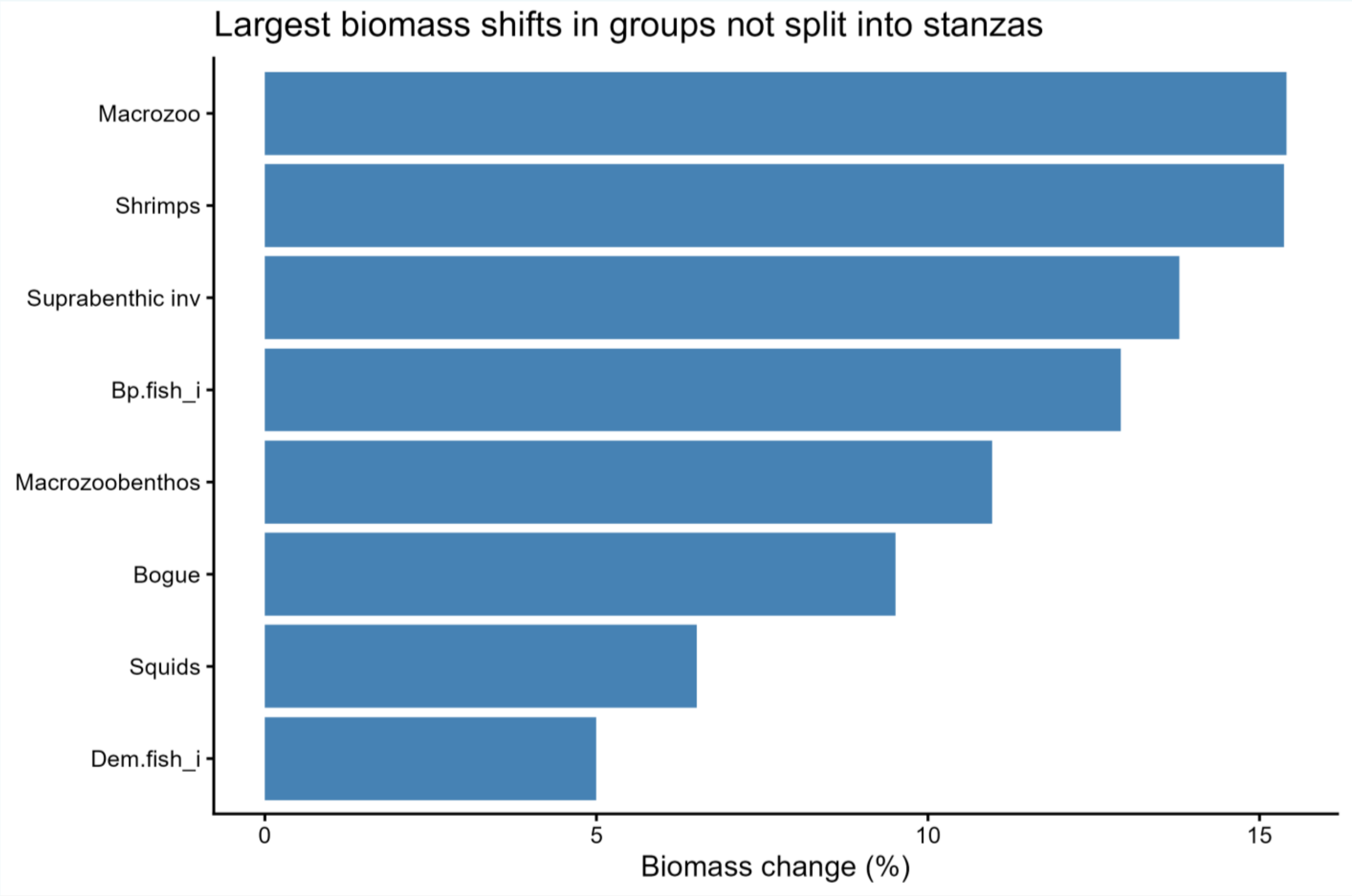
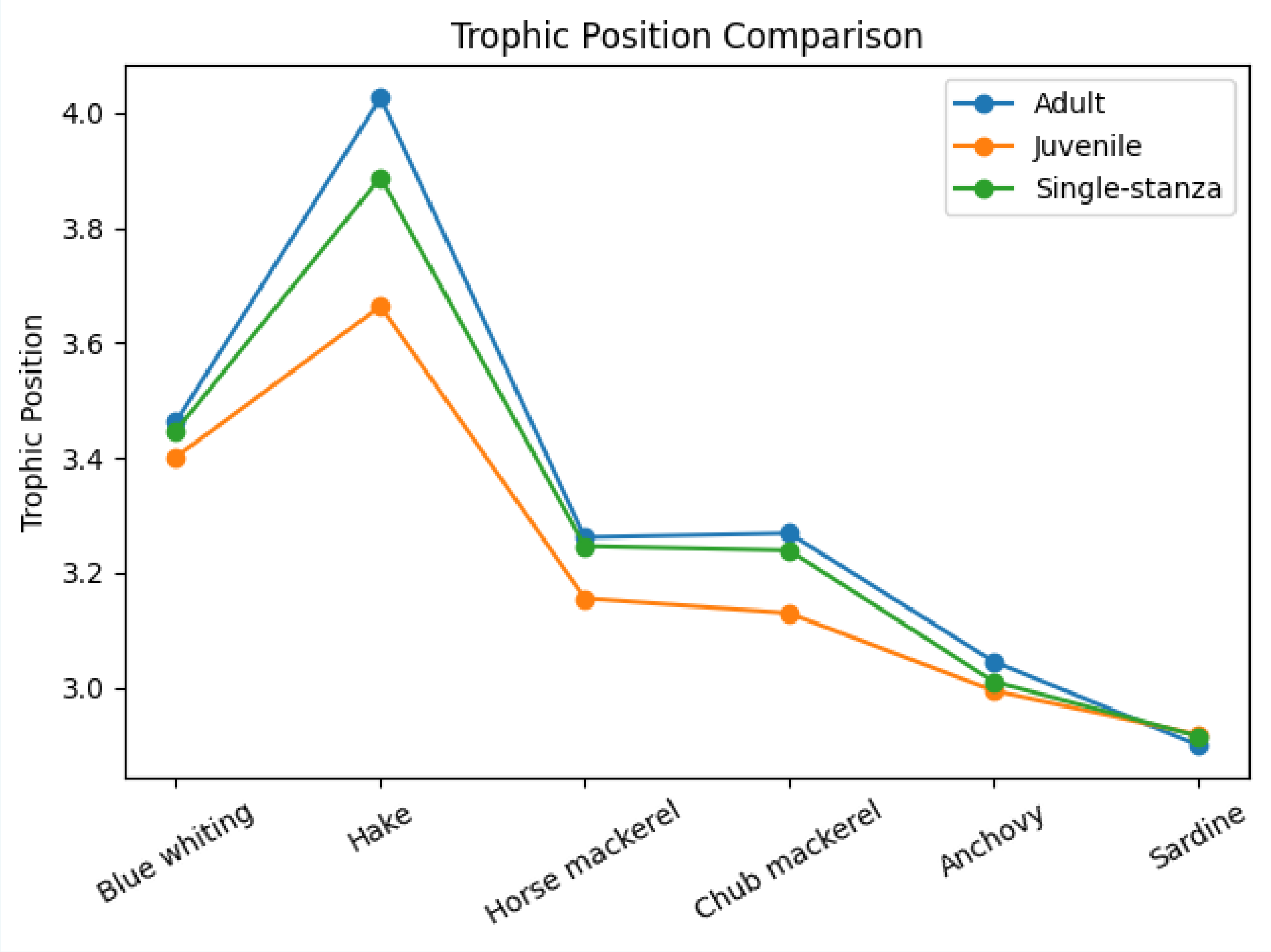
Biomass spillover effects on groups not split into stanzas



Trophic position



Main pattern

- Adults occupy higher trophic positions than juveniles.
- Hake shows the strongest adult-juvenile separation.

Single-stanza effect

- The aggregated model produces an average trophic position.
- This can mask ontogenetic variability in predation pathways.

Exception

- Sardine remains at the same lower trophic level in both stages

Synthesis: what does the multi-stanza model tell us?

- Overall food-web picture remains similar
- Differences observed in trophic structure
- Increase in model uncertainty
- Improve biological interpretation

Conclusions: what does the comparison tell us?

Ontogeny matters
Multi-stanza models reveal stage-specific trophic roles that are hidden in aggregated groups

Aggregation masks variability
Single-stanza models smooth differences in diet, trophic position, EE and predation exposure

Balancing becomes informative
EE > 1 helped identify unrealistic predation pressure and diet assumptions.

Implications for future Ecosim work
Stage-specific parameterization may influence dynamic simulations, vulnerability assumptions and management scenarios.

Final take-home message
Life-stage structure should be considered when modelling key species with strong ontogenetic shifts, especially forage fish and major predators.

Thank you for your attention

Activity 2 – Food web processes: Comparative paper ?

Conclusion

Case studies

Similar patterns

Food-web models

Interest and time

If you interested in contributing, please reach out to me or Pedro

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References

Sources

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