The role of small pelagic fish in diverse ecosystems: information gleaned from food-web models

Jim Ruzicka, Luciano Chiaverano, Marta Coll, Susana Garrido, Jorge Tam, Hiroto Murase, Kelly Robinson, Giovanni Romagnoni, Lynne Shannon, Alexandra Silva, Dorota Szalaj, Shingo Watari

- review physiological rate parameters, production rates, & landing rates for SPF within *EwE* food webs of diverse ecosystems
- derive metrics of SPF demand on ecosystem production (“footprint”) & contribution to higher trophic level and fishery production (“reach”)
- quantify sensitivities to changes in SPF abundance

1. Get models

ecobase.ecopath.org

EcoBase: a database of Ecopath with Ecosim models

ecobase.ecopath.org

Home | Documentation and dataset | Discovery tools | The Team

205 EwE models available for download
471 EwE models with metadata
1 EwE pending model(s)

What is EcoBase?

EcoBase is an open-access database of Ecopath with Ecosim (EwE) models published worldwide in the scientific literature. More precisely, EcoBase is an information repository of EwE models freely accessible online here or via the free EwE software - version 6.5.

Who manages EcoBase?

EcoBase was created in 2015 by a group of scientists interested in conducting global meta-analyses based on existing EwE models . Since 2014, EcoBase is managed and supported by the members of the Model repository working group of the Ecopath Research and Development Consortium (ERDC) . The ERDC is a global, cooperative network focused on the research, development and sustainability of the EwE approach and software, its information basis, and complementary activities and capabilities.

What is EcoBase for?

EcoBase was created with the intention of making EwE models discoverable, accessible, and reusable to the scientific community, as soon as they are published. Only the Ecopath models are freely accessible at this stage (Ecosim and Ecospace parameters are not available). The main goals of EcoBase are to:

- 1. Provide a comprehensive and up-to-date list of EwE models and EwE-based publications;
- 2. Gather information from the referenced models and publications, and notably critical metadata ;
- 3. Facilitate the search, sharing and reuse of published EwE models for future studies;
- 4. Enhance interactions and collaborations within the scientific community, and particularly the EwE community.

Why using EcoBase?

- **If you are not yet an EwE user…** then let's briefly introduce EwE: EwE is a modeling software offering a wide range of different tools and allowing analyses of various ecological phenomena, which is why it has been applied to hundreds of ecosystems worldwide. Building EwE models require the collection, compilation and harmonization of various types of information on these ecosystems. Thus, a large amount of data has been gathered in EwE-based studies.
- **If you already are an EwE user…** then you know that: Building EwE models help summarizing available knowledge on the ecosystems of interest and deriving various ecosystem properties, so that EwE applications may be seen as an important source of data.

EcoBase offers a framework where these data may be properly stored, so that they can be properly reused for future applications, such as models comparisons, meta-analyses, etc.

1. Get models

2. Confirm mass balance

ecobase.ecopath.org

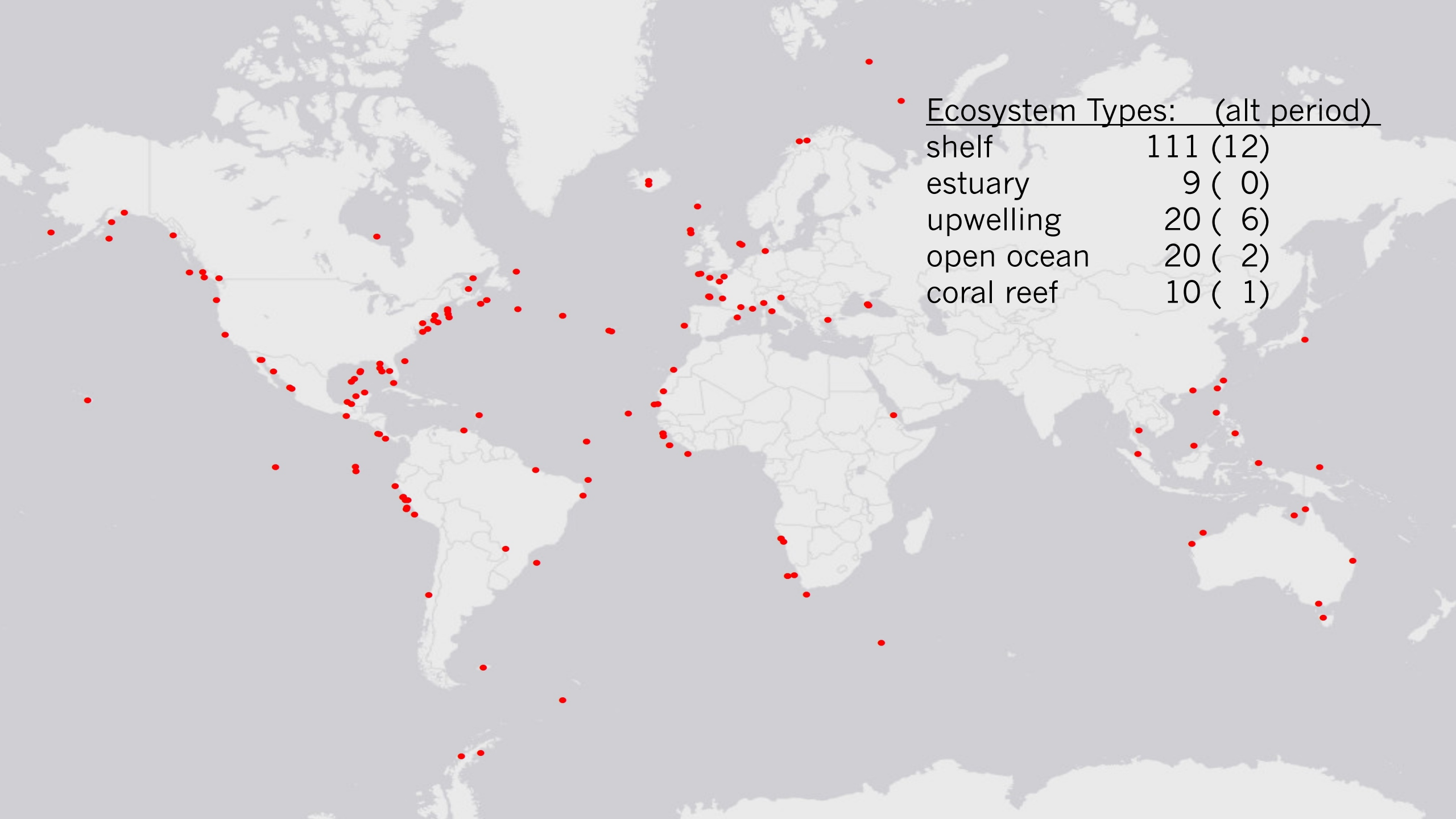
156 balanced models

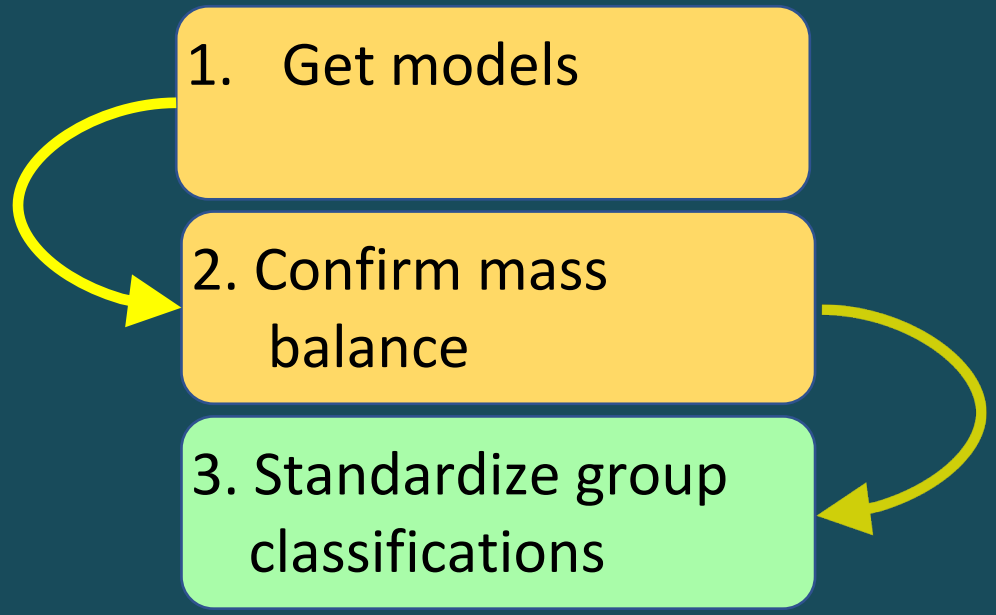
Each of our own models

15 balanced models

---

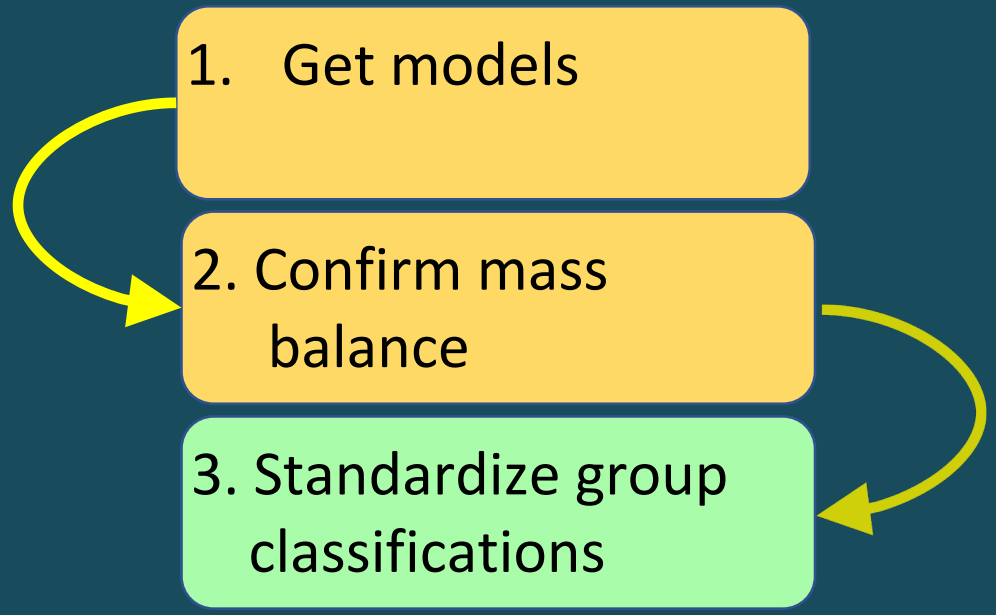
171 models in this presentation


Ecosystem Types: (alt period)
shelf 111 (12)
estuary 9 (0)
upwelling 20 (6)
open ocean 20 (2)
coral reef 10 (1)



3915 different functional groups

	pelagic	demersal
primary producer	2.1	2.2
zooplankton, infauna/epifauna	3.11	3.21
micronekton	3.12	--
cephalopods	3.13	3.23
pelagic fish, demersal fish	3.14	3.24
seabirds	3.15	--
mammals	3.16	--
fleets	5	
detritus	4	
unknown fish	3.04	
unknown demersal consumer	--	3.20
unknown consumer	3.00	



“Anchovy” ← OK!

“Pelagics” ← *???*

What is a small pelagic fish?

Mostly planktivorous
Exclude mackerels
Exclude juvenile stage of non-SPF adults

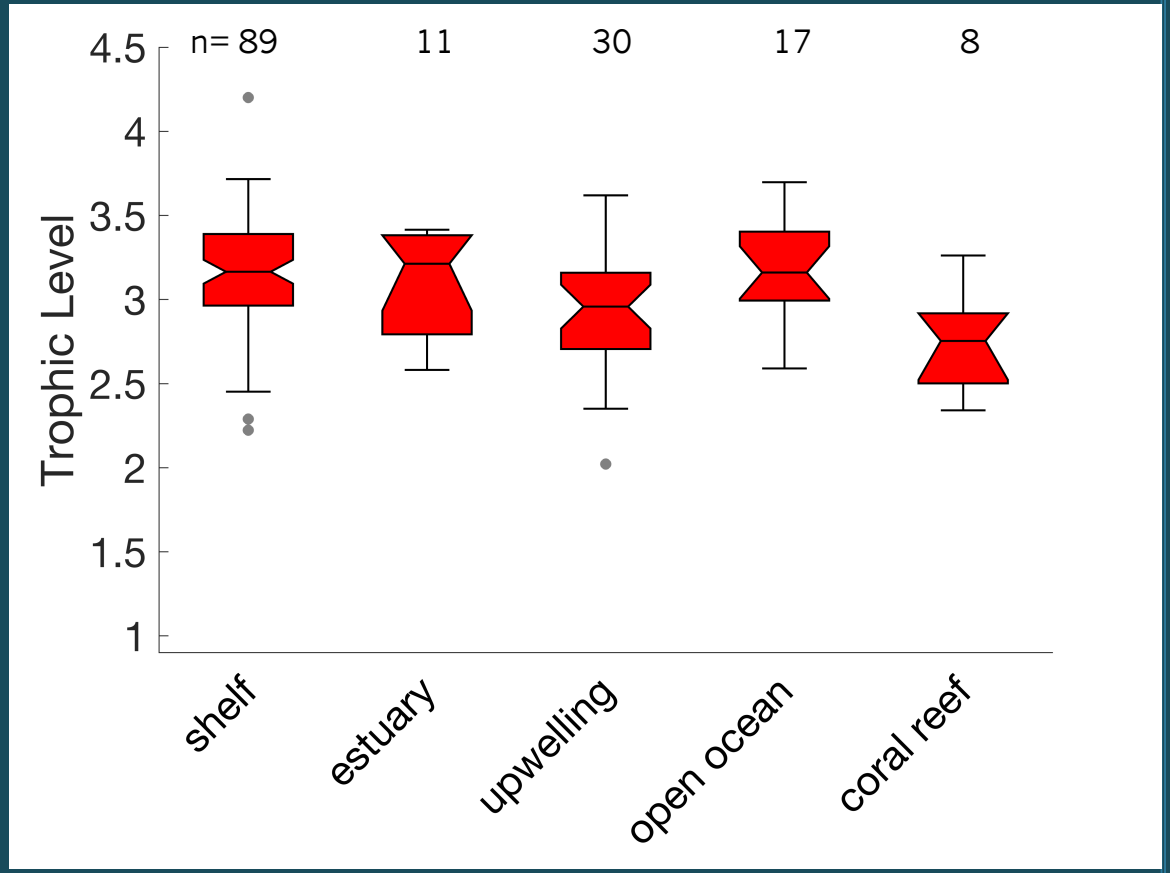
Could it be an SPF?

1) Is it pelagic?
2) Is it a fish?
3) Is it planktivorous?
4) Is it “small” (no big plankton feeders)
5) No hybrids (“sardine & small squid”)

Obvious groups:

sardine, herring, anchovy, smelt, shad, menhaden, sandlance, flyingfish

1. Get models
2. Confirm mass balance
3. Standardize group classifications
4. Collect EwE parameters & rates

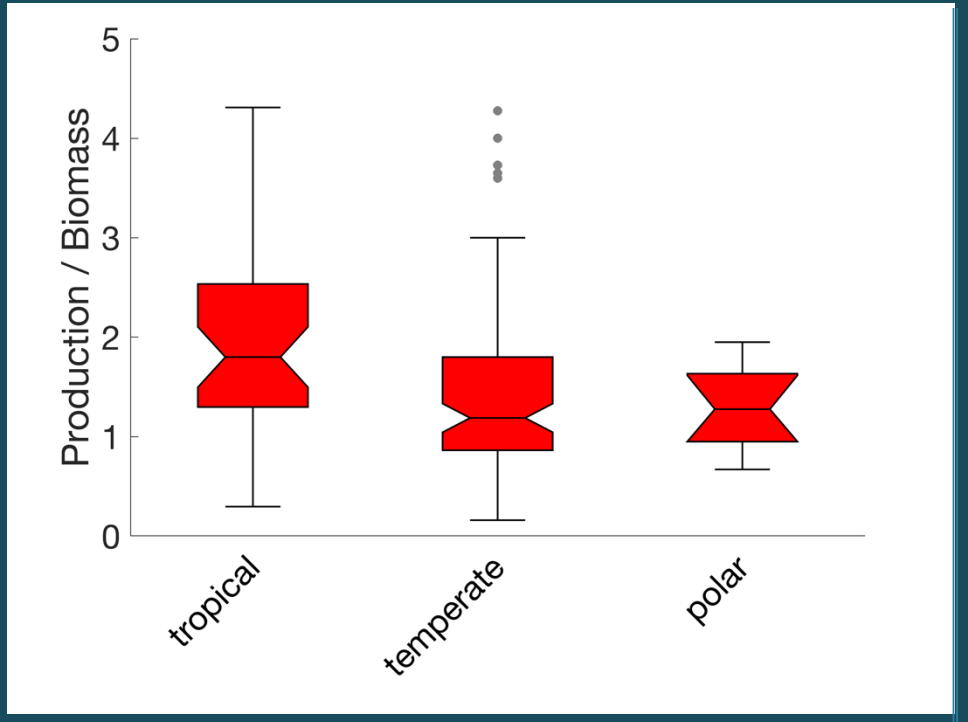


SPF Trophic level by ecosystem type

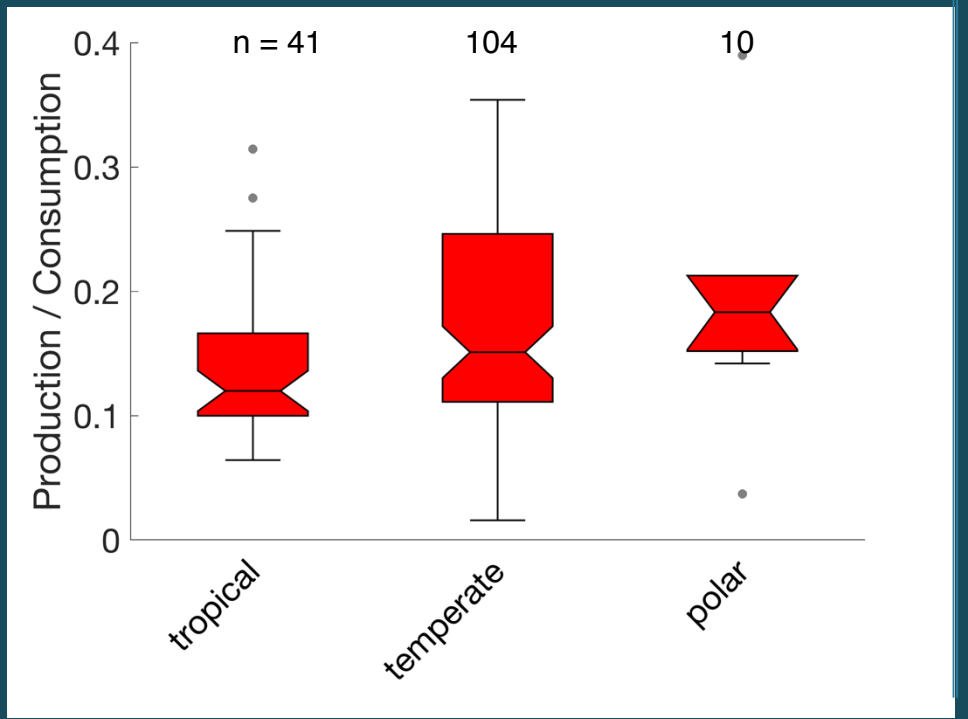
- Trophic levels generally between 2.5 – 3.5
- TL lower in upwelling settings than shelf
- Lower TL in coral reef systems (but small sample size)

1. Get models
2. Confirm mass balance
3. Standardize group classifications
4. Collect EwE parameters & rates

production / biomass (1/y)



growth efficiency production / consumption

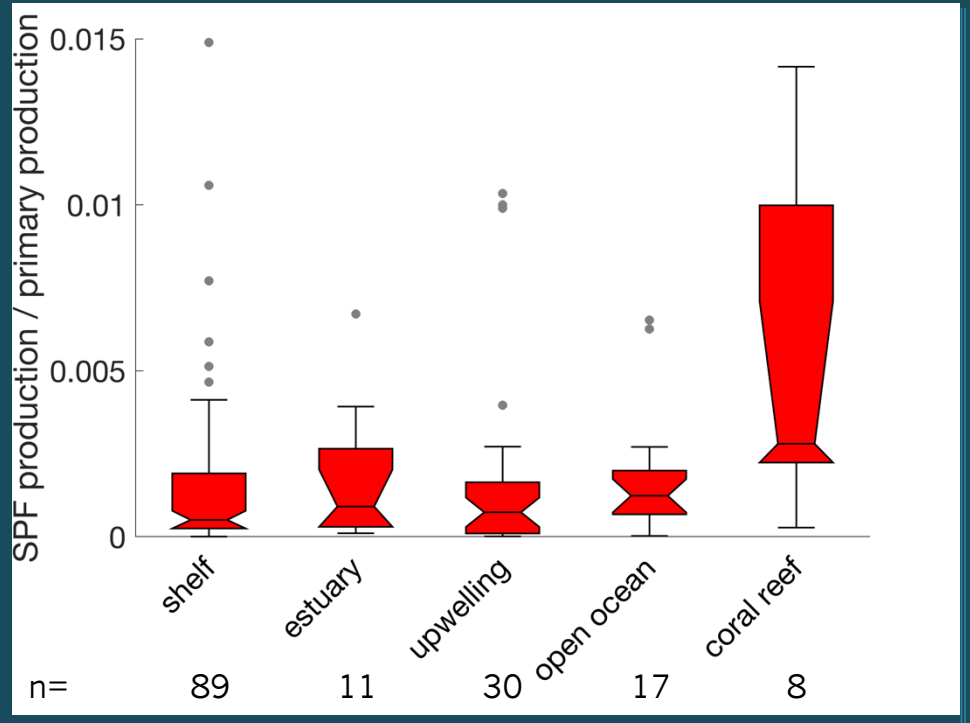


small pelagic fish production parameters by latitude zone

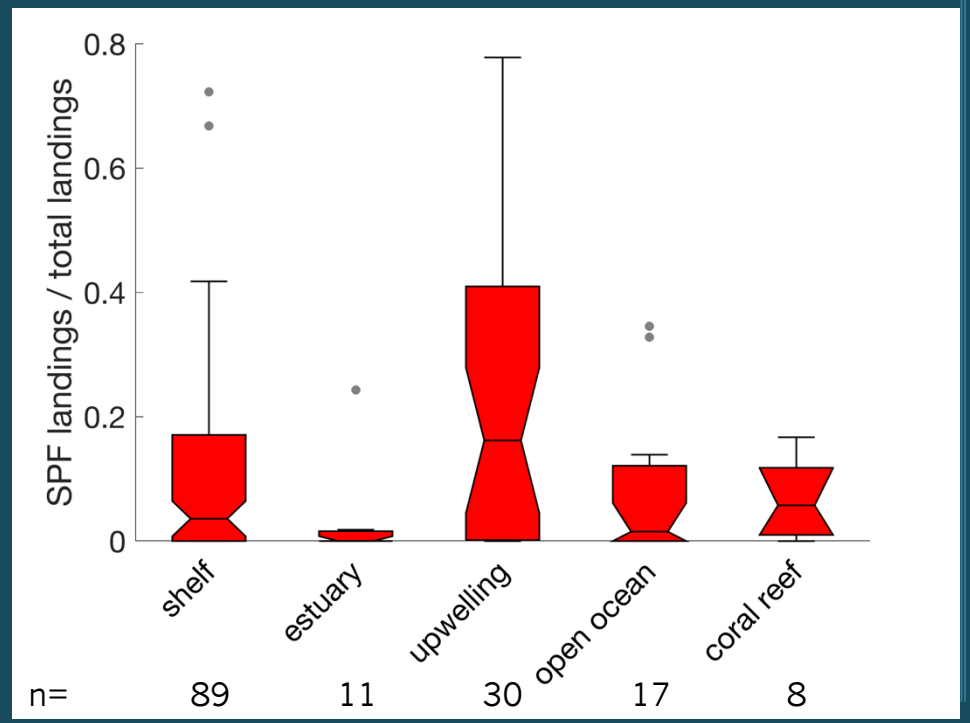
- Higher size-specific production rates at lower latitudes
  Expected relation with warmer temperature
- Higher growth efficiency at higher latitudes
- Implies higher size–specific consumption rates in tropics

1. Get models
2. Confirm mass balance
3. Standardize group classifications
4. Collect EwE parameters & rates

SPF production
primary production



SPF landings
total landings

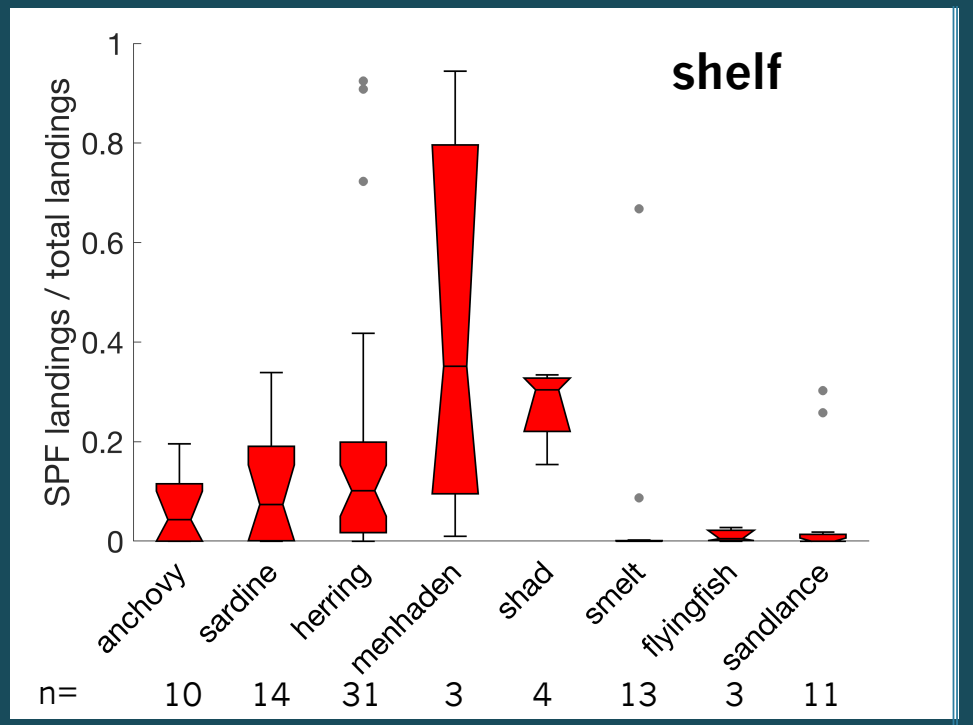


Scale of small pelagic fish production by ecosystem type

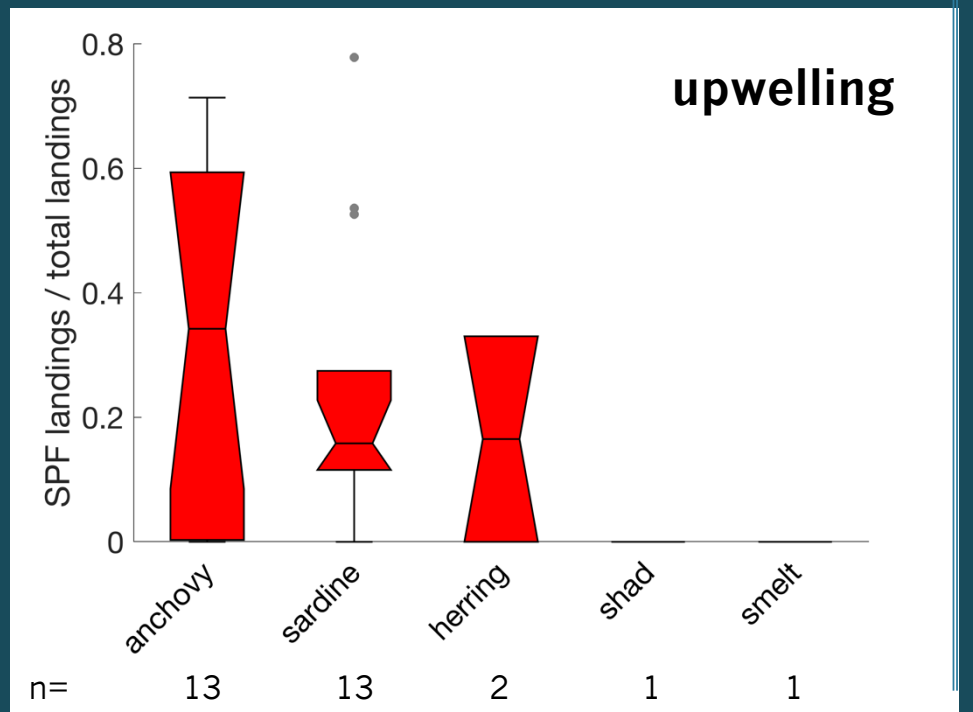
- SPF comparable in scale to pooled non-SPF pelagic fish in each ecosystem type (maybe important in reef, but small sample size)
- SPF are especially large contributors to landings in upwelling & shelf systems

1. Get models
2. Confirm mass balance
3. Standardize group classifications
4. Collect EwE parameters & rates

SPF landings / total landings



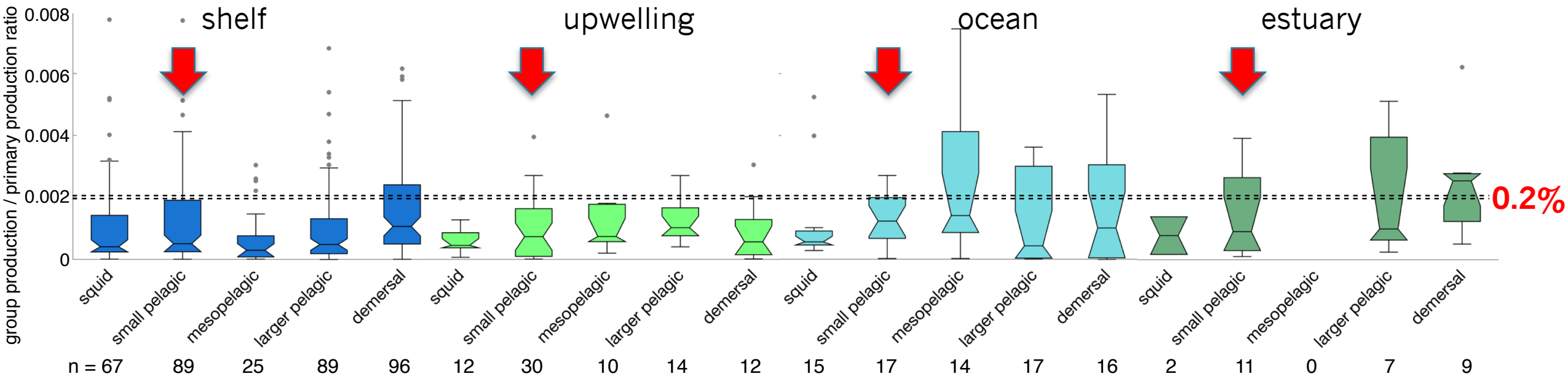
SPF landings / total landings



Scale of small pelagic fish contribution to fishing by type in upwelling & shelf ecosystems

- In shelf systems, menhaden are especially important (e.g., Gulf of Mexico)
- In upwelling systems anchovy are especially important, but the range is large 0%-60% of total landings
- In upwelling systems, sardine account for 10%-30% of landings

Group production / total primary production ratio



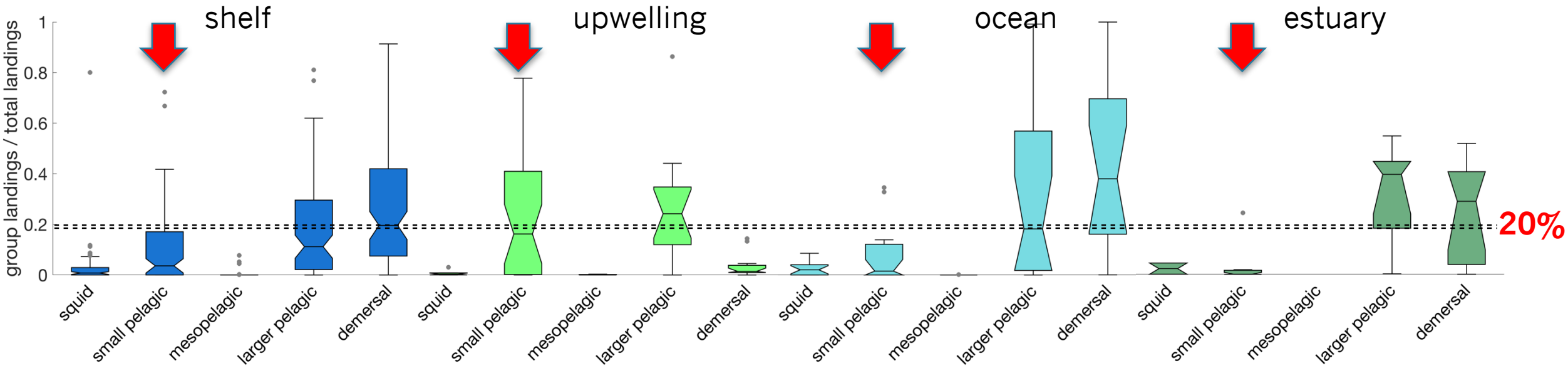
Scale of small pelagic fish production by ecosystem type

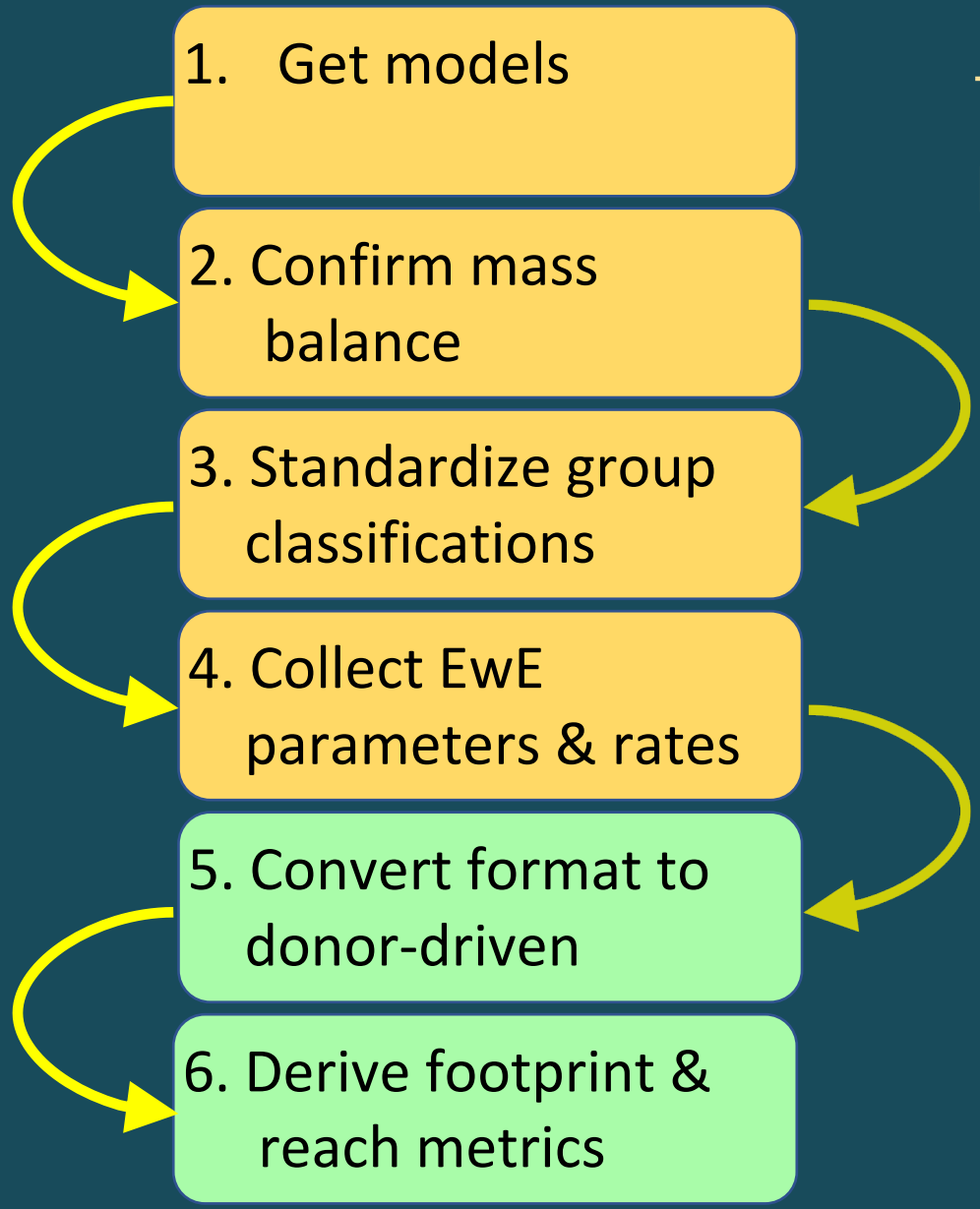
- Generally, SPF are comparable in production scale to the combined size of all the other non-SPF pelagics in each ecosystem
- Demersal fish are larger slightly more productive than SPF in shelf systems
- Mesopelagics are relatively more productive in open ocean
- Production of all fish groups is relatively greater in open ocean (but demersal role highlights mixed shelf/ocean models in database)

Scale of small pelagic fish landings by ecosystem type

- SPF are important contributor to fisheries in upwelling systems, comparable in importance to the combined landings of all other pelagic fish
- Demersal fish tend to be more important to fisheries than SPF in shelf & open ocean ecosystems

Group landings / total landings ratio





The previous was a comparison of given EwE parameters.
Now consider the role of food web structure...

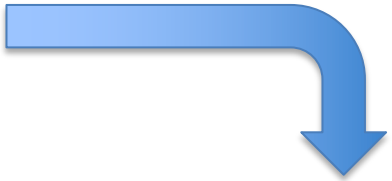
consumers

producers Q_{pc}	P_1	C_1	C_2	F_1
P_1	0	180	20	0
C_1	0	20	35	5
C_2	0	0	8	2
F_1	0	0	0	0

ECOPATH "solution"

Consumption Matrix:

Who eats how much of what?



Production Matrix:

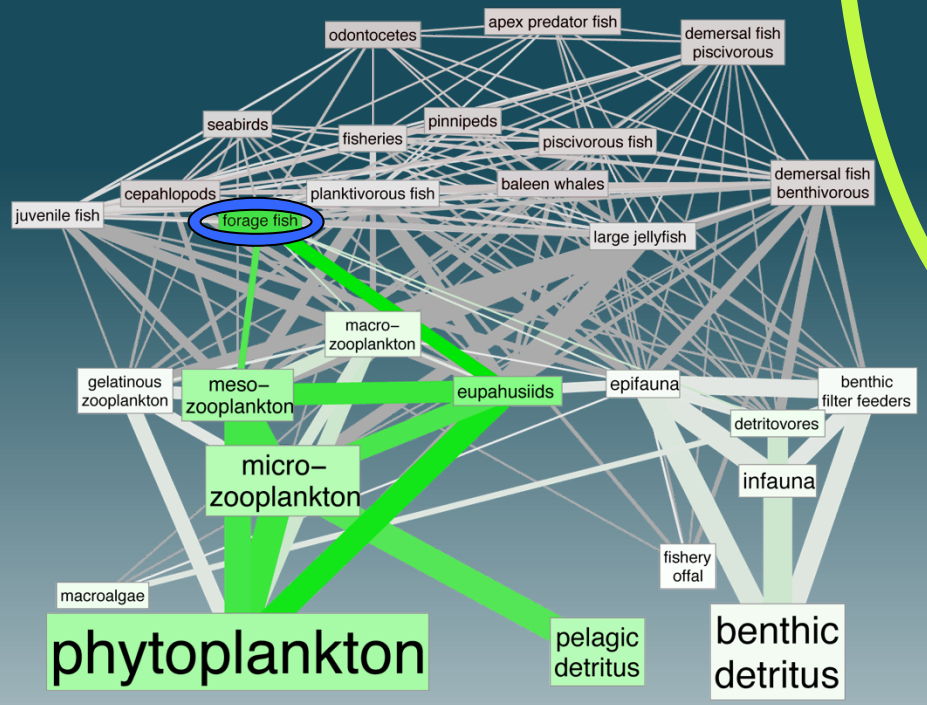
What is the fate of production?

producers

consumers A_{cp}	P_1	C_1	C_2	F_1
P_1	0	0	0	0
C_1	0.9	0.3	0	0
C_2	0.1	0.6	0.8	0
F_1	0	0.1	0.2	0

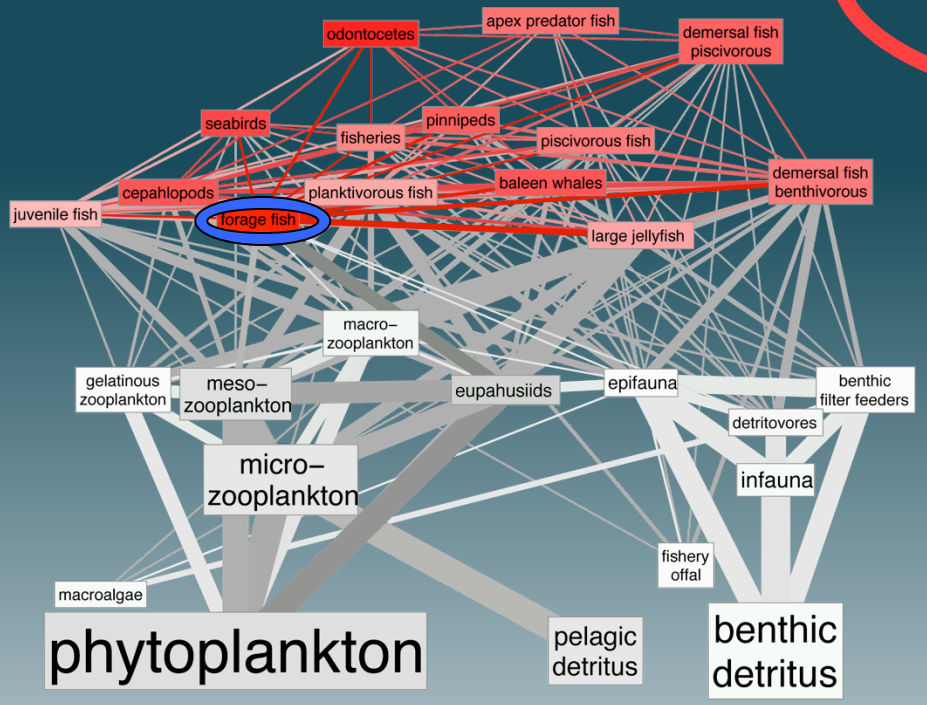
Steele & Ruzicka, 2011. Constructing end-to-end models using ECOPATH data. *Journal of Marine Systems*, 87: 227-238.

FOOTPRINT: SPF demand across all trophic paths relative to total consumer demand in ecosystem

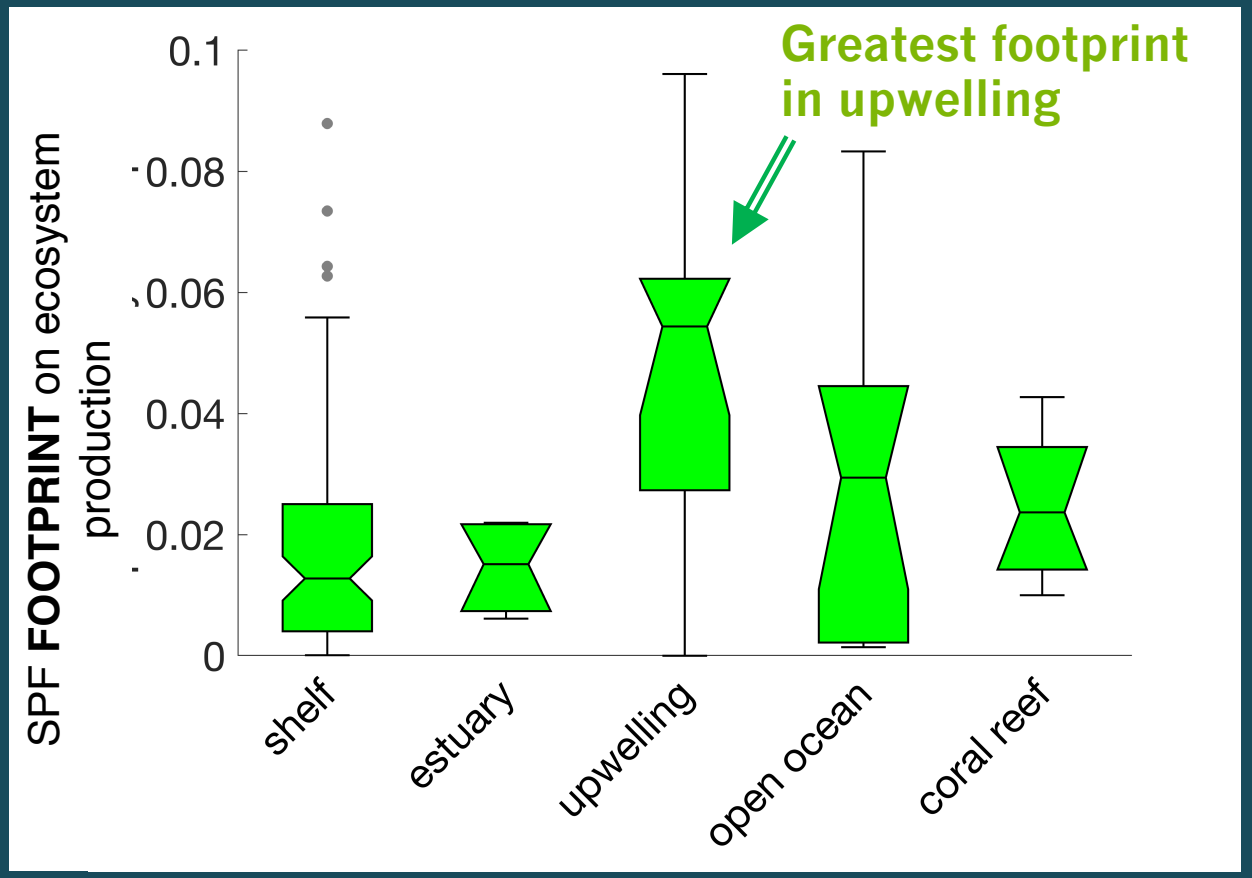


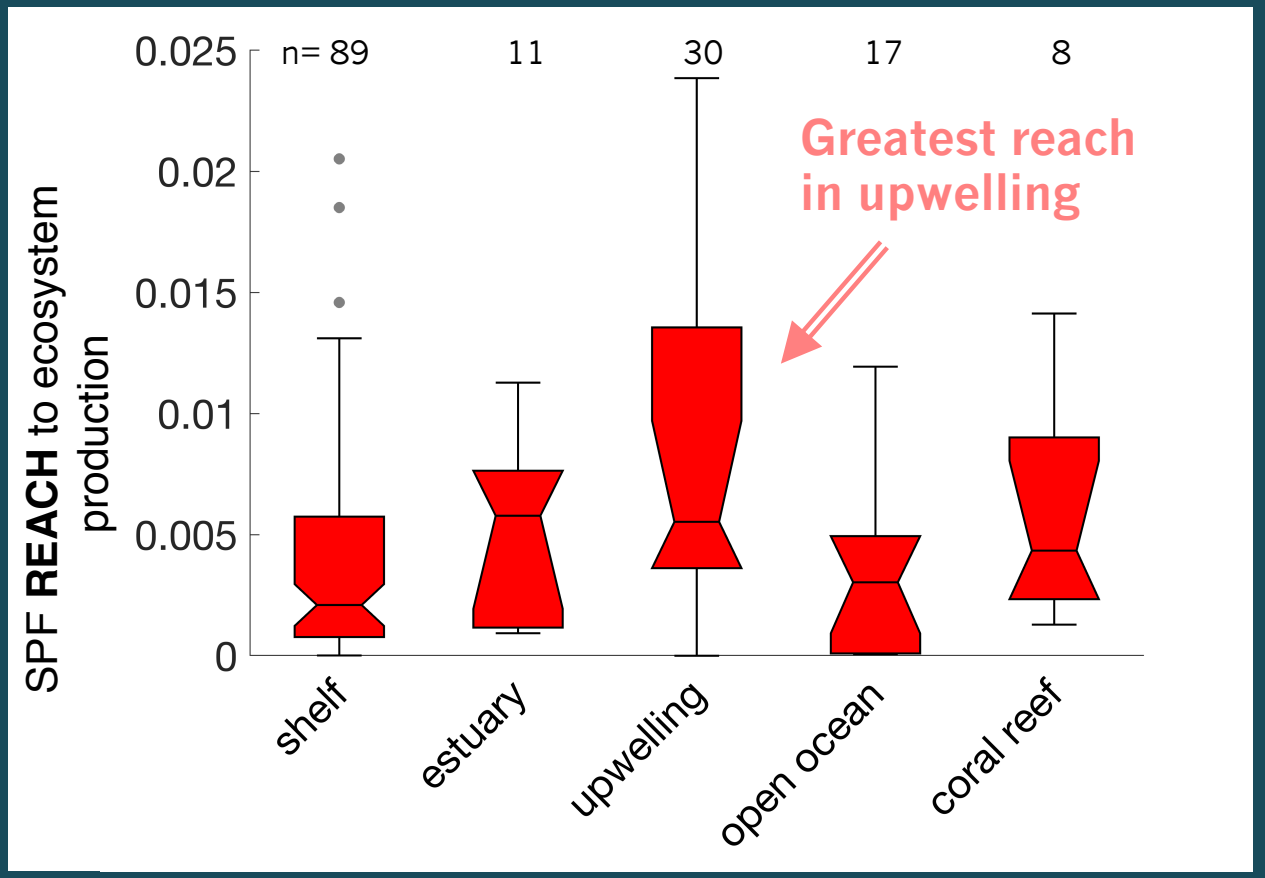
Via **Direct** & **Indirect** Links

REACH: SPF production flow through all trophic paths relative to total consumer production in ecosystem



Via **Direct** & **Indirect** Links



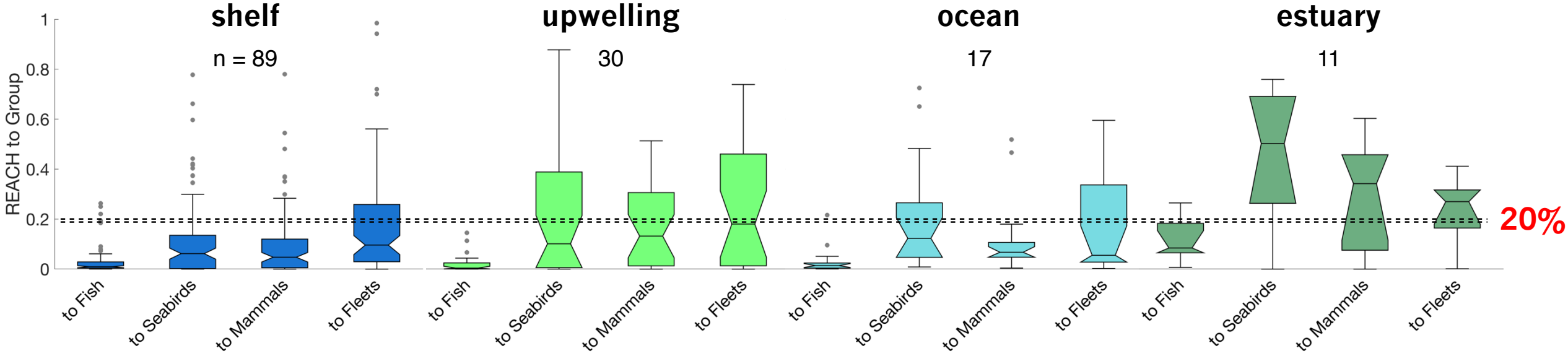


FOOTPRINT: SPF demand upon all trophic paths relative to total consumer demand in ecosystem

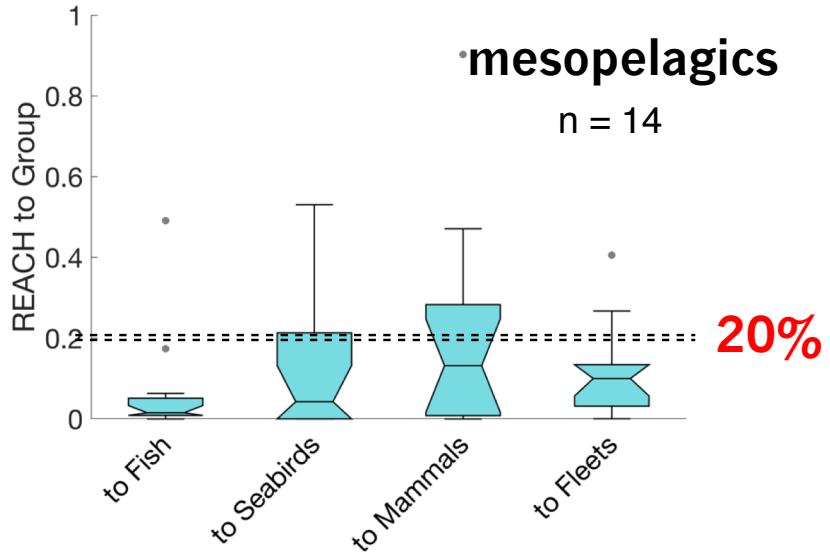
REACH: SPF production flow through all trophic paths relative to total consumer production in ecosystem

To whom are SPF most important, and in which ecosystem types?

Small pelagic fish REACH to other groups (fractional contribution to a group's production)

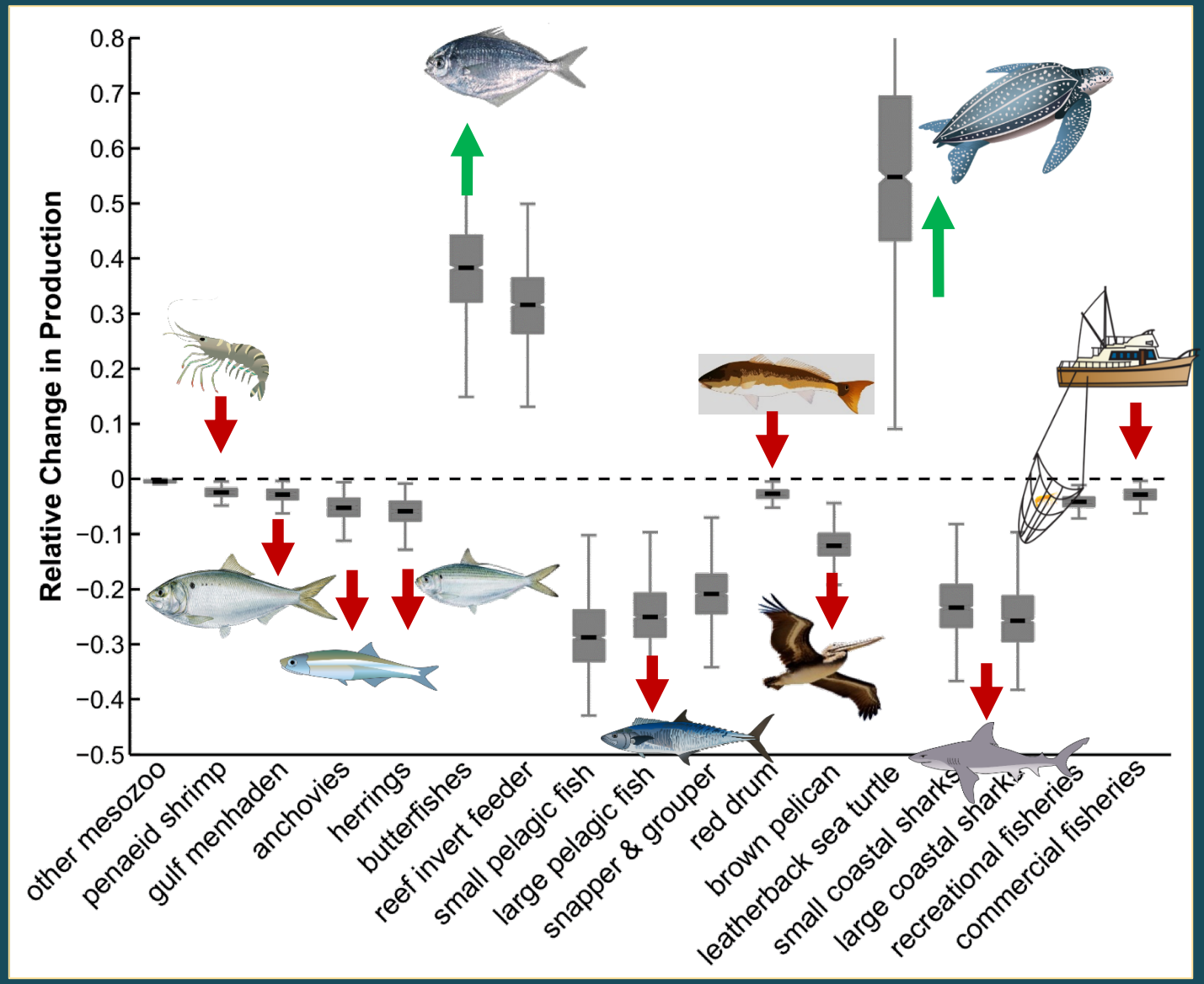


- SPF stand out as important in upwelling & estuary systems
- In upwelling, SPF support on average 10% of seabird & mammal production (30% of seabird & 40% of mammal production in top quartile)
- In estuaries, SPF support on average 40% of seabird & 30% of mammal production
- In open ocean, support 10% of seabird & 5% of mammal production.
  (see mesopelagics comparison → similar to SPF, but less to fleets)

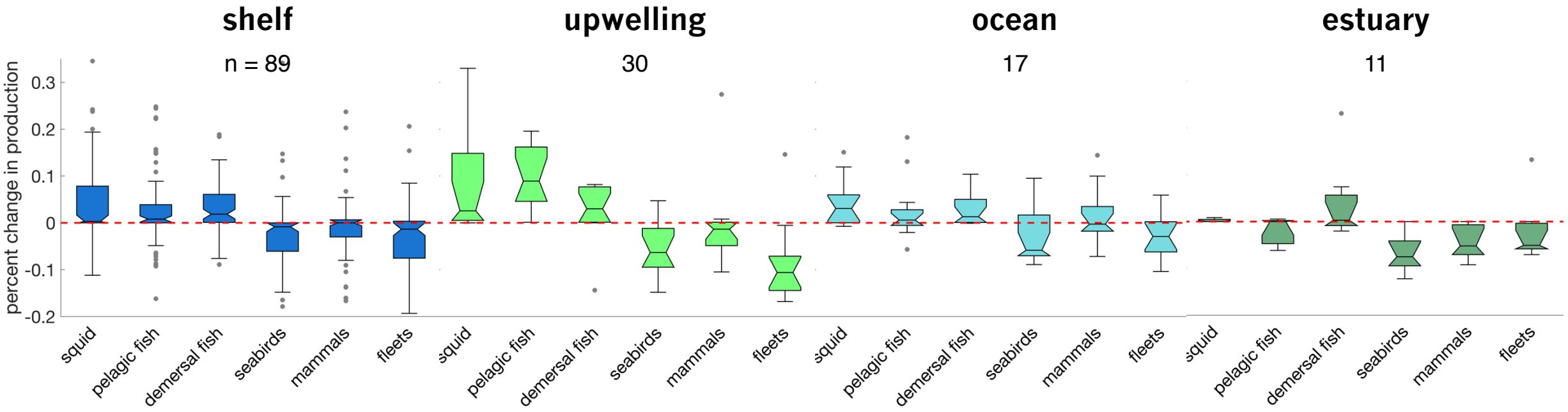


1. Get models
2. Confirm mass balance
3. Standardize group classifications
4. Collect EwE parameters & rates
5. Convert format to donor-driven
6. Derive footprint & reach metrics
7. Sensitivity analysis 20% reduction in SPF

Structural scenario: net effect of food web structural change



Relative change in production (20% decrease in small pelagic fish)



What effect does a 20% reduction in SPF have on different ecosystems?

- Harm to seabirds, mammals & fleets in all system types
- Harm to non-SPF pelagic fish in estuary systems
- Benefit to squid & demersal fish in all system types
- Biggest effect in upwelling systems

*Note: scenario assumes no change in predation pressure. It looks at reallocation of resources

Conclusions:

- **SPF productivity comparable in scale to all non-SPF pelagic fish, pooled**
  - Mesopelagics are more productive than SPF in open ocean systems
  - Demersal fish are larger slightly more productive than SPF in shelf systems

- **SPF are especially large contributors to landings in upwelling & shelf systems**
  - SPF contribute 20% of total landings on average (up to 40% for top quartile model)
  - In upwelling systems, anchovy are especially important (range is 0%-60% of total landings), and sardine account for 10%-30% of total landings
  - Demersal fish tend to be more important to fisheries than SPF in shelf ecosystems

- **SPF place biggest demand (footprint) on resources and are greater contributor to ecosystem production (reach) in upwelling & estuary systems**
  - In upwelling, SPF support on average 10% of seabird & mammal production (30% of seabird & 40% of mammal production in top quartile)
  - In estuaries, SPF support on average 40% of seabird & 30% of mammal production

- **Reduction in SPF causes harm to seabirds, mammals, & fleets in all system types**
  - Benefit to squid & demersal fish in all system types

Next steps:

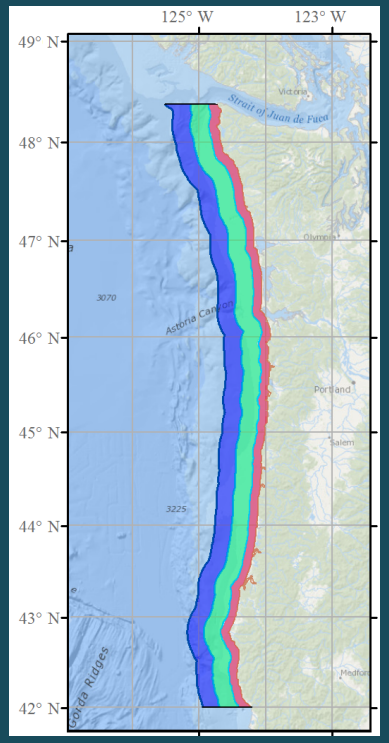
- Quality control
  - recover 49 Ecobase models that had processing error and not included here
  - proof functional group definitions. Add pooled SPF functional groups (“small pelagics”)

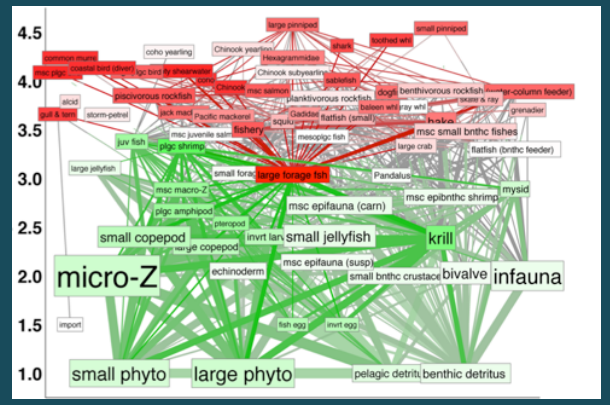
- Include more non-Ecobase models (which are most important?)

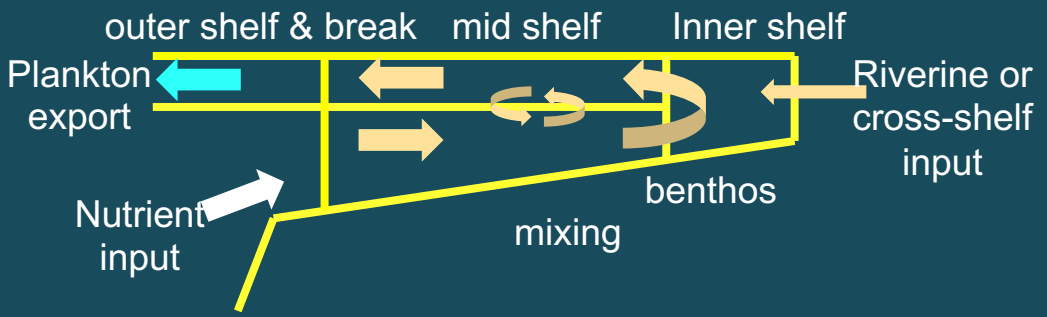
- Dynamic sensitivity tests in native physical settings for select models →

Next step: Dynamic sensitivity tests in native setting for select models

NCC-ECOTRAN







Sardine skill-assessment

Dylan Gomes (Oregon State University)