

# Comisión Interamericana del Atún Tropical Inter-American Tropical Tuna Commission



**Using an updated ecosystem model of the eastern tropical Pacific Ocean to explore potential impacts of increased fishing effort on floating objects**

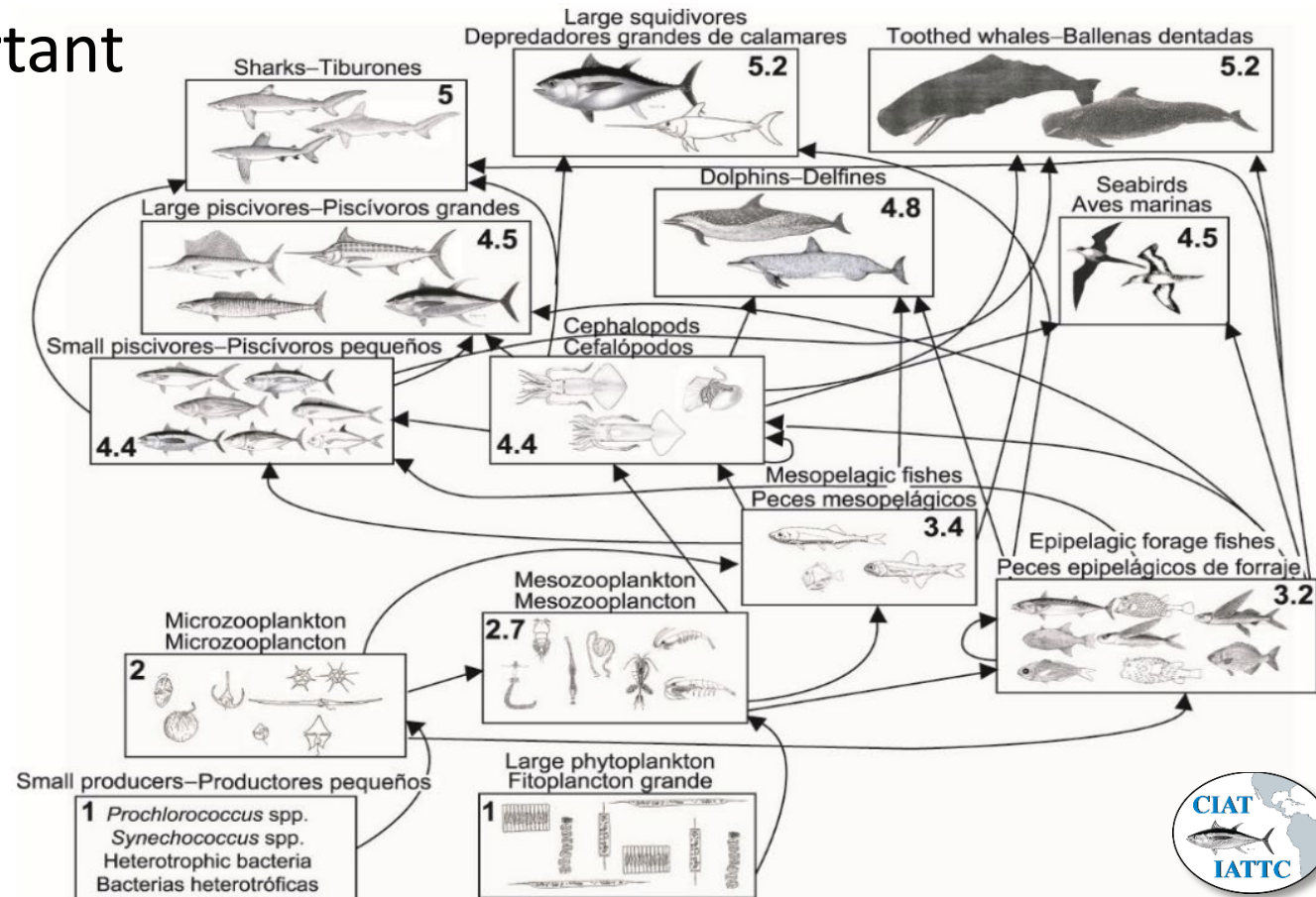
Shane Griffiths, Leanne Fuller, Juan Valero, Carolina Minte-Vera, Haikun Xu & Cleridy Lennert-Cody

# Ecological sustainability

- IATTC mandated to ensure ecological sustainability of EPO tuna fisheries
  - Antigua Convention, IATTC Resolutions, and improved reporting ([SAC-10-14](#), [SAC-10 INF-B](#))
  - Development of the “EASI-Fish” ERA model for data-poor species ([SAC-09-12](#), [BYC-09-01](#))
- Single species assessments important

# Ecological sustainability

- IATTC mandated to ensure ecological sustainability of EPO tuna fisheries
  - Antigua Convention, IATTC Resolutions, and improved reporting ([SAC-10-14](#), [SAC-10 INF-B](#))
  - Development of the “EASI-Fish” ERA model for data-poor species ([SAC-09-12](#), [BYC-09-01](#))
- Single species assessments important
- But how does tuna fishing affect ecosystem dynamics?
- Diet analysis in 1990s and 2000s
- ETP ecosystem model (“ETP7”)



# ETP7 ecosystem model

- ETP7 used early software (v5.1) from 2003 and not used for reporting
- EwE (v6.6) improved with many ecological indicators
- In 2017, staff updated the ETP7 model with new data 1970-2014
- Since 2017, staff update ETP7 annually with catch and effort data and report on indicators in “*Ecosystem Considerations*” report (**SAC-12-12**)
- 2021 update (ETP-21) was required to:
  - Improve model structure to link ontogenetic stages (*e.g.*, small and large YFT)
  - Update biological parameters with new information since 2003
  - Rebalance the model after including revised longline catch estimates (**SAC-12-12**)
  - Calibrate the model to new time series data available for target and bycatch species



# ETP7 ecosystem model

- Why not develop a new EPO model?

# ETP7 ecosystem model

- Why not develop a new EPO model? A very long process

## Parameterization (Ecopath)

Group name	Sub-area (groupings)	Biomass in sub-area (tonnes)	Total mortality (year)	Production / harvest (tonnes/year)	Consumption (tonnes/year)	Ecotrophic Efficiency	Other mortality	Production / consumption	Uneaten consumption
1	Pomul-Bels	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
2	Onway-Bels	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
3	Baken-Vhals	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
4	Tuylent-Vhals	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
5	Spartel-Dolphin	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
6	Moss-Dolphin	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
7	Sea Turtle	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
8	Sea Yellows	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
9	EE	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
10	Sea Eel	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
11	Sea Herring	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
12	Sea Mackerel	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
13	Sea Salmon	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
14	Sea Trout	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
15	Sea Cod	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
16	Sea Haddock	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
17	Sea Sculpin	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
18	Sea Goby	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
19	Sea Sole	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
20	Sea Hake	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
21	Sea Nototheniid	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
22	Sea Rockfish	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
23	Sea Skate	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
24	Sea Crab	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
25	Sea Shrimp	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
26	Sea Lobster	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
27	Sea Star	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
28	Sea Jellyfish	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
29	Misc. Plac.	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
30	King Fish	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
31	Misc. Fish	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
32	Misc. Shellfish	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
33	Crustaceans	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
34	Cnidaria	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
35	Mollusks	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
36	Microzooplankton	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
37	La Phaeocystis	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
38	Sea Products	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
39	Detritus	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000

# ETP7 ecosystem model

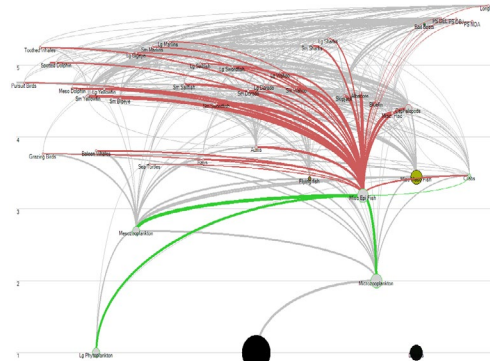
- Why not develop a new EPO model? A very long process

Parameterization  
(Ecopath)



Balancing  
(Ecopath)

Group name	Sub-area (group)	Biomass in sub-area (t)	Total mortality (year)	Production / harvest (t/year)	Consumption (t/year)	Ecotrophic Efficiency	Other mortality	Production / consumption	Uneaten consumption
1	Pompidi Bats	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
2	Greeny Bats	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
3	Brown N-hares	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
4	Turkey N-hares	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
5	Spotted Dolphins	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
6	Manx Dolphins	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
7	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
8	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
9	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
10	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
11	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
12	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
13	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
14	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
15	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
16	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
17	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
18	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
19	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
20	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
21	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
22	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
23	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
24	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
25	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
26	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
27	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
28	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
29	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
30	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
31	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
32	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
33	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
34	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
35	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
36	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
37	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
38	Sea Turtles	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000



# ETP7 ecosystem model

- Why not develop a new EPO model? A very long process

Parameterization  
(Ecopath)

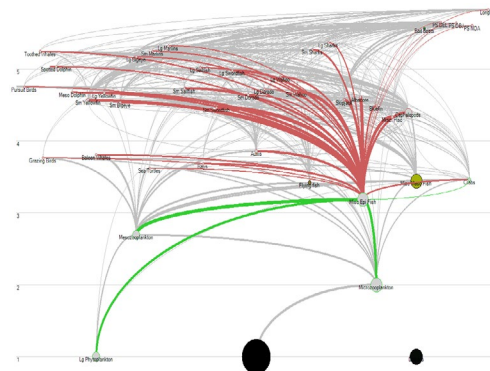


Balancing  
(Ecopath)

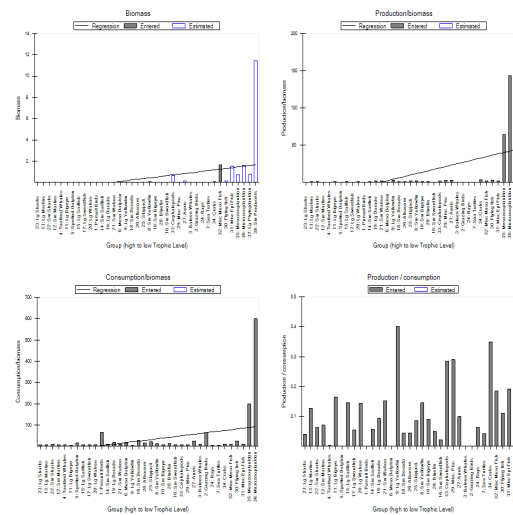


Diagnostics  
(Ecopath)

Group name	Hub area (group/area)	Biomass in hub area (tonnes)	Total mortality (year)	Production / harvest (tonnes/year)	Consumption (tonnes/year)	Ecotrophic Efficiency	Other mortality	Production / consumption	Uneaten consumption
1 Furcled Bats	1.000000	0.00000000	0.01700000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
2 Greyed Bats	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
3 Baked Fishes	1.000000	0.00000000	0.01700000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
4 Tulefish/Bass	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
5 Spotted Dolphin	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
6 New Dolphin	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
7 Sea Turtles	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
8 Sea Yellowfish	1.000000	0.04912641	1.700000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
9 Sea Yellowfish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
10 Sea Squire	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
11 Sea Squire	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
12 Sea Mackerel	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
13 Sea Mackerel	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
14 Sea Saffish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
15 Sea Saffish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
16 Sea Saffish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
17 Sea Saffish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
18 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
19 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
20 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
21 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
22 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
23 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
24 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
25 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
26 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
27 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
28 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
29 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
30 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
31 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
32 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
33 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
34 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
35 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
36 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
37 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000
38 Sea Devils	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.000000	0.000000	0.000000	0.000000



Pre-balance diagnostics





# ETP7 ecosystem model

- Why not develop a new EPO model? A very long process

Parameterization  
(Ecopath)



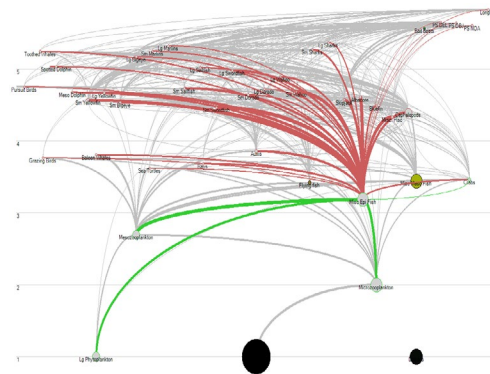
Balancing  
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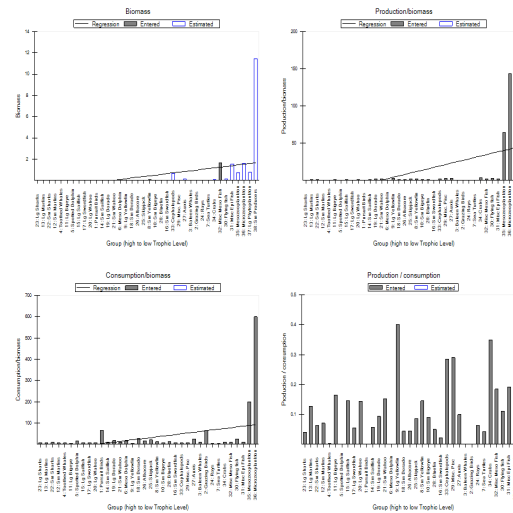
Diagnostics  
(Ecopath)



Group name	Sub-area (group)	Biomass in sub-area (t/ha)	Total mortality (year)	Production / harvest (t/ha/yr)	Consumption (t/ha/yr)	Ecotrophic Efficiency	Other mortality	Production / consumption	Uneaten consumption
1	Pompidi Bait	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	Greeny Bait	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	Bakeri Fishes	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	Tropical Fishes	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	Opened Dolphin	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	Manx Dolphin	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	Sea Turtle	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	Sea Yellowfish	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	EEF	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	Sea Eagle	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
11	Sea Mackerel	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
12	Sea Mullet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
13	Sea Trout	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14	Sea Salmon	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15	Sea Bass	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
16	Sea Scorpionfish	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
17	Sea Herring	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
18	Sea Octopus	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
19	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
20	Sea Shark	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
21	Sea Lion	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
22	Sea Elephant	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
23	Sea Seal	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
24	Sea Otter	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25	Sea Bear	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
26	Sea Pig	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
27	Sea Cow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
28	Sea Horse	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
29	Sea Piglet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
30	Sea Piglet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
31	Sea Piglet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
32	Sea Piglet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
33	Sea Piglet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
34	Sea Piglet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
35	Sea Piglet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
36	Sea Piglet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
37	Sea Piglet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
38	Sea Piglet	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000



Pre-balance diagnostics



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- Why not develop a new EPO model? A very long process

Parameterization  
(Ecopath)



Balancing  
(Ecopath)

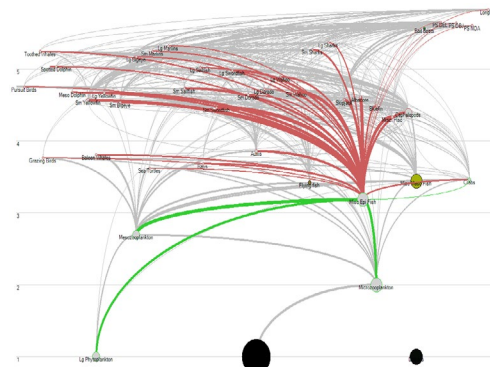


Diagnostics  
(Ecopath)

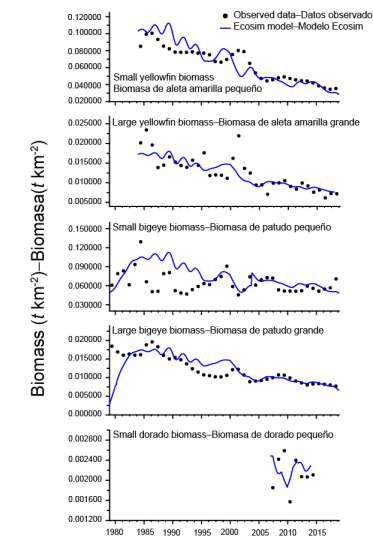
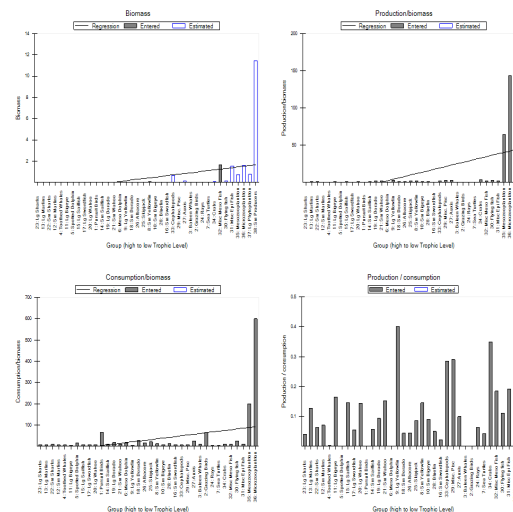


Calibration  
(Ecosim)

Group name	Sub-area (group)	Biomass in sub-area (t)	Total mortality (year)	Production/biomass (year)	Consumption/biomass (year)	Ecotrophic Efficiency	Other mortality	Production/consumption	Uneaten consumption
1	Pinnac Bats	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	Grayed Bats	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3	Brown Nighth	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4	Yulebird Nighth	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5	Spotted Dolphin	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6	Mex Dolphin	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7	Sea Turtle	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	Sea Yellowfin	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9	EE	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
11	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
12	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
13	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
16	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
17	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
18	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
19	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
20	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
21	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
22	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
23	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
24	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
26	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
27	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
28	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
29	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
30	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
31	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
32	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
33	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
34	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
35	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
36	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
37	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
38	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
39	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
40	Sea Sparrow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000



Pre-balance diagnostics



# ETP7 ecosystem model

- Why not develop a new EPO model? A very long process

Parameterization  
(Ecopath)



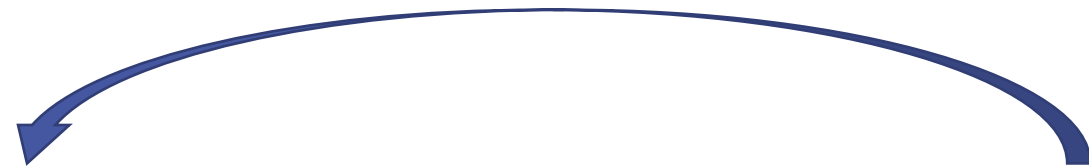
Balancing  
(Ecopath)



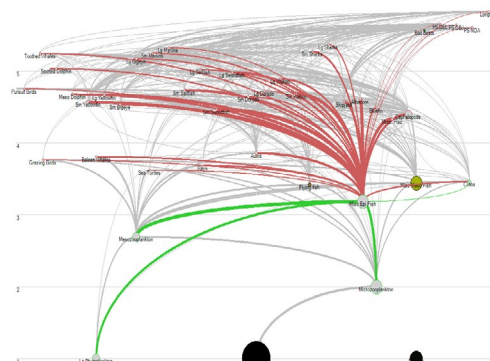
Diagnostics  
(Ecopath)



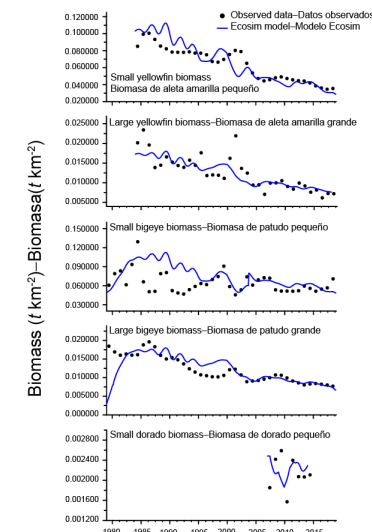
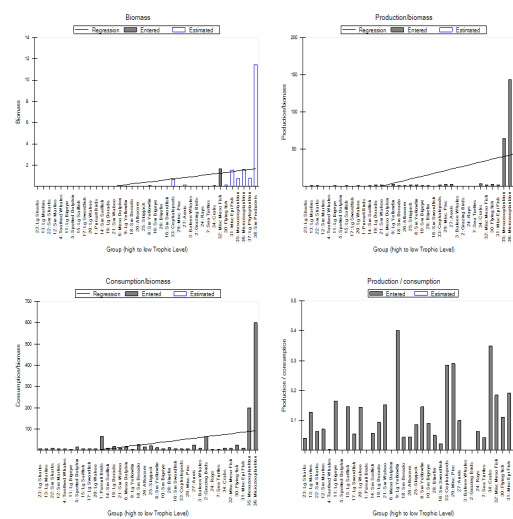
Calibration  
(Ecosim)



Group name	Hub area (km <sup>2</sup> )	Biomass in hub area (tonnes)	Total mortality (year)	Production/biomass (year)	Consumption/biomass (year)	Ecotrophic Efficiency	Other mortality	Production/consumption	Linearized consumption
1 Purcell Shark	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2 Grey Nurse Shark	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3 Basking Shark	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4 Tiger Shark	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5 Spotted Dolphin	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6 New Dolphin	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7 Sea Turtle	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8 Sn Yellowfin	1.000000	0.04919461	1.700000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9 La Yellowfin	1.000000	0.00000000	2.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10 Sn Squire	1.000000	0.00000000	0.700000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
11 La Squire	1.000000	0.00000000	0.700000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
12 Sn Marlin	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
13 La Marlin	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14 Sn Sailfin	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15 La Sailfin	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
16 Sn Snoutfish	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
17 La Snoutfish	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
18 Sn Dorado	1.000000	0.00000000	1.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
19 La Dorado	1.000000	0.00000000	1.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
20 La Yellow	1.000000	0.00000000	1.200000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
21 Sn Shark	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
22 La Shark	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
23 Sn Shark	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
24 La Shark	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25 Pir	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
26 Albacore	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
27 Skipjack	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
28 Aun	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
29 Mac Pac	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
30 Kingfish	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
31 Mac Sp Fish	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
32 Mac New Fish	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
33 Cephalopoda	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
34 Crab	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
35 Mesozooplankton	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
36 Microzooplankton	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
37 La Phaeoplankton	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
38 Sn Predator	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
39 Detritus	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000



Pre-balance diagnostics



# ETP7 ecosystem model

- Why not develop a new EPO model? A very long process

Parameterization  
(Ecopath)



Balancing  
(Ecopath)



Diagnostics  
(Ecopath)

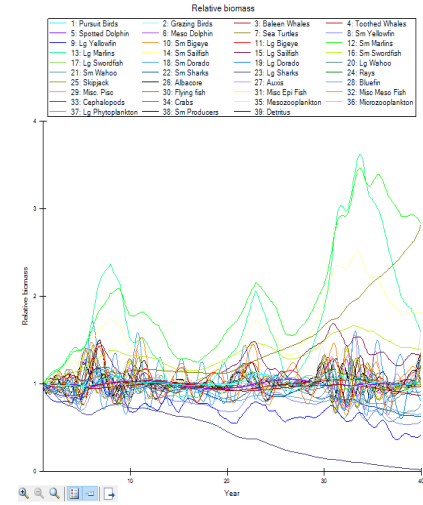
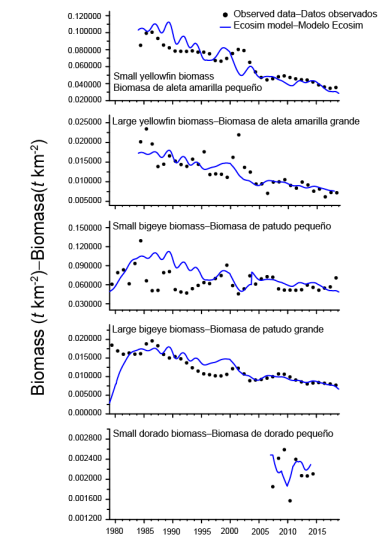
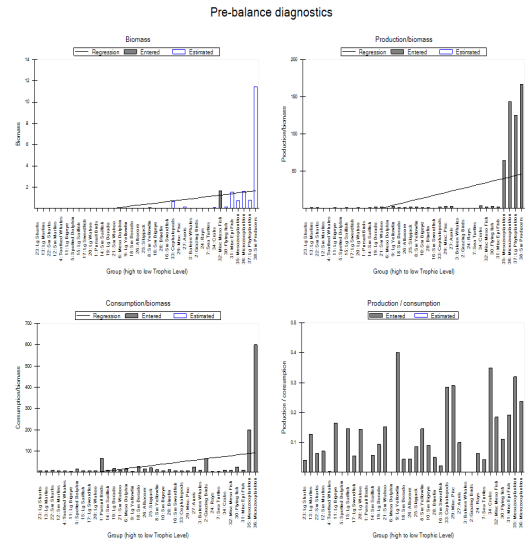
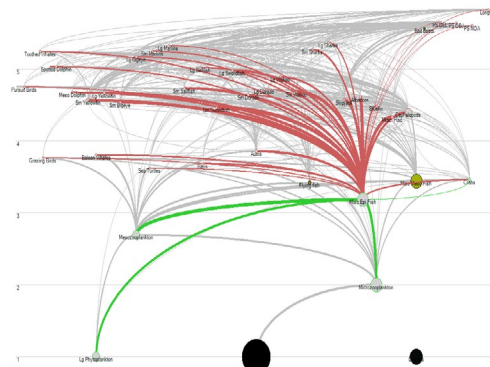


Calibration  
(Ecosim)



Simulation  
(Ecosim)

Group name	Hub area (km²)	Biomass in hub area (t)	Total mortality (year)	Production/biomass (year)	Consumption/biomass (year)	Ecotrophic Efficiency	Other mortality	Production/consumption	Unsims consumption
1 Pinnac Bats	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2 Grayish Bats	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
3 Baken Whales	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
4 Tusked Whales	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5 Spotted Dolphins	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
6 New Dolphins	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
7 Sea Turtles	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8 Sm Yellowfin	1.000000	0.04919461	1.780000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
9 Lg Yellowfin	1.000000	0.02002189	2.349999	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
10 Sm Spigone	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
11 Lg Spigone	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
12 Sm Marlins	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
13 Lg Marlins	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14 Sm Sailfin	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15 Lg Sailfin	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
16 Sm Scaevfin	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
17 Lg Scaevfin	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
18 Sm Dorado	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
19 Lg Dorado	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
20 Sm Sharks	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
21 Lg Sharks	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
22 Sm Rays	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
23 Lg Rays	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
24 Sm Manta	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25 Lg Manta	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
26 Sm Squid	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
27 Lg Squid	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
28 Sm Fish	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
29 Lg Fish	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
30 Sm MFC	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
31 Lg MFC	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
32 Sm MFC	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
33 Lg MFC	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
34 Crabs	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
35 Cephalopods	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
36 Macrozooplankton	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
37 Lg Phytoplankton	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
38 Sm Producers	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
39 Detritus	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000



# Revising ETP7 model structure

ETP7

	Group name
1	Pursuit Birds
2	Grazing Birds
3	Baleen Whales
4	Toothed Whales
5	Spotted Dolphin
6	Meso Dolphin
7	Sea Turtles
8	Sm Yellowfin
9	Lg Yellowfin
10	Sm Bigeye
11	Lg Bigeye
12	Sm Marlins
13	Lg Marlins
14	Sm Sailfish
15	Lg Sailfish
16	Sm Swordfish
17	Lg Swordfish
18	Sm Dorado
19	Lg Dorado
20	Sm Wahoo
21	Lg Wahoo
22	Sm Sharks
23	Lg Sharks

- ETP7 contained ontogenetic stages to reflect known differences in diet and biology
  - But stages not linked - act as independent biomass pools

# Revising ETP7 model structure

ETP7	
	Group name
1	Pursuit Birds
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13	Lg Marlins
14	Sm Sailfish
15	Lg Sailfish
16	Sm Swordfish
17	Lg Swordfish
18	Sm Dorado
19	Lg Dorado
20	Sm Wahoo
21	Lg Wahoo
22	Sm Sharks
23	Lg Sharks

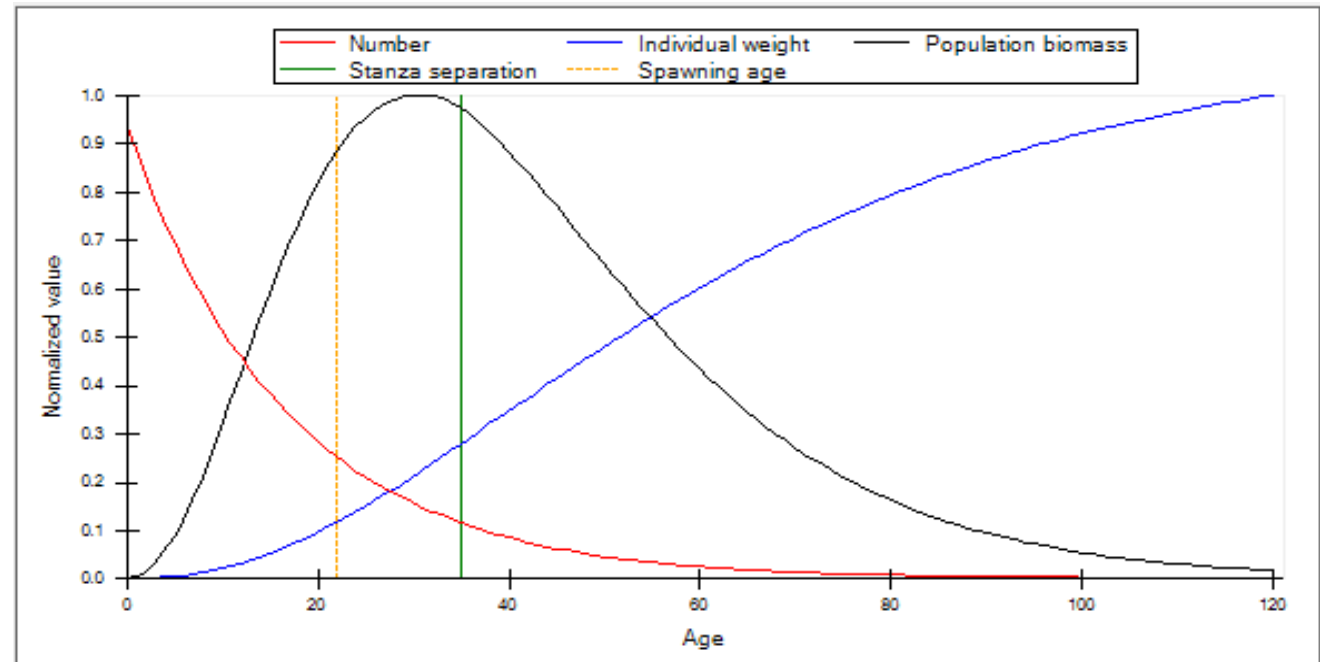
ETP-21	
	Group name
1	Pursuit Birds
2	Grazing Birds
3	Baleen Whales
4	Toothed Whales
5	Spotted Dolphin
6	Meso Dolphin
7	Sea Turtles
8	YELLOWFIN TUNA
9	Sm Yellowfin
10	Lg Yellowfin
11	BIGEYE TUNA
12	Sm Bigeye
13	Lg Bigeye
14	SAILFISH
15	Sm Sailfish
16	Lg Sailfish
17	SWORDFISH
18	Sm Swordfish
19	Lg Swordfish
20	DORADO
21	Sm Dorado
22	Lg Dorado
23	WAHOO
24	Sm Wahoo
25	Lg Wahoo
26	Sm Sharks
27	Lg Sharks

- ETP7 contained ontogenetic stages to reflect known differences in diet and biology
  - But stages not linked - act as independent biomass pools
- ETP-21 linked 12 groups (6 species) as multi-stanza delay-difference sub-models

# Revising ETP7 model structure

ETP7		ETP-21	
	Group name		Group name
1	Pursuit Birds	1	Pursuit Birds
2	Grazing Birds	2	Grazing Birds
3	Baleen Whales	3	Baleen Whales
4	Toothed Whales	4	Toothed Whales
5	Spotted Dolphin	5	Spotted Dolphin
6	Meso Dolphin	6	Meso Dolphin
7	Sea Turtles	7	Sea Turtles
8	Sm Yellowfin	8	Sm Yellowfin
9	Lg Yellowfin	9	Lg Yellowfin
10	Sm Bigeye	10	Sm Bigeye
11	Lg Bigeye	11	Lg Bigeye
12	Sm Marlins	12	Sm Marlins
13	Lg Marlins	13	Lg Marlins
14	Sm Sailfish	14	Sm Sailfish
15	Lg Sailfish	15	Lg Sailfish
16	Sm Swordfish	16	Sm Swordfish
17	Lg Swordfish	17	Lg Swordfish
18	Sm Dorado	18	Sm Dorado
19	Lg Dorado	19	Lg Dorado
20	Sm Wahoo	20	Sm Wahoo
21	Lg Wahoo	21	Lg Wahoo
22	Sm Sharks	22	Sm Sharks
23	Lg Sharks	23	Lg Sharks

- ETP7 contained ontogenetic stages to reflect known differences in diet and biology
  - But stages not linked - act as independent biomass pools
- ETP-21 linked 12 groups (6 species) as multi-stanza delay-difference sub-models

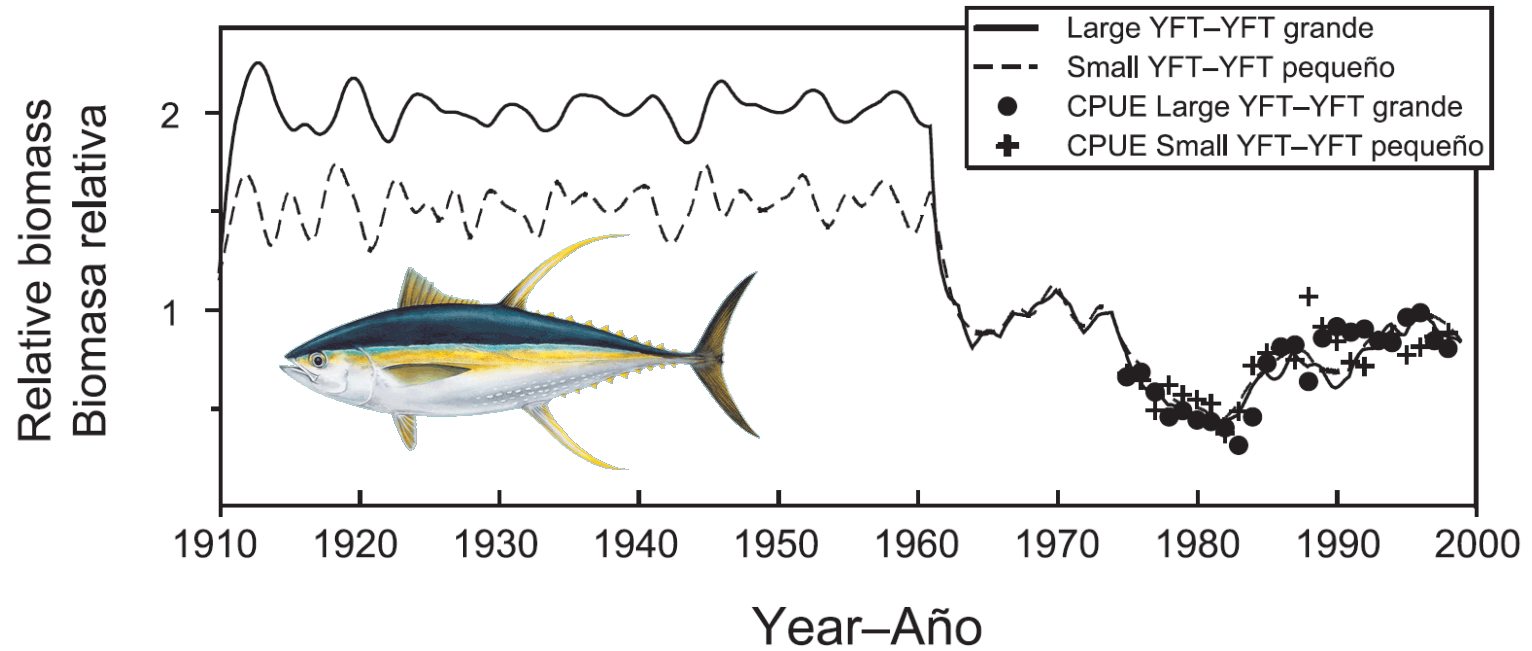


## Model Calibration to Time Series Data



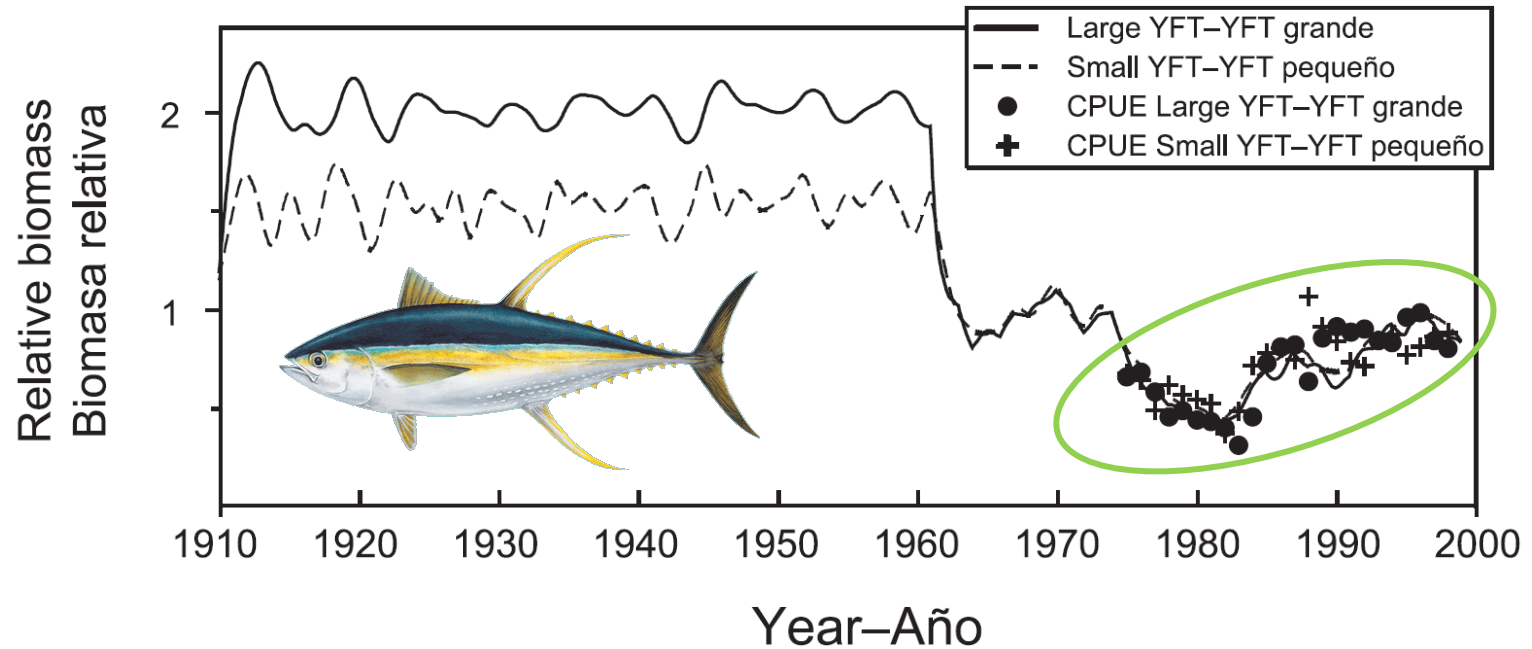
# Model Calibration

- ETP7 calibrated using time series 1975-1999 from stock assessments
  - Relative biomass
  - Total mortality ( $Z$ )
- Small & Large YFT
  - Excellent fit to CPUE data



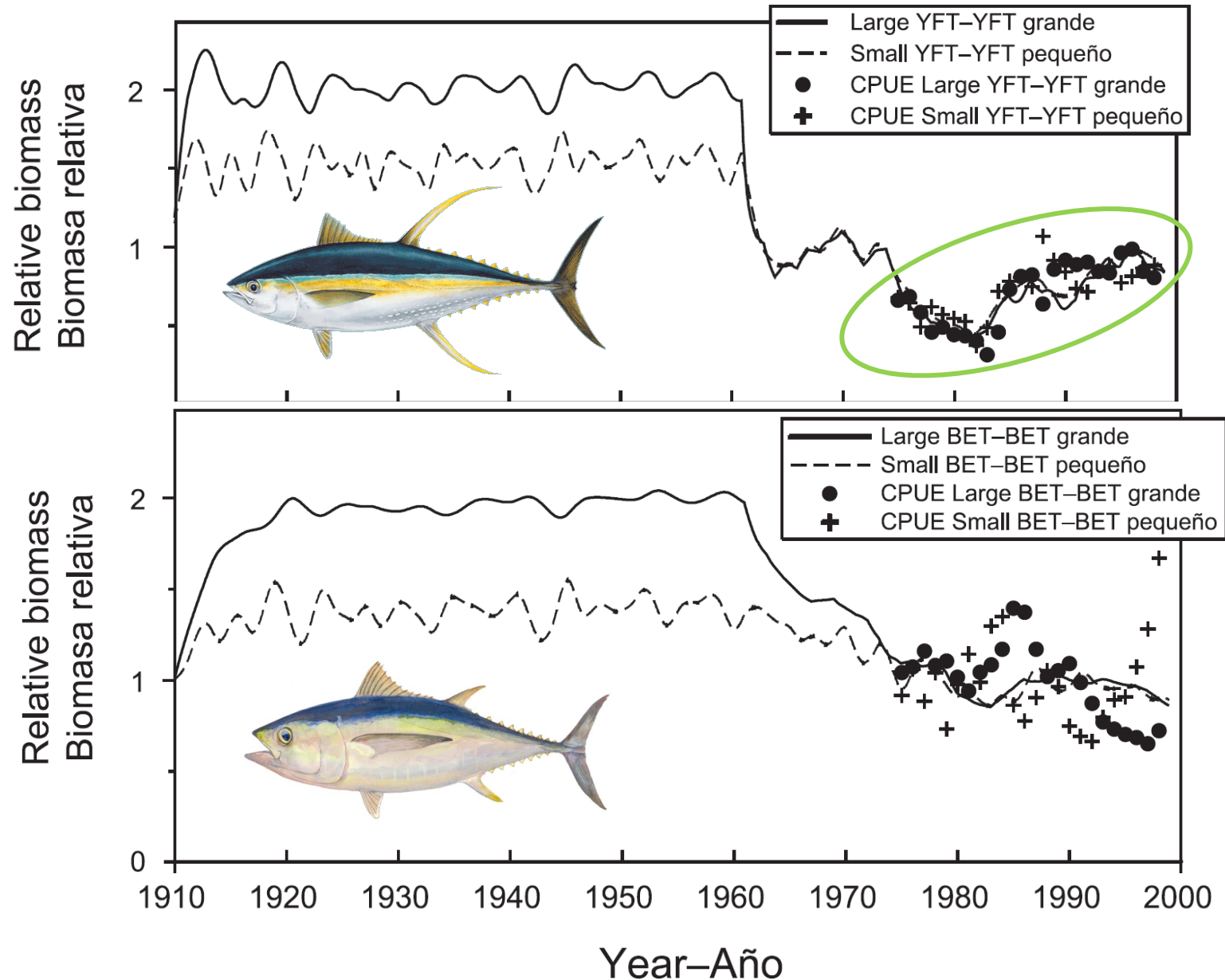
# Model Calibration

- ETP7 calibrated using time series 1975-1999 from stock assessments
  - Relative biomass
  - Total mortality ( $Z$ )
- Small & Large YFT
  - Excellent fit to CPUE data



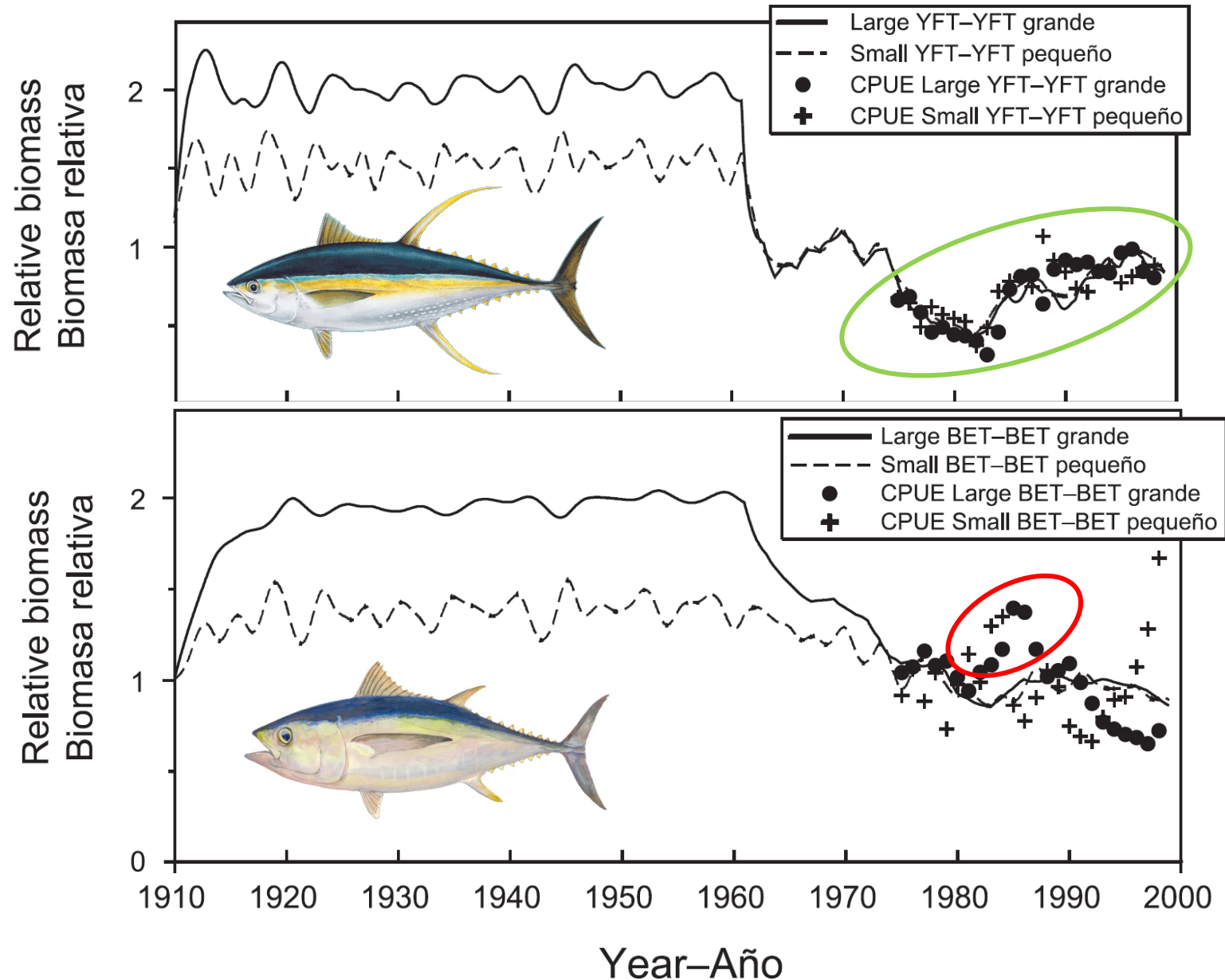
# Model Calibration

- ETP7 calibrated using time series 1975-1999 from stock assessments
  - Relative biomass
  - Total mortality ( $Z$ )
- Small & Large YFT
  - Excellent fit to CPUE data
- Small & Large BET
  - Poor fit to CPUE data
  - Small & large stanzas not linked?



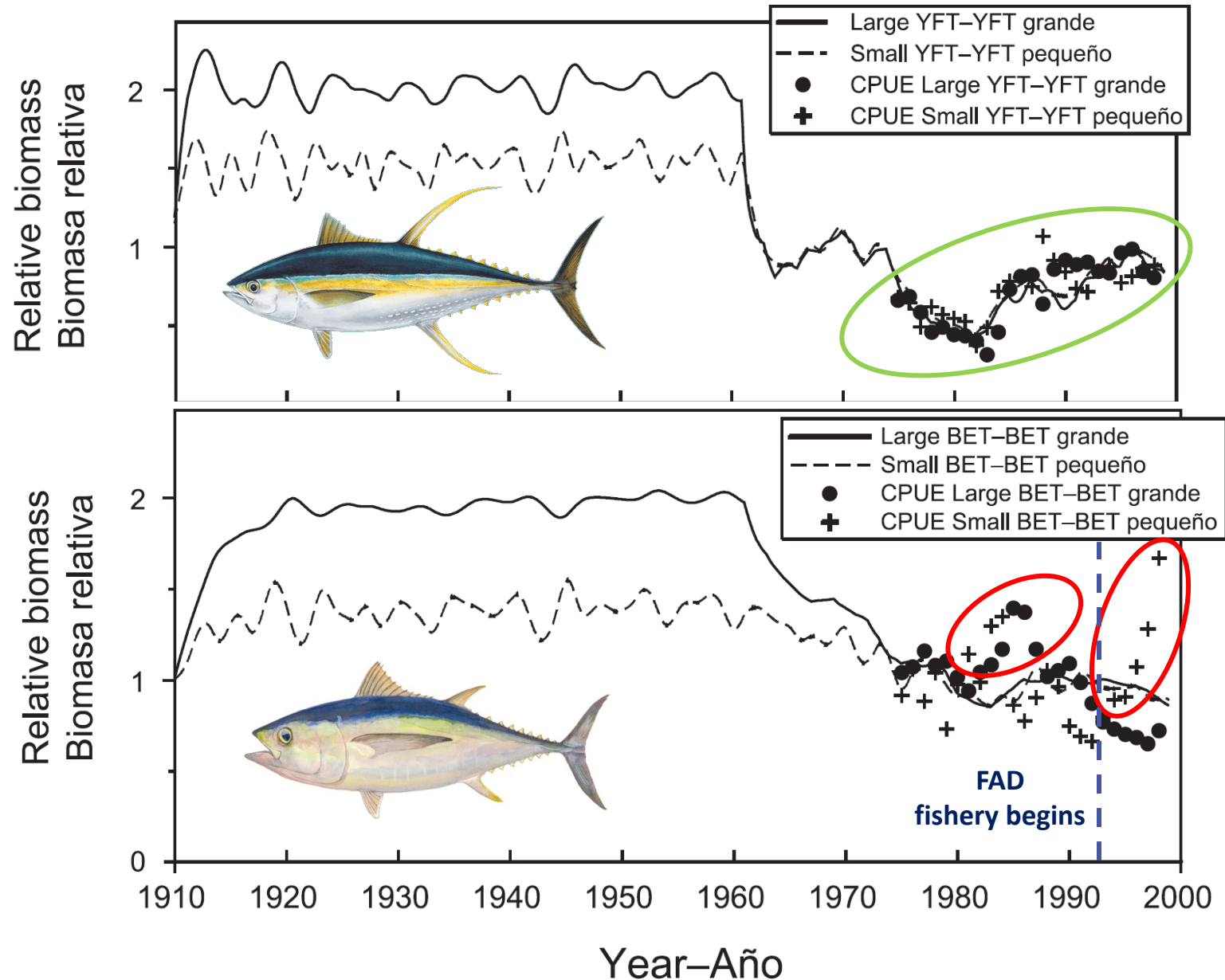
# Model Calibration

- ETP7 calibrated using time series 1975-1999 from stock assessments
  - Relative biomass
  - Total mortality ( $Z$ )
- Small & Large YFT
  - Excellent fit to CPUE data
- Small & Large BET
  - Poor fit to CPUE data
  - Small & large stanzas not linked?



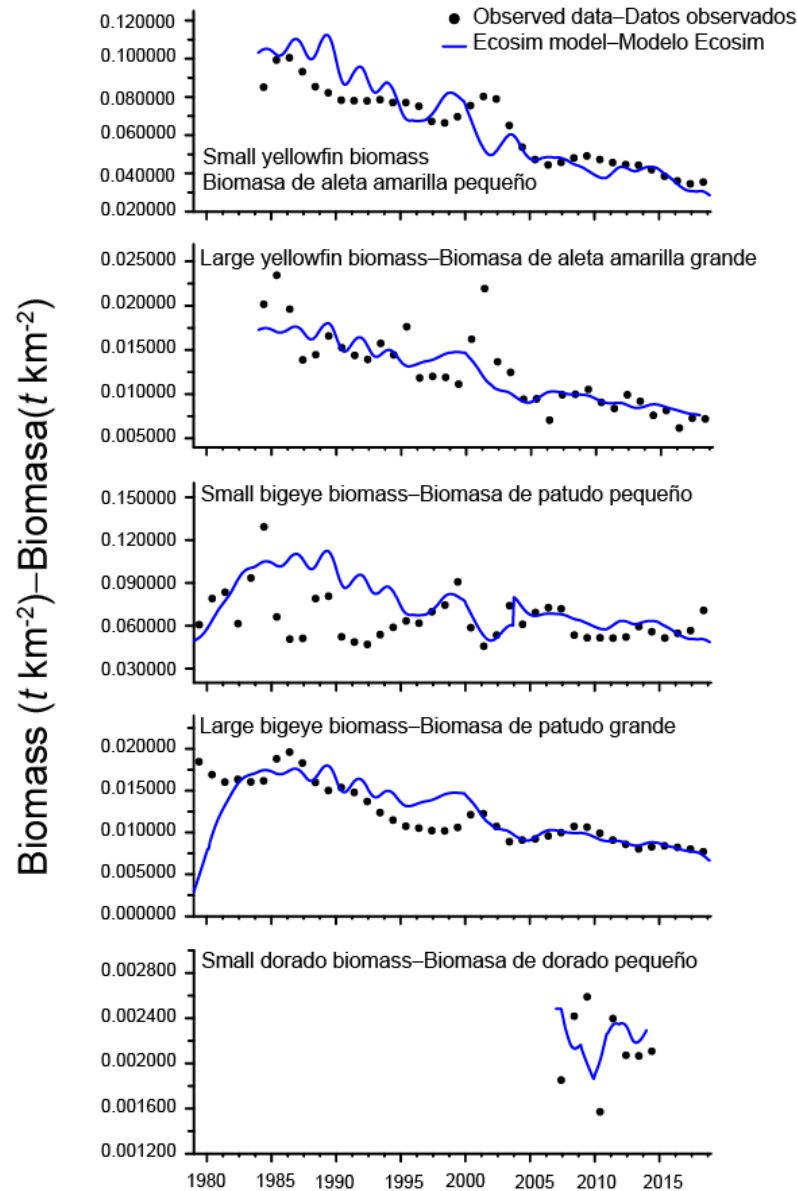
# Model Calibration

- ETP7 calibrated using time series 1975-1999 from stock assessments
  - Relative biomass
  - Total mortality ( $Z$ )
- Small & Large YFT
  - Excellent fit to CPUE data
- Small & Large BET
  - Poor fit to CPUE data
  - Small & large stanzas not linked?
  - Nominal OBJ CPUE  $\neq$  abundance?
- Poor predictive ability



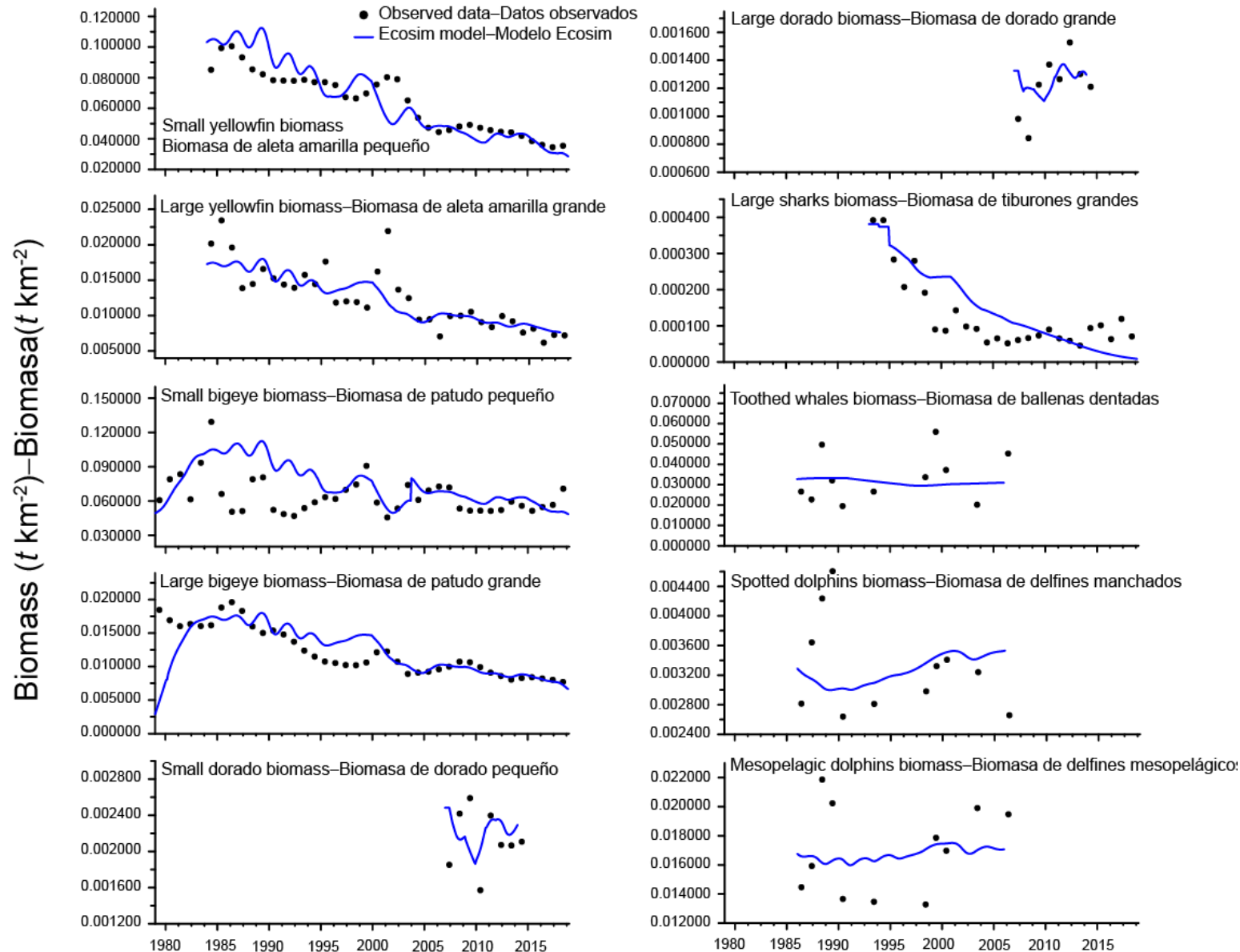
# Model Calibration

- Time series
  - Relative biomass
  - Fishing mortality ( $F$ )
  - Catch (retained + discarded)
- 25 functional groups
  - Small & large size classes
- Biomass and catch
  - Assessed species



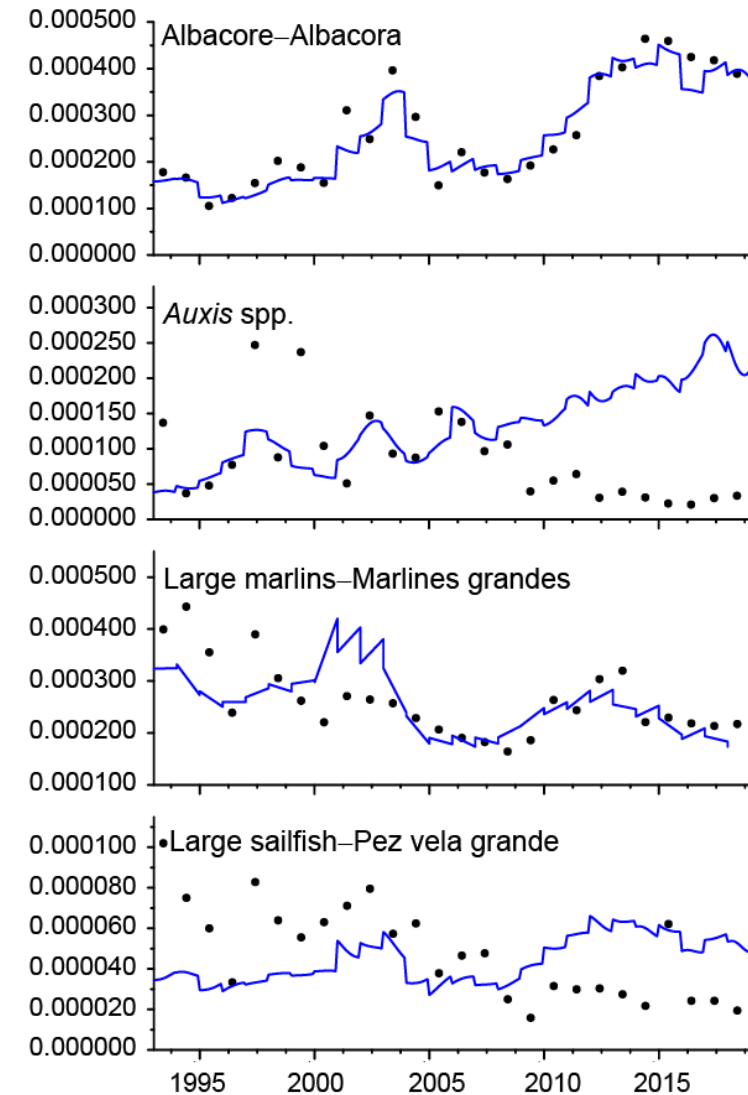
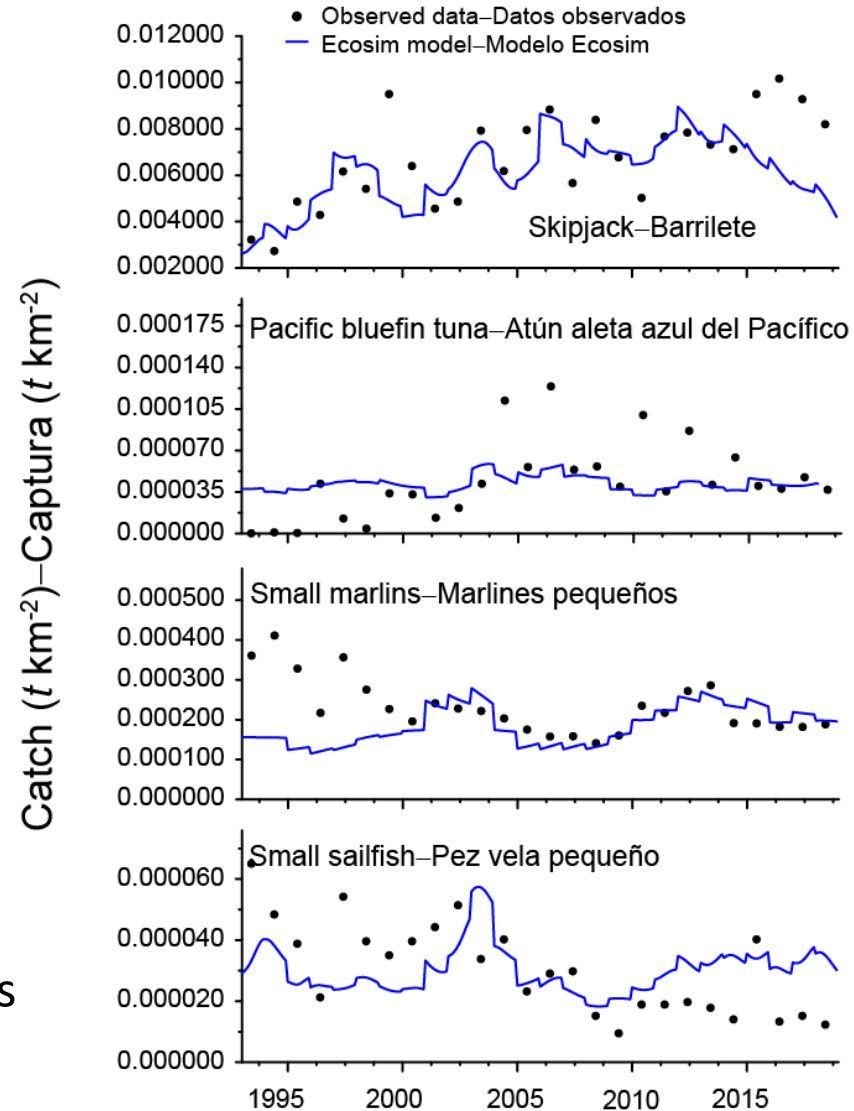
# Model Calibration

- Time series
  - Relative biomass
  - Fishing mortality ( $F$ )
  - Catch (retained + discarded)
- 25 functional groups
  - Small & large size classes
- Biomass and catch
  - Assessed species



# Model Calibration

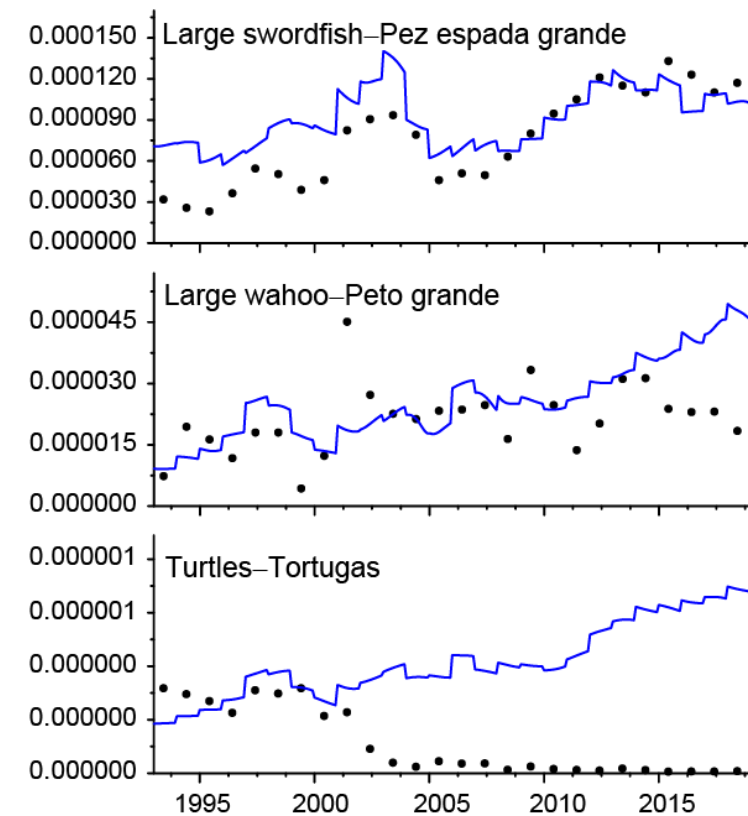
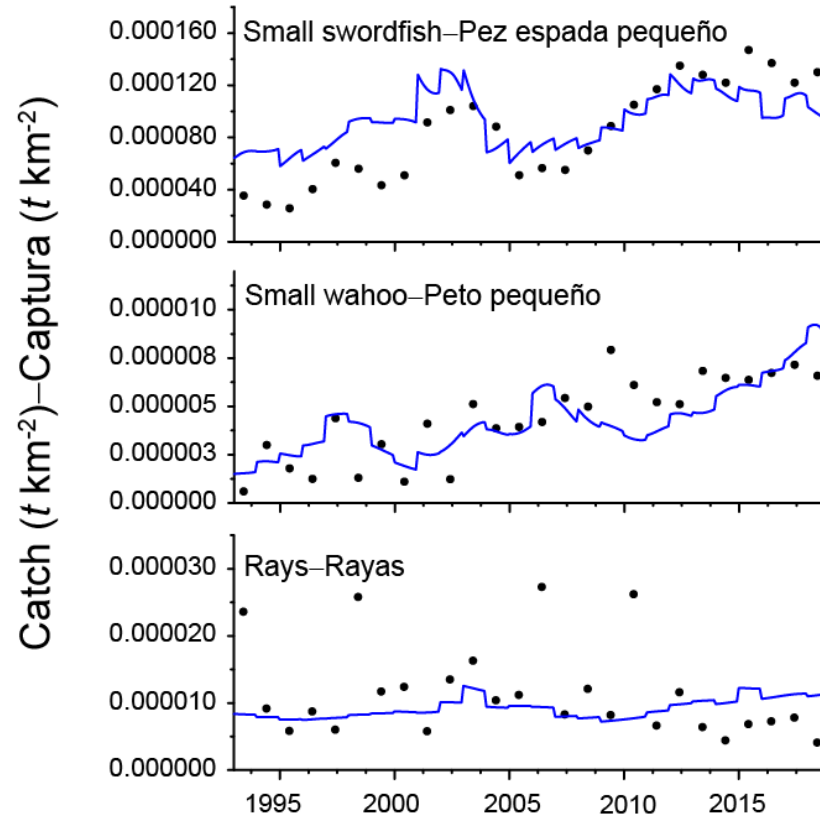
- Time series
  - Relative biomass
  - Fishing mortality ( $F$ )
  - Catch (retained + discarded)
- 25 functional groups
  - Small & large size classes
- Biomass and catch
  - Assessed species
- Catch only
  - Non-assessed & bycatch species





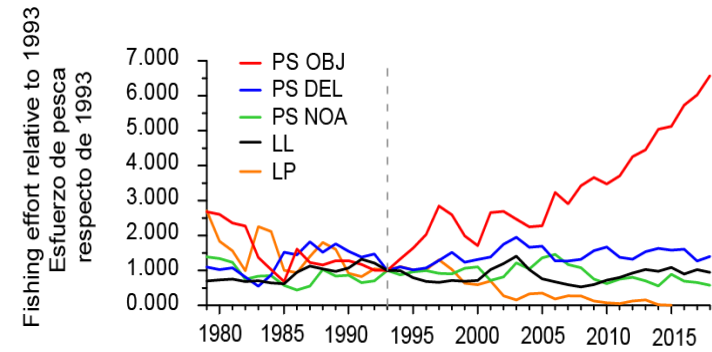
# Model Calibration

- Time series
  - Relative biomass
  - Fishing mortality ( $F$ )
  - Catch (retained + discarded)
- 25 functional groups
  - Small & large size classes
- Biomass and catch
  - Assessed species
- Catch only
  - Non-assessed & bycatch species



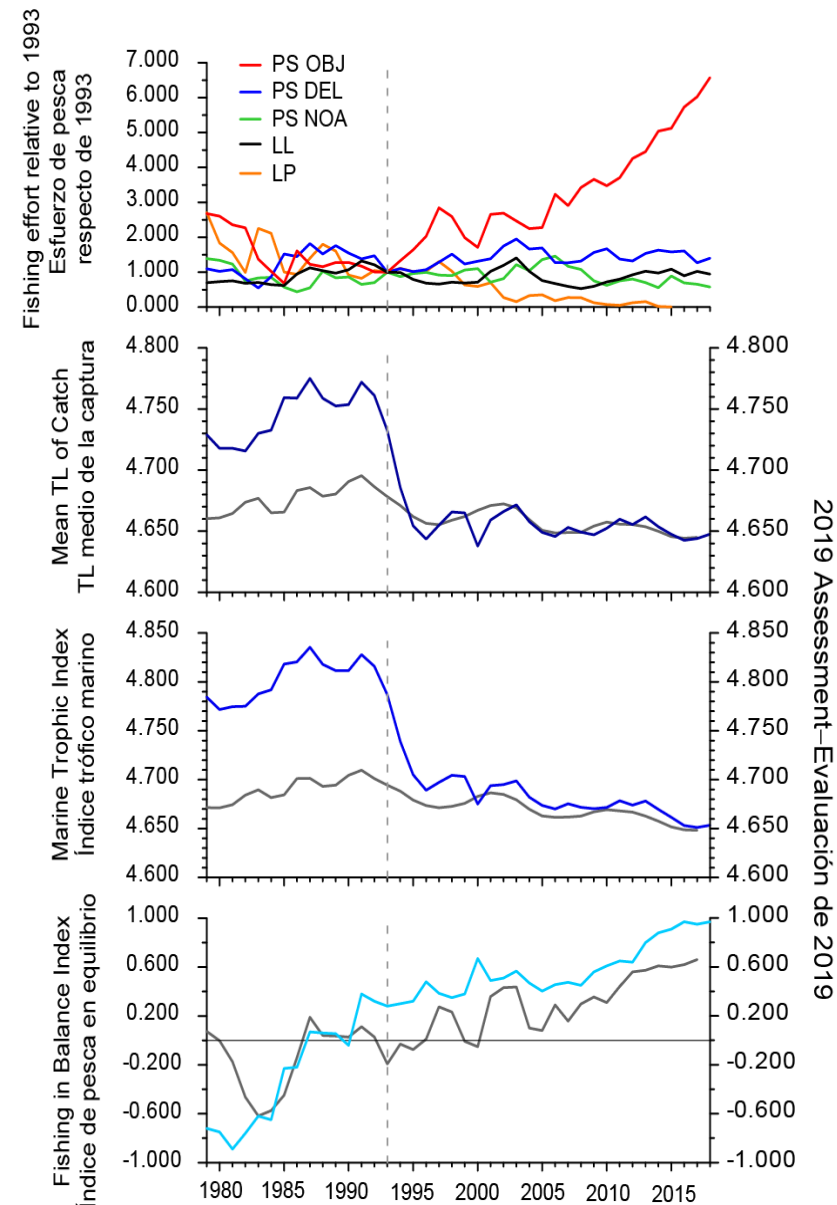
## Historical changes in the structure of the ETP ecosystem for the period 1979-2018

# Fishing-based indicators



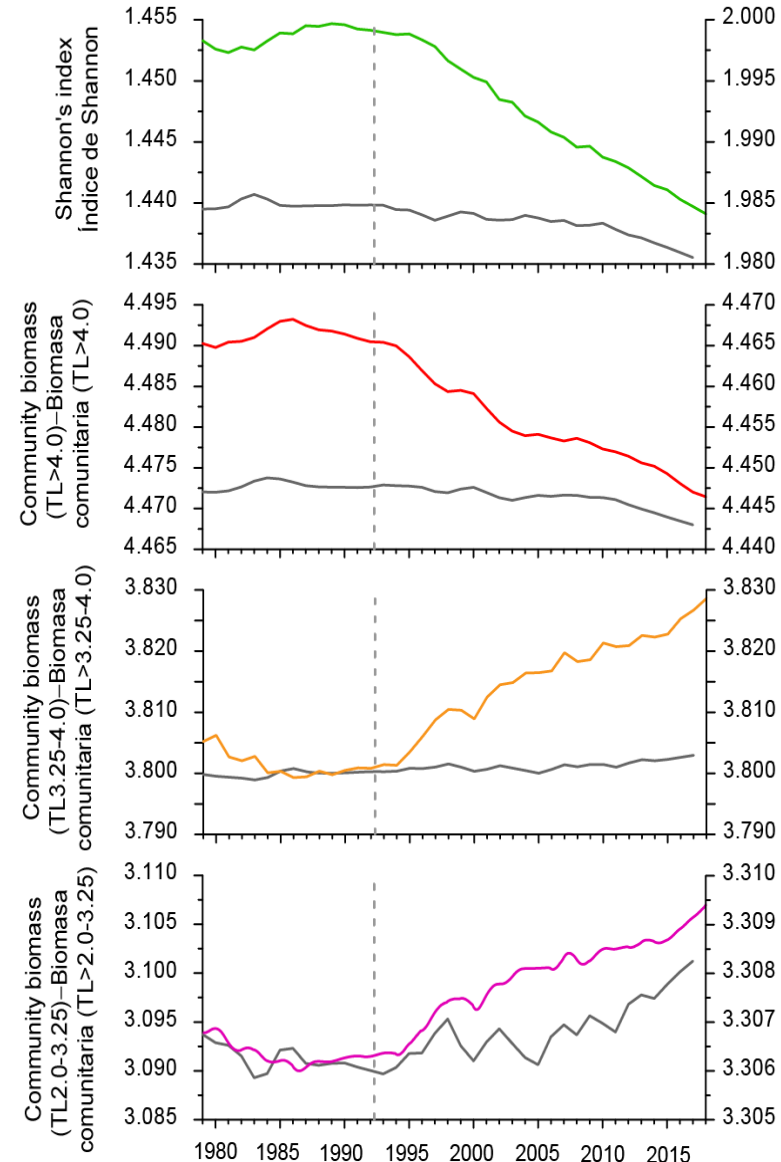
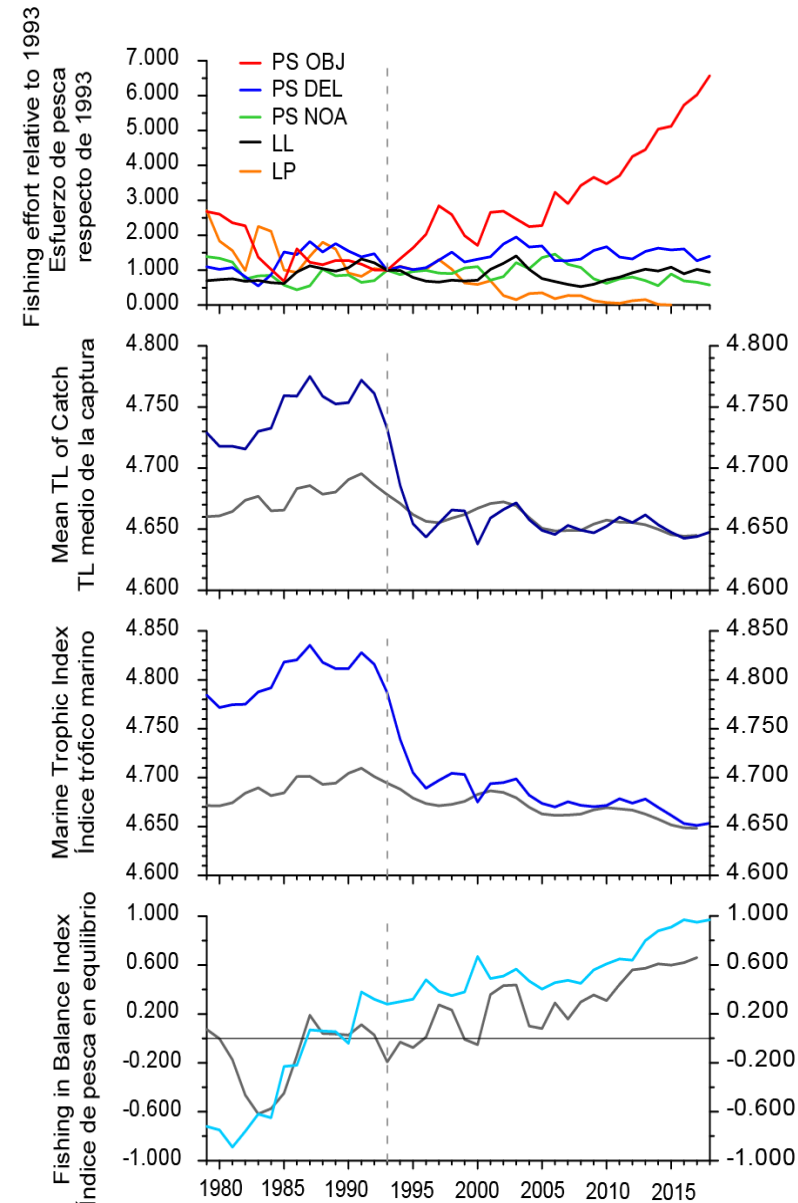
- Nominal fishing effort scaled from 1993
  - Coincidentally, start of the FAD fishery
  - ~7-fold increase in number of OBJ sets 1993-2018

# Fishing-based indicators



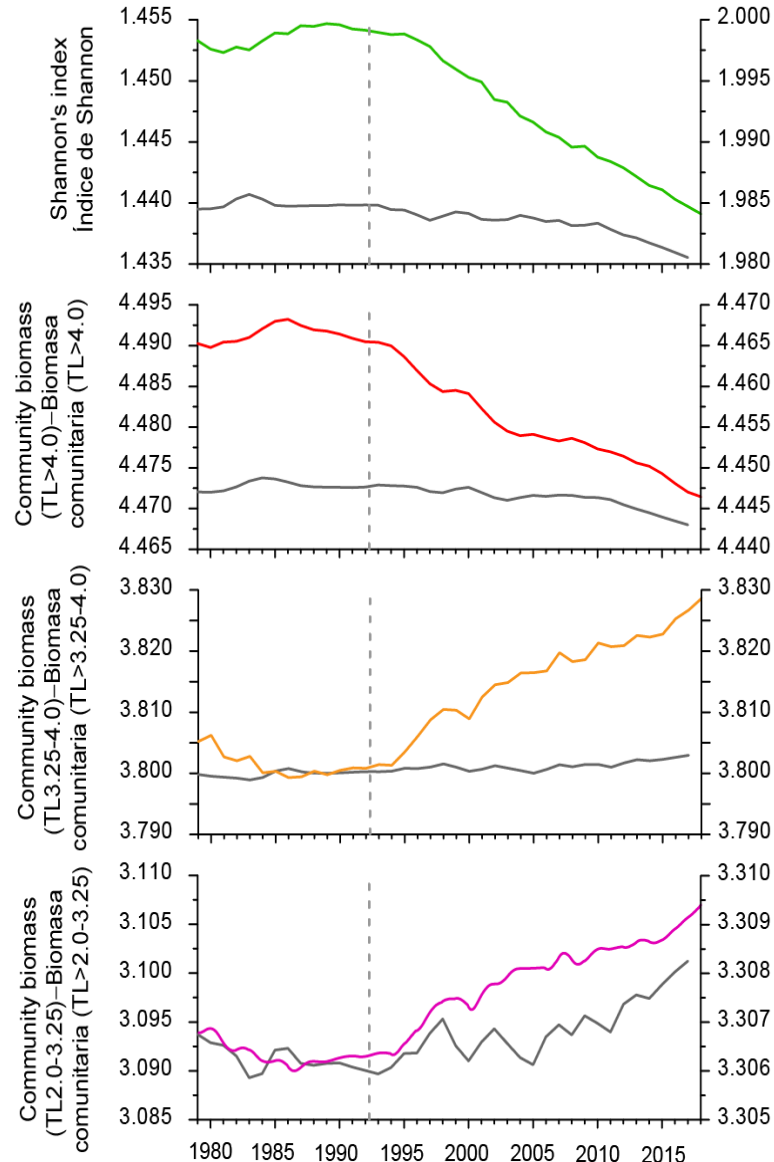
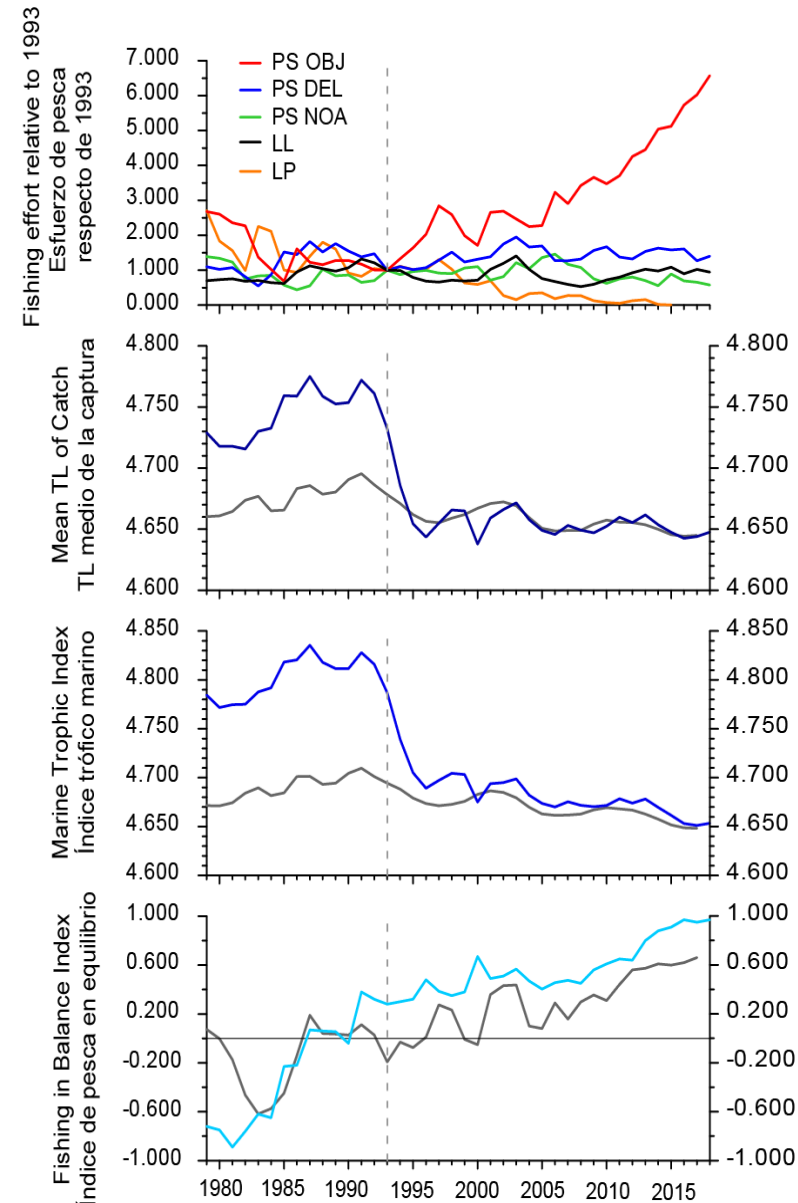
- Nominal fishing effort scaled from 1993
  - Coincidentally, start of the FAD fishery
  - ~7-fold increase in number of OBJ sets 1993-2018
- $TL_c$  and MTI declined by 0.05 for 1991-2018
  - Change in  $TL_c$  of  $\geq 0.1$  per decade is significant
- FIB  $>0$  since 1991
  - Indicates expansion of fishery, likely due to increasing catch of bycatch species

# Community-based indicators



- Declining “evenness”
  - Changing relative biomass
- Alternating biomass trends by TL
  - Decline of predators (>4.0)
  - Increase of prey (3.25-4.0)
- Minor trophic cascade

# Community-based indicators



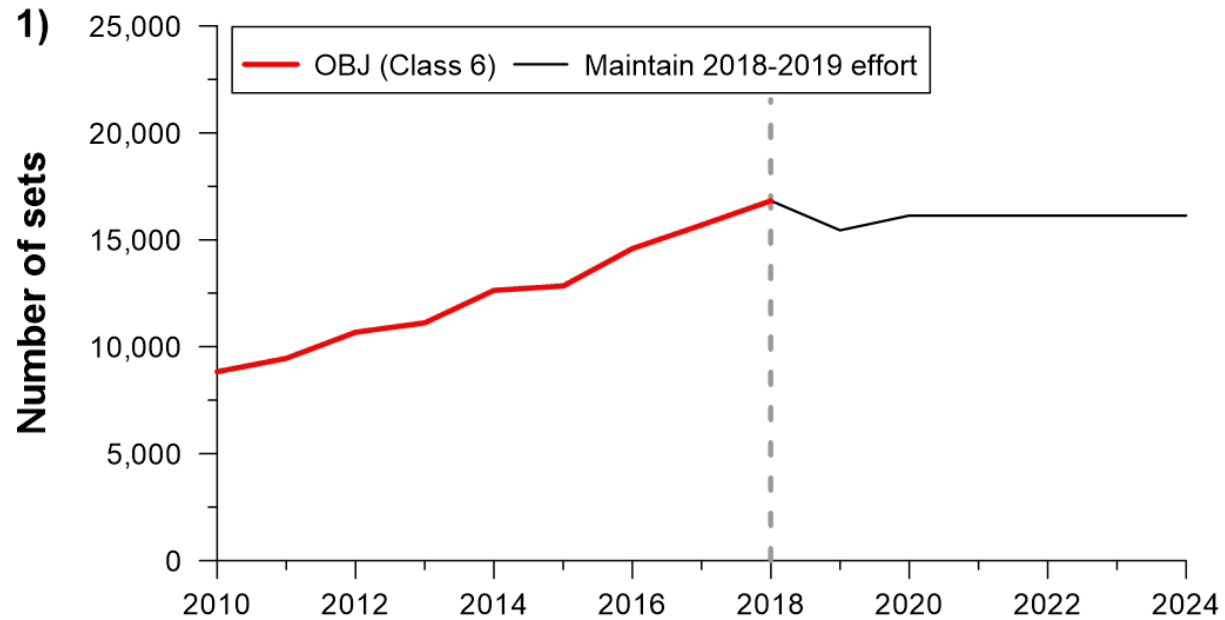
2019 Assessment-Evaluación de 2019

- Declining “evenness”
  - Changing relative biomass
- Alternating biomass trends by TL
  - Decline of predators (>4.0)
  - Increase of prey (3.25-4.0)
- Minor trophic cascade
- Continued trends, certainly requires monitoring

Simulating the potential impacts of FAD fishing on  
key species and ecosystem structure

# Modelled scenarios

1. Average no. of OBJ sets for 2018-2019 maintained from 2018 to 2024
  - Effort for all other fisheries maintained at 2018 levels

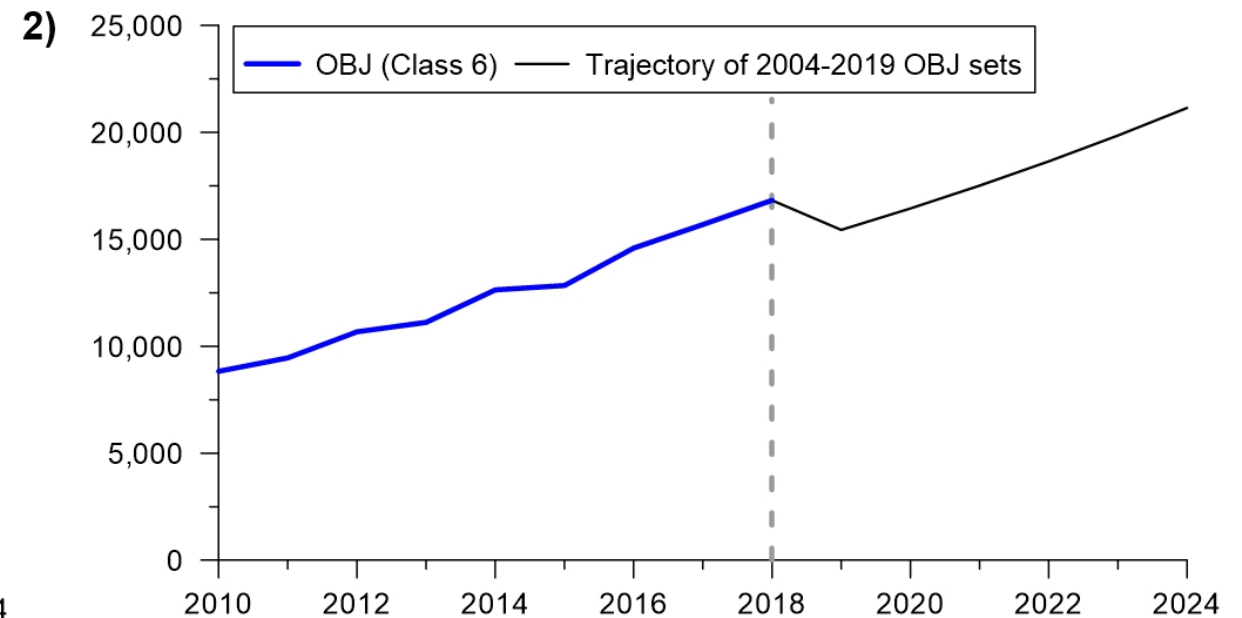
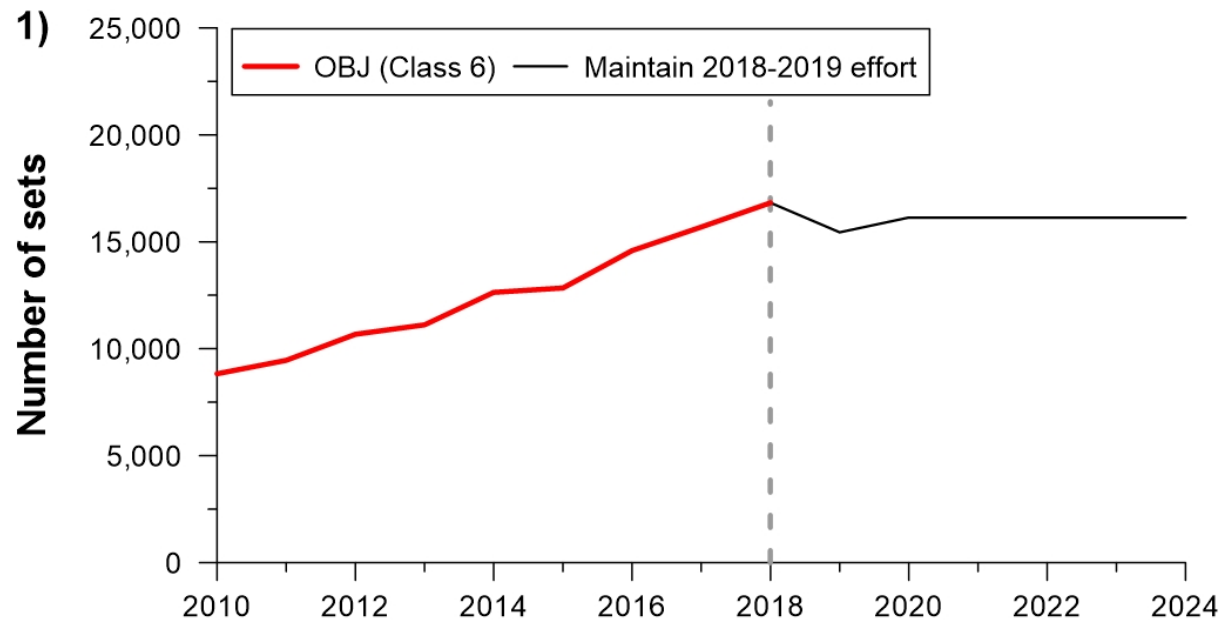




# Modelled scenarios

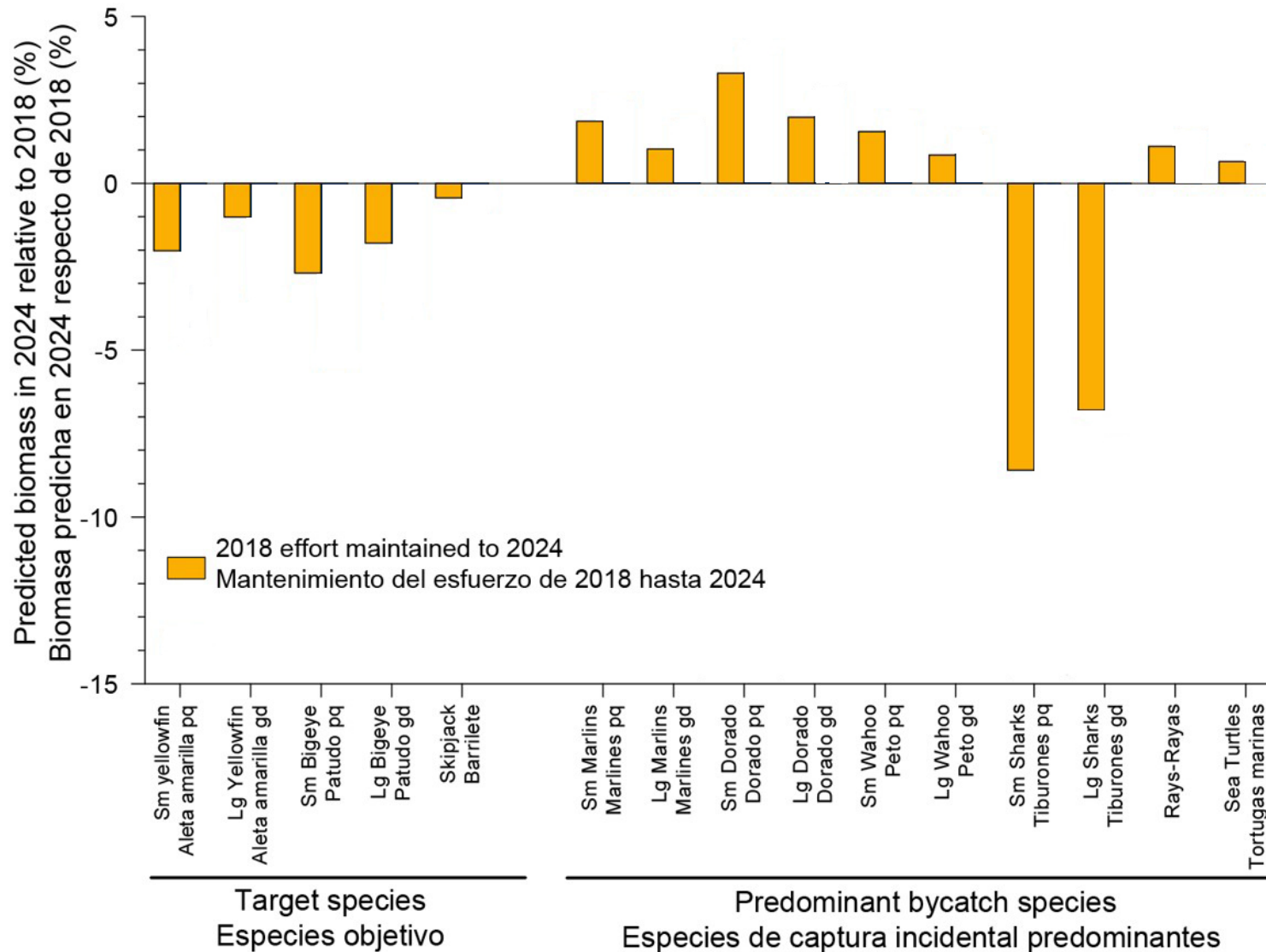
## 2. Increase OBJ sets following the trajectory from 2004-2019

- Effort for all other fisheries maintained at 2018 levels



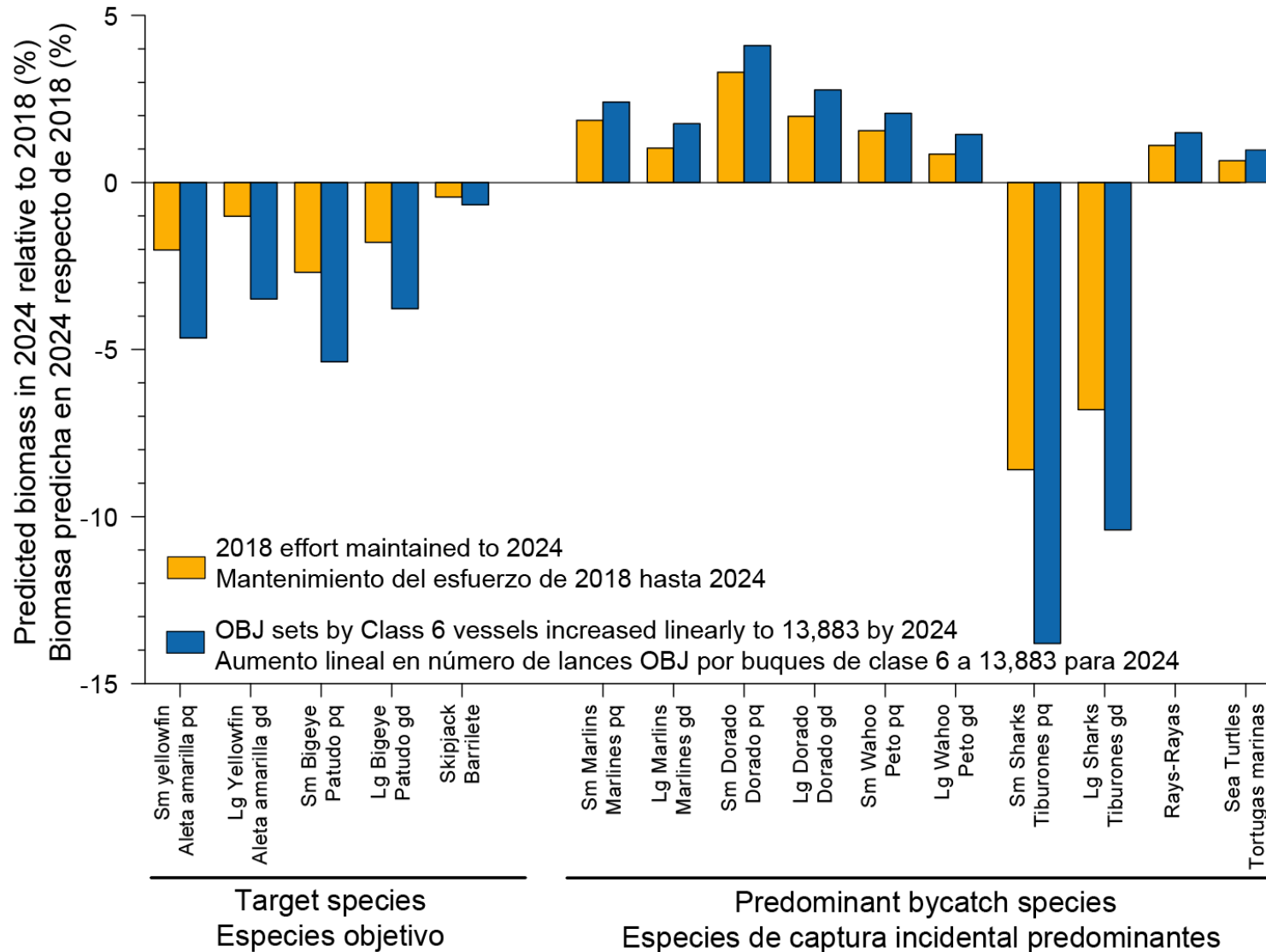
# 1) Maintain 2018/2019 effort

- Biomass of tunas  $\downarrow$ 1-3%, retained bycatch  $\uparrow$ 1-3%, sharks  $\downarrow$ 7-9%



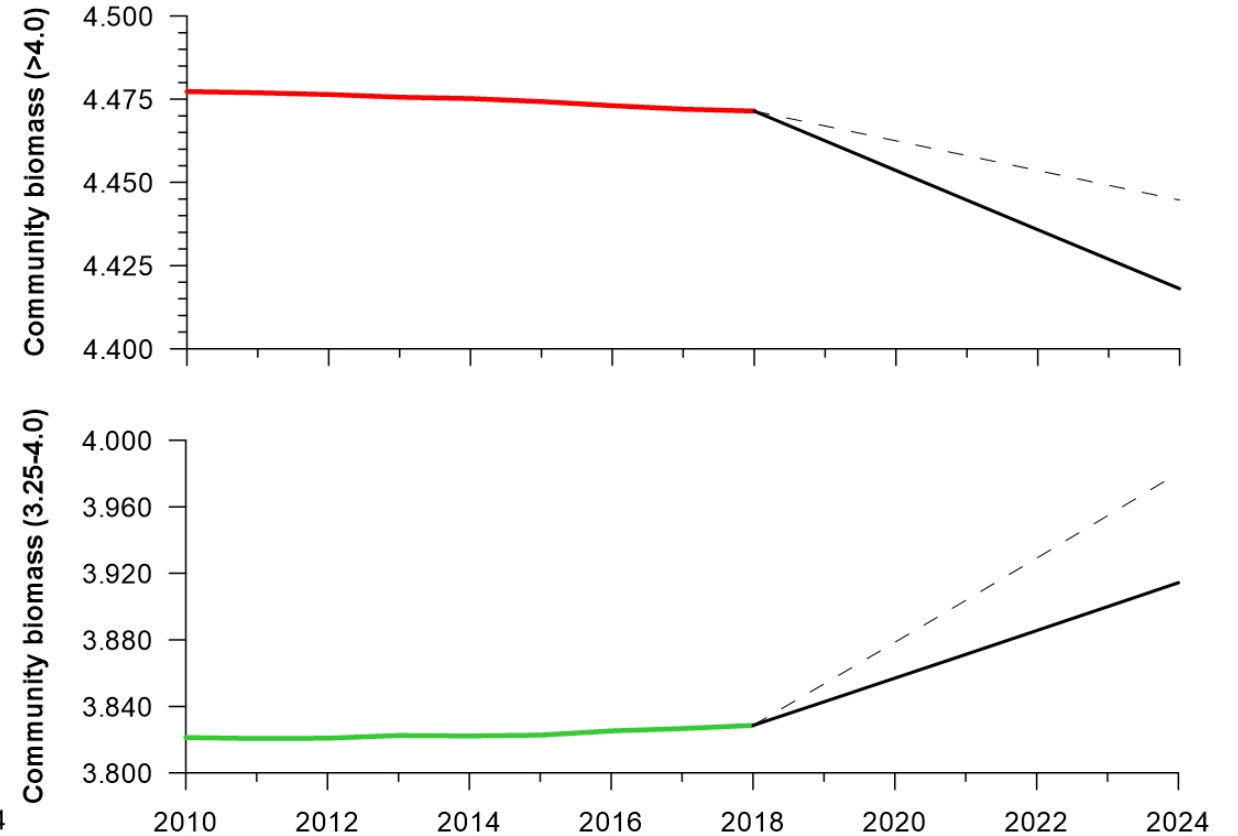
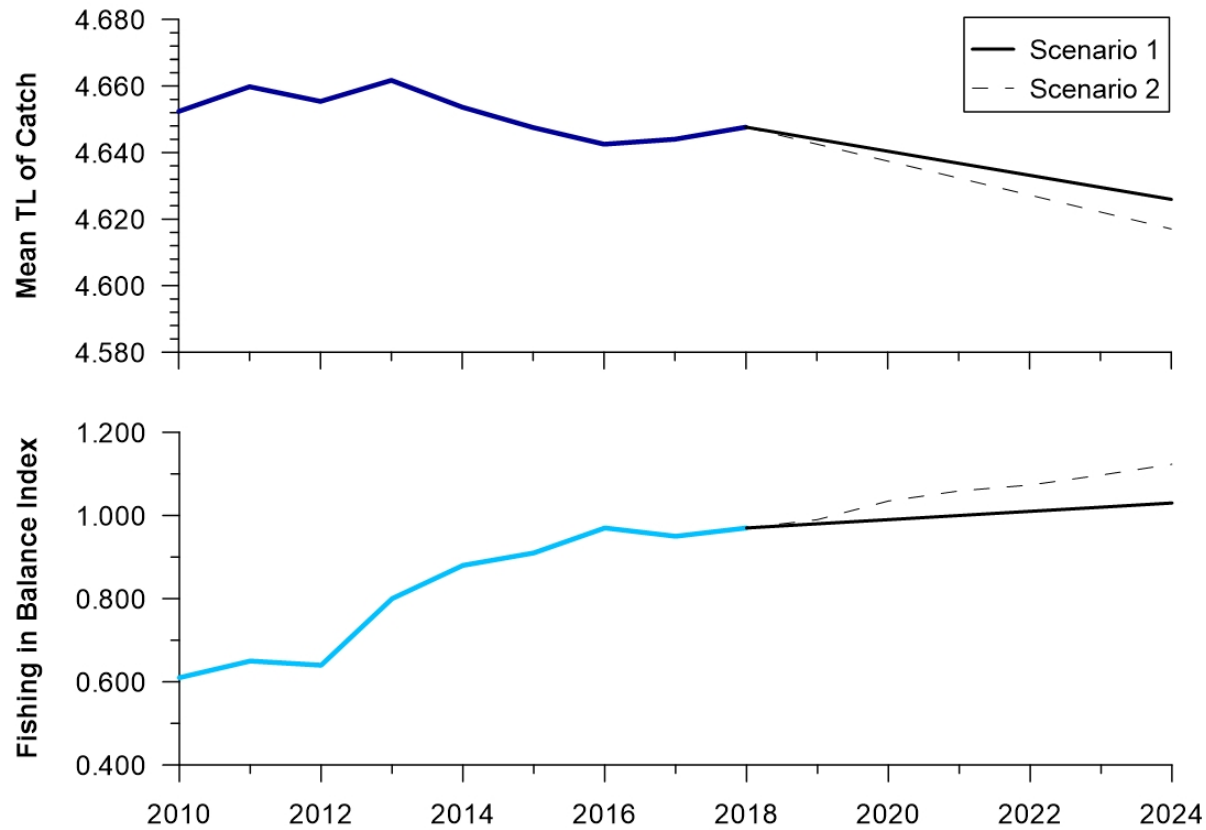
## 2) Increase OBJ effort

- Biomass of tunas ↓1-5%, retained bycatch ↑1-6%, sharks ↓11-14%



# Changes to ecosystem structure

- Continued decline of TLc & TL>4.0; increase FIB & TL 3.25

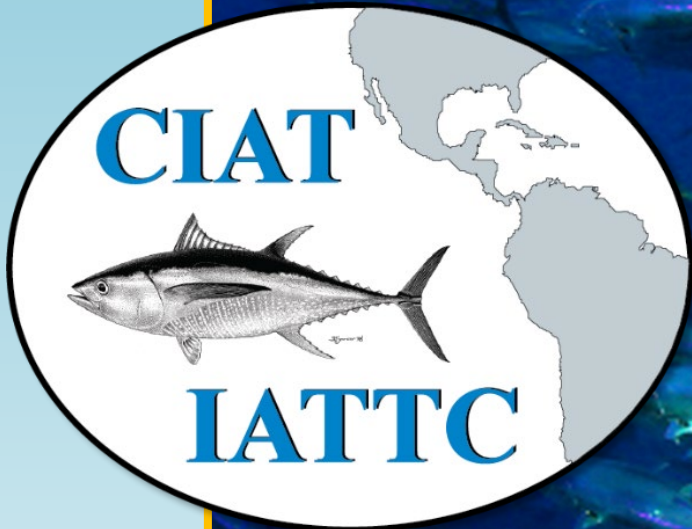


# Summary

- ETP-21 improved realism of the ETP ecosystem and calibration improved reliability of forecasts by reproducing past population trends.
- The structure of the ETP substantial changed over the history of the EPO tuna fishery, and more pessimistic than 2019 assessment.
- Changes most significant since the early 1990s coinciding with the increase in OBJ sets, increasing by ~50% every 5 years; 7-fold since 1993.
- Maintaining 2018-2019 effort levels resulted in biomass declines of target species, but especially small and large sharks.
- Increase in OBJ effort predicted to result in further biomass declines for tuna and sharks and compromise the ETP structure.

# Future research

- If ETP-21 or new model used, data improvements are required
- Data for catch (retained and discards) & effort (**SAC-12-09**)
  - Longline (especially shallow vs. deep sets)
  - Purse-seine class 1-5 by set type
  - Coastal 'artisanal' fleets (longline & gillnets)
- Foundation of the model is diet data from early 1990s
  - EPO has experienced some of the strongest El Nino events on record
  - FAD impacts may have altered predator-prey dynamics
- EPO ecological sampling program required to update diet matrix and key model parameters (*e.g.* consumption rates, **SAC-10 INF-E**)



Questions?

