

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

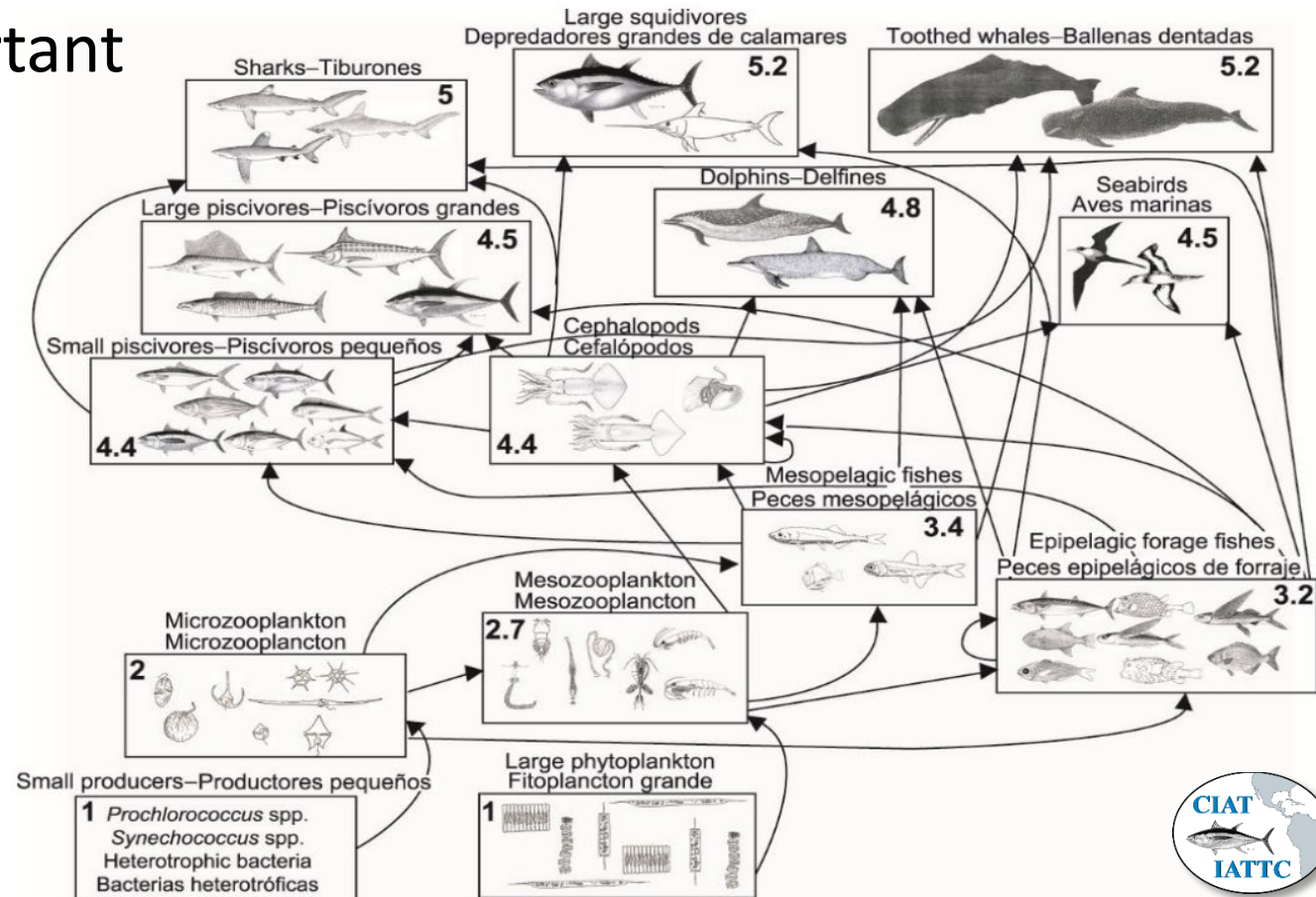
Shane Griffiths, Leanne Fuller, Juan Valero, Carolina Minte-Vera, Haikun Xu & Cleridy Lennert-Cody

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

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 - 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 (group)	Biomass in sub-area (tonnes)	Total mortality (year)	Production / harvest (tonnes/year)	Consumption (tonnes/year)	Ecotrophic Efficiency	Other mortality	Production / consumption	Uneaten consumption
1	Pompidi-Bels	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
2	Onopio-Bels	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
3	Bakeri-Pharus	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
4	Touloni-Pharus	1.000000	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
6	Mass 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	La Yellows	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
10	Sea Spines	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
11	La Spines	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
12	Sea Marlin	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
13	La Marlin	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
14	Sea Sailfish	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
15	La Sailfish	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
16	Sea Scaevola	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
17	La Scaevola	1.000000	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
19	La Octopus	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
20	La Yellow	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
21	Sea Shark	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
22	Sea Shark	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
23	La Shark	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
24	Sea	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
25	Shark	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
26	Albacore	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
27	Sea	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
28	Baika	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
29	Misc. Fish	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. Fish	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
33	Capelin	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
34	Cod	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
35	Macropodidae	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
36	Macropodidae	1.000000	0.000000	0.000000	0.000000	0.000000			0.000000
37	La Phyllophaga	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

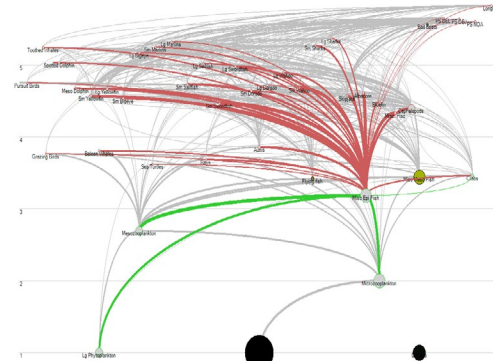
- Why not develop a new EPO model? A very long process

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 Fishes	1.000000	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
5	Opened Dolphins	1.000000	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
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)

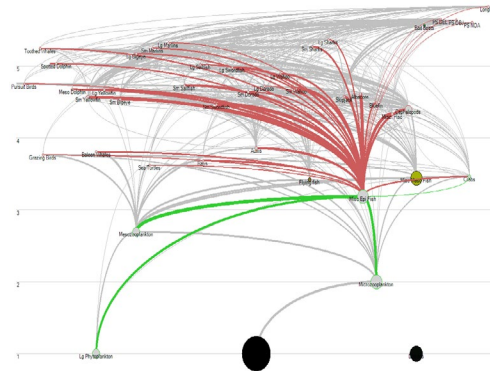


Balancing
(Ecopath)

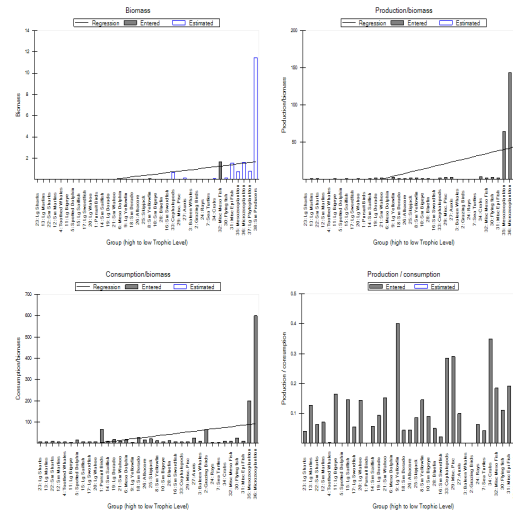


Diagnostics
(Ecopath)

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 Beak	1.000000	0.00000000		0.07999999	0.000000	0.000000		0.000000	0.000000
2 Greyed Beak	1.000000	0.00000000		0.10000001	0.000000	0.000000		0.000000	0.000000
3 Baked Fishes	1.000000	0.00000000		0.07999999	0.000000	0.000000		0.000000	0.000000
4 Tulefish-Hakes	1.000000	0.00000000		0.00000002	0.000000	0.000000		0.000000	0.000000
5 Spotted Dolphin	1.000000	0.00000001		0.00000000	0.000000	0.000000		0.000000	0.000000
6 New Dolphin	1.000000	0.00000001		0.00000000	0.000000	0.000000		0.000000	0.000000
7 Sea Turtles	1.000000	0.00000001		0.00000000	0.000000	0.000000		0.000000	0.000000
8 Sea Yellowfish	1.000000	0.04919461	1.700000		0.000000			0.000000	0.000000
9 Sea Yellowfish	1.000000	0.00000000	2.049999		0.000000			0.000000	0.000000
10 Sea Sigsbee	1.000000	0.00000000	0.700000		0.000000			0.000000	0.000000
11 Sea Sigsbee	1.000000	0.00000000	0.700000		0.000000			0.000000	0.000000
12 Sea Hakes	1.000000			0.000000	0.000000	0.000000		0.000000	0.000000
13 Sea Hakes	1.000000			0.000000	0.000000	0.000000		0.000000	0.000000
14 Sea Saltfish	1.000000			0.000000	0.000000	0.000000		0.000000	0.000000
15 Sea Saltfish	1.000000			0.000000	0.000000	0.000000		0.000000	0.000000
16 Sea Scorfish	1.000000			0.000000	0.000000	0.000000		0.000000	0.000000
17 Sea Scorfish	1.000000			0.000000	0.000000	0.000000		0.000000	0.000000
18 Sea Devils	1.000000	0.00000000	1.200000		0.000000			0.000000	0.000000
19 Sea Devils	1.000000	0.00000000	1.200000		0.000000			0.000000	0.000000
20 Sea Hakes	1.000000	0.00000000	1.200000		0.000000			0.000000	0.000000
21 Sea Hakes	1.000000	0.00000000	1.200000		0.000000			0.000000	0.000000
22 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
23 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
24 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
25 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
26 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
27 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
28 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
29 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
30 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
31 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
32 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
33 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
34 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
35 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
36 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
37 Sea Sharks	1.000000	0.00000000	0.500000		0.000000			0.000000	0.000000
38 Sea Sharks	1.000000	0.00000000	0.500000		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)



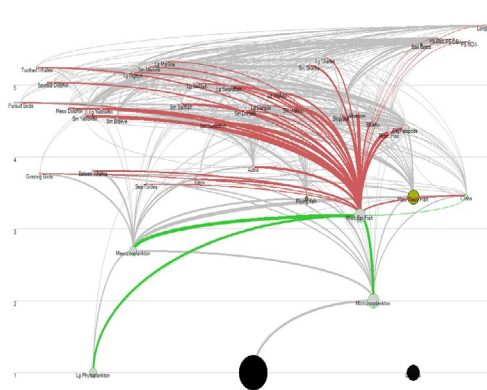
Balancing
(Ecopath)



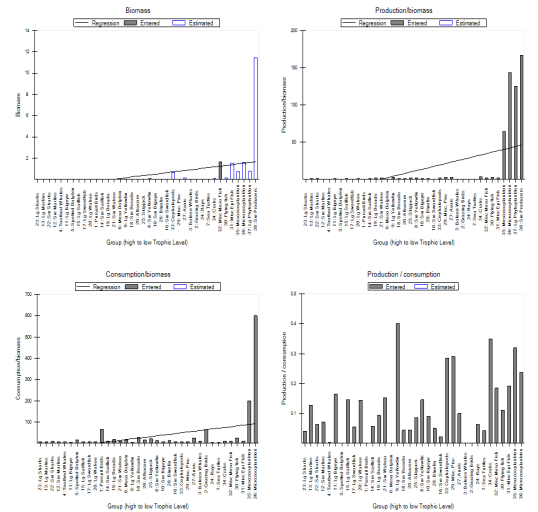
Diagnostics
(Ecopath)



Group name	Sub-area (group)	Biomass in sub-area (ton)	Total mortality (year)	Production / harvest (ton/year)	Consumption (ton/year)	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 Eel	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
11	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
12	Sea Manta	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
13	Sea Lion	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
14	Sea Seal	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15	Sea Elephant	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
16	Sea Leopard	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
17	Sea Cow	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
18	Sea Otter	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
19	Sea Lion	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
20	Sea Elephant	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
21	Sea Manta	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
22	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
23	Sea Eel	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
24	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
26	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
27	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
28	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
29	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
30	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
31	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
32	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
33	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
34	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
35	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
36	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
37	Sea Snake	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
38	Sea Snake	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)

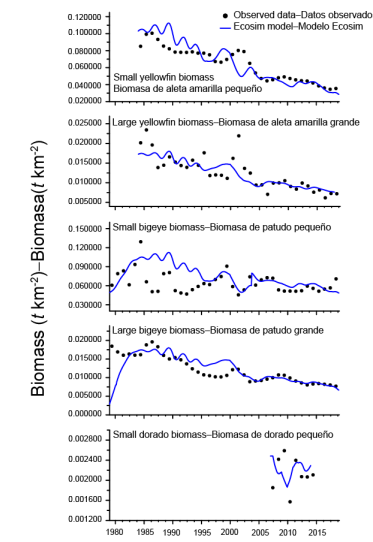
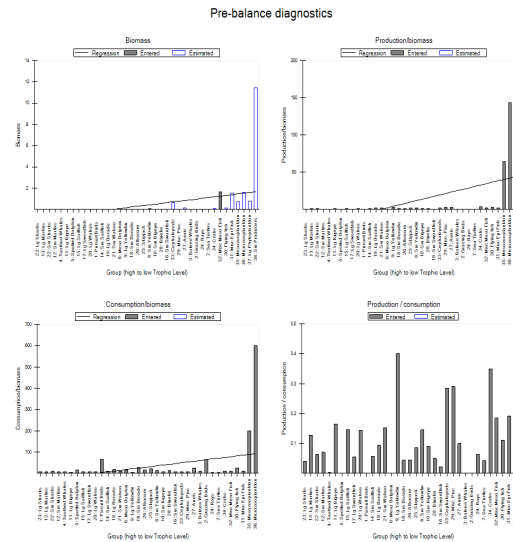
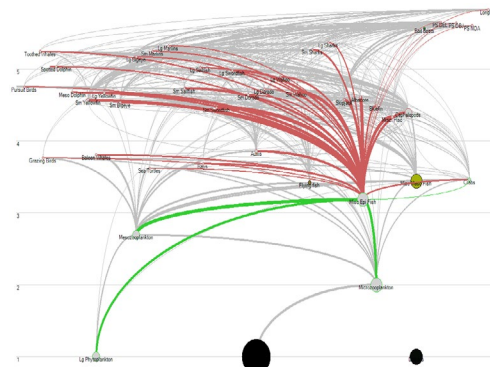


Diagnostics
(Ecopath)



Calibration
(Ecosim)

Group name	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	Pompidi 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 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 Dolphins	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 Turtles	1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
8	Sea Yellowfish	1.000000	0.04919461	1.780000	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



ETP7 ecosystem model

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

Parameterization
(Ecopath)



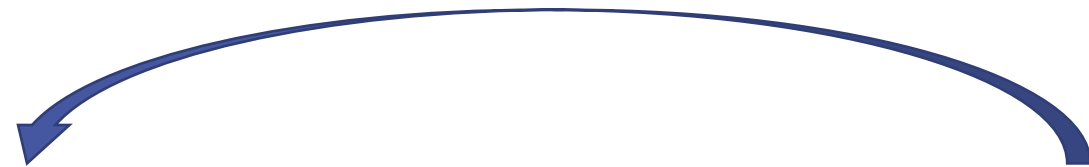
Balancing
(Ecopath)



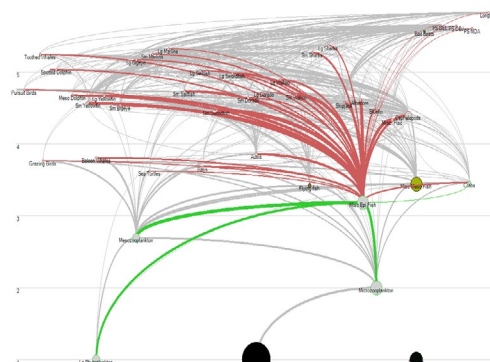
Diagnostics
(Ecopath)



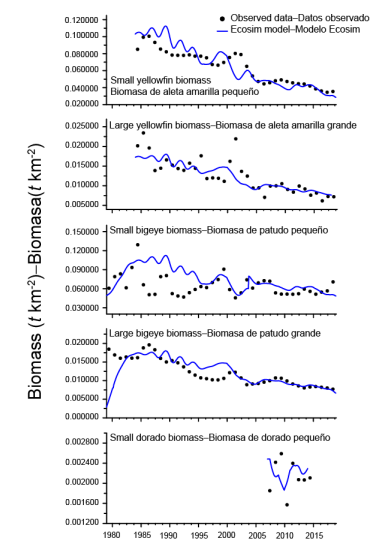
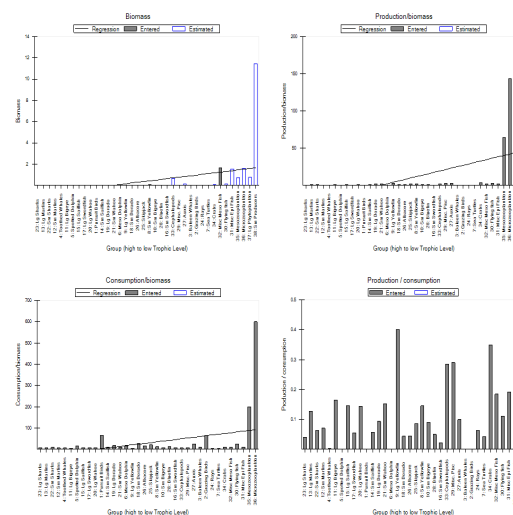
Calibration
(Ecosim)



Group name	Hub area (km ²)	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	0.04912641	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 Sn 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 Pir	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25 Shark	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 Aun	1.000000	0.00000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
28 Bunk	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 King Fish	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)

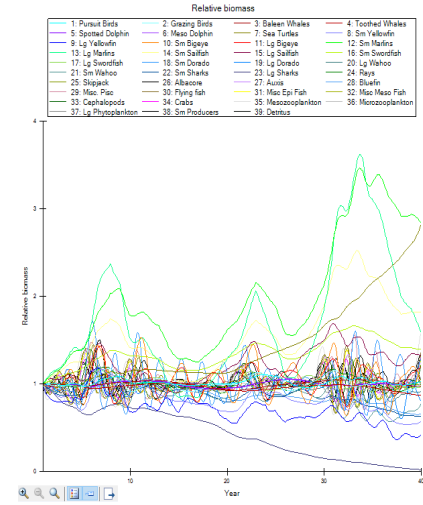
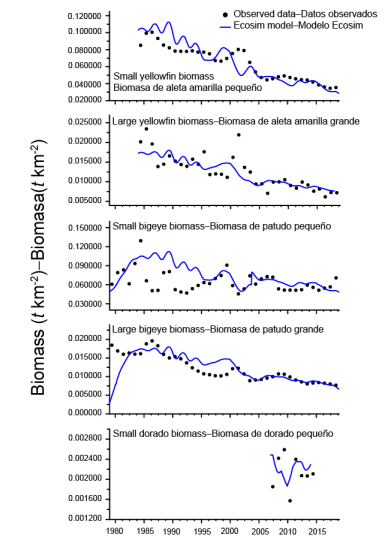
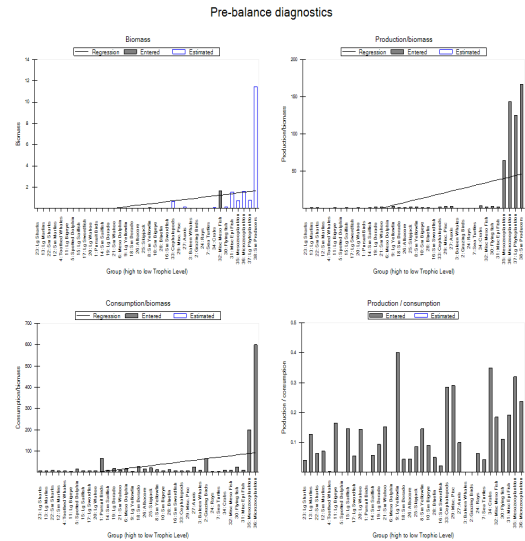
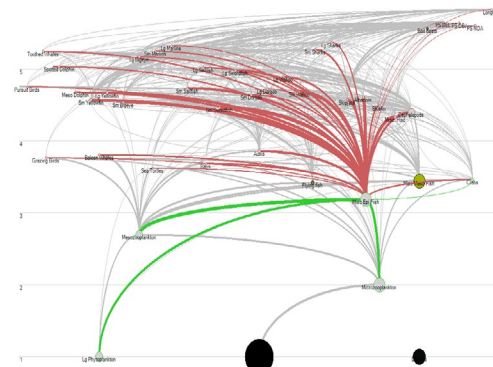


Calibration
(Ecosim)



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	0.01999999	0.01999999	0.00000000	0.00000000	0.00000000	0.01999999	0.00000000
2 Grayn Bats	1.000000	0.00000000	0.19000001	0.19000000	0.00000000	0.00000000	0.00000000	0.19000000	0.00000000
3 Baken Whales	1.000000	0.00000000	0.01799999	0.01799999	0.00000000	0.00000000	0.00000000	0.01799999	0.00000000
4 Tusked Whales	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
5 Spotted Dolphins	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
6 Mass Dolphins	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
7 Sea Turtles	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
8 Sm Yellowfin	1.000000	0.04919461	1.700000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
9 Lg Yellowfin	1.000000	0.00000000	2.049999	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
10 Sm Squire	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
11 Lg Squire	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
12 Sm Marlin	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
13 Lg Marlin	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
14 Sm Sailfin	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
15 Lg Sailfin	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
16 Sm Snoutfish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
17 Lg Snoutfish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
18 Sm Dorado	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
19 Lg Dorado	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
20 Sm Shark	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
21 Lg Shark	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
22 Sm Mako	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
23 Lg Mako	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
24 Sm Shark	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
25 Lg Shark	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
26 Albacore	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
27 Skipjack	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
28 Bluefish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
29 Mac Pac	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
30 Flying Fish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
31 Mac Sp Fish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
32 Mac Sp Fish	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
33 Cephalopoda	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
34 Crabs	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
35 Macrozooplankton	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
36 Microzooplankton	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
37 Lg Phytoplankton	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
38 Sm Producers	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
39 Detritus	1.000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000



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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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

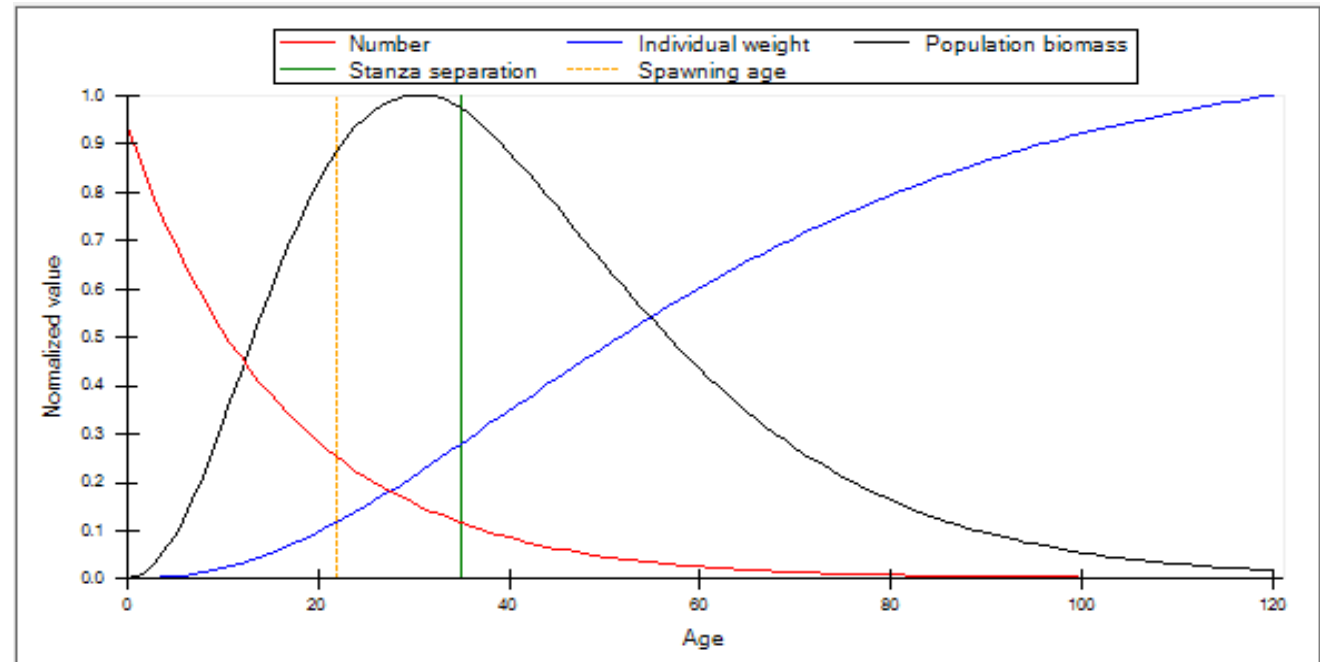
ETP-21	
	Group name
1	Pursuit Birds
2	Grazing Birds
3	Baleen Whales
4	Toothed Whales
5	Spotted Dolphin
6	Meso Dolphin
7	Sea Turtles
8	YELLOWFIN TUNA
9	Sm Yellowfin
10	Lg Yellowfin
11	BIGEYE TUNA
12	Sm Bigeye
13	Lg Bigeye
14	SAILFISH
15	Sm Sailfish
16	Lg Sailfish
17	SWORDFISH
18	Sm Swordfish
19	Lg Swordfish
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

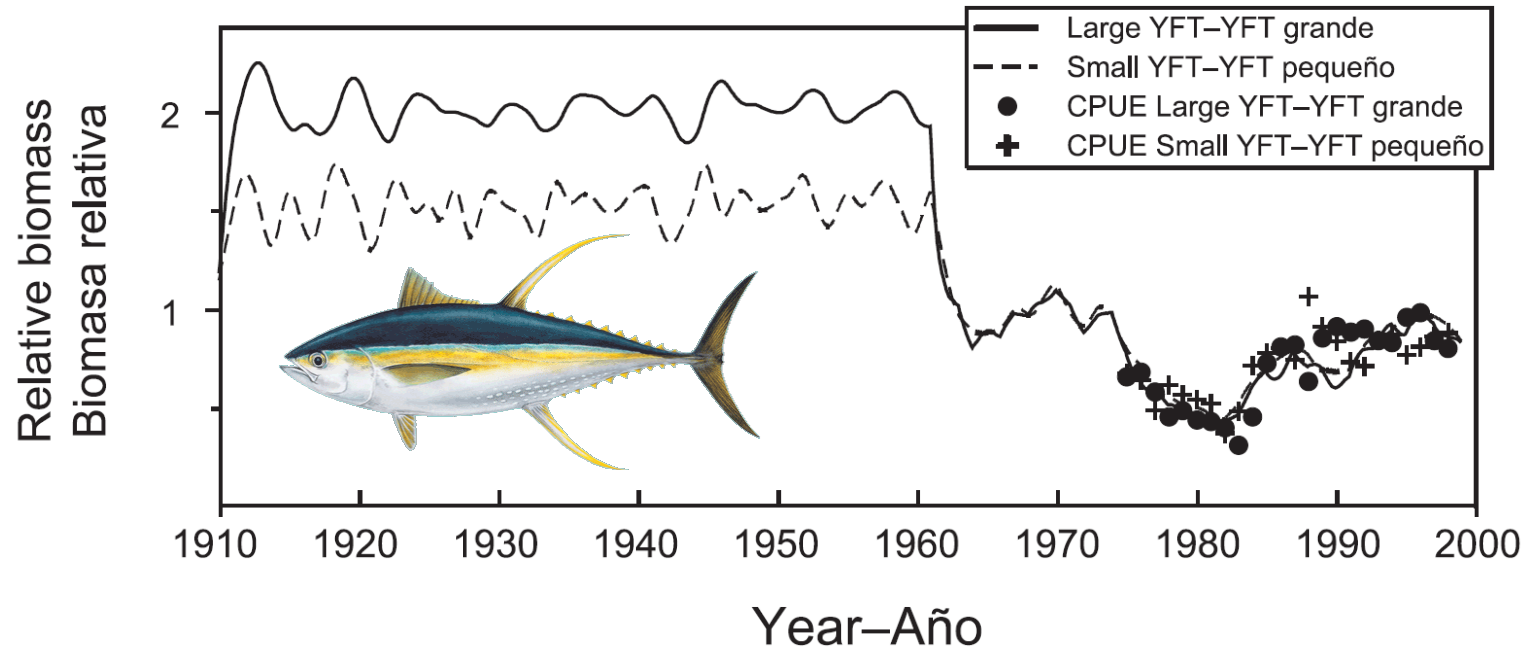
- ETP7 contained ontogenetic stages to reflect known differences in diet and biology
 - But stages not linked - act as independent biomass pools
- ETP-21 linked 12 groups (6 species) as multi-stanza delay-difference sub-models



Model Calibration to Time Series Data

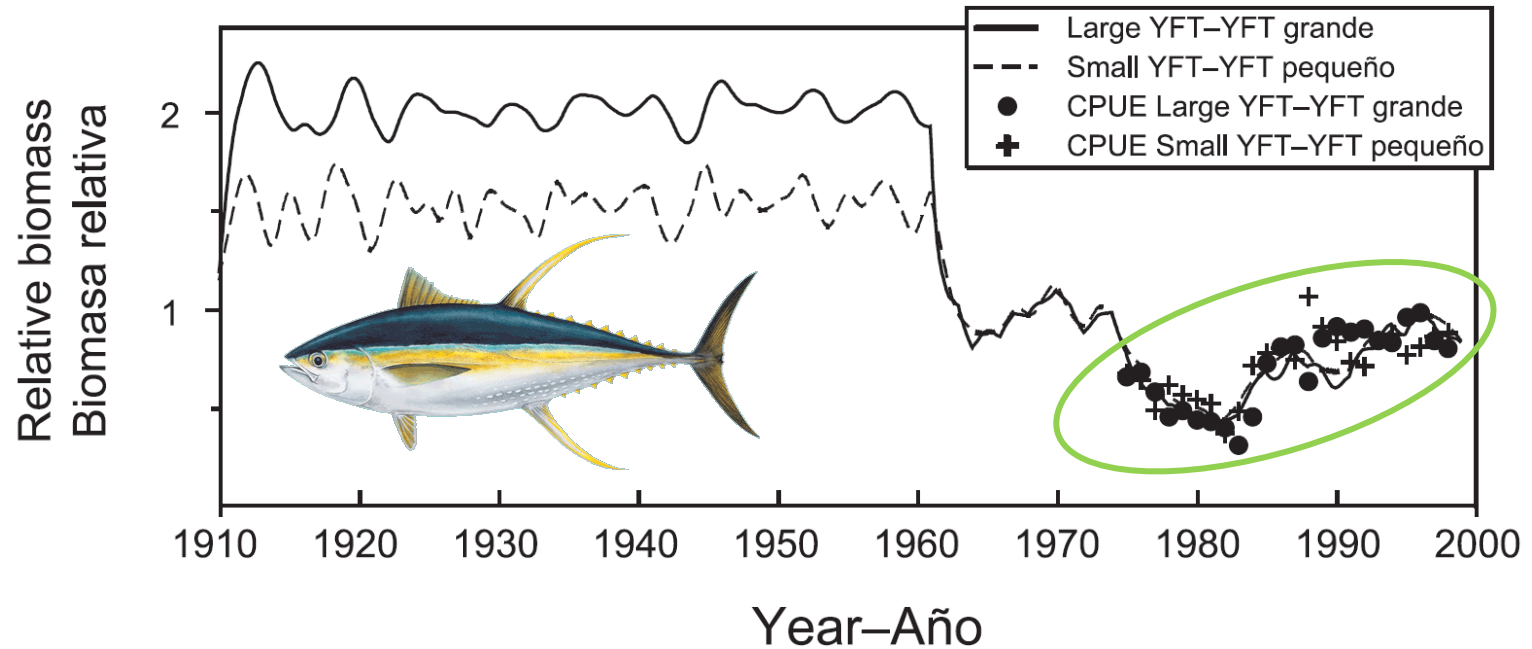
Model Calibration

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



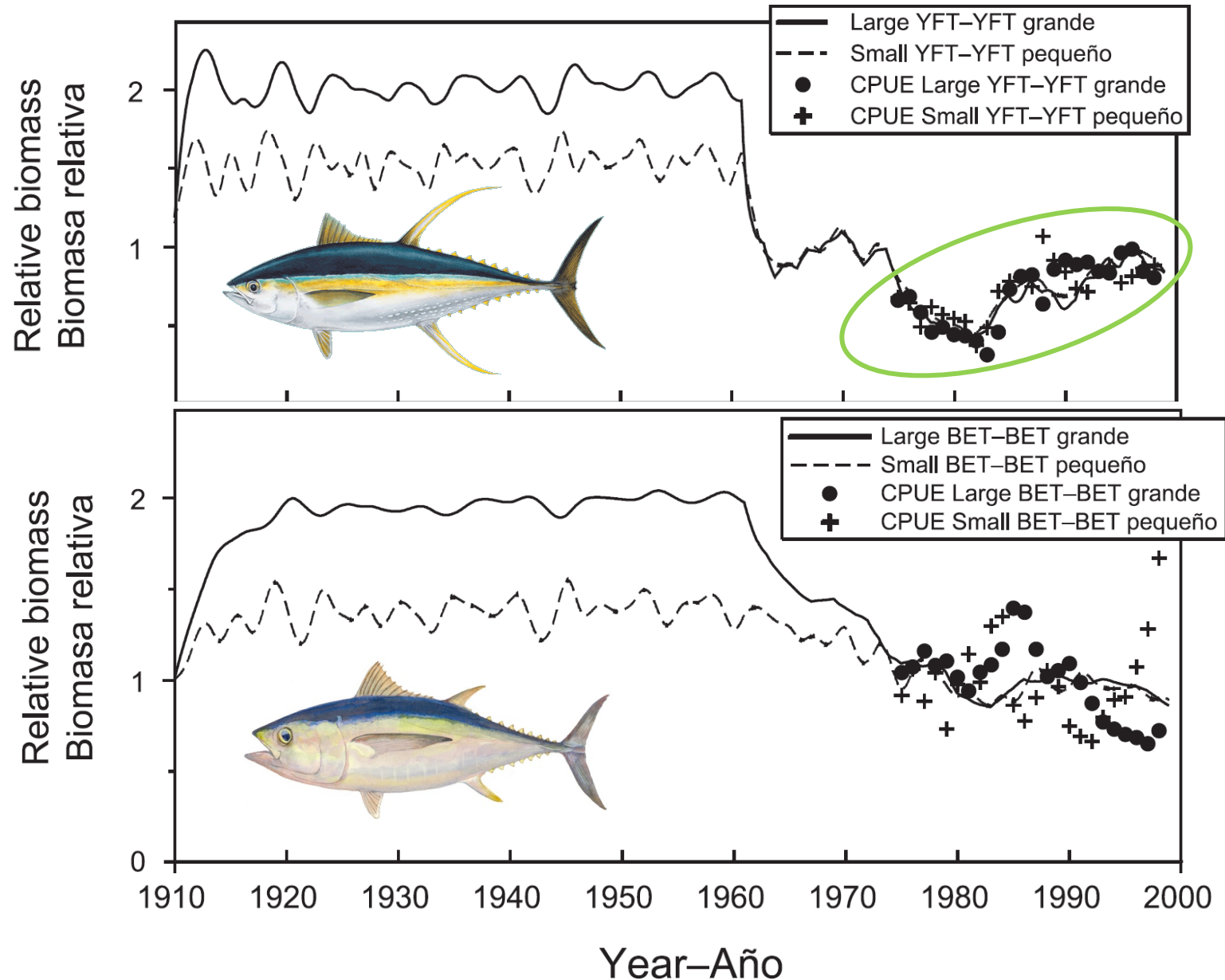
Model Calibration

- ETP7 calibrated using time series 1975-1999 from stock assessments
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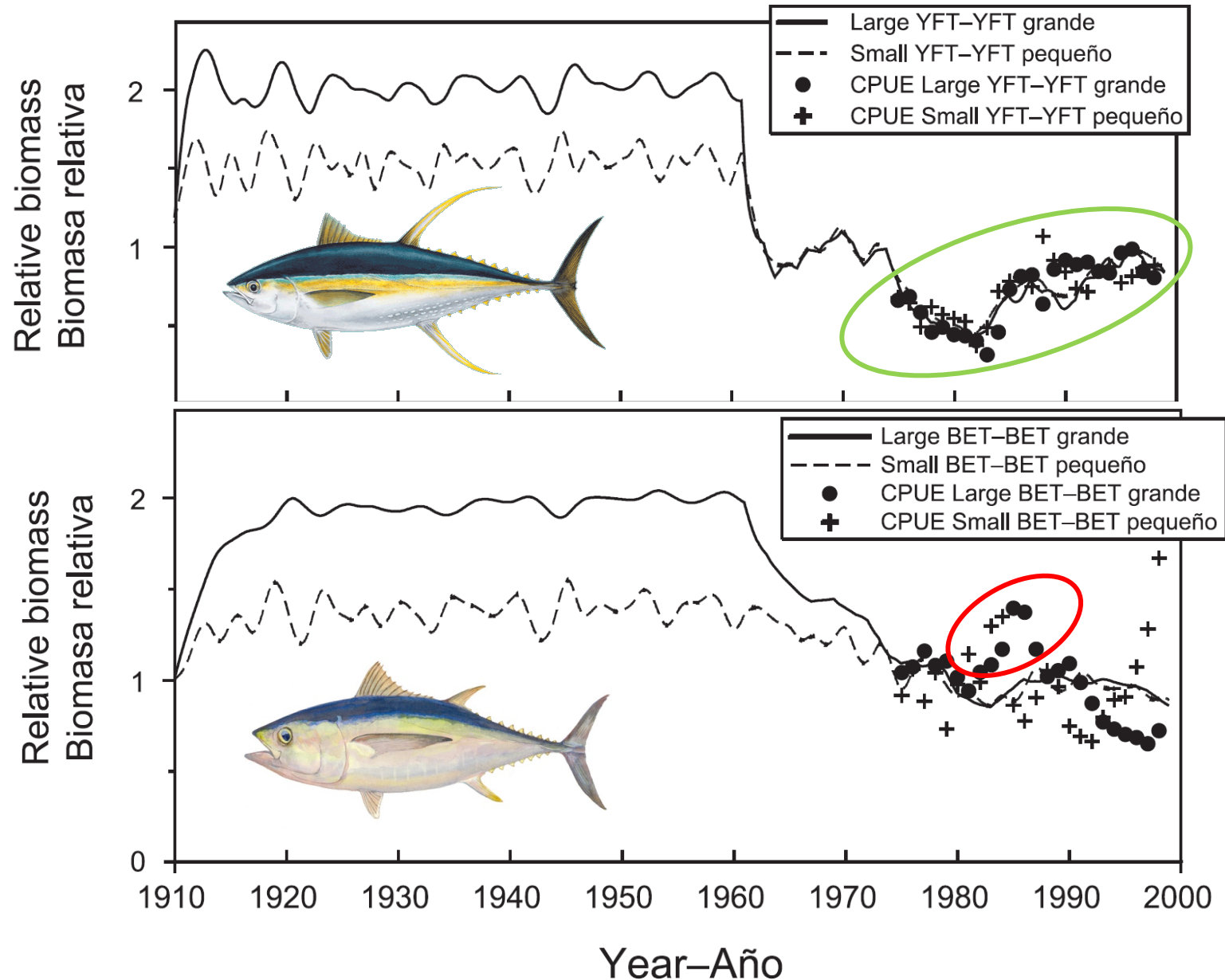
Model Calibration

- 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?



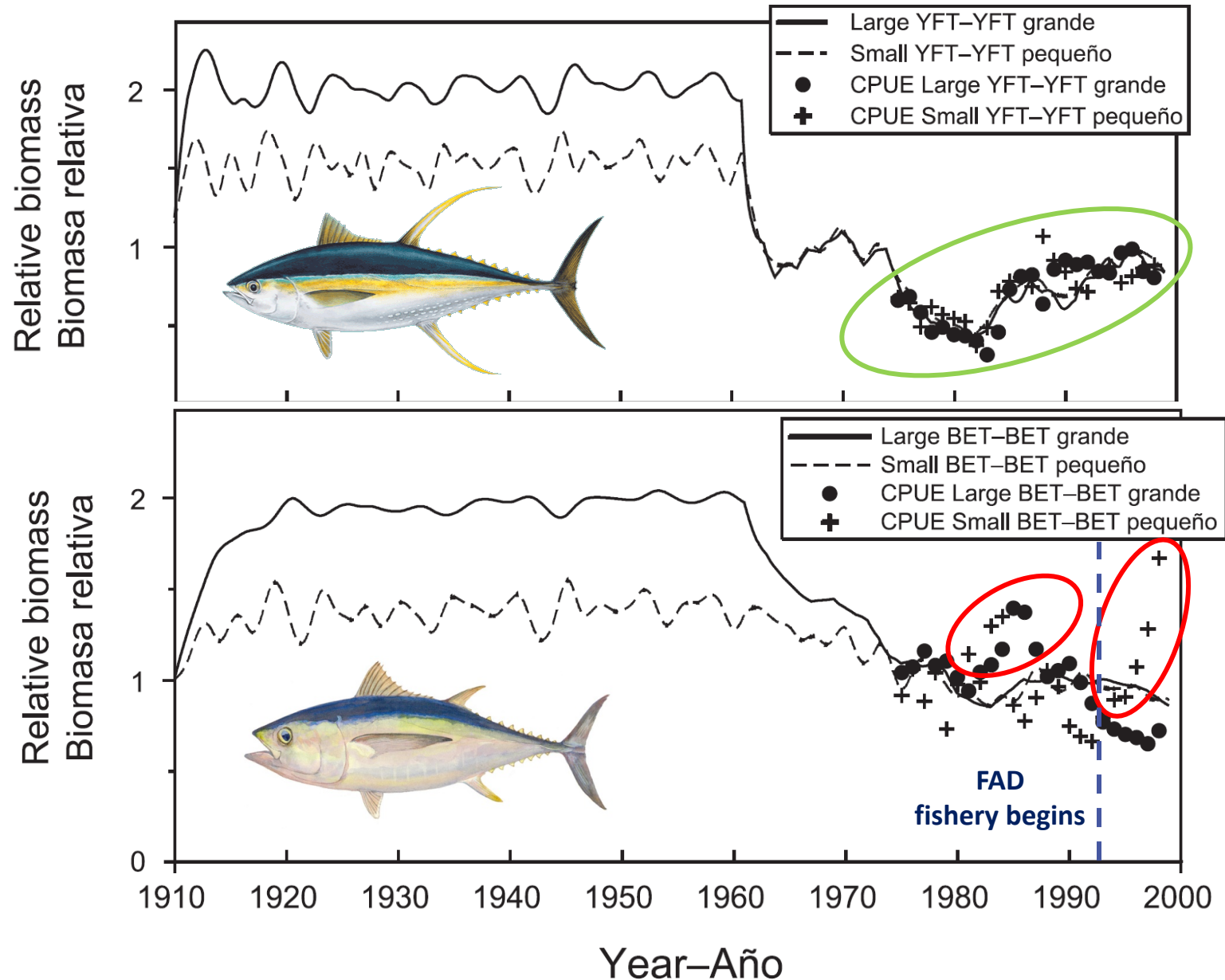
Model Calibration

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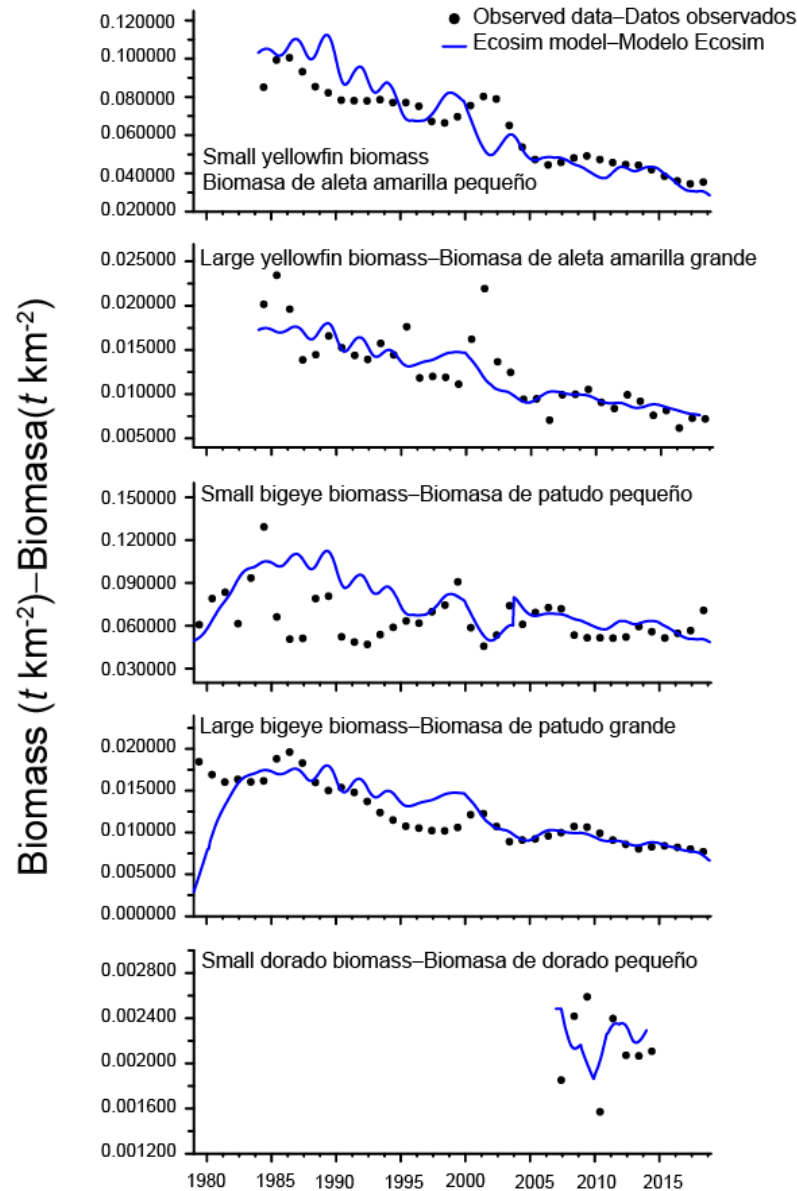
Model Calibration

- 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



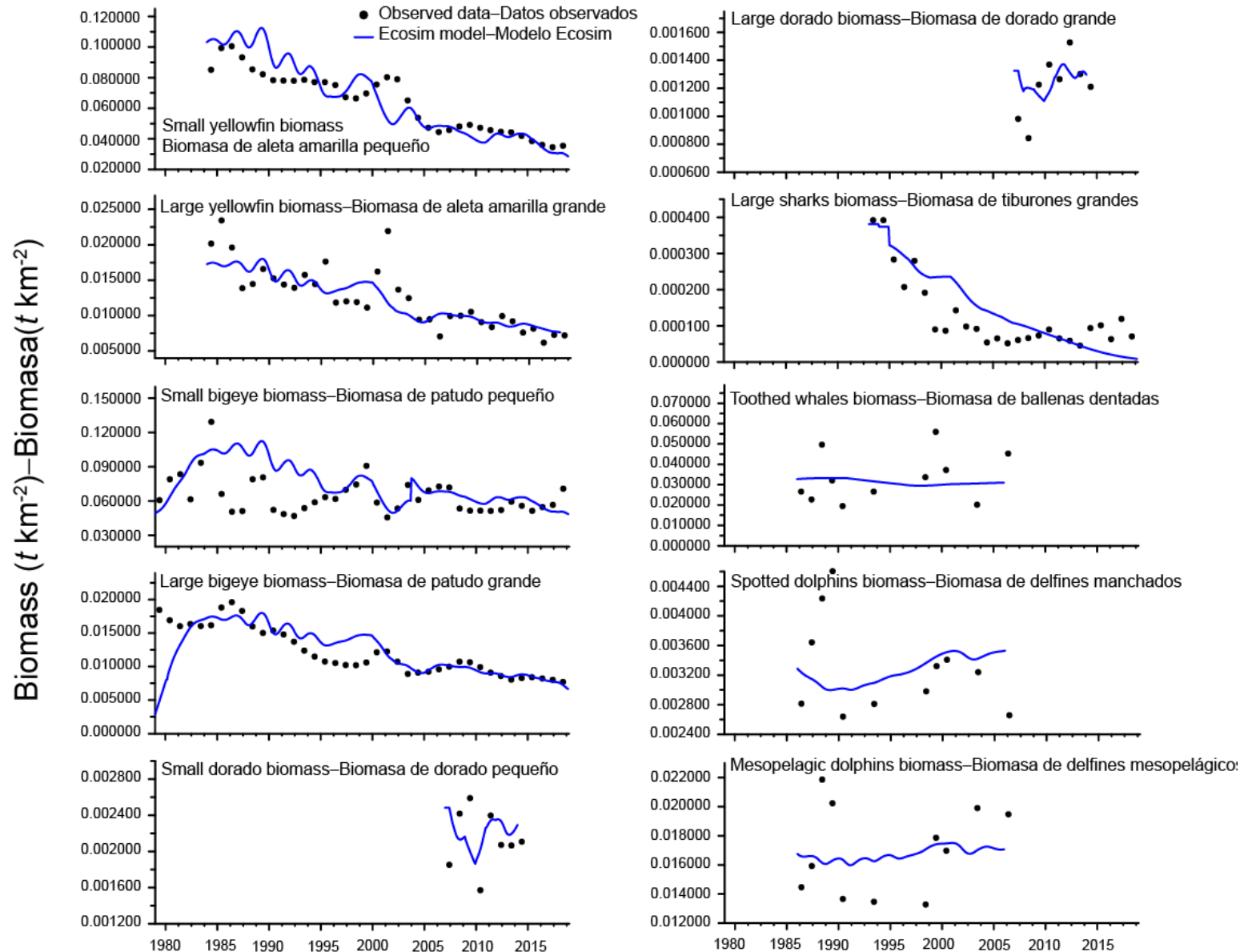
Model Calibration

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



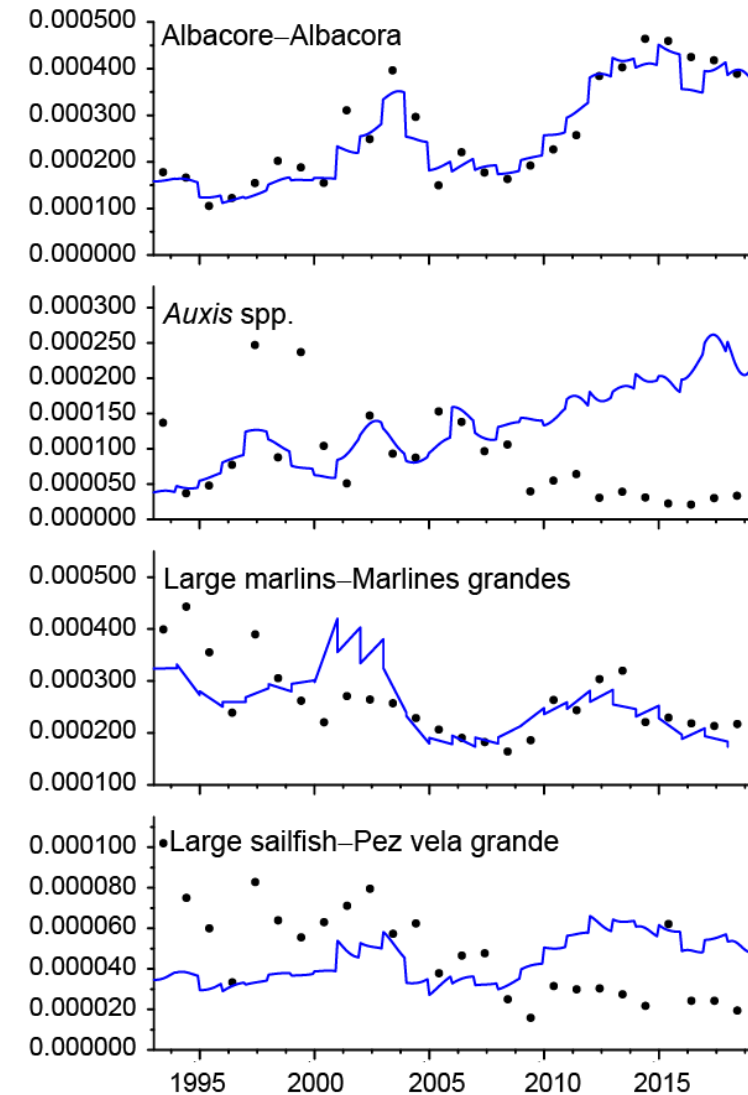
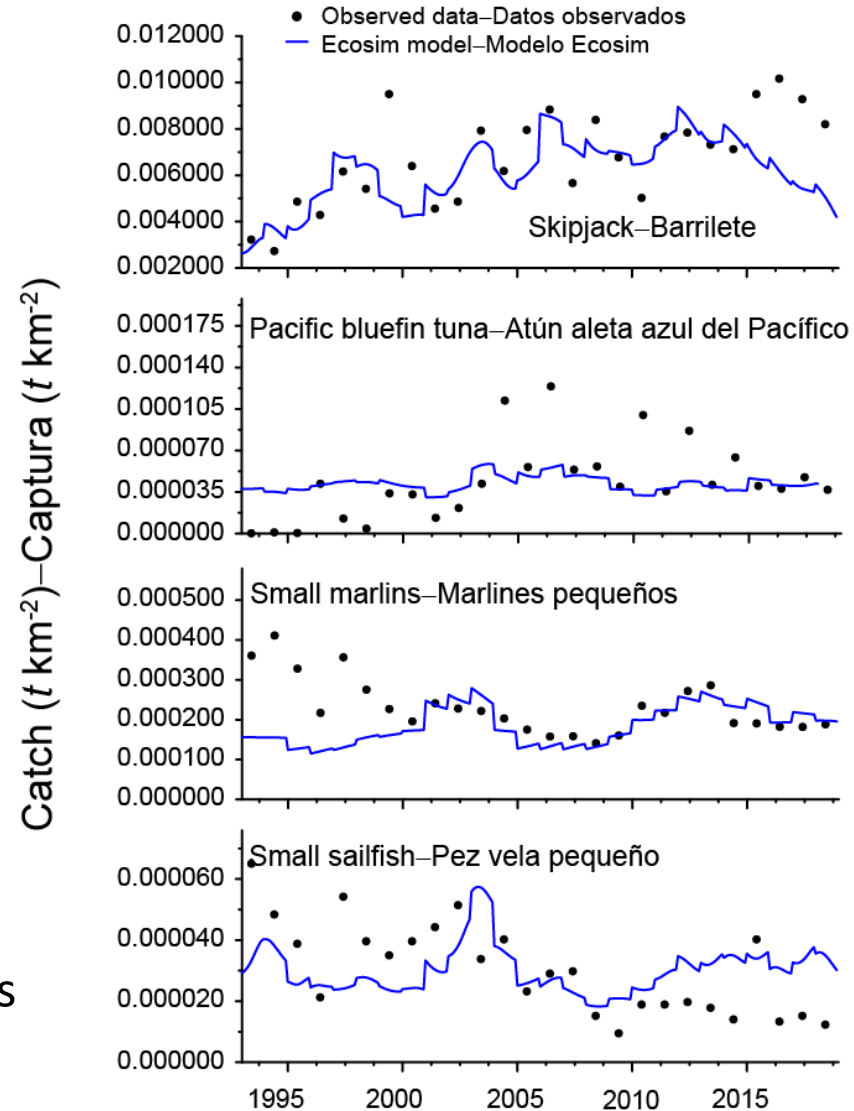
Model Calibration

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



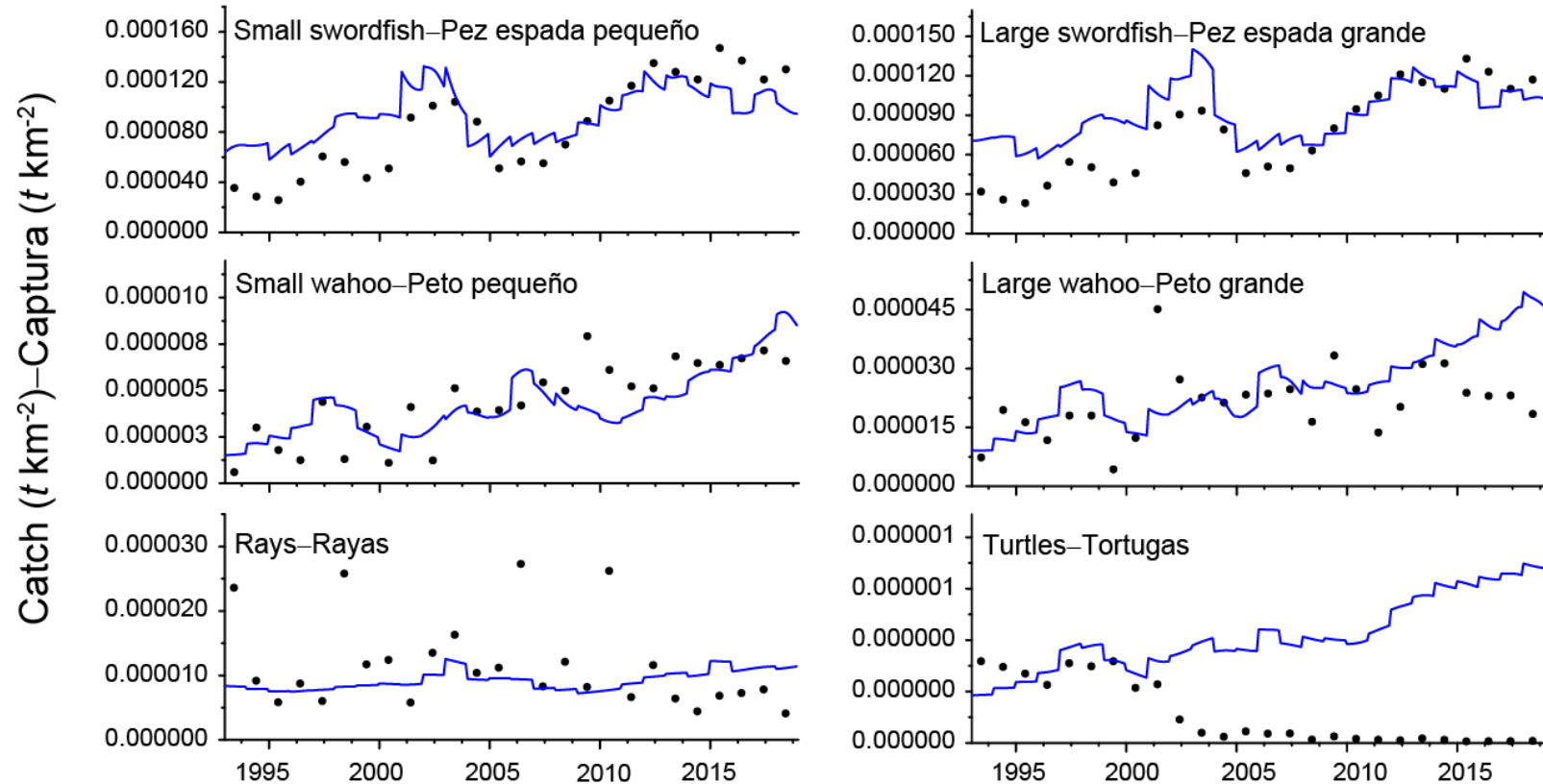
Model Calibration

- 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



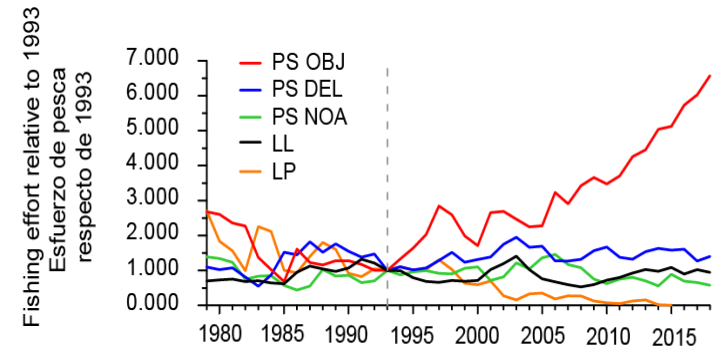
Model Calibration

- Time series
 - Relative biomass
 - Fishing mortality (F)
 - Catch (retained + discarded)
- 25 functional groups
 - Small & large size classes
- Biomass and catch
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- Catch only
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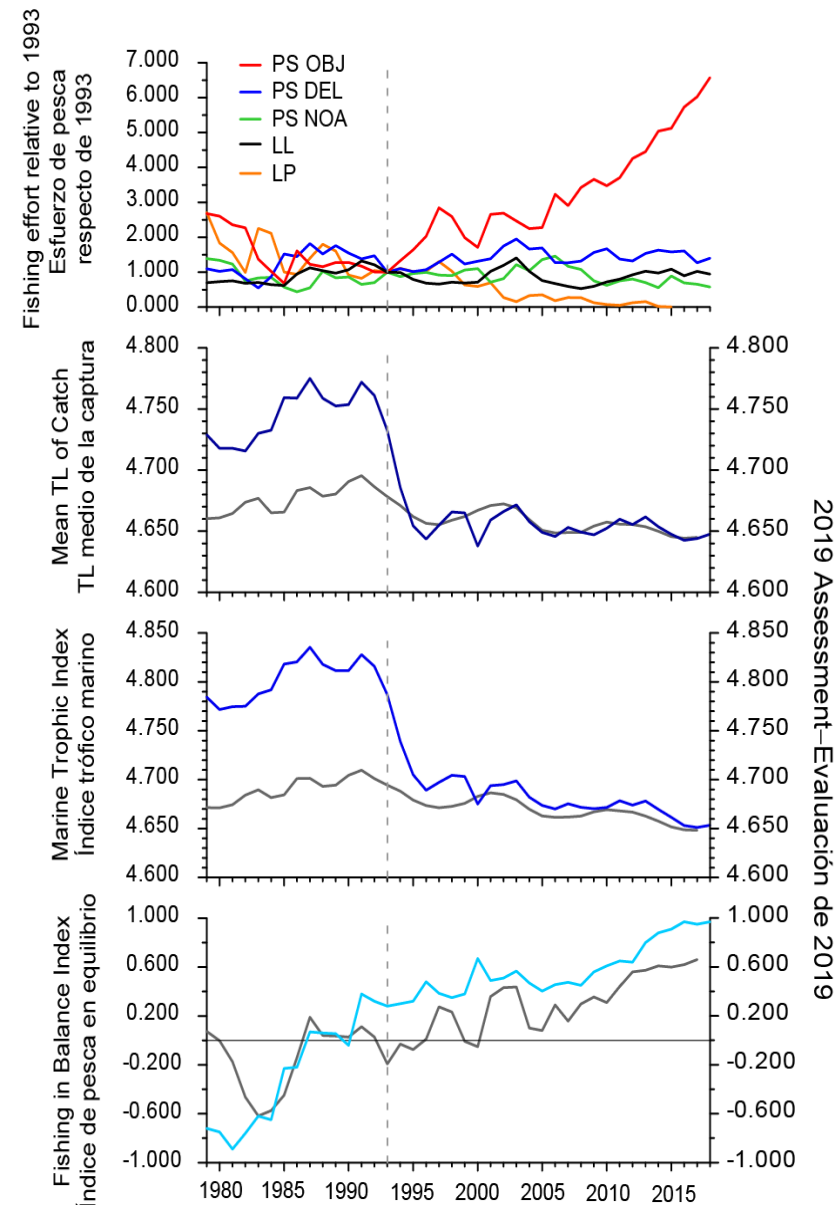
Historical changes in the structure of the ETP ecosystem for the period 1979-2018

Fishing-based indicators



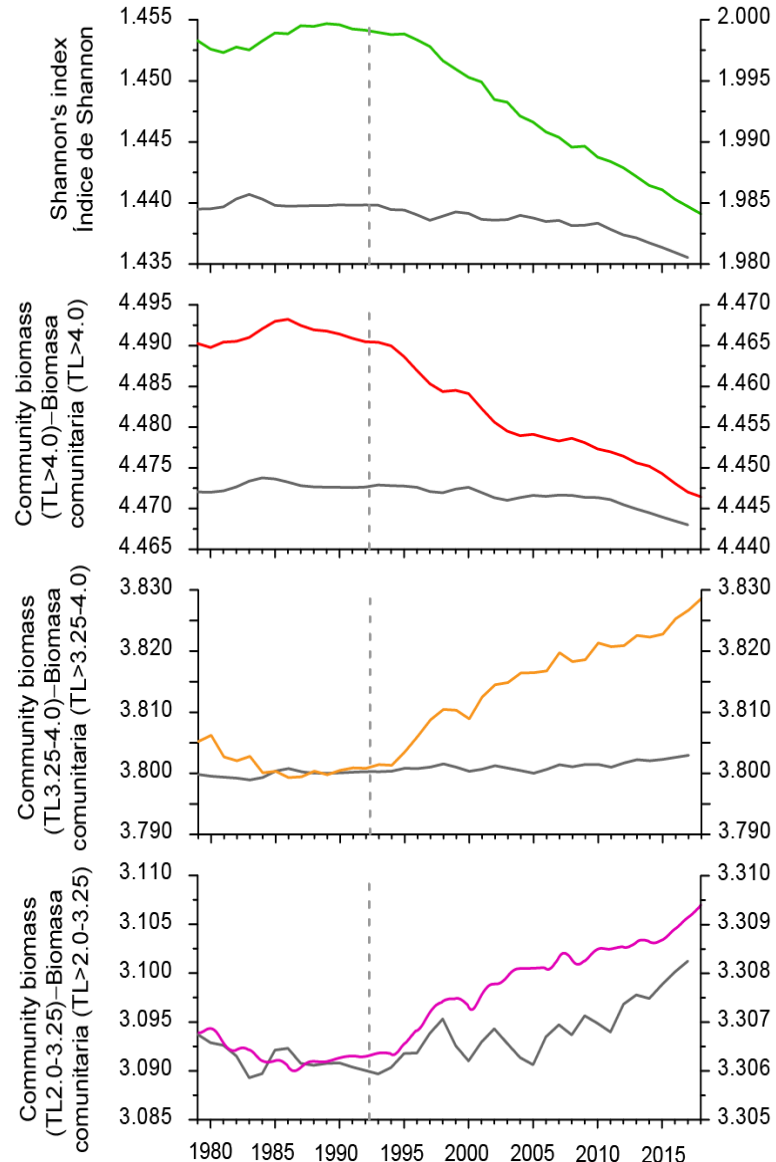
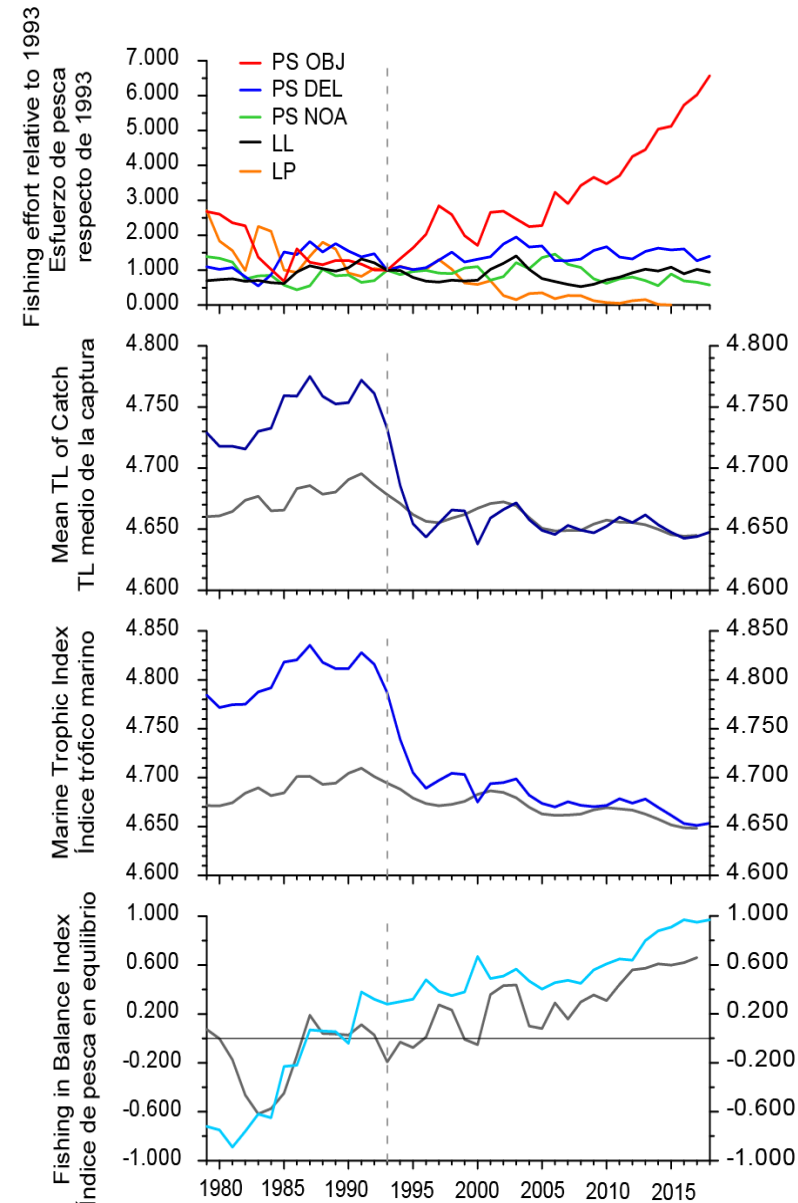
- Nominal fishing effort scaled from 1993
 - Coincidentally, start of the FAD fishery
 - ~7-fold increase in number of OBJ sets 1993-2018

Fishing-based indicators



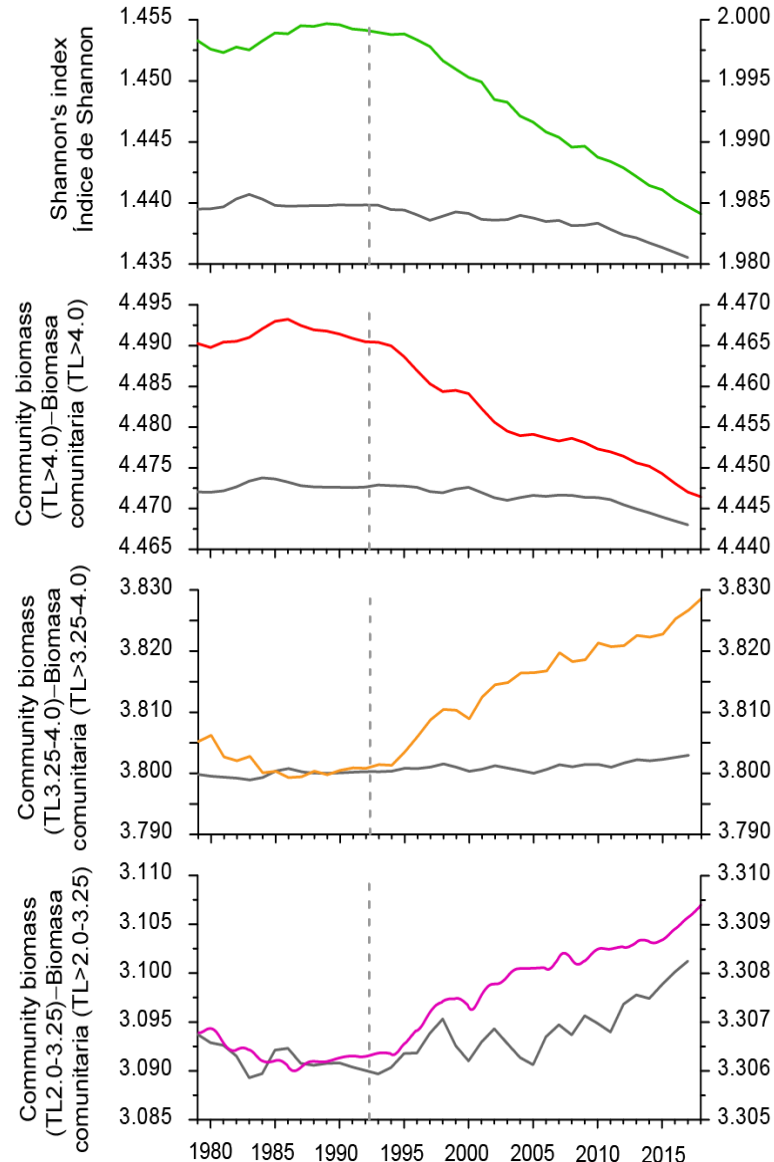
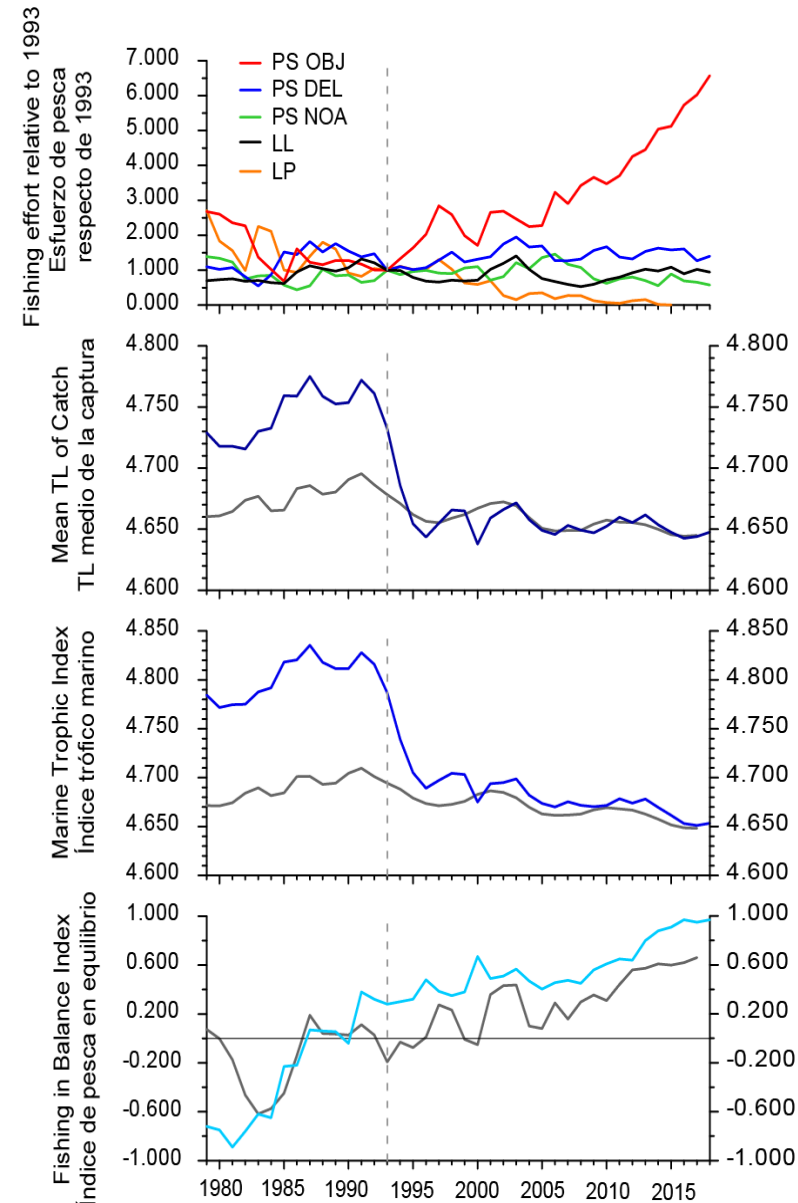
- Nominal fishing effort scaled from 1993
 - Coincidentally, start of the FAD fishery
 - ~7-fold increase in number of OBJ sets 1993-2018
- TL_c and MTI declined by 0.05 for 1991-2018
 - Change in TL_c of ≥ 0.1 per decade is significant
- FIB >0 since 1991
 - Indicates expansion of fishery, likely due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



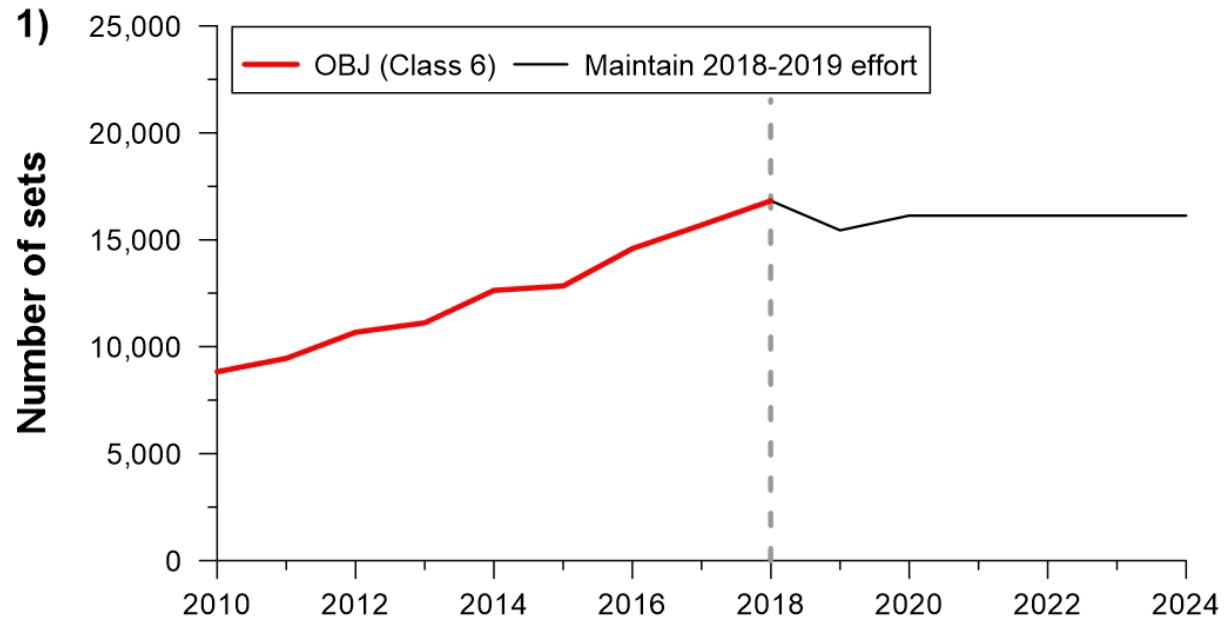
2019 Assessment-Evaluación de 2019

- 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

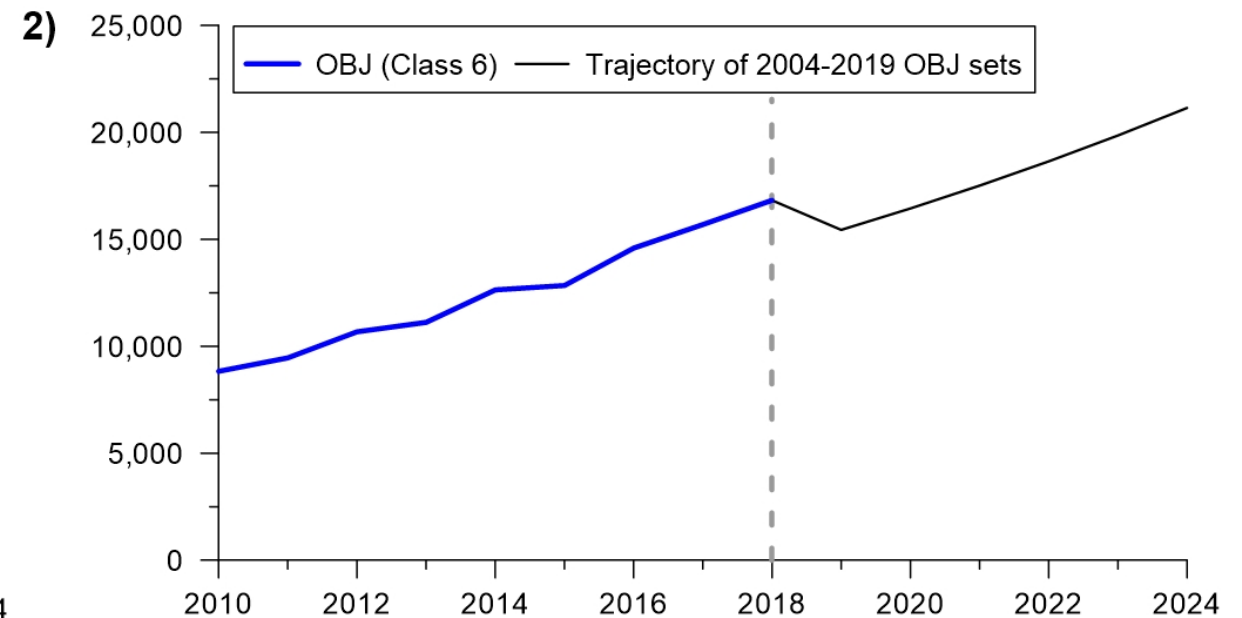
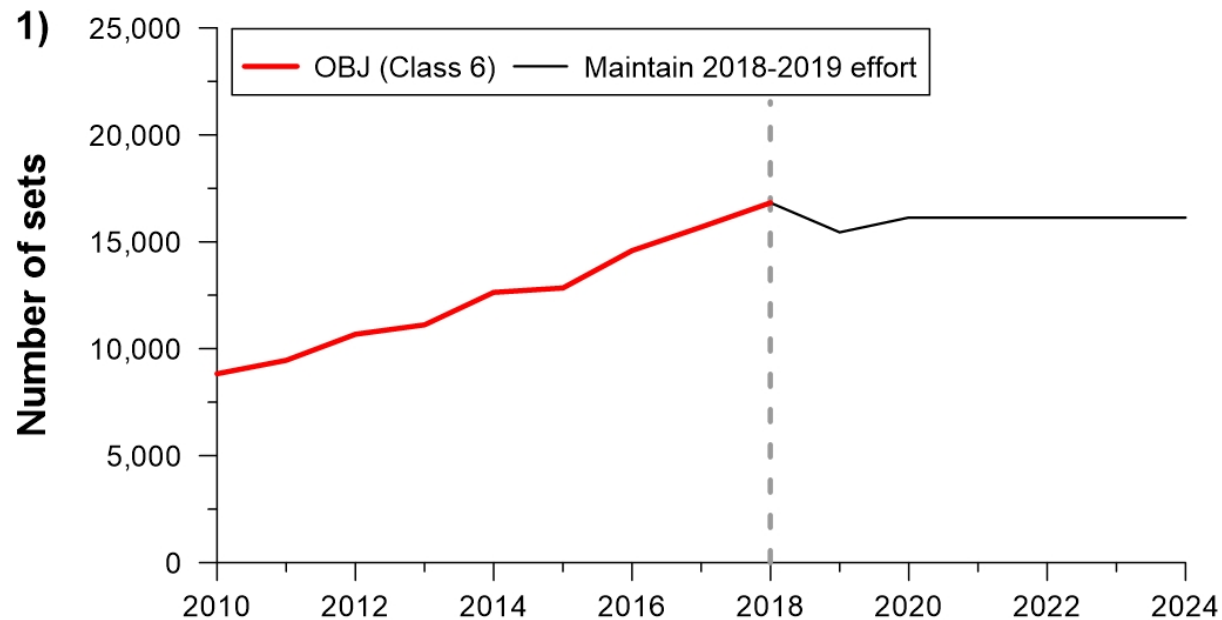
1. Average no. of OBJ sets for 2018-2019 maintained from 2018 to 2024
 - Effort for all other fisheries maintained at 2018 levels



Modelled scenarios

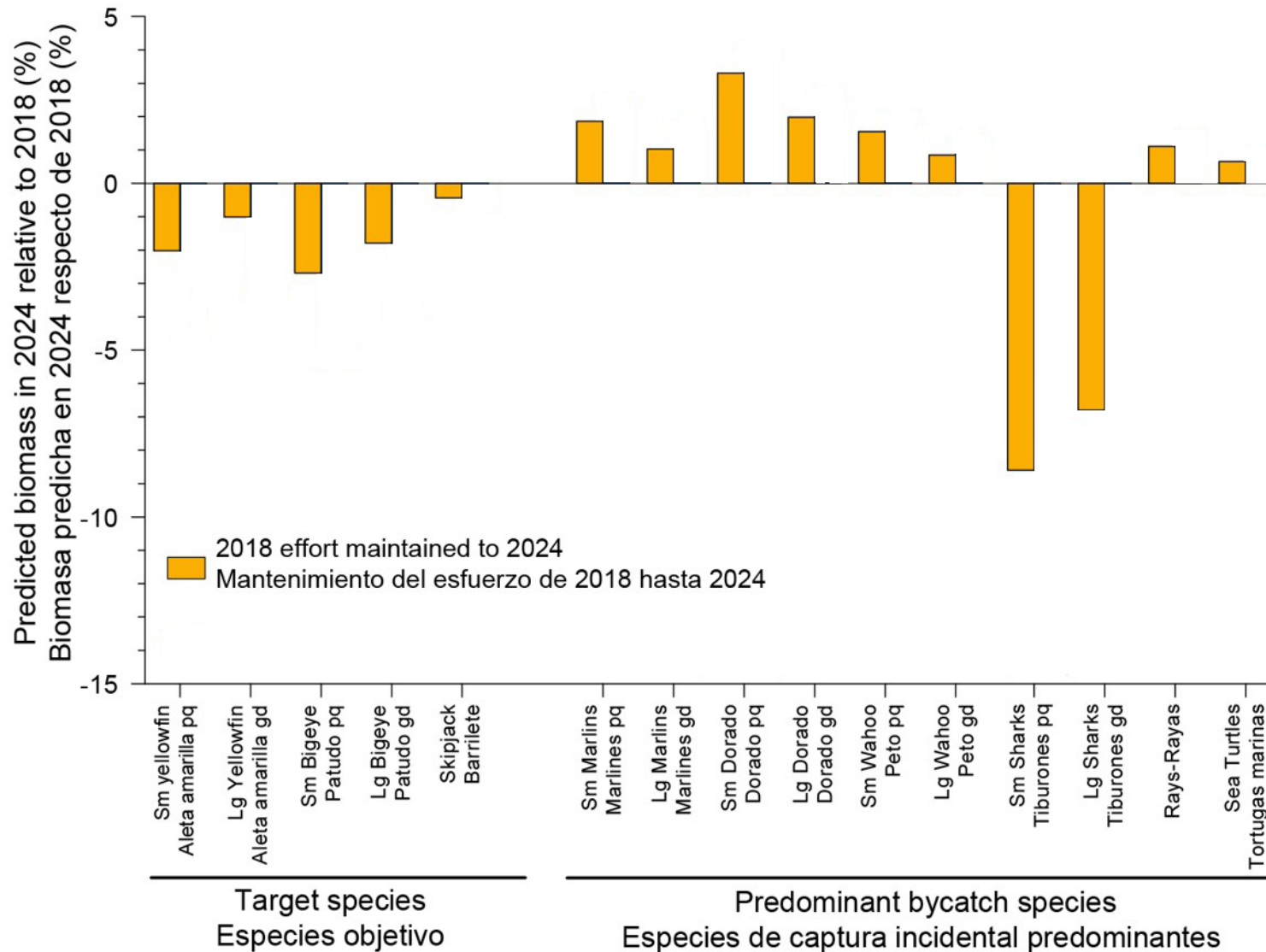
2. Increase OBJ sets following the trajectory from 2004-2019

- Effort for all other fisheries maintained at 2018 levels



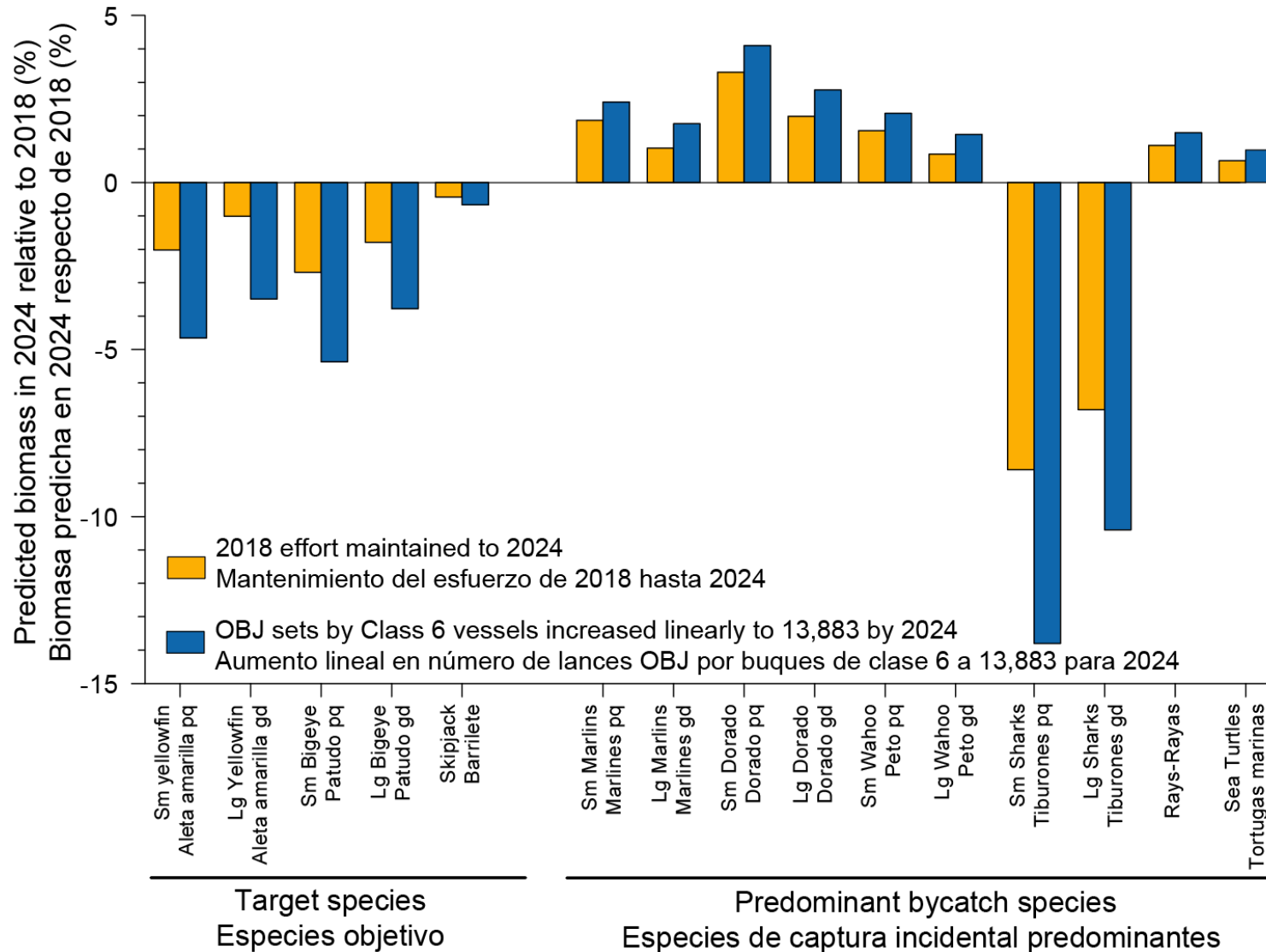
1) Maintain 2018/2019 effort

- Biomass of tunas ↓1-3%, retained bycatch ↑1-3%, sharks ↓7-9%



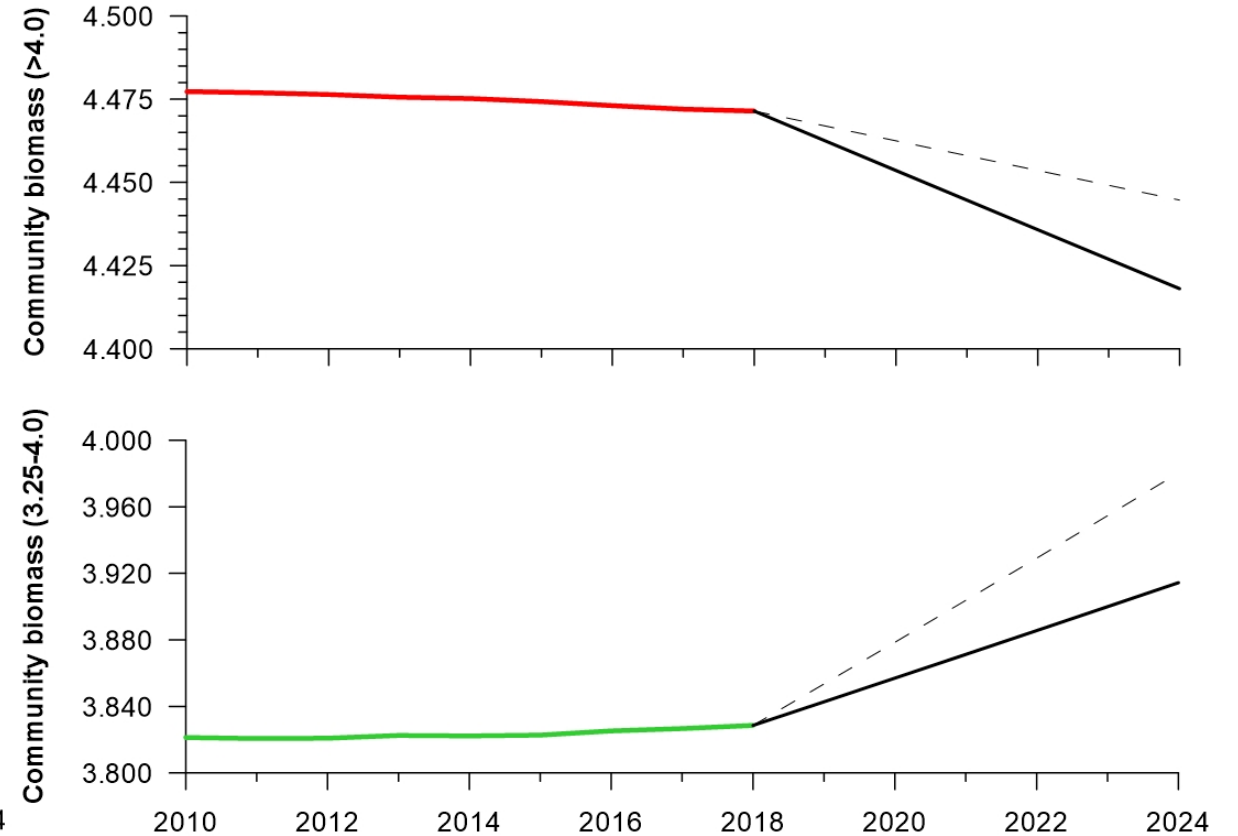
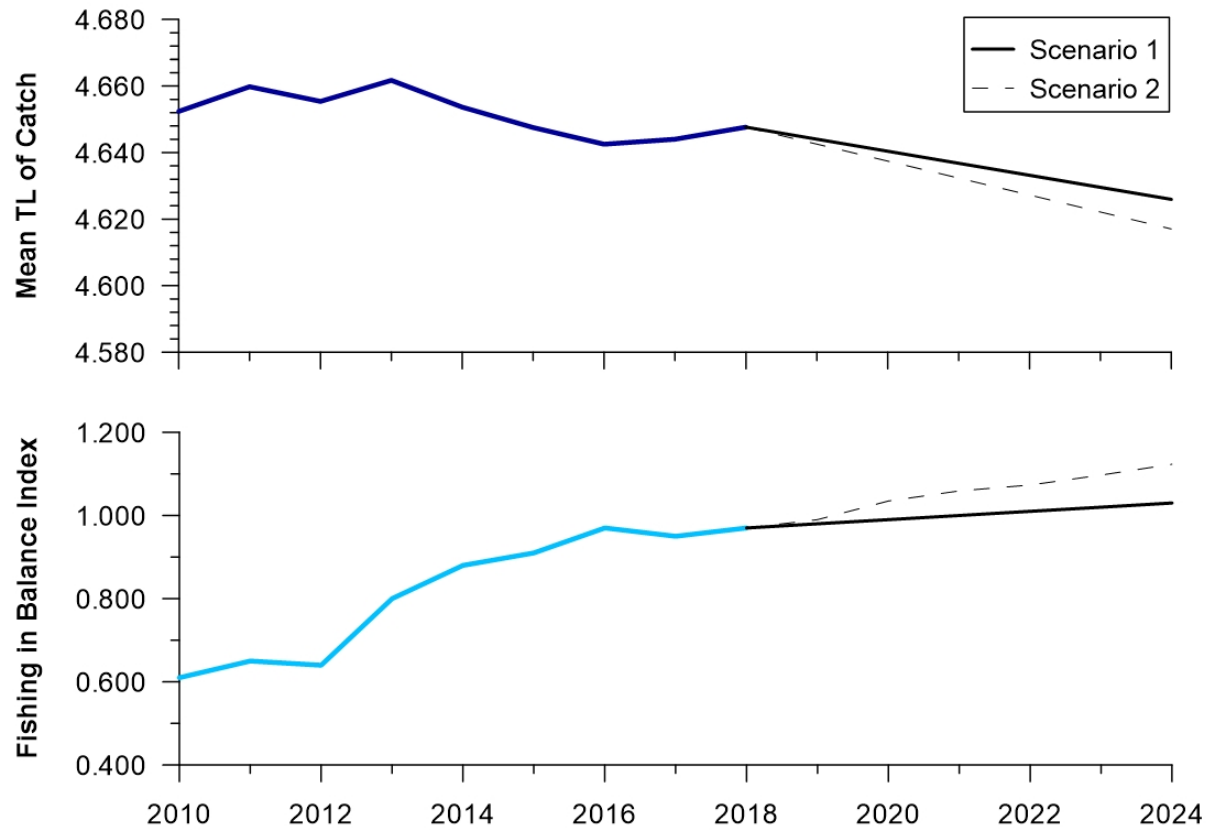
2) Increase OBJ effort

- 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

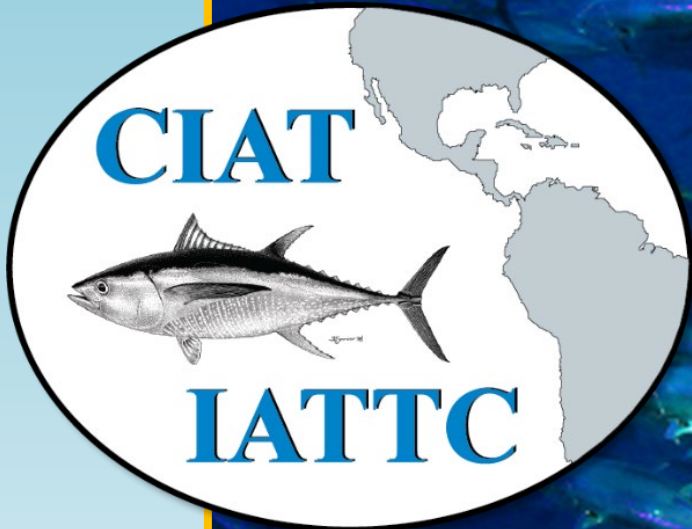


Summary

- 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?

