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Indian Ocean tropical tunas in MyFISH, the European FP7 project aiming to develop new MSY indicators

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Abstract

The Indian Ocean (IO) is an area of great commercial interest for European fishing industries. Among others, European fleets target bigeye, yellowfin and skipjack, three tuna species that conform the known as tropical tuna fisheries in the IO. These species inhabit international and national jurisdiction waters, which makes them prone for their collective management through Regional Fisheries Management Organizations (RFMO). The Indian Ocean Tuna Commission (IOTC) is an intergovernmental organization responsible for the management of tuna and tuna-like species in the IO. The Commission has among other functions, responsibilities on (1) data collection, (2) research coordination, (3) the adoption of conservation and management measures to ensure the conservation of fish stocks and to promote their optimal utilization, and (4) consider socioeconomic aspects of fisheries considering the interests of developing coastal States. Within IOTC, the Maximum Sustainable Yield (MSY) has been used as a recommended target reference point for the tropical tuna fisheries. MyFISH aims to investigate a series of alternative target reference points in order to satisfy management preferences from stakeholders through numerical modelling and, interviews with interested parties in order to show their view on the challenges and potential solutions for the management of fisheries.

Following the structure of the project, this study is based on the MSY variants proposed in the Widely Ranging Regional Fisheries Advisory Council (RFMO) in the kick-off workshop in Vigo in April 2012. This information has been used to (1) define variants, constraints and to develop a numerical model framework, which has been used to (2) evaluate these variants, producing output in the form of a Decision Support Table (DST); finally, we discussed alternative ways to (3) implement the MSY variants in order to most effectively improve fisheries' performance and respect management constraints.

Introduction

MyFISH at a glance

"MyFISH (Maximizing Yield of Fisheries while Balancing Ecosystem, Economic and Social Concerns is a EU (Frameworl Program 7) project which aims at developing new Maximum Sustainable Yield indicators that can ensure high levels of fishery yield while respecting ecological, economic and social sustainability thus contributing to achieve Good Environmental Status (GES) foreseen in the EU Marine Strategy Framework Directive". The project follows a regional approach in which the Indian Ocean tropical tuna fishery is included by integrating stakeholders and Regional Advisory Councils (RAC) throughout the project.

The initial definitions of MSY variants and constraints by scientists together with stakeholders in WP1 (DEFINE) is followed by evaluations of the models capable of describing biological interactions and related uncertainties within the fisheries. After that, under WP2 (EVALUATE), the impact of different environmental and economic scenarios will be investigated through the use of Decision Support Tables, which will be presented to stakeholders for consultation. The social and environmental impact of the alternative scenarios is investigated in the detail in WP3 (IMPLEMENT) in close cooperation with stakeholders. Information gathered from stakeholders will be included as feedback into WP 1 and 2. The results from WP1, WP2 and WP3 will be synthesized in WP4. Knowledge transfer, including dialogue with managers, policy makers and stakeholders, demonstration and promotional activities take place in all work-packages using tools set in WP5 (DISSEMINATION).

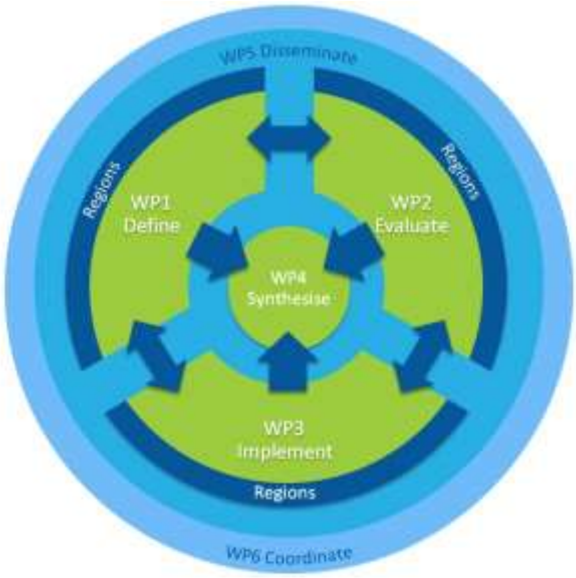

Figure 1. Structure of MyFISH

Progress of the IOTC tropical tuna case study within MyFISH in brief

The European fleets targeting tropical tunas in the Indian Ocean are mostly French and Spanish fleets using both Free School and Fish Aggregation Devices (FAD) sets. The catch from European fleets represents approximately a third of the total harvest of bigeye, yellowfin and skipjack in the IO. Therefore, there is a strong interest in the adequate management of these stocks. For this, the application of robust methods in the management process is paramount, which requires advanced quantitative methods to increase the robustness of the scientific advice with respect to both the intrinsic properties of natural systems and our ability to understand, monitor and control them. IOTC and other tuna RFMOs are in the process of developing Management Strategy Evaluation (MSE) frameworks in order to produce robust management due to the many uncertainties on tuna species dynamics.

MSE uses complex models which are primarily used to test the robustness of simpler assessment-management rules before their implementation. The MSE process demands a frequent communication with stakeholders in order to know in advance the fishery indicators they would like to optimize and this aspect suits well with the objectives of MyFISH, which promotes stakeholders' participation in the management process.

Until now, the stakeholders' involvement in this project has reduced to the participation of the Long Distance RAC in the kick off meeting in Vigo (Spain) where MSY variants were proposed and interviews with representatives of the European industries operating in the area. Therefore, we expect to take advantage of the IOTC's TTWG activities to discuss this project further with other parties interested in the adequate management of this fishery.

To do so, we present some preliminary results and expect to receive feedback on the DST and possible measures to improve the management of IOTC tropical tunas fisheries' performance.

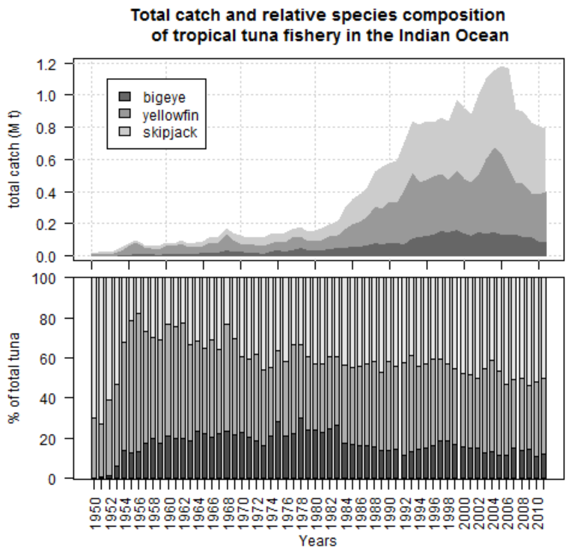

Figure 1. Catch and % of total of bigeye, yellowfin and skipjack in the Indian Ocean.

Methods

Modelling

The MSE approach requires mathematical representations of two systems: a “true” system and an “observed” one. The true system is represented by the Operating Models (OM) that simulate the real world and include hypotheses about the full dynamics of the exploited populations, including their interaction with environmental factors. In contrast, the observed system represents the conventional Management Procedure (MP) from data collection through stock assessment and management implementation. Here, we combine hypotheses on the fish stocks interaction with the Southern Oceanic Index (SOI) as OMs and a MP that simulates the assessment and management process of tropical tunas under IOTC. This MP uses harvest control rules (HCR) in order to calculate the recommended fishing mortality and annual quotas for each stock, and the OMs can be used to evaluate its effectiveness to achieve the management objectives defined by stakeholders and GES standards.

The use of HCR requires defining target, precautionary (or buffer) and limit reference points (TRP, PRF and LRP). This aligns with the concept of Precautionary Approach, recommended in the FAO Fishery Code of Conduct and other international agreements. For this case study, we will evaluate the capacity of a suite of target reference points to fulfill the management objectives of stakeholders while maintaining fish stocks at healthy levels with high probability.

In addition, we also investigated the possibility of an easier management system, based on the overall productivity of large pelagic fisheries: Tropical tunas’ appear to operate in a single species environment, but in fact make decisions in a multispecies context. In the case of tropical tunas, this is a salient aspect due to the compensatory influence of the Southern Oceanic Index in the main three species considered (bigeye, yellowfin and skipjack tunas) and that the three species are targeted by European fleets. In order to explore this scenario, we use hypotheses on the interaction of SOI on the individual stocks and the overall productivity of the three aggregated species.

We build a numerical framework to include the impact of the Southern Oscillation Index (SOI) on the tropical tuna fisheries dynamics and management. The impact of alternative levels of target Biomass Reference Points (BRP) will be assessed for each of the three stocks (bigeye, yellowfin and skipjack). The numerical framework will be composed by an Operating Model that will be driven by a surplus production function and by the impact of SOI. In contrast, the Management Procedure model will be composed by the same surplus production model without any environmental driver but with alternative target Biomass Reference Points for management. The aim of this investigation is finding robust target BRP to ensure that biomass is aboveMSY levels with high probability accounting for the uncertainty on the environmental impact of these fisheries in the future.

Management Procedure, Harvest Control Rules and Reference Points

When managing fisheries, decisions have to be made with incomplete knowledge. Therefore, to reduce risk, Precautionary Approach (PA) principles are adopted (García, 1966). The PA recommends the use of Limit and Target Reference Points (LRP and TRP). If a LRP is reached, management action should limit fishery development and corrective action should be taken (García, 1966). LRP and TRP are used to define a Harvest Control Rule (HCR) to specify in advance what actions should be taken when the limits are reached. Figure 3 shows a HCR plotted on a phase plot of harvest rate (F) relative to F_{msy} and stock biomass (B) relative to B_{msy}. Annual catch (TAC) will be estimated with a harvest rate corresponding to the estimated biomass in the HCR. For example, if the assessed biomass is above the LRP (in this case B_{msy}), the annual quotas will be estimated for a Target harvest rate (TRP). In contrast, if the estimated biomass is below the LRP (B_{msy}), the quotas will be estimated with the fishing mortality corresponding to the assessed biomass, lower than the TRP.

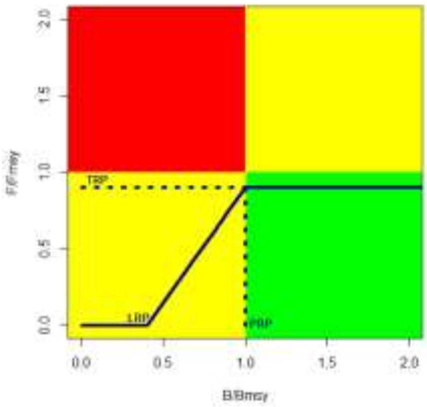

Figure 3. Harvest Control Rule (blue) plotted on a phase plot of harvest rate relative to Fmsy and biomass relative to Bmsy. TRP is Target Reference Point (Ftarget) and LRP is Bmsy (Blimit).

The aforementioned HCR is embedded in a Management Procedure, which includes a stock assessment model. Here, we use a surplus production model (Schaefer, 1954) initially conditioned with the assessed biomass of the three stocks from the latest stock assessments (Langley et al 2012, 2013; Sharma, 2012). The MP model and the HCR equations are explained in the Appendix.

The Reference Points that we used for the HCR are B_{msy} as PRP, 0.4 x B_{msy} as LRP, and a series of TRP ranging from F_{msy} and $F_{msy}/1.5$.

The indicators of constraints are the probability of a stock being above B_{msy}, i.e. $p(B/B_{msy})>1$.

The MSE framework will seek for the stocks to be above this LRP with a probability of 0.9 or above. This condition will have to be fulfilled with the management actions aimed at maximizing stakeholders' objectives.

The Operating Models

Harvest Control Rules (HCR) are not necessarily precautionary if they are not formally evaluated to determine how well they actually achieve their goals given uncertainty related to the status of the stock relative to reference points, biology and environmental events inherent to the system being managed (Kirkwood and Smith, 1995).

Here, we use different hypotheses about the influence of the Southern Oceanic Index (SOI) on the dynamics of the three stocks evaluated to build the Operation Models of the MSE framework. We formally evaluate the impact of the annual TACs calculated with the HCR of the Management Procedure (MP) with a set of OMs. These OM are Generalized Additive Models (GAM) where the Annual Surplus Production (ASP) of the stocks is fitted to historical catch and assessed biomass series (Figure 4).

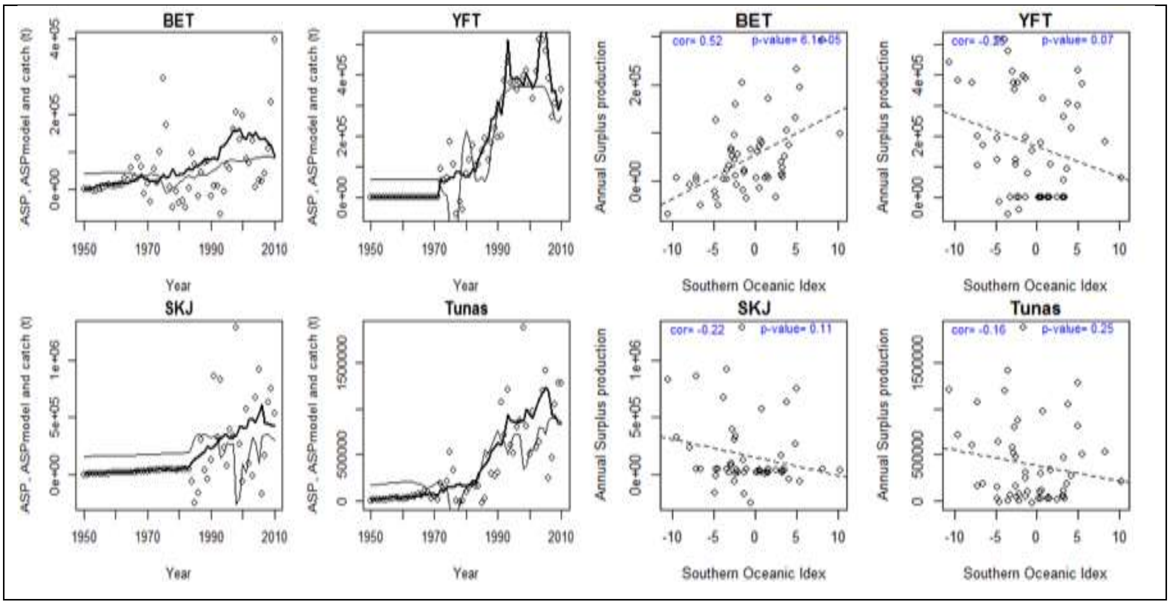

Figure 4. Fit of ASP with GAM of the form: ASP~aB+bB^2+cSOI. The linear relation between SOI and ASP is also shown.

Preliminary results

WP 1 – Define

The stakeholders involved in the Wide Ranging Fish working group of MyFISH chose a series of MSY variants. In order of preference, stakeholders aim to maximize: (1) *Catch*, (2) *Inclusive governance*, (3) *Stability*, (4) *Yield*, (5) *Useful knowledge*. In addition, we define a MSY variant named (6) *Multispecies MSY*, as the maximum response to fishing from the total aggregated biomass in the highest trophic level of the pelagic ecosystem. In this case, we propose that this aggregated biomass is the sum of the biomasses of the three tuna species considered as Indian Ocean tropical tunas.

The constraints, the conditions that the proposed MSY variants will have to fulfill, correspond to the high probability of the three stocks to be at biomass levels above the one corresponding to MSY (B_{msy}) and to the low probability of their fishing mortality to be above that of MSY (F_{msy}). These constraints are summarized in the *high probability of fish stocks to be in the green zone of the Kobe plot (cf. p.13).*

The management measures contemplated in the modelling framework are restrictions to the annual catch (*Total Allowable Catch*). The harvest control rules in the MP are used to calculate the amount of total catch that can be produced annually.

WP2 – Evaluate

Three performance measures were used to evaluate the alternative target reference points: Average quota (TAC), probability of being in the green zone of the Kobe plot (pGreen) and the InterAnnual Variability of catch (IAV) (Table 1).

Table 1

					Single Species				
		TAC (t)			pGreen			IAV (%)	
Ftarget	BET	YFT	SKJ	BET	YFT	SKJ	BET	YFT	SKJ
1.00	88256.74	177816.60	193856.90	0.41	0.03	0.20	5.92	93.29	25.23
1.10	85633.42	309746.40	189846.30	0.95	0.13	0.40	4.44	95.75	21.31
1.20	83088.80	318042.10	182196.60	1.00	0.26	0.58	3.70	86.08	18.46
1.30	80372.66	329723.40	175267.70	1.00	0.52	0.73	3.31	54.10	15.87
1.40	76928.51	327306.90	168800.60	1.00	0.93	0.82	3.05	25.66	14.02
1.50	73780.54	316957.00	162048.50	1.00	1.00	0.89	2.89	15.53	12.54
					Multispecies				
		TAC (t)			pGreen			IAV (%)	
Ftarget	BET	YFT	SKJ	BET	YFT	SKJ	BET	YFT	SKJ
1.00	80364.60	123020.90	180810.60	0.44	1.00	0.34	31.55	3.89	22.20
1.10	79112.79	109839.60	183353.30	0.72	1.00	0.58	30.81	3.43	21.08
1.20	76134.14	99459.94	180942.40	0.90	1.00	0.77	29.60	3.08	19.96
1.30	72351.27	90676.60	177039.90	1.00	1.00	0.89	28.23	2.78	19.12
1.40	68598.82	83534.52	173638.00	1.00	1.00	0.98	26.65	2.57	18.23
1.50	64579.46	76884.23	171681.70	1.00	1.00	1.00	24.87	2.37	17.38

The single species approach will allow higher sustainable catch than the multispecific. A trade-off is observed between average catch and the probability of being green and the stability of catch in the single species scenario. For example, a reduction of 3% of annual catch increases the probability being in the green zone to 95%. The reduction of variability while increasing the level of precaution is notable for skipjack, where the variability is halved by reducing the catch in 16%. The case of yellowfin is not clear from the simulation results: The estimated catch is predicted to increase greatly in the future due to the projected beneficial impact of SOI in ASP in the future in this species but the numbers require further analyses.

Additional figures expand the results presented in the DST and are presented in the Appendix.

WP3 – Implement

The implementation of the scenarios presented above would require that the total catch limitations for these fisheries to be adopted by all members. However, the best course of action to implement the management of these fisheries is to be discussed with stakeholders. Among other options, MyFISH considers the following table to be discussed in each case study:

	1	2	3	4
	Measures and constraints	**Topics discussed in DST** **(tick off with an "X")**	**How constraining do you expect this measure/ constraint to become?** **(0-3 or Na)***	**Comments**
1	ITQs			
2	Fishing licenses			
3	On board observers			
4	Gear restrictions			
5	TAC			
6	Area closures			
7	Season closures			
8	Effort restrictions			
9	Effort transfer scheme between vessels			
10	Decommissioning			
11	Minimum landings size			
12	discard ban			
13	In season management			
14	Maximum landings size			
15	Maintain relative stability			
16	Human accidents at sea below a specified level			
17	GES descriptors of commercial species above reference level			
18	GES descriptors of biodiversity above reference level			
19	GES descriptors of food web functioning above reference level			
20	GES descriptors of seafloor integrity above reference level			
21	Mortality of PET and other vulnerable species below specified level			

* Please indicate in the third column in the table:
Na = don't know;
0 = not relevant / constraining / threatening
1 = might become relevant / constraining / threatening

2 = relevant / constraining / threatening
3 = most relevant / constraining / threatening

Initially, the measures that are contemplated within the IOTC framework are recommended catch limitations, fishing capacity limitations, gear restrictions and spation/temporal closures.

References

Garcia, D. The Precautionary Approach to fisheries and its implications for fishery research, technology and management: an updated review. FAO Fisheries Technical Paper:1-76; 1996
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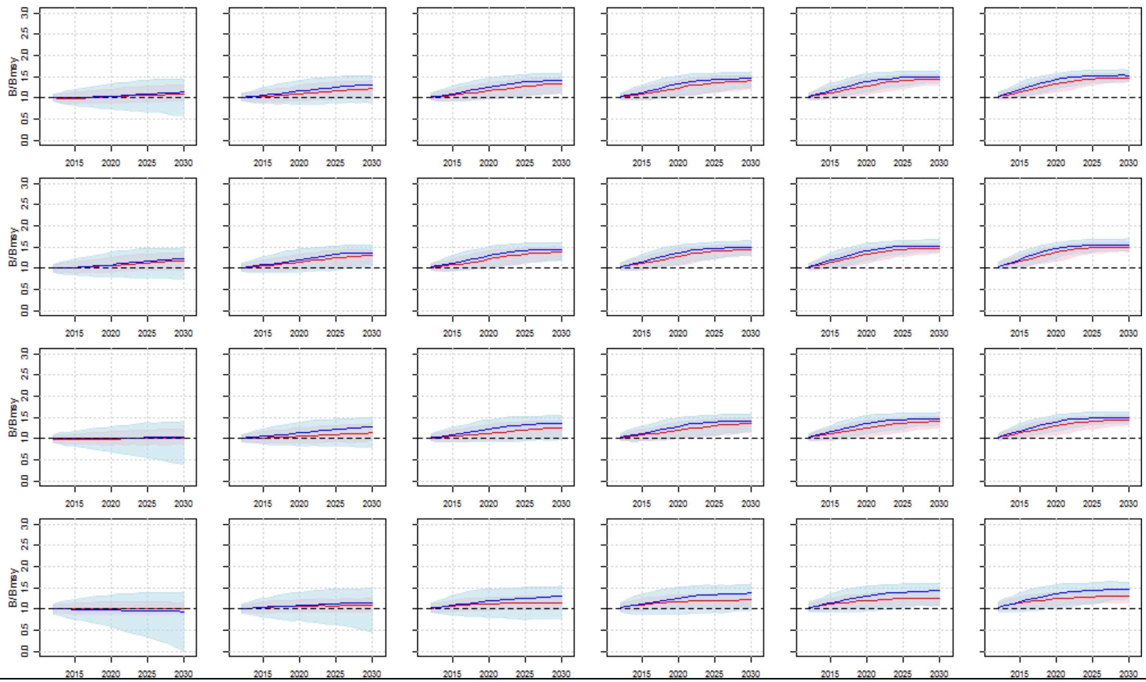
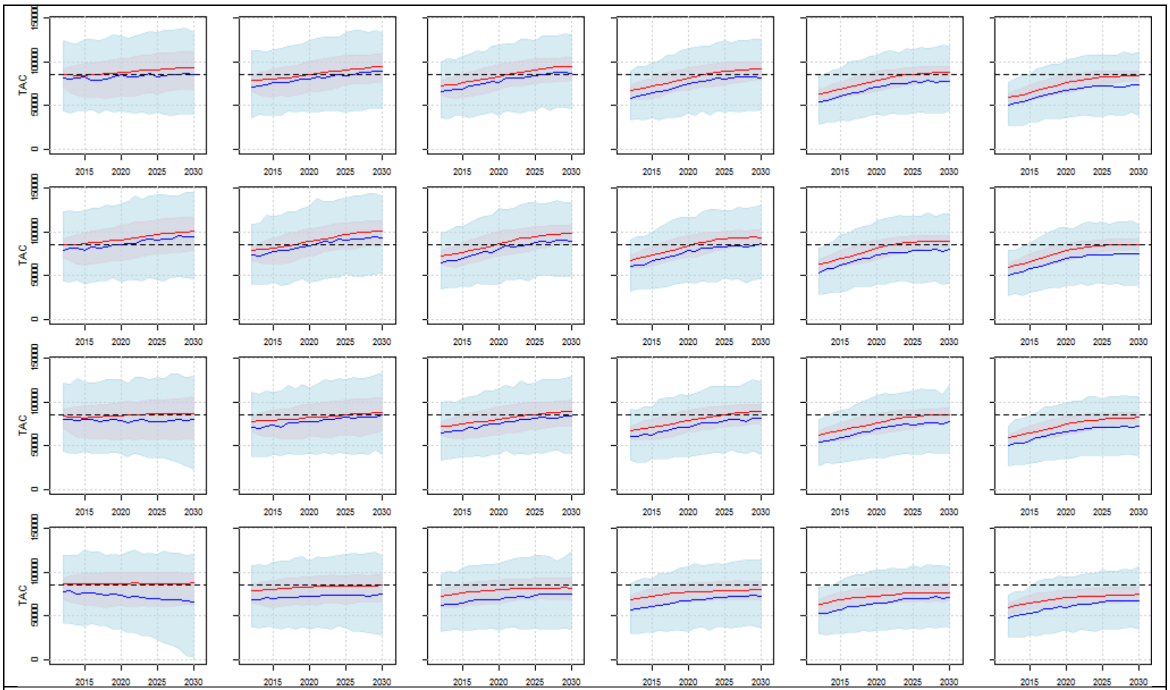
Langley, A., Herrera, M., Sharma, R. 2013. Stock assessment of bigeye tuna in the Indian Ocean for 2012. IOTC-2013-WPTT15-30.
Kirkwood, G.P., Smith, A.D.M. 1995 Assessing the precautionary nature of fishery management strategies. FAO, Rome.
Sharma, R. 2012. Indian Ocean skipjack tuna stock assessment 1950-2011 (Stock Synthesis). 2012. IOTC-2012-WPTT14-29.

Appendix

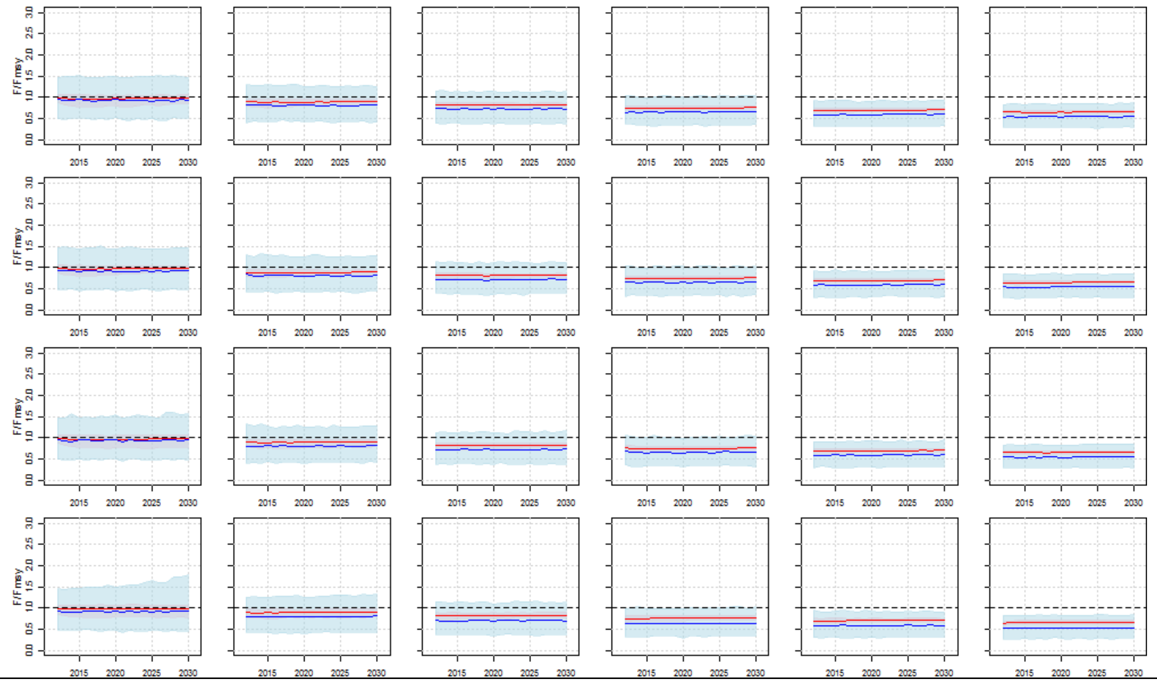
BET (biomass)



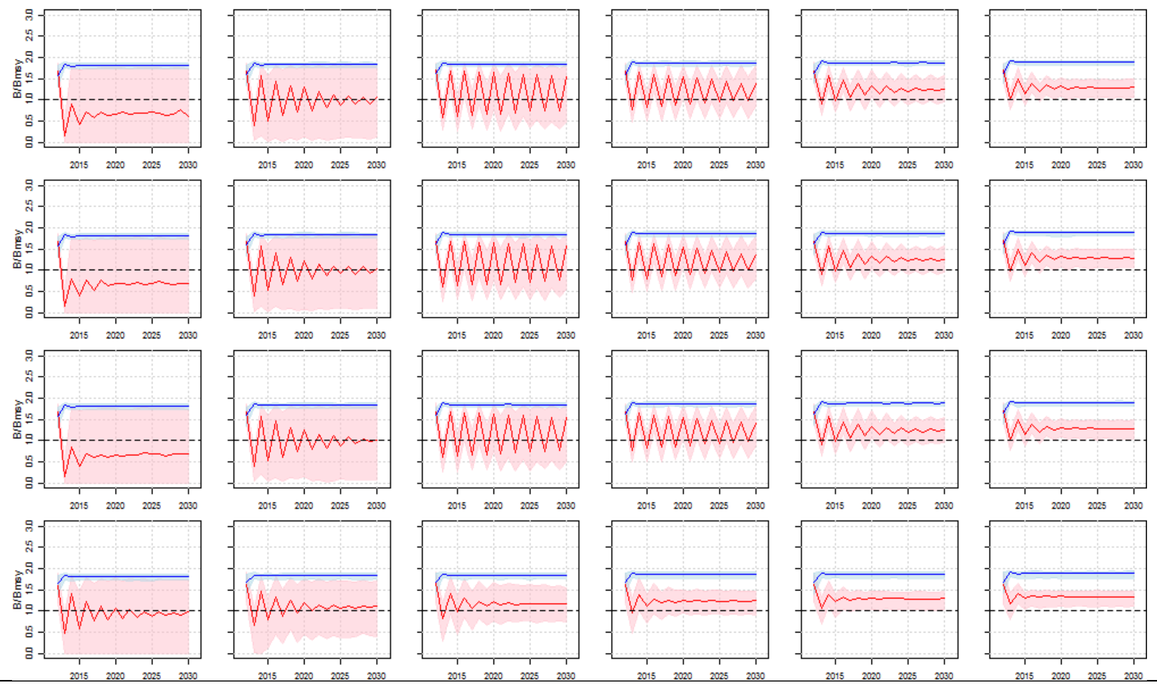
BET (quota)



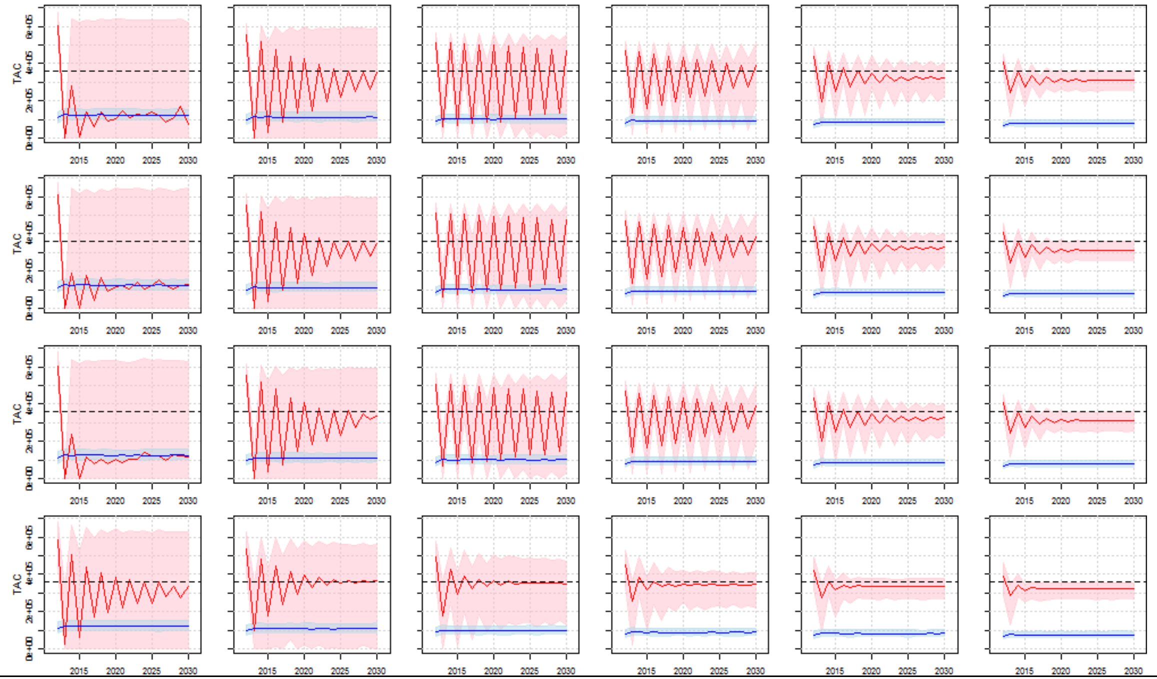
BET (harvest)



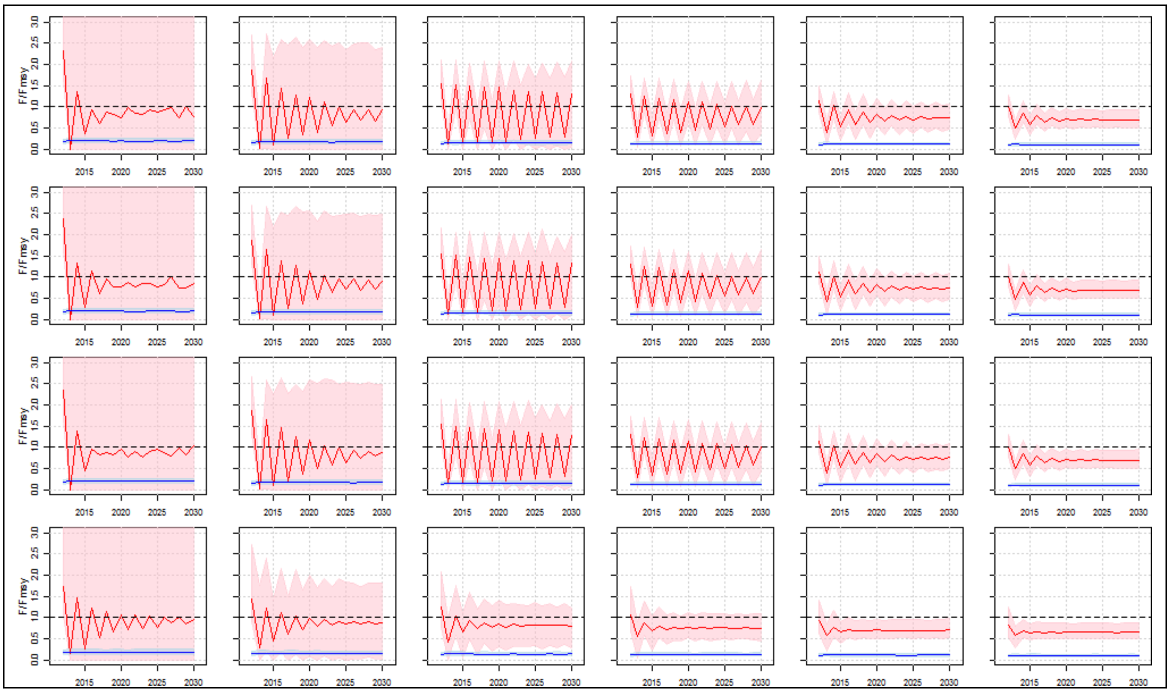
YFT (biomass)



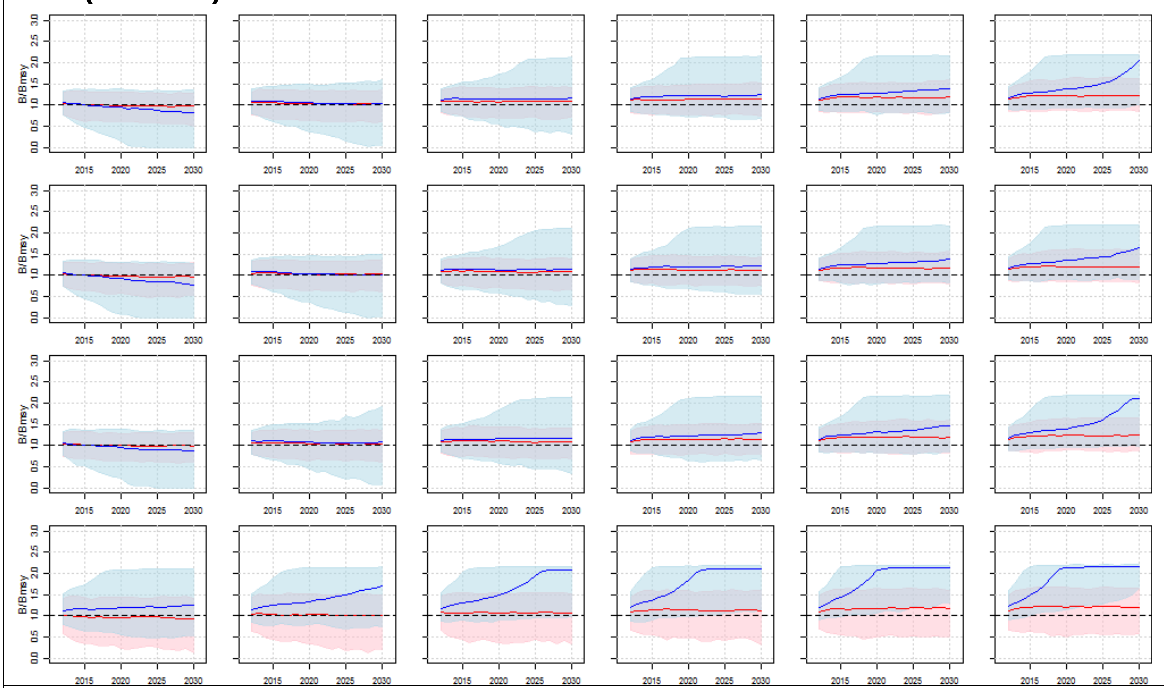
YFT (quota)



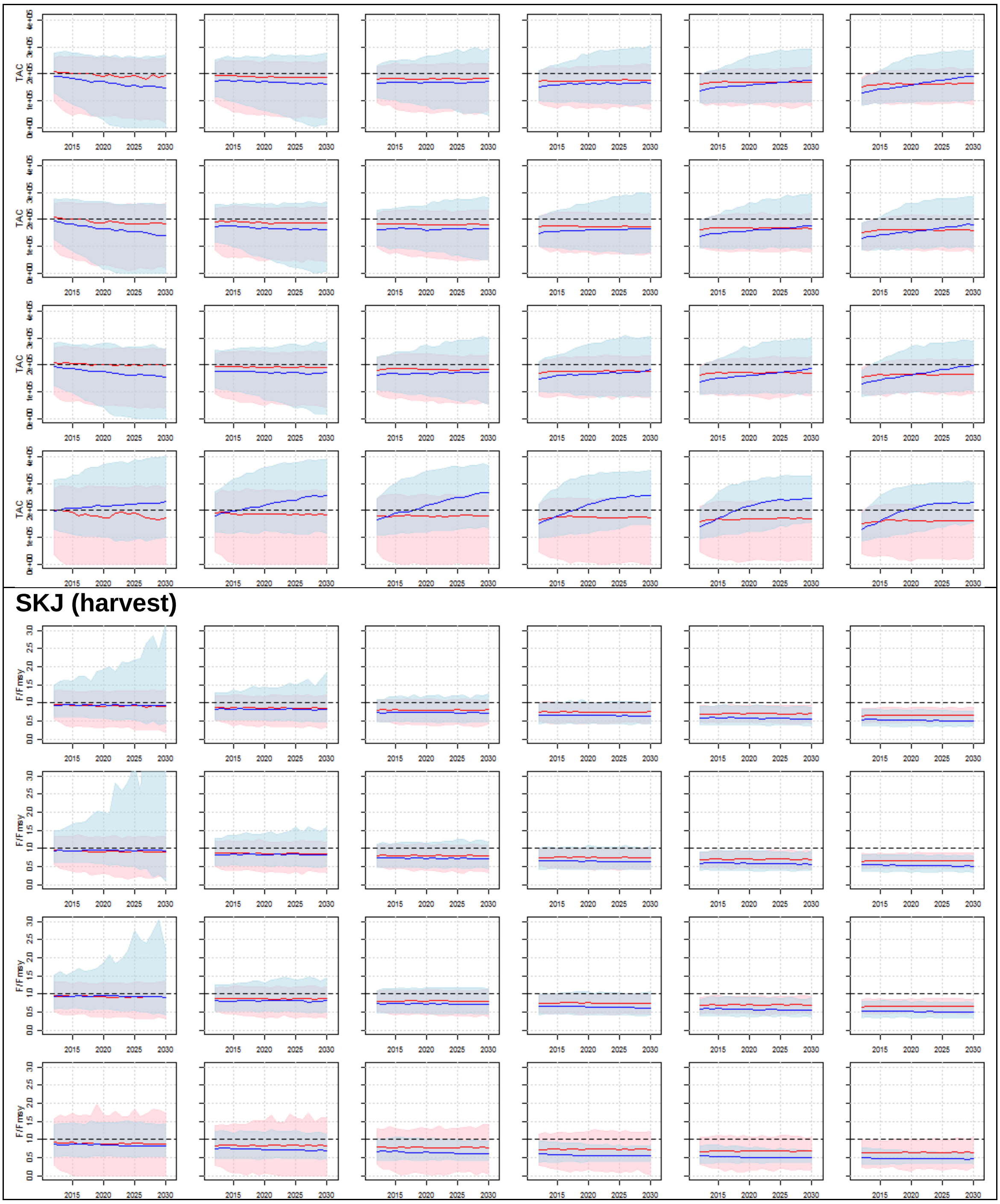
YFT (harvest)



SKJ (biomass)



SKJ (quota)


TAC
SKJ (harvest)
F/Fmsy

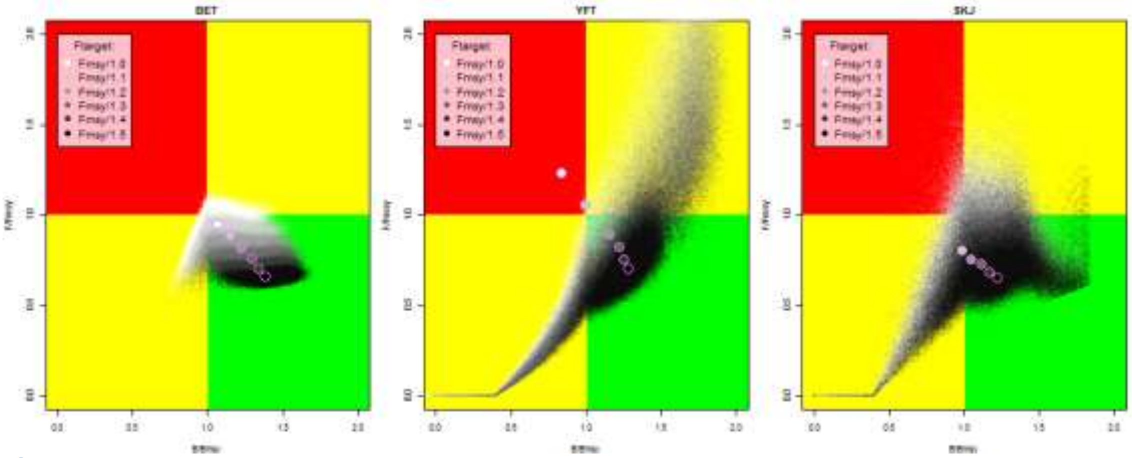


Figure 2SINGLE SPECIES

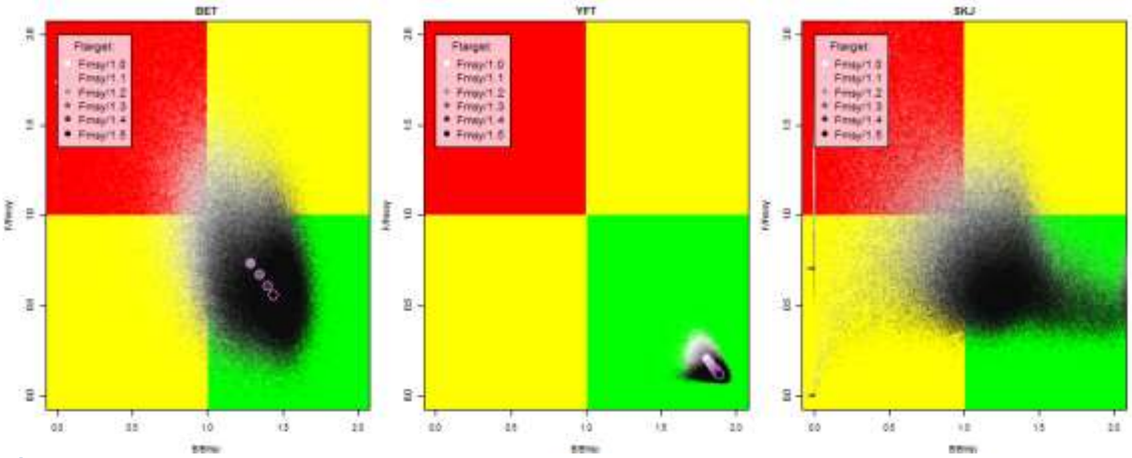


Figure 3 MULTISPECIES

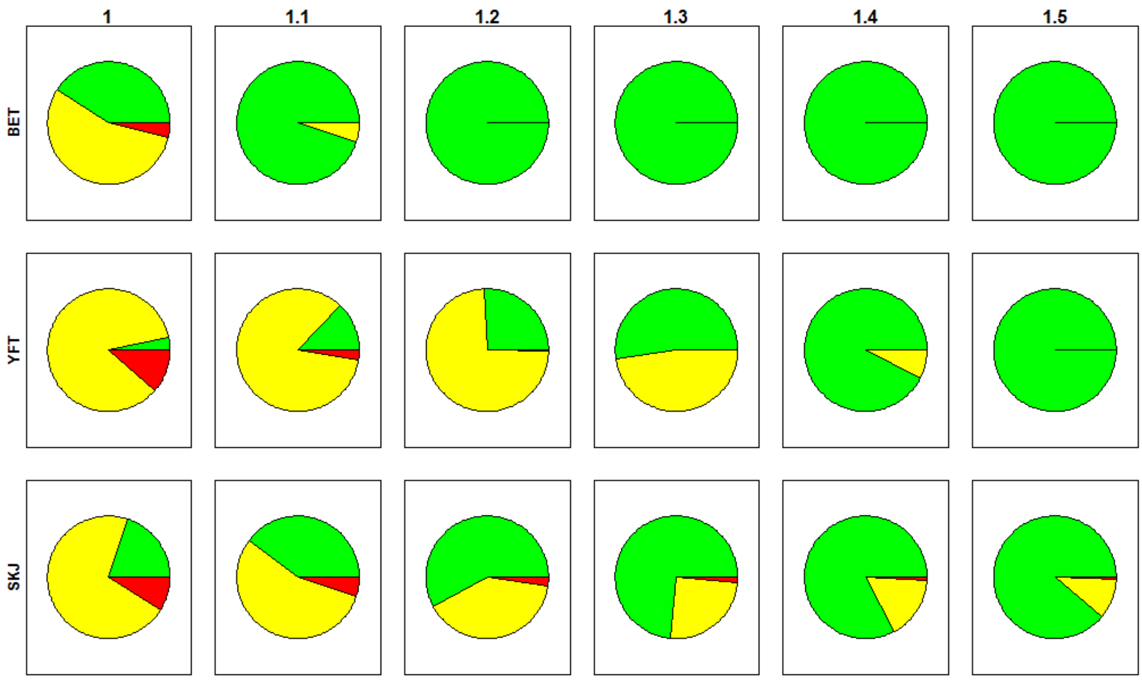


Figure 4 SINGLE SPECIES

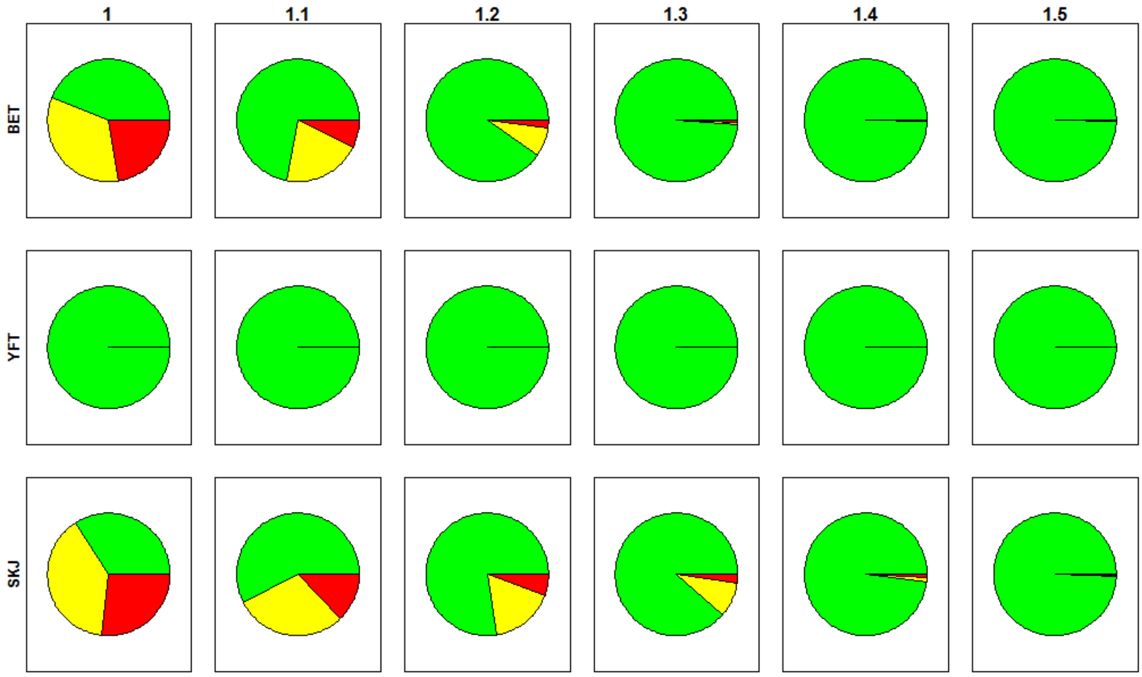


Figure 5 MULTISPECEIS