Identifying appropriate reference points for elasmobranchs within the WCPFC

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CSIRO

enhancing the benefits of New Zealand's natural resources

NIWA Taihoro Nukurangi

Terms of reference

1. Recalculate the risk-based limit reference points **(LRPs) for assessed stocks** using the updated LHPs.
2. **Advise on ways of estimating current fishing mortality** for unassessed stocks and **develop LRPs for all WCPFC key shark** species.
3. Where the stock-recruitment relationship is highly uncertain, compare $F_{current}$ to **SPR-based LRP** such as $F_{60\%SPR,unfished}$ and discuss any new insights into the recommended estimated LRPs.
4. Review **other potential LRPs** based on SPR, reduction of recruitment or empirical measures.
5. Advise on any changes to the recommended LRPs, including any suggestions for **further technical work**.
6. Review the work on the development of **stock-recruitment relationships and steepness for North Pacific blue shark** and assess the applicability of extending this work to other key shark species.

Estimating F-based reference points: data

- Life history parameters:
  - Expert workshop, Cairns, 2015. 14 WCPFC key shark species (16 stocks).
  - Silky shark: Grant et al. 2018.
  - Bigeye Thresher shark: Fu et al. 2018.
  - Porbeagle shark: Hoyle et al. 2017.
- Selectivity:
  - Blue shark: Carvalho and Sippel 2016.
  - Ocean whitetip: Rice and Harley2012.
  - Silky shark: Rice and Harley 2013.

- Grant, M. I., et al. 2018. Life history characteristics of the silky shark *Carcharhinus falciformis* from the central west Pacific. Marine and Freshwater Research: 10–11.
- Fu, D., et al. 2018. Pacific-wide sustainability risk assessment of bigeye thresher shark (Alopias superciliosus). NIWA, Wellington, April 2018.
- Hoyle, S. D. et al. 2017. Southern hemisphere porbeagle shark (Lamna nasus) stock status assessment. WCPFC-SC13-2017/SA-WP-12.
- Carvalho, F., and Sippel, T. 2016. Direct estimates of gear selectivity for the North Pacific Blue Shark using catch-at-length data: implications for stock. ISC/16/SHARKWG-1/13.
- Rice, J., and Harley, S. 2012. Stock assessment of oceanic whitetip sharks in the western and central Pacific Ocean. WCPFC-SC8-2012/SA-WP-06 Rev
- Rice, J., and Harley, S. 2013. Updated Stock Assessment of Silky Sharks in the Western and Central Pacific Ocean. WCPFC-SC9-2013/ SA-WP-03.

Two categories of reference points

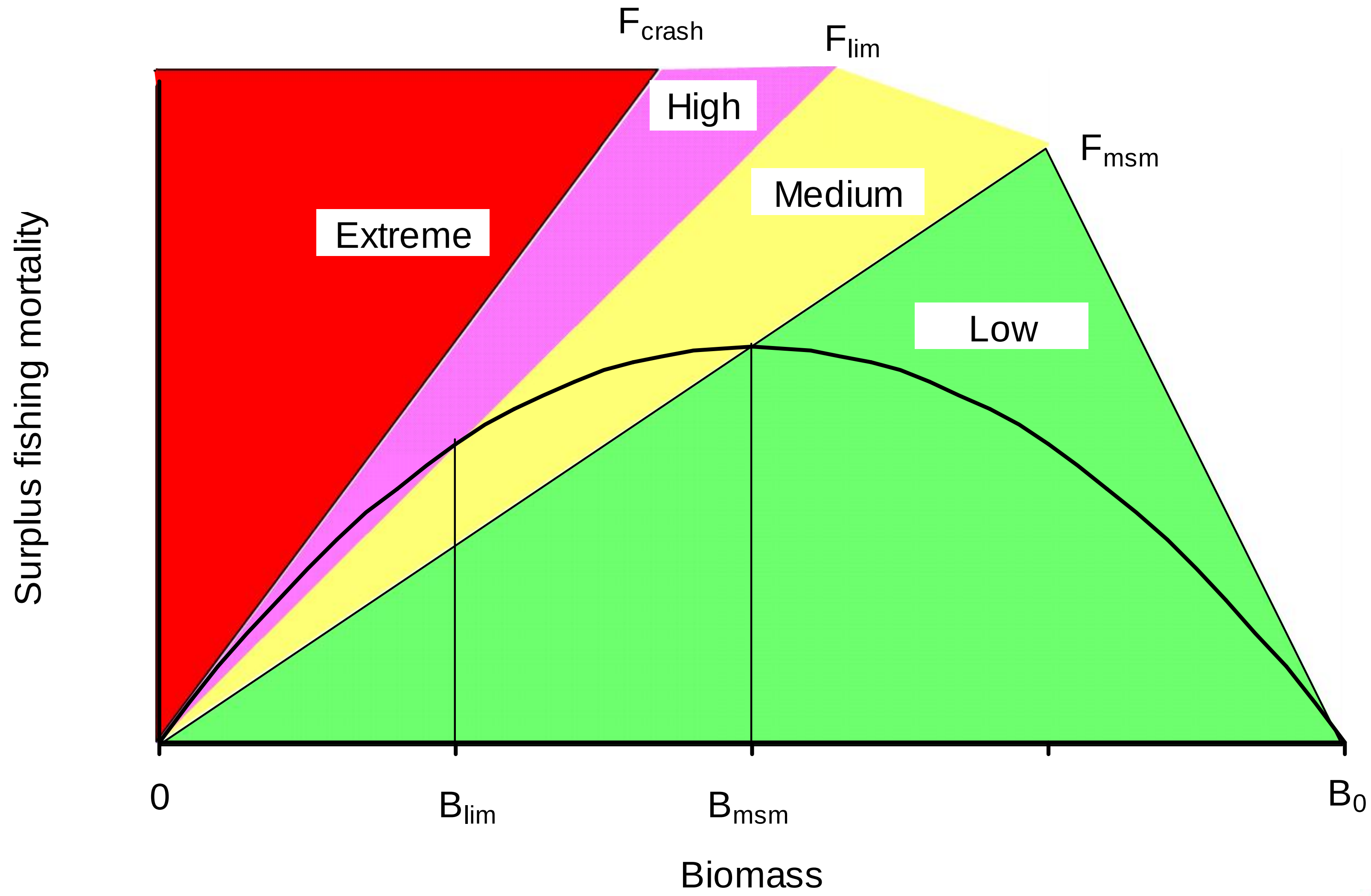
- Biomass-based (B-based):

  e.g. B_{msy}, B_{mey}, B_{lim}, B_{pa}, x%SSB_0, x% B_0 (depletion).
- Fishing mortality-based (F-based):

  e.g. F_{msy}, F_{mey}, F_{lim}, F_{pa}, $F_{x\%SPR}$ ($F_{x\%}$)

Spawning biomass per recruit (SPR) approach is a F-based reference points.

Risk-based reference points



F_{msm} = 0.5r; F_{lim} = 0.75r; F_{crash} = r

Reference points and ecological risk

	$F < F_{msm}$	$F_{lim} > F \geq F_{msm}$	$F_{crash} > F \geq F_{lim}$	$F \geq F_{crash}$
Risk	**Low (L)**	**Medium (M)**	**High (H)**	**Extreme high (E)**
Ecological consequence	**Overfishing not occurring. May keep population above 50% of virgin level**	**Overfishing is occurring but population can be sustainable**	**May drive population to very low levels in longer term**	**Population is unsustainable in long term – possibility of extinction**

Estimating M

	Method	Source
1.	Based on life span T_{max}:	Then 1
2.	Based on growth parameters K, L_{inf}:	Then 2
3.	Based on growth rate K:	Frisk 1
4.	Based on age at maturation T_{mat}:	Frisk 2
5.	Based on age at maturation T_{mat} and t_0:	Hisano
6.	Based on growth parameter K, t_0:	Chen
7.	M from literature	

1 and 2 largely using teleosts data (4 elasmobranchs in 230 species)

3 and 4 using elasmobranchs data only (30 species)

5 modified from Jensen for elasmobranchs

6 age-dependent

Methods for estimating F-based reference points

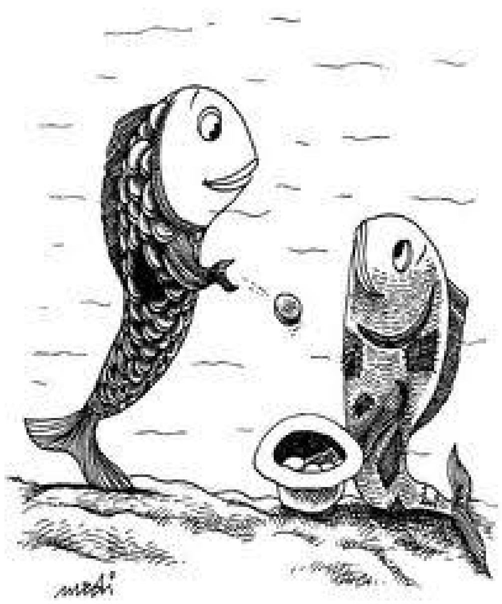
1. Empirical relationship: RPs ~ LHPs
2. Demographic analysis: Euler-Lotka equation
3. Intrinsic population growth rate from literature
4. SPR

Empirical relationship

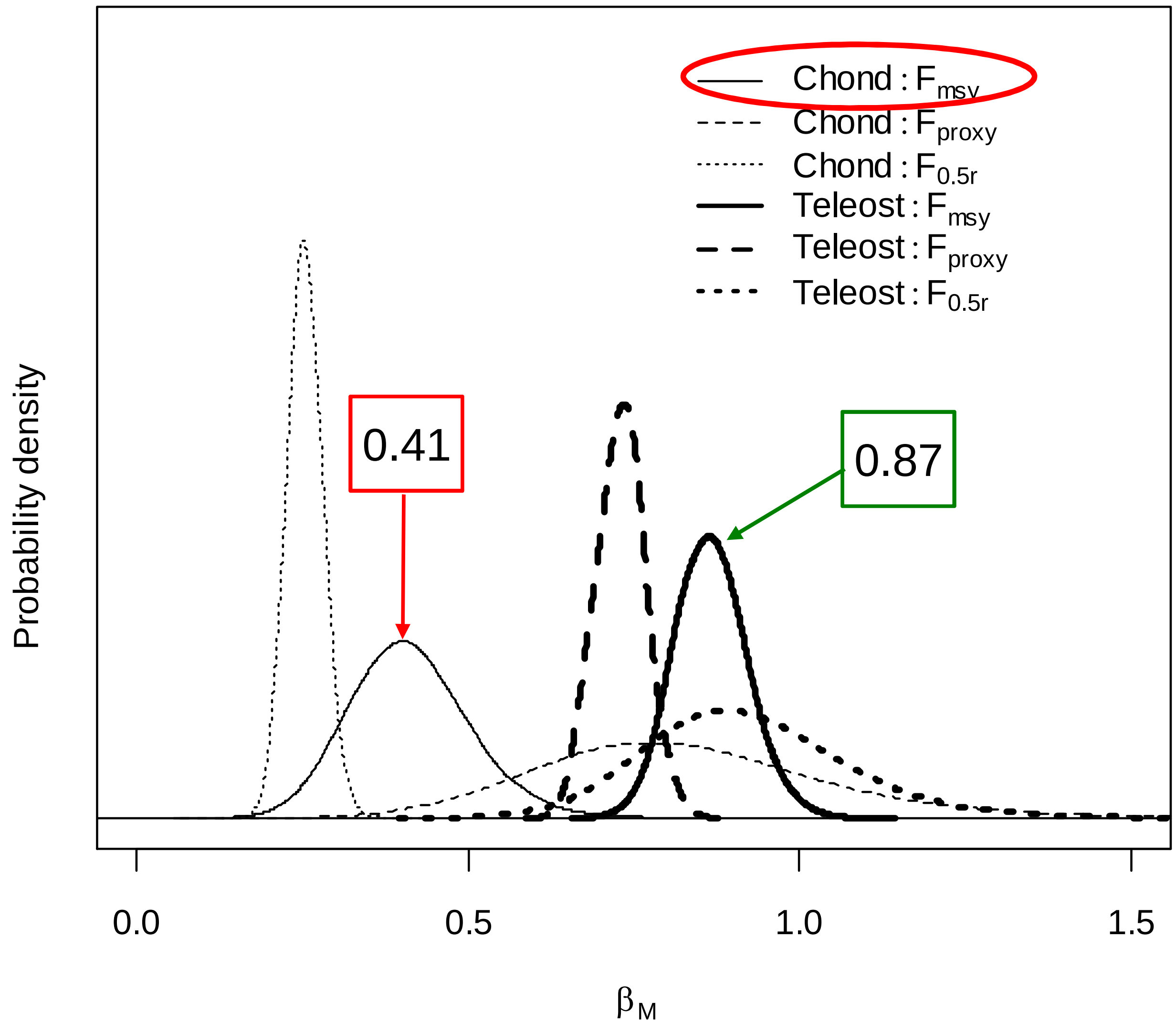
Borrowing information from the rich for the poor

$$F_{BRP} = f(\mathrm{LHP})$$

- Data from 245 data-rich species worldwide (66 elasmobranchs, 10 with F_{msy}). **F_{msy} derived from stock assessments.**
- LHP: natural mortality, growth rate, asymptotic length, maximum age, habitat, etc.
- Two taxonomic levels: Class and Order
- Bayesian hierarchical measurement error models



Probability distribution of F_{BRP} / M



Zhou, S., Yin, S., Thorson, J. T., and Smith, A. D. M. 2012. Linking fishing mortality reference points to life history traits: an empirical study. Canadian Journal for Fisheries and Aquatic Science, 69: 1292–1301.

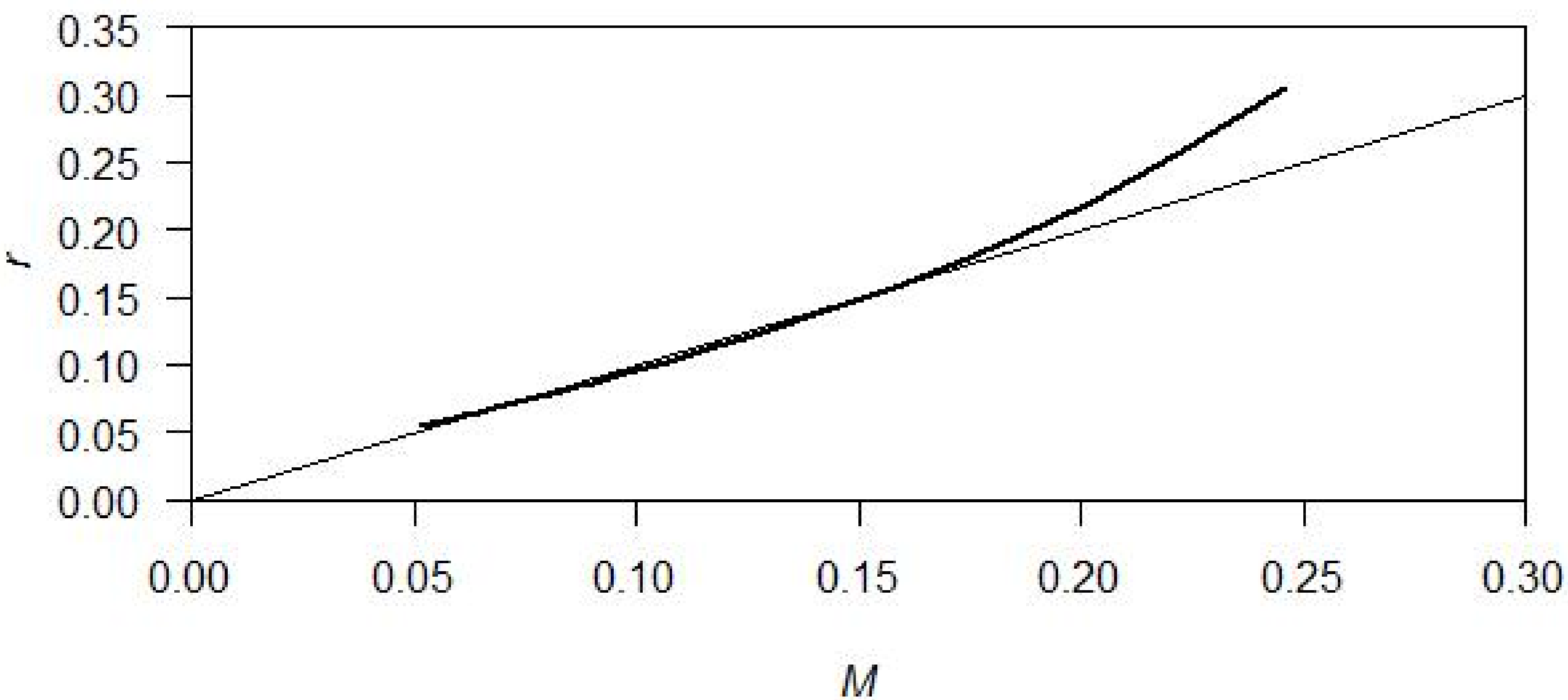
Modified Euler-Lotka equation

- $- \quad (\quad) \quad - \quad \frac{}{} \quad = 0$

Solving r (intrinsic population growth rate) requires:

1. *M*
2. t_{mat}: maturity age
3. *ls*: litter size
4. *Rc*: reproductive cycle

r as a function of *M*: Euler-Lotka eqn



$M = 1/(0.44t_{mat} + 1.87)$
ls = 13.3 (mean of the WCPFC sharks, excluding whale shark)
Rc = 1

r from literature

Spawning potential ratio (SPR)

- $\quad = \frac{\quad}{\quad}$

Deriving spawning stock biomass per recruit requires:

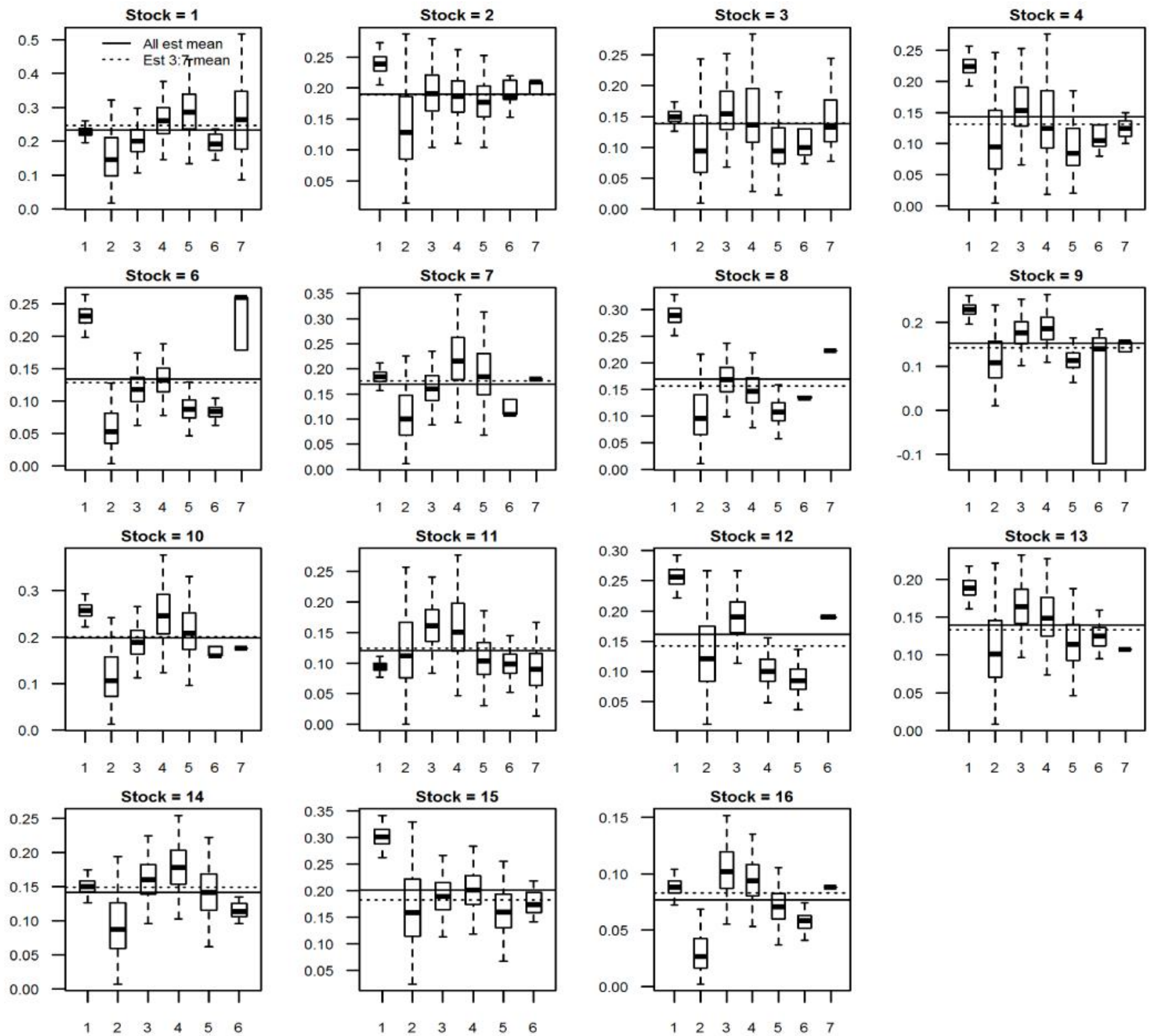
1. M;
2. growth parameters (K, L_{inf}, and t_0);
3. length at maturity L_{mat} or maturity ogive m_o;
4. maximum age t_{max};
5. length-weight relationship;
6. gear selectivity.

- Assuming $F_{60\%}$ as F_{msm}, $F_{40\%}$ as F_{lim}, and $F_{10\%}$ as F_{crash}.

WCPFC shark stocks

ID	Stock	Code
1	Blue shark – North Pacific	BSH-N
2	Blue shark – South Pacific	BSH-S
3	Shortfin mako North Pacific	SMA-N
4	Shortfin mako South Pacific	SMA-S
5	Longfin mako	LMA
6	Silky shark (WCPO)	FAL
7	Oceanic whitetip (WCPO)	OCS
8	Bigeye thresher (Pacific)	BTH
9	Pelagic thresher shark	PTH
10	Common thresher shark	ALV
11	Porbeagle shark (Southern hemisphere)	POR
12	Smooth hammerhead	SPZ
13	Scalloped hammerhead	SPL
14	Great hammerhead	SPK
15	Winghead	EUB
16	Whale shark (Pacific)	RHN

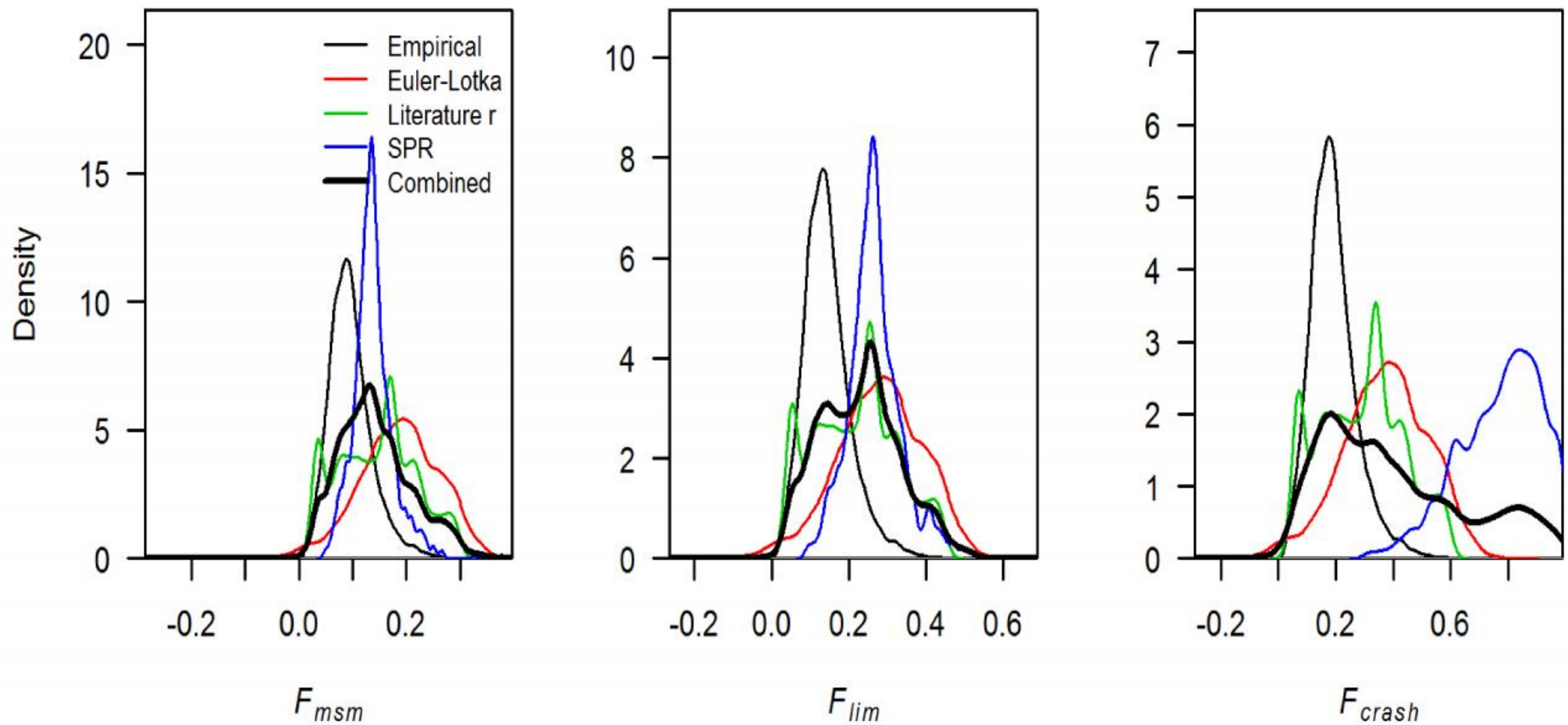
Results of natural mortality estimation



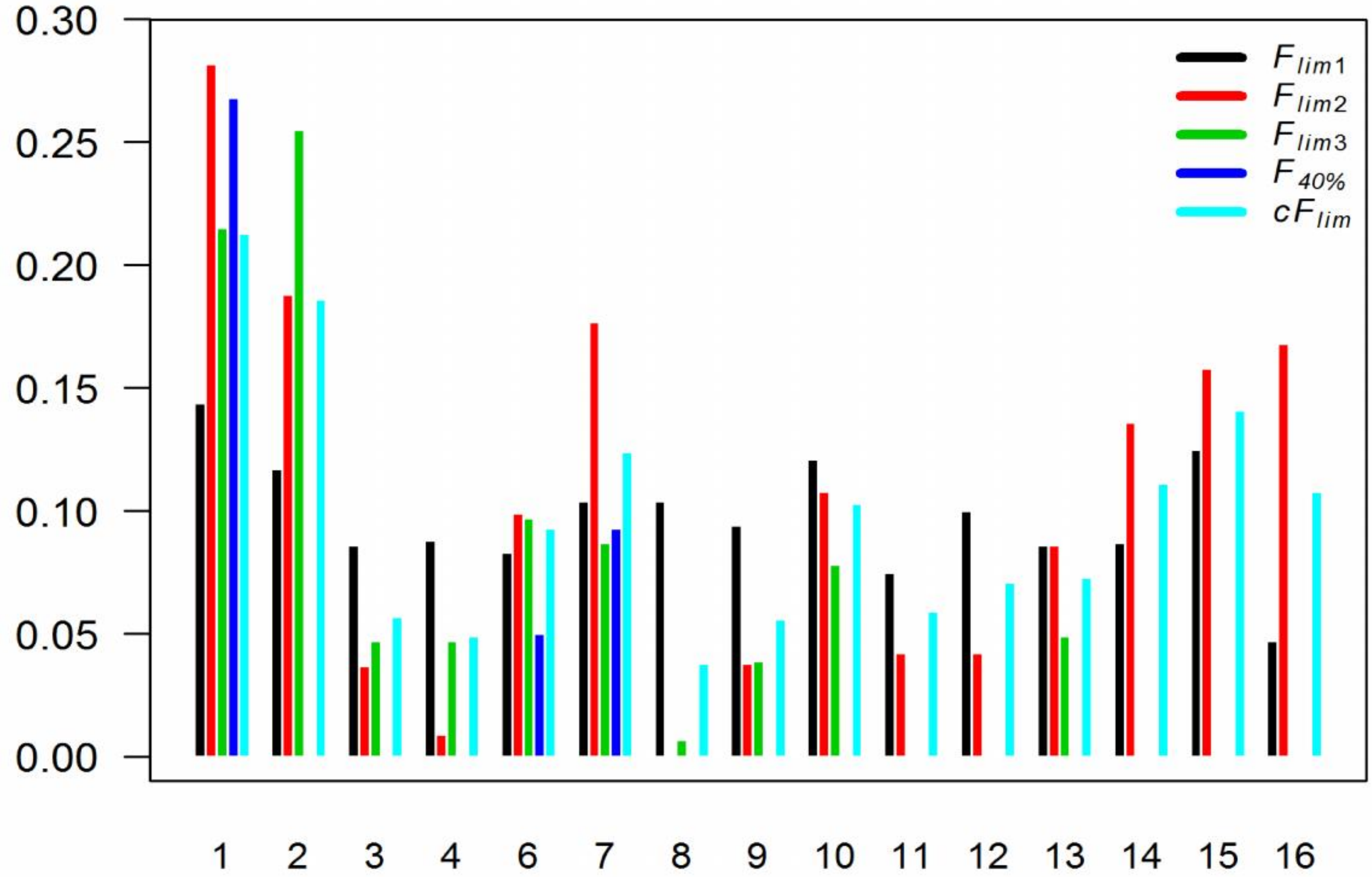
Compare M estimators 1 and 2 with overall

ID	Stock	M.1/M.all	M.2/M.all
1	BSH-N	0.98	0.73
2	BSH-S	1.26	0.78
3	SMA-N	1.09	0.88
4	SMA-S	1.57	0.85
5	LMA		
6	FAL	1.73	0.47
7	OCS	1.09	0.69
8	BTH	1.71	0.66
9	PTH	1.50	0.83
10	ALV	1.30	0.63
11	POR	0.78	1.09
12	SPZ	1.60	0.87
13	SPL	1.36	0.84
14	SPK	1.06	0.72
15	EUB	1.50	0.88
16	RHN	1.15	0.44
	Mean	**1.23**	**0.71**

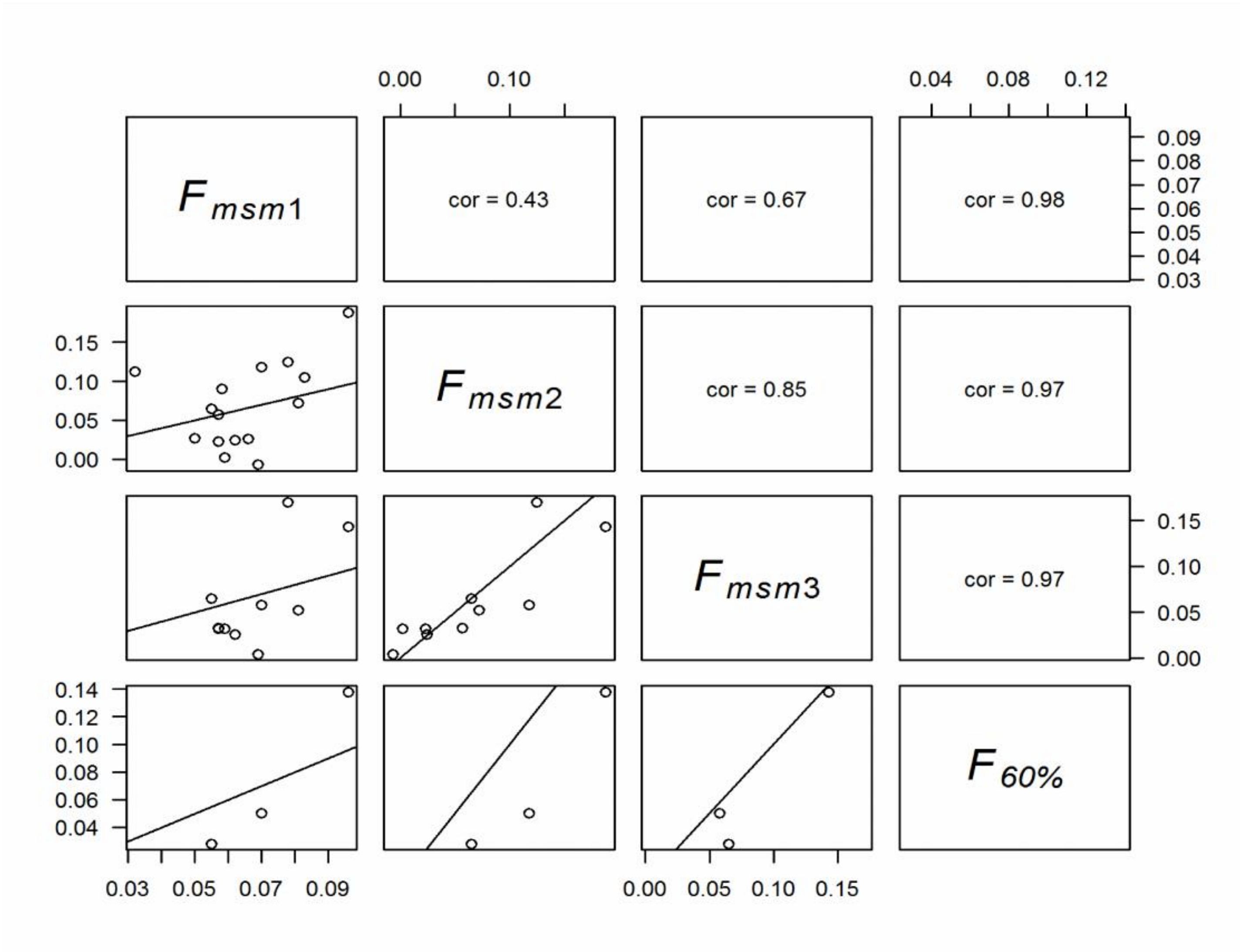
Blue shark in the North Pacific Ocean (BSH-N)



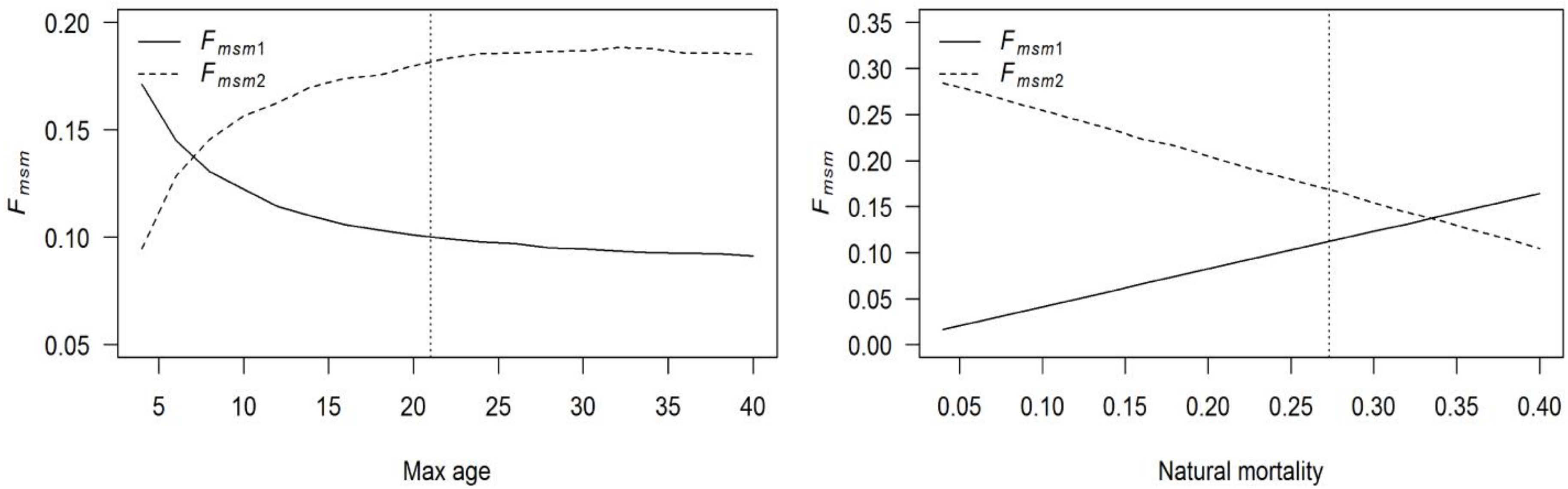
Compare F_{lim}



Comparison of F_{msm}



Empirical (Methods 1) and demographic (Method 2) sensitivity



Method 1 more intuitive and conservative

Discussion: natural mortality

- No information: for example
  - Most LHPs for Longfin mako shark
  - Reproductive cycle for several stocks
  - Selectivity
  - Age at zero length: t_0
- Uncertainty in LHPs:
  - Longevity
- Estimators:
  - Most estimators are largely based on teleosts
  - Then et al. methods may be inappropriate for elasmobranchs

Future research on natural mortality

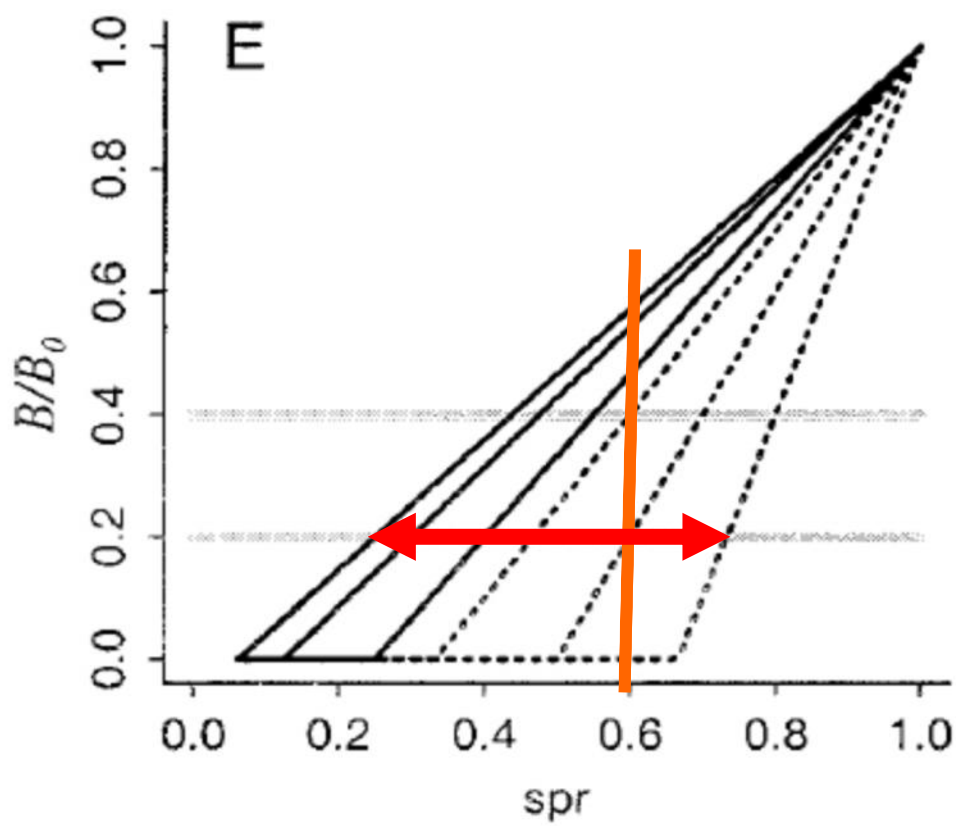
Improved LHP estimation

- Biological work:
  - Increase sample coverage and sample size
  - Use new ageing technology
- Modelling:
  - Focusing on elasmobranchs
  - Meta-analysis of LHPs using original data
  - Use new modelling techniques

Discussion: Methods for reference points

- Method 1 (empirical relationship):
  - based on real F_{msy} from stock assessment,
  - is more flexible,
  - can be applied to all stocks,
  - less likely to produce extreme estimate,
  - main concern is uncertainty: in original stock assessment, LHPs, and taxonomic groups.
- Method 2 (demographic analysis):
  - requires more information,
  - assumes knife-edge selectivity at age 1,
  - does not take density-dependence into account so the estimate is likely to be realized r rather than the maximum population growth rate.
- Bias in M has opposite effect on Methods 1 and 2 so it may be beneficial not to rely on one method

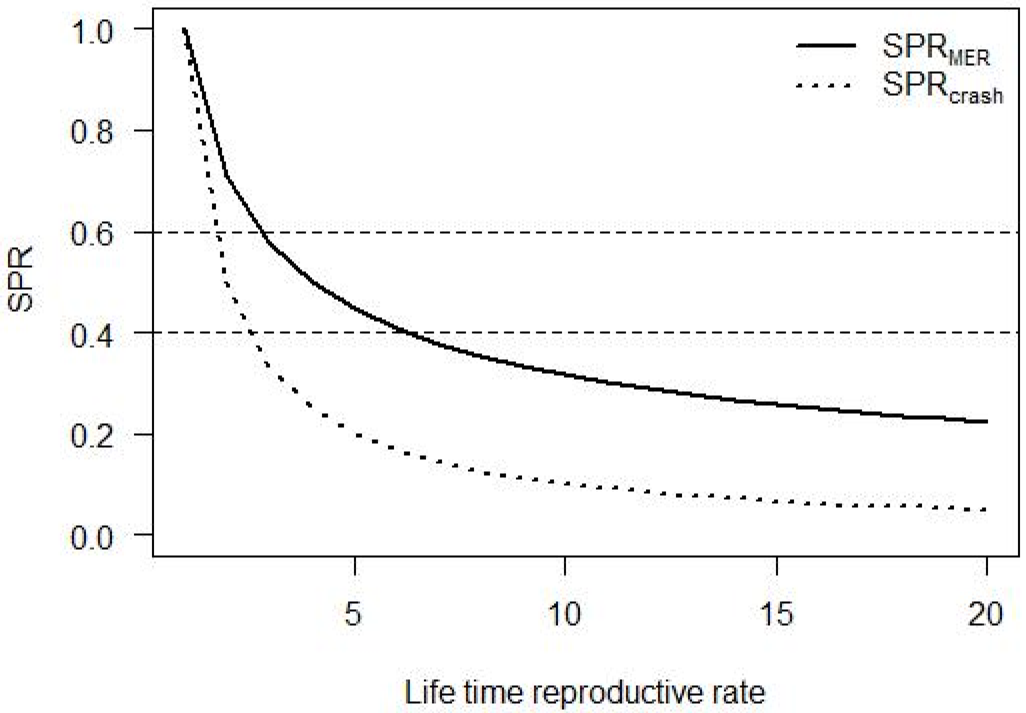
Biomass depletion as a function of SPR and productivity



D = 1.5, 2, 3, 4, 8, 16

Clark, W.G. 2002. F35% revisited ten years later. NAJFM 22: 251-257.

Effect of stock productivity on particular %SPR



SPR_{MER}: Spawning potential ratio at maximum excess recruitment in number

Brooks, E. N., Powers, J. E., and Corte, E. 2010. Analytical reference points for age-structured models: application to data-poor fisheries. ICES Journal of Marine Science, 67: 165–175

Discussion on SPR approach

1. A species' intrinsic productivity determines its ability to sustain fishing impact.
2. SPR approach is based on "per recruit" and examines a single cohort; it basically ignores species productivity.
3. There lacks a direct link between spawning stock biomass per recruit (SSBR) and the actual stock biomass.
4. Choosing a specific x%SPR as a proxy for B_{msy} is arbitrary, and is equivalent to assume a constant steepness for all species.
5. Studies on SPR have focused on "typical" target teleost species; a range of x%SPR from 20% to 70% has been suggested.
6. A particular x%SPR is a function of stock productivity:

   $= \frac{}{\sqrt{}}$. F_{MER} tends to be larger than F_{MSY}.

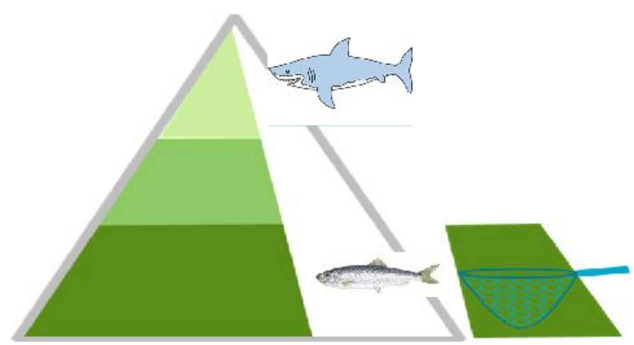
7. Using $SPR_{40\%}$ as a proxy of SPR_{MER} is similar to assuming h = 0.61.
8. If use $F_{60\%}$ as proxy for F_{msm}, what $F_{x\%}$ as proxies for F_{lim} and F_{crash}?

Future research on reference points

- Develop empirical relationship based on basic LHPs rather than M. Focus on elasmobranchs, or include taxonomy as an independent variable.
- Incorporate selectivity into Euler-Lotka equation.
- Potential application of SPR approach for elasmobranchs.

Recommended reference points

- For stocks assessed using a stock assessment model, reference points estimated in the same stock-assessment should be adopted.
- For stock without stock assessment, or when the results are not robust, use risk-based RPs.
- If the focus is for single stock management, using F_{lim} as limit reference point is more consistent with 20%$SB_{dynamic10,unfished}$.
- If ecological interactions and ecosystem structure are considered essential in management decision, using F_{msm} as LRP is less risky.



Thank you

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Compare F_{msm}