Calculating Spawning Potential Ratio in Fishery Groups from a Seasonal Stock Assessment Model

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Summary

The working paper details a methodology for replicating spawning potential ratio (SPR) from the stock assessment and calculating fleet-specific SPRs, emphasizing the intricate processes involved in managing the Pacific Bluefin tuna stock. The findings underscore the reliability and reproducibility of the SPR calculations, affirming the method's effectiveness.

Introduction

The Regional Fisheries Management Organizations (RFMOs) oversee the management of the Pacific Bluefin tuna (PBF) stock. This stock has been harvested by multiple fisheries and fleets, each employing specified gear-selection methods and targeting specific age groups. Given that fleets exhibit specific selectivities, the proportional fishery impact associated with a specific management measure relies on the relative exploitation pattern across fleets.

The term "Spawning potential ratio (SPR)" refers to a key metric used in PBF fisheries management to assess the reproductive potential of PBF. Fleets-specific SPRs become indispensable in accurately capturing the exploitation pattern across various age groups and fleets, contributing valuable insights to the management strategies employed.

This working paper outlines the methodology employed to replicate the SPR from the stock assessment and to calculate fleets-specific SPRs, shedding light on the processes involved in assessing and managing the Pacific Bluefin tuna stock.

Methods

Spawning potential ratio (SPR) is the ratio of spawn produced over the cohort's lifespan (assuming equilibrium) under specific annual fishing rate relative to the spawn that would occur if there were no fishing. The term "spawn" denotes the number of eggs produced by a cohort throughout its lifespan, and this is proportional to the total weight of mature females, known as spawning stock biomass (SSB). Any alterations in the rate of fishing or changes in the fishing schedule across different age groups will result in corresponding changes to the SPR.

1. *Calculation of spawning potential ratio for a user-specific fishery group*

Number at age without fishing, $N'_{a,s,y}$:

$$N'_{a,s+1,y} = N'_{a,s,y} * \exp(-M_a/4), \text{ if s = 1, 2, and 3,}$$

$$N'_{a+1,s=1,y} = N'_{a,s,y} * \exp(-M_a/4), \text{ if s = 4.} \quad (1)$$

, where *a* is age, *s* is season, *y* is year, and M_a is annual instantaneous natural mortality rate at age.

Spawning potential without fishing during the spawning season, $SP_{F=0,s=4,y}$:

$$SP_{F=0,s=4,y} = \sum_a N'_{a,s=4,y} * \text{Fecudity}_a * \text{Maturity}_a \quad (2)$$

Number at age with fishing for specific fishery group, $N_{a,s,f,y}$:

$$N_{a,s+1,f,y} = N_{a,s,f,y} * \exp\left(-\left(\sum_f F_{a,s,f,y} + M_a\right)/4\right), \text{ if s = 1, 2, and 3,}$$

$$N_{a+1,s=1,f,y} = N_{a,s,f,y} * \exp\left(-\left(\sum_f F_{a,s,f,y} + M_a\right)/4\right), \text{ if s = 4.} \quad (3)$$

, where f is fishery group, and $F_{a,s,y}$ is true fishing mortality rate at age for season, s and year, y.

Spawning potential with fishing for specific fishery group during the spawning season, $SP_{F,s=4,f,y}$:

$$SP_{F,s=4,f,y} = \sum_a N_{a,s=4,f,y} * \text{Fecudity}_a * \text{Maturity}_a \quad (4)$$

Spawning potential ratio for specific fishery group is the ratio of equation (4) to equation (2), $SPR_{f,y}$:

$$SPR_{f,y} = \frac{SP_{F,s=4,f,y}}{SP_{F=0,s=4,y}} \quad (5)$$

2. *Calculation of the overall spawning potential ratio from all user-specific fishery groups*

$$SPR_y = \exp\left(\sum_f ln\left(SPR_{f,y}\right)\right)$$

$$\text{or} \quad SPR_y = \prod_f SPR_{f,y} \quad (6)$$

To test the calculation method, we first computed the SPR and compared the estimates with the SPR generated in the 2022 stock assessment by Stock Synthesis (ISC 2022). Subsequently, we illustrated the process using two fishery groups, calculating the SPR for each group. The comparison was then made between the overall SPR from these two fishery groups and the SPR generated in the 2022 stock assessment by Stock Synthesis

Results

The SPR, calculated using equation (5) and including all the fisheries, closely matched with precision to at least the fourth decimal place (Table 1). This suggests that the SPR can be reliably reproduced using this calculation method.

As an example, we divided the fisheries into two groups: one comprising all the fisheries operating in the western Pacific Ocean (WPO) and the other comprising those in the eastern Pacific Ocean (EPO). Again, SPRs for WPO and EPO were calculated using equation (5). The overall SPR (WPO and EPO) using equation (6) matched with precision to at least the second decimal place (Table 1).

Conclusions

The SPR calculations, inclusive of all fisheries and demonstrated through the PBF stock assessment, exhibited a remarkable level of precision. These findings support the reliability and reproducibility of the SPR derived from the employed calculation method. The division of SPR calculations into distinct fishery groups (WPO and EPO), yielded results with commendable precision. The outcomes revealed close matches, with precision extending to at least the fourth decimal place for the collective fisheries and to the second decimal place for specific regional divisions.

References

ISC 2022. Stock Assessment of Pacific Bluefin Tuna in the Pacific Ocean in 2022. Annex 13 22nd Meeting of the International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean. Available at https://isc.fra.go.jp/pdf/ISC22/ISC22_ANNEX13_Stock_Assessment_for_Pacific_Bluefin_Tuna.pdf

Table 1. Comparison of the spawning potential ratio (SPR) across fishery groups using the proposed method with the estimates from the 2022 stock assessment.

Year	SPR from SS	Overall SPR equ. (5)	SPR_WPO equ. (5)	SPR_EPO equ. (5)	$SPR_{WPO+EPO}$ equ. (6)	$SPR_{WPO+EPO}$ – SPR from SS
1952	0.1163	0.1163	0.1801	0.6457	0.1163	0.0000
1953	0.1290	0.1290	0.2848	0.4527	0.1289	-0.0001
1954	0.0793	0.0793	0.1973	0.3993	0.0788	-0.0005
1955	0.1140	0.1140	0.1287	0.8855	0.1139	0.0000
1956	0.1583	0.1583	0.2080	0.7599	0.1580	-0.0003
1957	0.1085	0.1085	0.1706	0.6357	0.1084	0.0000
1958	0.1950	0.1950	0.3628	0.5374	0.1950	0.0000
1959	0.2391	0.2391	0.3326	0.7186	0.2390	-0.0001
1960	0.1734	0.1734	0.2607	0.6643	0.1732	-0.0002
1961	0.0337	0.0337	0.2189	0.1541	0.0337	0.0000
1962	0.1086	0.1086	0.3027	0.3586	0.1086	0.0000
1963	0.0662	0.0662	0.2212	0.2994	0.0662	0.0000
1964	0.0755	0.0755	0.1241	0.6079	0.0755	0.0000
1965	0.0301	0.0301	0.2098	0.1437	0.0301	0.0000
1966	0.0009	0.0009	0.0494	0.0192	0.0009	0.0000

1967	0.0109	0.0109	0.0496	0.2196	0.0109	0.0000
1968	0.0142	0.0142	0.0988	0.1433	0.0142	0.0000
1969	0.0863	0.0864	0.2417	0.3572	0.0863	0.0000
1970	0.0291	0.0291	0.1064	0.2729	0.0291	0.0000
1971	0.0127	0.0127	0.0869	0.1465	0.0127	0.0000
1972	0.0029	0.0029	0.0896	0.0317	0.0028	0.0000
1973	0.0564	0.0564	0.1418	0.3975	0.0564	-0.0001
1974	0.0632	0.0632	0.1272	0.4965	0.0632	-0.0001
1975	0.0895	0.0895	0.2560	0.3494	0.0894	0.0000
1976	0.0306	0.0306	0.1014	0.2923	0.0297	-0.0009
1977	0.0366	0.0366	0.0666	0.5371	0.0358	-0.0009
1978	0.0502	0.0502	0.0806	0.6229	0.0502	0.0000
1979	0.0816	0.0816	0.1287	0.6343	0.0816	0.0000
1980	0.0618	0.0618	0.0750	0.8239	0.0618	0.0000
1981	0.0029	0.0029	0.0035	0.8484	0.0029	0.0000
1982	0.0003	0.0003	0.0007	0.5203	0.0003	0.0000
1983	0.0596	0.0596	0.0727	0.8181	0.0595	-0.0001
1984	0.0527	0.0528	0.0723	0.7283	0.0527	-0.0001
1985	0.0273	0.0273	0.0458	0.5945	0.0272	-0.0001
1986	0.0111	0.0112	0.0277	0.4027	0.0111	0.0000
1987	0.0816	0.0816	0.1038	0.7853	0.0815	-0.0001
1988	0.1105	0.1105	0.1406	0.7859	0.1105	0.0000
1989	0.1455	0.1456	0.1745	0.8328	0.1453	-0.0002
1990	0.1839	0.1840	0.2365	0.7776	0.1839	-0.0001
1991	0.0983	0.0983	0.1025	0.9578	0.0982	-0.0001
1992	0.1466	0.1467	0.1816	0.8067	0.1465	-0.0001
1993	0.1684	0.1685	0.1959	0.8576	0.1680	-0.0004
1994	0.1351	0.1351	0.1795	0.7524	0.1350	-0.0001
1995	0.0516	0.0516	0.0616	0.8346	0.0514	-0.0001
1996	0.0883	0.0883	0.2067	0.4267	0.0882	-0.0001
1997	0.0602	0.0602	0.0808	0.7445	0.0601	0.0000
1998	0.0424	0.0424	0.0787	0.5343	0.0420	-0.0003
1999	0.0345	0.0345	0.0441	0.7700	0.0339	-0.0005
2000	0.0166	0.0166	0.0260	0.6353	0.0165	0.0000
2001	0.0949	0.0949	0.1284	0.7344	0.0943	-0.0006
2002	0.0566	0.0566	0.0867	0.6434	0.0558	-0.0008
2003	0.0226	0.0226	0.0619	0.3570	0.0221	-0.0005
2004	0.0138	0.0138	0.0651	0.2018	0.0131	-0.0007
2005	0.0068	0.0068	0.0374	0.1701	0.0064	-0.0004
2006	0.0110	0.0110	0.0338	0.3248	0.0110	0.0000
2007	0.0046	0.0046	0.0166	0.2590	0.0043	-0.0002
2008	0.0056	0.0056	0.0130	0.3711	0.0048	-0.0008
2009	0.0122	0.0122	0.0357	0.2533	0.0090	-0.0031
2010	0.0236	0.0236	0.0723	0.3252	0.0235	-0.0001
2011	0.0487	0.0487	0.1057	0.4458	0.0471	-0.0016
2012	0.0817	0.0817	0.2084	0.3885	0.0810	-0.0007
2013	0.0569	0.0569	0.1355	0.4012	0.0544	-0.0025

2014	0.1108	0.1108	0.1936	0.5671	0.1098	-0.0010
2015	0.1246	0.1246	0.1676	0.7398	0.1240	-0.0006
2016	0.1277	0.1277	0.1952	0.6401	0.1250	-0.0027
2017	0.2191	0.2191	0.3165	0.6766	0.2141	-0.0050
2018	0.2828	0.2828	0.3702	0.7551	0.2795	-0.0032
2019	0.2884	0.2884	0.3517	0.8012	0.2818	-0.0066
2020	0.3510	0.3511	0.4180	0.8342	0.3486	-0.0024