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Assessment on Indian albacore stock based mainly on Taiwanese longline data

Feng-Chen Chang[1], Chiee-Young Chen[2], Liang-Kang Lee[3], and Shean-Ya Yeh[4]

SUMMARY

Mainly based on 1967-2011 Taiwanese longline and historic Japanese longline catch & effort data and annual Indian albacore catch compiled by IOTC, an age-structured production model algorithm was adopted and exercised for assessing the stock surplus potentials of Indian albacore. Further assumed that (1) official VBGE parameters of South Atlantic albacore and (2) selectivity patterns of Taiwanese & Japanese longline fisheries operating in the South Atlantic Ocean were adequate to transfer to Indian albacore resource as a first trial for this study.

Results thus obtained indicated that (1) estimates of B/K appeared to decline from 1968 to 1979, then rose slightly in the early 1980s and appeared leveled off in 2011; (2) current exploitable biomass is estimated to be 98 % of that in 1950 (the beginning of albacore longline fishery in the Indian is assumed); (3) ratio of B_{2011}/K *appeared to be larger than 0.2, which deemed as a threshold of "something bad" when the biomass falling below this level (Francis, 1992); (3) ratio of* B^{mat}/B^{mat}_{MSY} *is larger than 1.0 from 1950 to 2011; (4) ratio of* B^{mat}/B^{mat}_{MSY} *is currently equal to 2.03; (5) fishing mortality* F_{2011} *is estimated as 53.5% of* $F_{MSY;}$ *and (5) although MSY level estimated by the data to be about 44,000 mt per year, projecting results for various TACs indicate that the 42,000 mt level will introduce about 40% risk endurance whereas 40,000 mt level will exert about 30% risk endurance if taking precautions measures into consideration.*

1 Overseas Fisheries Development Council, Taipei, Taiwan; E-mail: fengchen@ofdc.org.tw; d93241008@ntu.edu.tw;

2 Dept. of Marine Environmental Engineering, National Kaoshiung Marine University, Kaohsiung, Taiwan; E-mail: chency@mail.nkmu.edu.tw;

3 Dept. of Fisheries production and Management, National Kaoshiung Marine University, Kaohsiung, Taiwan; E-mail: leelk@mail.nkmu.edu.tw;

4 Institute of Oceanography, National Taiwan University, Taipei, Taiwan; E-mail: sheanya@ntu.edu.tw.

Introdction

Longliners from Japan and Taiwan have been operating in the Indian Ocean since the early 1950s and they have been the major fishers for albacore since then (Herrera and Pierre, 2011; Fig. 1). While the Japanese albacore catch ranged from 8,000 t to 18,000 t in the period 1959 to 1969, in 1972 catches rapidly decreased to around 1,000 t, due to changing the target species mainly to southern bluefin tuna and bigeye tuna, then ranged between 200 t and 2,500 t as albacore became a bycatch of this fishery. In recent years the Japanese albacore catch has been around 2,000 to 6,000 t. In contrast, catches by Taiwan longliners increased steadily from the 1950s to average around 10,000 t by the mid-1970s. Between 1998 and 2002 catches ranged between 21,500 t and 26,900 t, equating to just over 60 % of the total Indian Ocean albacore catch. Between 2003 and 2010 the albacore catches by Taiwan longliners have been between 10,000 and 18,000 t, with catches appearing to be on the increase in recent years.

The total catches of Indian albacore increase steadily and have exceeded 30,000 mt in many years. The largest catch was recorded in the year of 2008 (44,410 mt). In recent years, the bulk of the annual catch from this stock has been taken by Taiwanese longline fleet.

On stock assessment, the production model is the most useful way to understand the resource status when the data of the age composition are not easy to obtain. Punt (1992) developed an age structured production model (ASPM) which internally having theoretical age-group structure yet externally all age-groups of the year acted as a whole entity and assumed follows the response pattern of a surplus production principle. It also brought stock-recruitment relationship into the model for estimation the theoretical recruitment in the next year or generation.

Mathematical Model expression of "ASPM"

The ASPM modeled the resource dynamics by the equations as:

$$N_{y+1,a} = \begin{cases} N_{y+1,0} & a = 0 \\ N_{y,a-1} e^{-(M_{a-1}+S_{y,\,a-1}F_y)} & a = 1,\dots,m-1 \\ N_{y,m-1} e^{-(M_{m-1}+S_{y,\,m-1}F_y)} + N_{y,m} e^{-(M_m+S_{y,m}F_y)} & a = m \end{cases}$$

where $N_{y,\,a}$: the number of fish of age a at the start of year y;

M_a: the rate of natural mortality on fish of age a;

$N_{y,0}$: the number of 0-year-olds at the start of year y;

$S_{y,a}$: the age-specific selectivity function (for all fleets and gears combined);

m: the maximum age considered (taken to be a plus-group);

F_y: the (asymptotic) fishing mortality during year y.

The strength of the 0-year-class is deterministically related to previous year's spawning stock size according to Beverton-Holt stock-recruitment relationship as:

$$N_{y,0} = \frac{\alpha B_y^s}{\beta + B_y^s}\text{, and } B_y^s = \sum_{a=1}^{m} f_a w_a N_{y,a}$$

where B_y^s : the spawner stock size at the start of year y;

w_a: the mass of a fish of age a at the start of the year;

f_a: the fecundity of a fish of age a;

α, β: the stock-recruitment relationship parameters.

Due to the recruitment is deterministic with spawning biomass fixed in ASPM model, Restrepo and Legault (1997) indicate that it may result in inconsistencies between the estimated level of recruitment and the observed level of catches and thus modified the ASPM with additional stochastic recruitment options into the model.

The stochastic ASPM model consists of a forward population projection. It is essentially similar to that of Punt (1994) but age 1 is assumed to be the age of recruitment. Besides, this model requires that a recruitment value be estimated for every year. The recruitment estimates are obtained with the stock recruitment relationship as $N_{1,y+1} = \frac{\alpha B_y^s}{\beta + B_y^s} e^{\varepsilon_{y+1}}$ with $\varepsilon_{y+1} = \rho\varepsilon_y + \eta_{y+1}$, $|\rho| < 1$, $\eta \sim (0, \sigma_\eta^2)$. In this study, the author adopted the ASPM with stochastic recruitment version not only in fitting with known historic catch and effort data sets of Indian albacore resource but also to project the future stock conditions by assuming utilization at a constant TAC level.

Output and its implications of "ASPM"

The stochastic ASPM model is used in present study for assessing the current status of Indian albacore. Data of (1) yields of fisheries (longline fisheries) starting in 1950; (2) abundance indices of 2 fishing fleets; and (3) the needed biological parameters were carefully prepared before running the model.

Two CPUE indices from 2 fleets: Taiwanese longline (1980~2011; Lognormal), Japanese longline (1966~2011; Negative Binomial) are used for this study, as shown in Table 1.

Catches in weight of longline fisheries from 1950 to 2010 were obtained from the IOTC database. Fleet specific domed shape selectivity pattern by age was also adopted from publications for this study. The selectivity at age that cited from Lee (2007) depicts the estimated selectivity patterns for Japanese longline and Taiwanese longline by blocks of years. In present study, the selectivities pattern have changed from 0.990 (which were used in 2007 assessment) at ages 9~13 to 0.583, which were the same value as used before age 8 in 2007 assessment. It is assumed that fish are not to live beyond their thirteenth year of life, so that the plus group is defined at age 13. Natural mortality is assumed to be equal to 0.3 per year for age 1 to age 13. The weight of a fish of age a is obtained by using the growth curve $L_a=147.5(1-e^{-0.126(a+1.89)})$ by Lee and Yeh (2007) and the length-weight relationship of Penney (1994): $W_a=1.3718\text{x}10^{-5}L_a^{3.0973}$. The fecundity relationship by age was given by: $f_a=\begin{cases}0 & if\ a<5\\ 0.5 & if\ a=5\\ 1 & if\ a>5.\end{cases}$

Figs. 2~7 show the fitting results of the case by stochastic ASPM. Fig. 2 shows the model fits to the CPUE series are reasonable with the Indian longline and the exception of the very early years of the Taiwanese longline CPUE series.

The obtained yearly MSY estimate has not changed significantly, yet in the period of 1980~1993 did show very slight fluctuation in figures, as shown in Fig 3. These MSY estimates are derived from the estimates of the stock recruitment relationship. The greatest and least ones are 44,842 mt from 1987 to 1990 and 43,518 mt from 1950 to 1979. In recent decade, the estimates of MSY have kept around 44,383 mt, which is very close to the figure obtained in the middle stage of this fishery.

The ratios between the yield and the MSY (Yield/MSY) are shown in Fig. 4. Though-out all those 60 some years of utilization, only in 2008 indicated that annual yield figure was the same as the estimated MSY level.

Fig. 5 shows the trend of the estimates of depletion (i.e. B/K). It decreased sharply since 1968 to its lowest level in 1979, then leveled off and rose slightly in recent years. All the estimates of depletion are higher than 0.2, which usually deemed as a threshold of "something bad" when the biomass falling below this level (Francis, 1992).

The ratios between the mature biomass and the mature biomass at MSY (B^{mat} / B^{mat}_{MSY}) are shown in Fig. 6. Although these ratios seemed decrease rapidly, the mature biomass (B^{mat}) was still larger than the mature biomass at MSY (B^{mat}_{MSY}) from 1950 to 2011. The value of $B^{mat}_{2011}/ B^{mat}_{MSY}$ is estimated to be 2.03, which is still in the acceptable range.

Fig. 7 shows the ratios between the fishing mortality and the fishing mortality at MSY (F / F_{MSY}). It indicates that the fishing mortality (F) is smaller than the mortality at MSY (F_{MSY}). The current fishing mortality F_{2011} is 0.535 of that at MSY level.

Fig. 8 shows the biomass trajectories with 40% risk endurance, assuming that at median of all boots projectings its risk endurance is nil, for various constant TAC catch strategies by the model's projecting into the future. The long term sustainable TAC harvesting level, which ensures that at 40% risk endurance the stock's spawning biomass will reach and beyond its MSY criteria in 5 years, is estimated to be about 42,000 metric tons per year.

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Table 1 The standardized CPUEs series of Indian albacore used in ASPM analysis.

	Japan LL	**Taiwan LL**
Catch Units	Number	Number
Effort Units	1000 hooks	1000 hooks
Model	Neg. Binomial	Lognormal
Year		
1950		
1960		
1961		
1962		
1963		
1964		
1965		
1966	6.8040	
1967	5.8030	
1968	4.5950	
1969	4.8000	
1970	3.8790	
1971	3.2120	
1972	3.0540	
1973	2.3940	
1974	2.7110	
1975	1.3040	
1976	1.7660	
1977	1.0160	
1978	0.6300	
1979	0.4920	
1980	0.5890	2.2573
1981	1.1190	2.6888
1982	1.1230	2.9207
1983	1.0400	2.1591
1984	1.2840	1.8182
1985	0.8890	1.5941
1986	2.0860	1.8400
1987	1.7070	1.7369
1988	1.1040	1.7114
1989	0.8190	0.9563
1990	0.9730	0.8406
1991	0.5770	0.9253
1992	1.1220	1.4094
1993	1.0230	1.4835
1994	1.2350	1.3872
1995	1.1150	1.0214
1996	0.8970	1.0870
1997	1.1030	1.3116
1998	1.2820	1.4907
1999	0.8130	0.9841
2000	1.5210	0.9233
2001	1.3310	1.3111
2002	1.1720	1.2635
2003	1.7790	1.2271
2004	2.0920	1.2600
2005	1.7200	1.0675
2006	1.6730	0.8163
2007	1.5310	0.7833
2008	1.8240	0.8051
2009	1.8520	0.8568
2010	2.2010	0.9121
2011	2.8590	0.8933

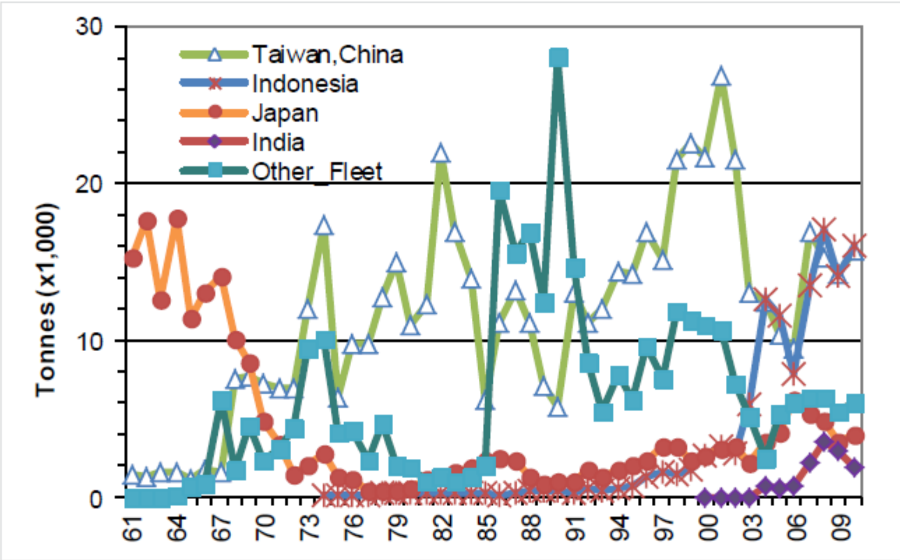

Fig. 1 Catches of albacore by fleet recorded in the IOTC Database (1961-2010).

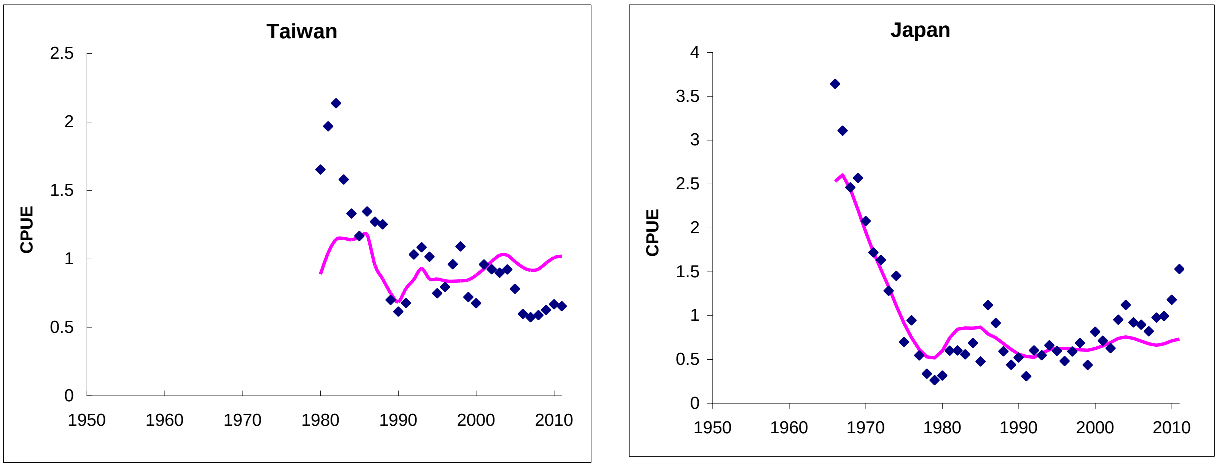

Fig. 2 ASPM model fit of the observed CPUE data of the fleets using the case run.

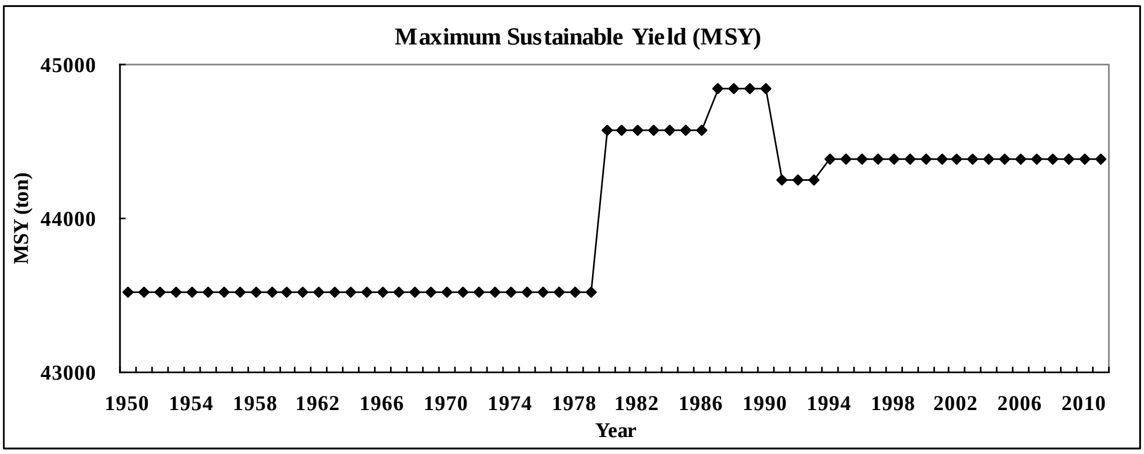

Fig. 3 Estimates of potential maximum sustainable yield (MSY) conditional on year-specific

selectivity patterns for the stochastic ASPM fit.

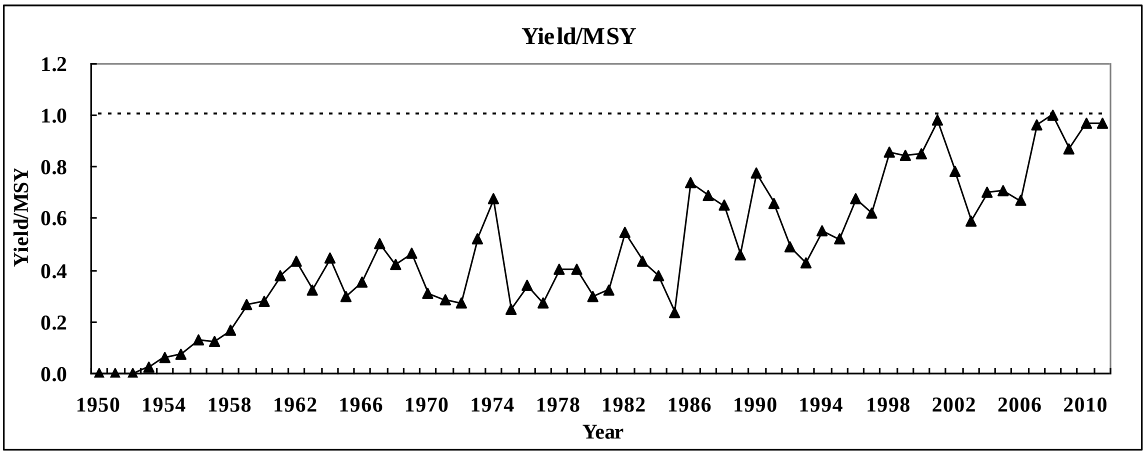

Fig. 4 The ratios between the yield and the MSY (Yield/MSY) of Indian albacore obtained from the case analysis.

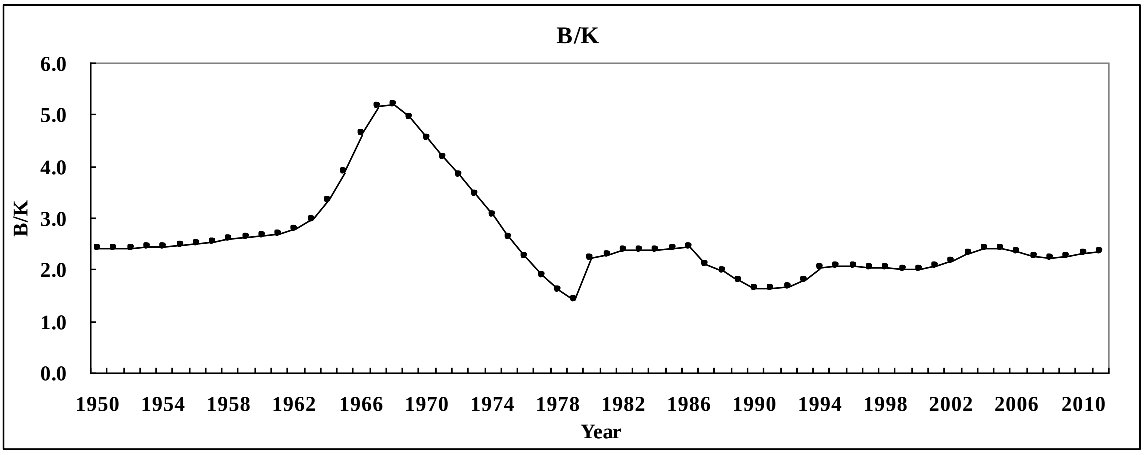

Fig. 5 Exploited biomass as a fraction of pre-exploited biomass (B/K) of Indian albacore obtained from the case analysis.

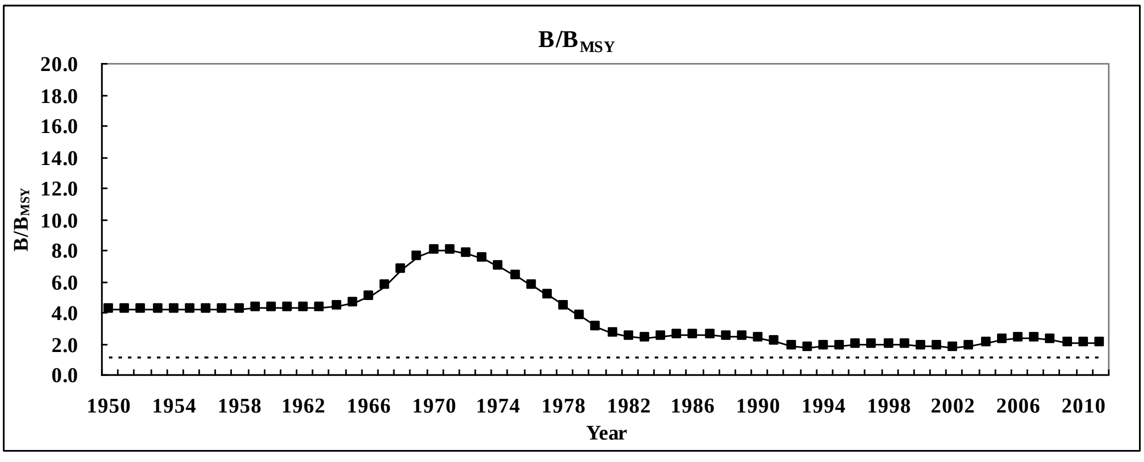

Fig. 6 The ratios between the mature biomass and the mature biomass at MSY (B^{mat} / B^{mat}_{MSY}) of Indian albacore obtained from the case analysis.

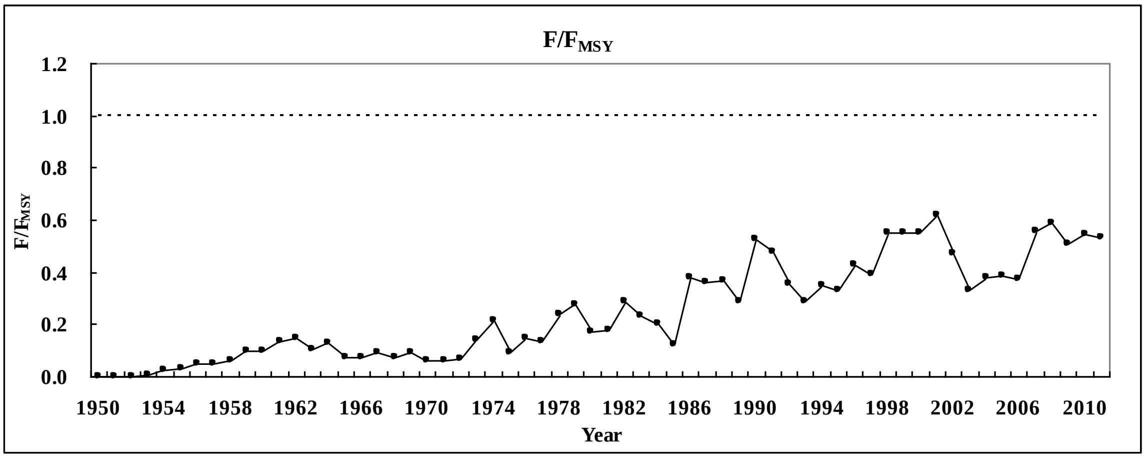

Fig. 7 The ratios between the fishing mortality and the fishing mortality at MSY (F/F_{MSY}) of Indian albacore obtained from the case analysis.

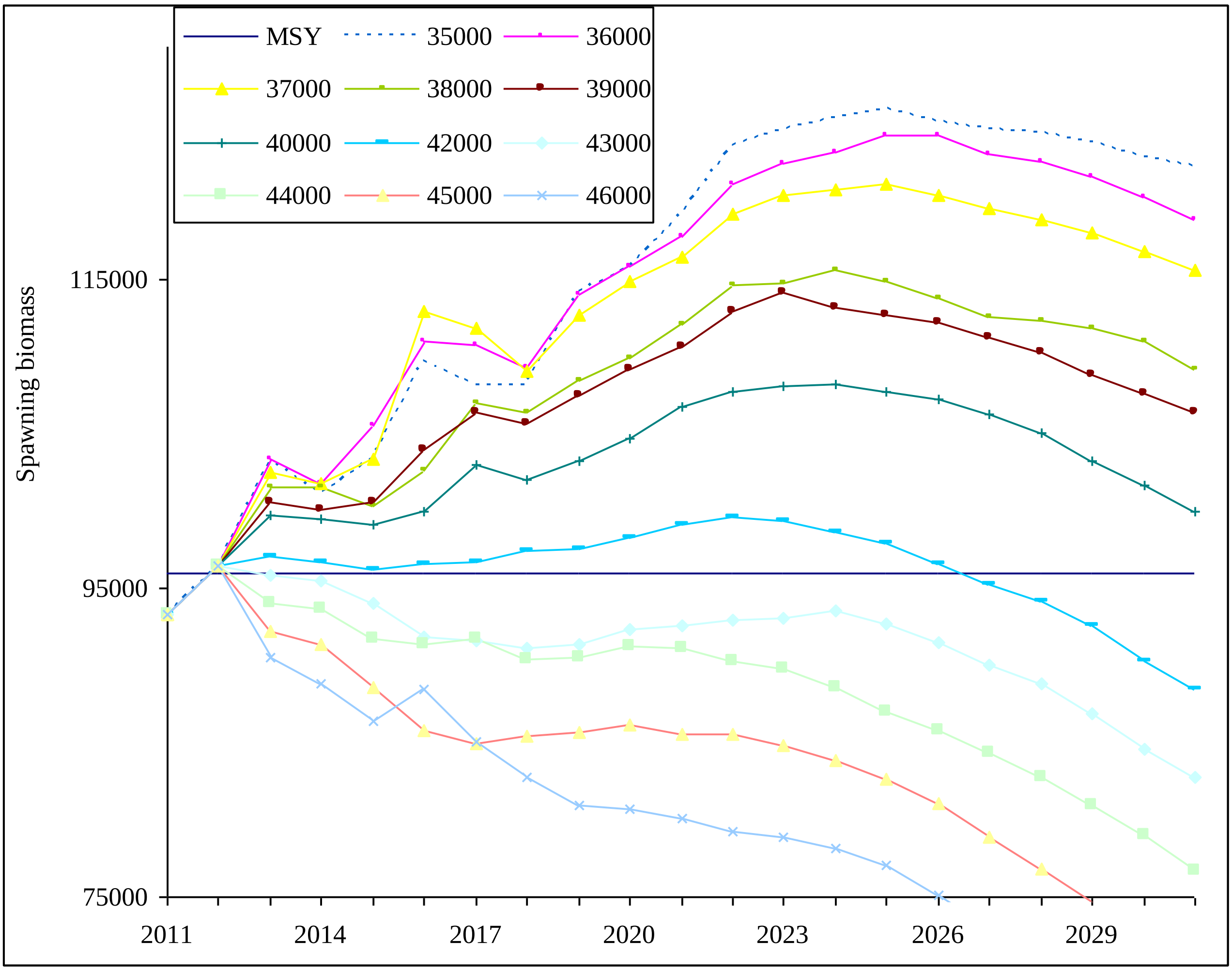

Fig. 8 ASPM biomass trajectories with 40% risk endurance for various constant catch strategies using the case run in the Indian albacore stock.