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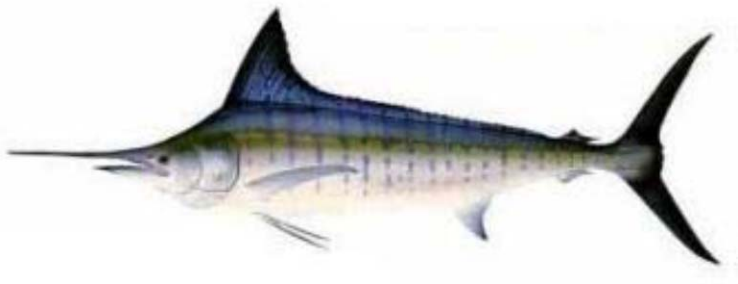
STOCK ASSESSMENT OF STRIPED MARLIN IN THE WESTERN AND CENTRAL NORTH PACIFIC OCEAN IN 2011



REPORT OF THE BILLFISH WORKING GROUP
STOCK ASSESSMENT WORKSHOP

International Scientific Committee for Tuna and Tuna-like Species in the North Pacific Ocean

Document prepared by Hui-Hua Lee, Kevin R. Piner,
Robert Humphreys, and Jon Brodziak

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Document prepared by

Hui-Hua Lee
University of Hawaii, Joint Institute for Marine and Atmospheric Research
2570 Dole St., Honolulu, HI 96822

Kevin R. Piner
NOAA, National Marine Fisheries Service
Southwest Fisheries Science Center
8604 La Jolla Shore Dr., La Jolla, CA 92037

Robert Humphreys
NOAA, National Marine Fisheries Service
Pacific Islands Fisheries Science Center
99-193 Aiea Heights Drive, Suite 417, Aiea, HI 9670

Jon Brodziak
NOAA, National Marine Fisheries Service
Pacific Islands Fisheries Science Center
2570 Dole St., Honolulu, HI 96822

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EXECUTIVE SUMMARY

Stock Identification and Distribution: The Western and Central North Pacific (WCNPO) striped marlin stock (*Kajikia audax*) is separated from the Eastern North Pacific stock based on newly-reported results of population genetic studies and empirical patterns in the spatial distribution of fishery catch-per-unit effort. The boundary of the Western and Central North Pacific stock is defined to be the waters of the Pacific Ocean west of 140°W and north of the equator.

Catches: Catches of WCNPO striped marlin have exhibited a long-term decline since the 1970s. Catches averaged roughly 8,100 mt per year during 1970-1979 and declined by roughly 50% to an average of roughly 3,800 mt per year during 2000-2009. Reported catches in 2009 totaled about 2,560 mt, which was the lowest reported catch since 1975 (Table A).

Data and Assessment: Catch data was collected from all ISC countries and from countries reporting catches to the the Western and Central Pacific Fisheries Commission (WCPFC) (Table A). The growth curve was re-estimated using newly developed ageing data and value of steepness and natural mortality were also re-estimated using available biological information. Standardized catch-per-unit effort data used to measure trends in relative abundance were provided by Japan, USA, and Chinese Taipei. The stock assessment was conducted using the Stock Synthesis assessment model. The assessment model was fit to relative abundance indices and size composition data in a likelihood-based statistical framework. Maximum likelihood estimates of model parameters, derived outputs, and their variances were used to characterize stock status and to develop stock projections.

Table A. Reported catch (mt), population biomass (mt), spawning biomass (mt), relative spawning biomass (SB/SB_{MSY}), recruitment (thousands), fishing mortality (average ages 3 and older), relative fishing mortality (F/F_{MSY}), exploitation rate, and spawning potential ratio of Western and Central North Pacific striped marlin.

Year	2004	2005	2006	2007	2008	2009	2010	Mean[1]	Min[1]	Max[1]
Reported Catch	4047	3703	3706	3195	3691	2560	2560[2]	6011	2560	10528
Population Biomass	11679	9545	10371	8430	7414	5335	6625	14141	5335	24886
Spawning Biomass	1731	2010	1992	1824	1625	1106	938	2439	909	5104
Relative Spawning Biomass	0.64	0.74	0.73	0.67	0.60	0.41	0.35	0.90	0.33	1.88
Recruitment (age 0)	116	434	125	204	133	349	326	453	116	1620
Fishing Mortality	0.58	0.56	0.62	0.58	0.86	0.84	0.75	0.79	0.53	1.46
Relative Fishing Mortality	1.22	0.95	0.92	1.01	0.95	1.41	1.37	1.30	0.86	2.38
Exploitation Rate	35%	39%	36%	38%	50%	48%	38%	44%	29%	69%
Spawning Potential Ratio	19%	19%	17%	19%	12%	13%	14%	14%	7%	21%

[1] During 1975-2010

[2] Assumed equal to 2009 value

Status of Stock: Estimates of population biomass of the WCNPO striped marlin stock exhibit a long-term decline (Figure A). Population biomass (age-1 and older) averaged roughly 18,200 mt, or 42% of unfished biomass during 1975-1979, the first 5 years of the assessment time frame, and declined to 6,625 mt, or 15% of unfished biomass in 2010. Spawning biomass (*SB*) is estimated to be 938 mt in 2010 (35% of SB_{MSY}, the spawning biomass to produce *MSY*, Figure B). Fishing mortality on the stock (average *F* on ages 3 and older) is currently high (Figure C) and averaged roughly $F = 0.76$ during 2007-2009, or 24% above F_{MSY}. The predicted value of the spawning potential ratio (*SPR*, the predicted spawning output at current *F* as a fraction of unfished spawning output) is currently $SPR_{2007\text{-}2009} = 14\%$ which is 19% below the level of *SPR* required to produce *MSY*. Recruitment averaged about 328 thousand recruits during 1994-2008, which was roughly 30% below the 1975-2010 average. No target or limit reference points have been established for the WCNPO striped marlin stock under the auspices of the WCPFC. Compared to *MSY*-based reference points, the current (2010) spawning biomass is 65% below SB_{MSY} and the current fishing mortality (average *F* for 2007-2009) exceeds F_{MSY} by 24% (Figures D and E). Therefore, overfishing is currently occurring relative to *MSY* and the stock is in an overfished state.

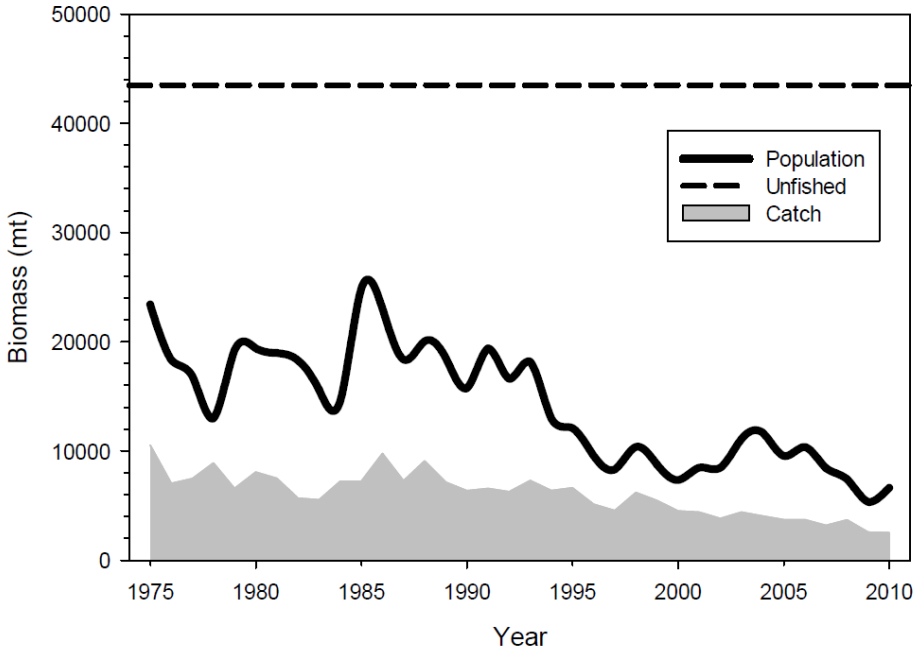

Figure A. Trends in population biomass and reported catch biomass of Western and Central North Pacific striped marlin (*Kajikia audax*) during 1975-2010.

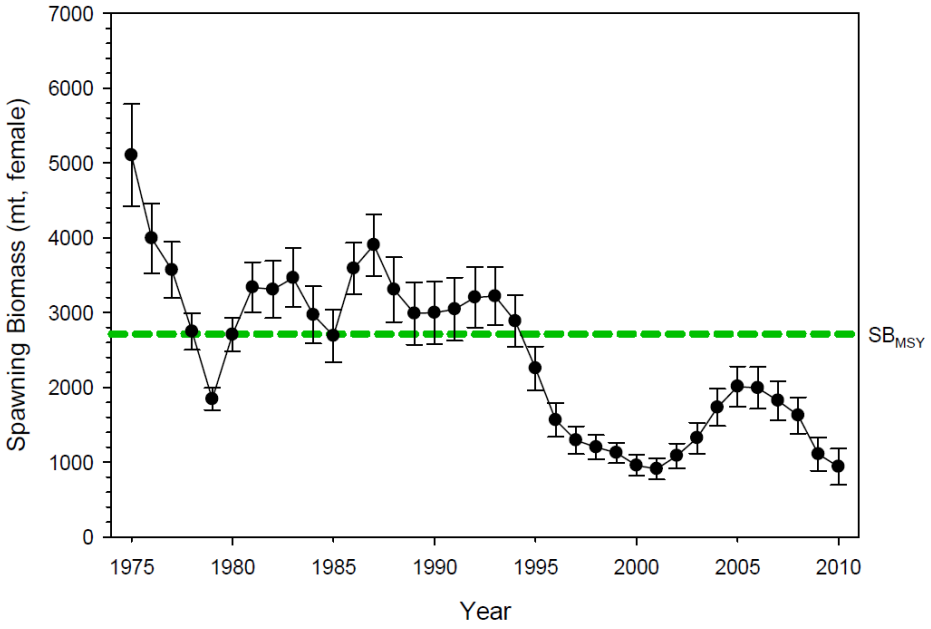

Figure B. Trends in estimates of spawning biomass of Western and Central North Pacific striped marlin (*Kajikia audax*) during 1975-2010 along with 80% confidence intervals.

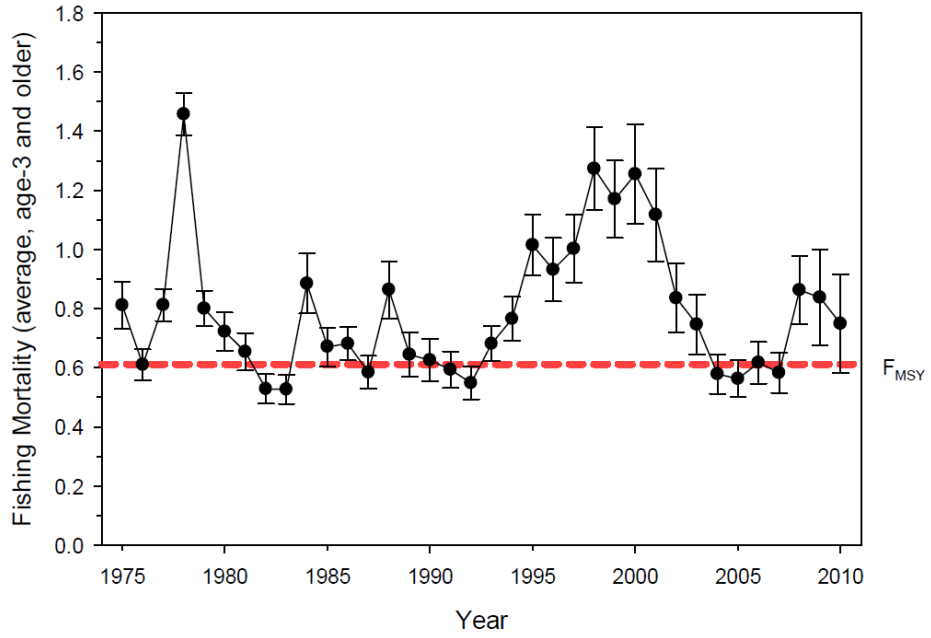

Figure C. Trends in estimates of fishing mortality of Western and Central North Pacific striped marlin (*Kajikia audax*) during 1975-2010 along with 80% confidence intervals.

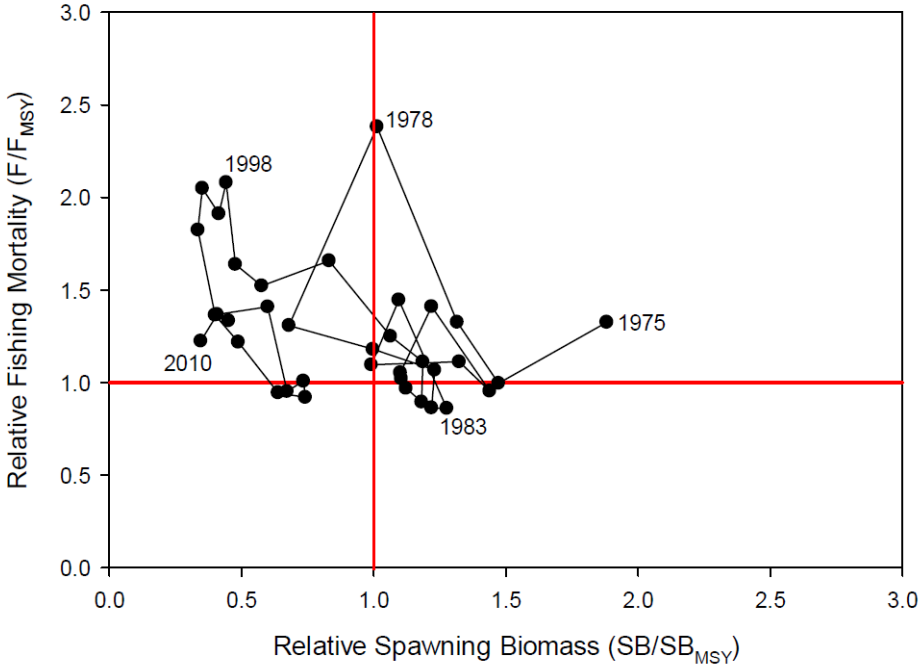

Figure D. Kobe plot of the trends in estimates of relative fishing mortality and relative spawning biomass of Western and Central North Pacific striped marlin (*Kajikia audax*) during 1975-2010.

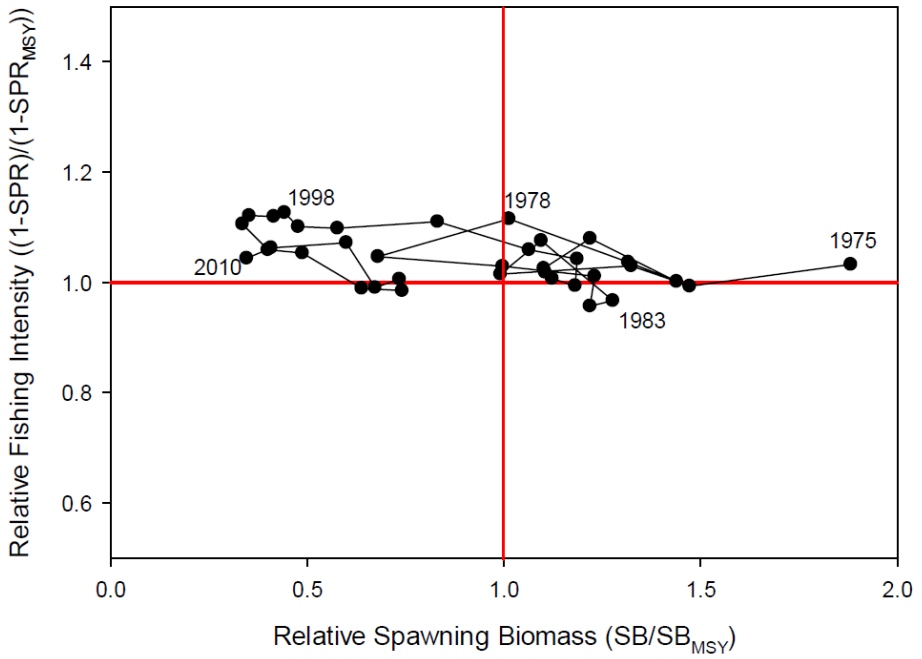

Figure E. Kobe plot of the trends in estimates of relative fishing intensity and relative spawning biomass of Western and Central North Pacific striped marlin (*Kajikia audax*) during 1975-2010.

Projections: Stock projections for landings, spawning biomass, and fishing mortality of WCNPO striped marlin during 2012 to 2017 account for uncertainty in future stock size and recruitment. Two equally-plausible states of nature for future recruitment were assumed for the projections. These were: **Recent Recruitment** in which the recent recruitment pattern (1994-2008) was randomly resampled; and Stock-Recruitment Curve in which the recruitment deviations from the estimated stock-recruitment curve (1975-2008) were randomly resampled. Projections were run using an age-structured simulation model and included estimation uncertainty for the initial population size at age.

Eight projected harvest scenarios[1] were analyzed: (1) constant fishing mortality equal to the current *F* (*SPR*=0.14), the 2007-2009 average (*SPR*=0.12); (2) constant fishing mortality equal to F_{MSY} (*SPR*=0.178); (3) constant fishing mortality equal to the 2001-2003 average ($F_{2001\text{-}2003}$ = 0.90); (4) constant fishing mortality equal to the *SPR* of 0.2; (5) constant fishing mortality equal to the *SPR* of 0.3; (6) no fishing; (7) constant annual catch (2,500 mt) equal to a 20% reduction from the 2007-2009 average annual catch of 3,150 mt; (8) constant annual catch (3,600 mt = 20% reduction from the highest catches during 2000-2003). The six fishing mortality-based scenarios assumed current fishing mortality ($F_{current}$) during 2010-2011 while the two catch-based scenarios assumed a constant annual catch during 2010-2011. Projection results show percentiles of projected relative spawning biomass in 2017 (Table B) and the median female spawning stock biomass and the median catch for each of the eight harvest scenarios (Table C1 and C2).

Conservation Advice: Reducing fishing mortality would likely increase spawning stock biomass and would improve the chances of higher recruitment. If one uses the median to measure the central tendency of the distributions of projected spawning biomass (Table B), then the projection results suggest that fishing at F_{MSY} would lead to spawning biomass increases of roughly 45% to 72% from 2012 to 2017. Fishing at a constant catch of 2,500 mt would lead to potential increases in spawning biomass of 133% to 223% by 2017. Fishing at a constant catch of 3,600 mt would lead to potential increases in spawning biomass of 48% to 120% by 2017. In comparison, fishing at the current fishing mortality rate would lead to spawning biomass increases of 14% to 29% by 2017, while fishing at the average 2001-2003 fishing mortality rate would lead to a spawning biomass decrease of 2% under recent recruitment to an increase of 6% under the stock-recruitment curve assumption by 2017.

Biological Reference Points: Reference points based on maximum sustainable yield (*MSY*) were estimated in the Stock Synthesis assessment model. The point estimate of maximum sustainable yield (± 1 standard error) was *MSY* = 5378 mt ± 144. The point estimate of the spawning biomass to produce *MSY* (adult biomass) was SB_{MSY} = 2713 mt ± 72. The point estimate of F_{MSY}, the fishing mortality rate to produce *MSY* (average fishing mortality on ages 3 and older) was F_{MSY}= 0.61 ± 0.01 and the corresponding equilibrium value of spawning potential ratio at *MSY* was SPR_{MSY} = 17.8% ± 0.1%.

Special Comments: The WCNPO striped marlin stock is expected to be highly productive due to its rapid growth and high resilience to reductions in spawning potential. The status of the stock is highly dependent on the magnitude of recruitment, which has been below its long-term average since 2004 (Table A). In addition, taking into account the fact that the WCNPO striped

marlin stock is overfished, fishery catches in areas near the stock boundary should be closely monitored.

Table B. Percentiles of projected relative spawning stock biomass (SB_{2017}/SB_{2012}) in 2017.

	Recent Recruitment					Stock-Recruitment Curve				
Harvest Scenario	5th	25th	50th	75th	95th	5th	25th	50th	75th	95th
(1) F = $F_{current}$	0.85	1.03	1.14	1.23	1.36	0.83	1.09	1.29	1.51	1.82
(2) F = F_{MSY}	1.12	1.32	1.45	1.55	1.69	1.14	1.47	1.72	1.98	2.34
(3) F = $F_{2001\text{-}2003}$	0.72	0.87	0.98	1.06	1.18	0.66	0.88	1.06	1.25	1.52
(4) F = F20%	1.26	1.48	1.62	1.72	1.88	1.32	1.68	1.95	2.24	2.62
(5) F = F30%	1.90	2.18	2.35	2.48	2.68	2.08	2.56	2.91	3.28	3.79
(6) F = 0	4.93	5.49	5.82	6.06	6.47	5.43	6.33	7.07	7.81	8.72
(7) Catch = 2500 mt	1.41	1.97	2.33	2.67	3.1	1.63	2.49	3.23	4.03	5.28
(8) Catch = 3600 mt	0.98	1.18	1.48	1.80	2.25	1.05	1.51	2.20	3.01	4.37

Table C1. Projected values of median spawning biomass and catch under recent recruitment.

Year	2012	2013	2014	2015	2016	2017
Scenario 1 Recent Recruitment Projection (Constant F = $F_{current}$, weights in mt)						
Spawning Biomass	1333	1439	1495	1510	1522	1525
Catch	3974	4113	4201	4240	4246	4224
Scenario 2 Recent Recruitment Projection (Constant F = F_{MSY}, weights in mt)						
Spawning Biomass	1333	1615	1790	1870	1916	1929
Catch	3267	3649	3868	3948	3971	3962
Scenario 3 Recent Recruitment Projection (Constant F = $F_{2001\text{-}2003}$, , weights in mt)						
Spawning Biomass	1333	1320	1311	1309	1309	1306
Catch	4471	4403	4378	4402	4399	4376
Scenario 4 Recent Recruitment Projection (Constant F = $F_{20\%}$, weights in mt)						
Spawning Biomass	1333	1692	1936	2064	2133	2162
Catch	2955	3412	3663	3782	3818	3819
Scenario 5 Recent Recruitment Projection (Constant F = $F_{30\%}$, weights in mt)						
Spawning Biomass	1333	1942	2447	2792	3015	3135
Catch	2001	2559	2912	3108	3187	3220
Scenario 6 Recent Recruitment Projection (Constant F = 0 or no fishing, weights in mt)						
Spawning Biomass	1333	2491	3890	5340	6639	7755
Catch	0	0	0	0	0	0
Scenario 7 Recent Recruitment Projection (Constant Catch = 2,500 mt, weights in mt)						
Spawning Biomass	1640	2145	2641	3109	3499	3825
Catch	2500	2500	2500	2500	2500	2500
Scenario 8 Recent Recruitment Projection (Constant Catch = 3,600 mt, weights in mt)						
Spawning Biomass	1640	1845	2023	2188	2313	2419
Catch	3600	3600	3600	3600	3600	3600

Table C2. Projected values of median spawning biomass and catch under stock-recruitment curve.

Year	2012	2013	2014	2015	2016	2017
Scenario 1 Stock-Recruitment Curve Projection (Constant F = $F_{current}$, weights in mt)						
Spawning Biomass	1317	1431	1529	1610	1667	1703
Catch	3884	4154	4374	4543	4652	4745
Scenario 2 Stock-Recruitment Curve Projection (Constant F = F_{MSY}, weights in mt)						
Spawning Biomass	1317	1601	1838	2024	2160	2261
Catch	3195	3685	4066	4374	4583	4740
Scenario 3 Stock-Recruitment Curve Projection (Constant F = $F_{2001-2003}$, weights in mt)						
Spawning Biomass	1317	1314	1342	1362	1383	1394
Catch	4373	4431	4520	4586	4588	4648
Scenario 4 Stock-Recruitment Curve Projection (Constant F = $F_{20\%}$, weights in mt)						
Spawning Biomass	1317	1679	1985	2238	2423	2572
Catch	2890	3441	3878	4232	4491	4680
Scenario 5 Stock-Recruitment Curve Projection (Constant F = $F_{30\%}$, weights in mt)						
Spawning Biomass	1317	1923	2509	3033	3483	3830
Catch	1957	2574	3103	3533	3881	4139
Scenario 6 Stock-Recruitment Curve Projection (Constant F = 0 or no fishing, weights in mt)						
Spawning Biomass	1317	2468	3957	5692	7524	9320
Catch	0	0	0	0	0	0
Scenario 7 Stock-Recruitment Curve Projection (Constant Catch = 2,500 mt, weights in mt)						
Spawning Biomass	1625	2141	2787	3546	4386	5243
Catch	2500	2500	2500	2500	2500	2500
Scenario 8 Stock-Recruitment Curve Projection (Constant Catch = 3,600 mt, weights in mt)						
Spawning Biomass	1625	1854	2171	2584	3056	3568
Catch	3600	3600	3600	3600	3600	3600