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BACKGROUND PAPER /
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STATUS OF STRIPED MARLIN IN THE EASTERN PACIFIC OCEAN IN 2001, AND OUTLOOK FOR 2003/2004

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STATUS OF STRIPED MARLIN IN THE EASTERN PACIC OCEAN

by

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CONTENTS

The stock structure of striped marlin, *Tetrapturus audax*, is not well known in the Pacific. There are indications that there is only limited exchange of striped marlin between the eastern Pacific Ocean (EPO) and the central and western Pacific Ocean, so it is considered herein that examinations of local depletions and independent assessments of the striped marlin of the EPO are meaningful.

This report is presents an update of the information presented in Background Paper A11, presented to the 69th Meeting of the IATTC, in June, 2002. As such, it is abbreviated and does not repeat large sections of information contained therein which have gone essentially unchanged, and instead it focuses specifically on the recommendation of Section 6.3 that "As more data become available these analyses should be updated to ensure that, if there develop indications that the condition of the stock(s) of striped marlin has deteriorated, action could be considered and taken in a timely manner."

1. EXECUTIVE SUMMARY

Striped marlin occur throughout the Pacific Ocean between about 45°N and 45°S. They are caught mostly by the longline fisheries of Far East and Western Hemisphere nations. Lesser amounts are caught by recreational, gillnet and other fisheries. During recent years the greatest catches in the EPO have been taken by fisheries of Japan, Costa Rica and Korea.

Striped marlin reach maturity when they are about 140 cm long, and spawning occurs in widely-scattered areas of the Pacific Ocean.

Few tagging data are available on the movements of striped marlin. Tagged fish released off the tip of the Baja California peninsula generally have been recaptured in the same general area as where tagged, but some have been recaptured around the Revillagigedo Islands, a few around Hawaii, and one near Norfolk Island.

The catch rates of striped marlin off California and Baja California tend to be greater when the sea-surface temperatures are higher and when the thermocline is shallow. The catch rates are greater on the shallower hooks of longlines, especially when the thermocline is shallow.

The stock structure of striped marlin is uncertain. A analysis of trends in catch rates in temporally-static subareas of the EPO suggest that the fish in the EPO consist of one stock. Previous genetic studies (Graves and McDowell 1994) suggests that there are separate stocks in the eastern and western south Pacific and that there may be a separate stocks with centers of distribution in the regions proximate to Hawaii in the north-central Pacific and to Ecuador and to Mexico in the EPO. A preliminary examination of the distributions of lengths of fish landed in northern and southern subareas of the EPO supports the results of the genetic analysis. Thus the conclusions reached herein for a single stock model, chosen on the basis of trends in catch rates, should be considered tentative, and efforts should be undertaken to resolve the question of stock structure of striped marlin in the EPO. To this end a collaborative study to investigate the stock structure and status of striped marlin in the Pacific has been undertaken. Results from analysis of genetic samples from about 800 fish is soon to be completed, but at this time it is suggested from preliminary analyses that the striped marlin in the regions off Mexico and Ecuador in the EPO are from a single stock. When the final results are available, the collaborative research into the structure and status of stocks of striped marlin in the Pacific will continue.

Analyses of stock status were made using two production models taking into account the time period when billfish were targeted by longline fishing in the EPO. The results from a Pella-Tomlinson model yielded estimates of maximum sustained yield (MSY) on the range of 3,700 to 5,000, with a current depletion ratio, or ratio of current biomass (B) to the estimated unfished population biomass (B_O), of about 0.47. The ratio of B to the biomass which may be expected to yield maximum sustained yield (B_{MSY}) ranged from about 1.0 to 1.9. The results from analyses using the Deriso-Schnute delay difference population model yielded estimates of MSY on the range of 8,700 to 9,200 mt, with current depletion ratios on the range of 0.68 to 0.70, and B to B_{MSY} ratios of about 1.2 to 1.6.

The current analysis of updated catch rate data using new models and methods presents results consistent with those presented in the previous assessment of striped marlin. Landings and standardized fishing effort for striped marlin decreased in the EPO from 1990-1991 through 1998, and this general decline has continued, reaching new lows in preliminary estimates of retained catch in 2000 and 2001 of about 1,500 mt, which are well below estimated MSY harvest levels. This may result in a continued increase in the biomass of the stock in the EPO.

Based on the analyses and hypotheses herein, it is considered that the striped marlin stocks in the EPO are in good condition, with current and near-term anticipated fishing effort less than F_{MSY}.

2. DATA

2.1. Effort, catch, and landing data

Landings of billfish are fairly well known due to value of these fish in commerce. However there remain unreported landings from artisanal and recreational fisheries and from components of the commercial longline fisheries operating in the region.

Most of the commercially-landed striped marlin are taken by the longline fisheries of Far East and Western Hemisphere nations. Lesser amounts of striped marlin are or have been landed by the other fisheries described in Hinton and Bayliff (2002, Section 2.1). Data on the commercial landings of striped marlin in the EPO are shown in Table 2.1.1.

3. ASSUMPTIONS AND PARAMETERS

3.1. Environmental influences

Information on the relationship of striped marlin to their environment is given by Squire (1974a, 1985, and 1987b), Hanamoto (1974, 1978 and 1979), Miyabe and Bayliff (1987), Holts and Bedford (1990), Nakano and Bayliff (1992), Brill *et al.* (1993) and Uosaki and Bayliff (1999).

Squire (1974a) examined the catch rates for San Diego-based recreational fishing vessels, and found that the catch rates per half-month period were 40.5 fish per period when the sea-surface temperatures (SSTs) were less the 20°C, 99.2 fish per period when the SSTs were between 20° and 21.1°C, and 122.7 fish per period when the SSTs were greater than 21.1°C. When the 21.1°C isotherm was continuous the catch rates were greater than when it was discontinuous. Squire (1985) found that the landings from off Southern California were greatest when there were continuous isotherms of 22.2°C. He stated that "it is reasonable to assume that the ocean temperatures … never attain values that would result in a maximum catch … because catches appear to be increasing at the peak continuous isotherm recorded (… 22.2°C)." Squire (1987b) reported that the landings of striped marlin were distributed further to the north during the 1983 El Niño event than during "normal" years. Hanamoto (1974) reported that the catch rates of striped marlin for longliners are greater off Baja California when the thermocline is shallow and attributed this to more abundant supplies of food during such conditions. Nakamura (1985) reported that the distribution of this species was generally bounded by the 20° and 25°C isotherms at least in the western Pacific Ocean.

Holts and Bedford (1990) described the vertical movements of 11 striped marlin that were tracked with ultrasonic tags off Southern California. The fish spent most of their time in the upper mixed layer, at temperatures of 19° to 20°C, but sometimes descended to depths where the temperatures were less than 12°C. Four of the fish occupied greater depths at night than during the day. The maximum depth to which a fish descended was about 90 m. Brill *et al.* (1993) tracked six striped marlin in the vicinity of Hawaii. The fish spent about 80 percent of their time in waters with temperatures between 25° and 27°C, and never occupied water with temperatures less than 18°C. The maximum depth to which a fish descended was about 170 m. Abitia *et al.* (1998) stated that in the vicinity of Cape San Lucas, Baja California Sur, striped marlin feed on pelagic fishes during the day and "occasionally migrate to deeper waters to consume prey which live near or on the sandy bottoms."

Analyses of the compiled data for this study indicated that the majority of the records with striped marlin occurred in waters with SST between 25°-27°C, with only 32 records of catch in area with SST below 17°C. These records were identified as outliers during preliminary data screening (see analysis using S-Plus below), and in the final analysis the areas within the region considered habitat for striped marlin were those areas with average bimonthly period SST > 16°C.

3.2. Stock structure

The stock structure of striped marlin in the Pacific has not been well determined. Striped marlin are distributed throughout the temperate and warmer waters of the Pacific (Nakamura, 1985). Yoshida (1981) indicated hypotheses of either a single pan-Pacific stock, or two stocks, one north and one south of the equator, with mixing in the EPO. Hinton and Bayliff (2002, Section 3.3) considered that the predominance of the information available at the time supported the one stock hypothesis, and recommended study of the stock structure of striped marlin in the Pacific.

Results from analysis of genetic samples from about 800 fish is expected to be completed in the next few months, but at this time it is suggested from preliminary analyses that the striped marlin in the regions off Mexico and Ecuador in the EPO are comprised of a single stock (Dr. John Graves, Virginia Institute of Marine Science, personal communication, May 2003). As a result, this analysis was restricted to updating the previously suggested model (Hinton and Bayliff 2002).

4. STOCK ASSESSMENT

4.1. Indices of abundance and previous assessments

Trends in catch rates of striped marlin in the EPO have previously been calculated, using data from longline fisheries, as catch per unit of nominal effort (CPUE; Kume and Schaefer, 1966; Kume and Joseph, 1969a; Joseph *et al.*, 1974; Shingu *et al.*, 1974; Miyabe and Bayliff, 1987; Skillman, 1989; Suzuki, 1989; Nakano and Bayliff, 1992; Uosaki and Bayliff, 1999; and Anonymous, 2002). Skillman (1989) considered that there was a single Pacific population, and, using data for 1952-1984 in stock production modeling, concluded that "the Pacific fishery for striped marlin is apparently still in the development stage, and the MSY [maximum sustainabvle yield] level has not yet been approached by the fishery." Suzuki (1989) used catch-rate-based boundaries for northern and southern stocks at the equator west of 130°W and at 10°N east of 130°W. He found that for the northern stock there were sustained landings over a wide range of fishing effort and there was no trend in CPUE. From this Suzuki "inferred that the fishing impact on the north stock may not be high enough to be a dominant factor in changing stock size." For the southern stock, Suzuki (1989) used data for 1952-1985 and production modeling to estimate that the MSY of this stock was on the order of 6,000 to

9,000 mt and that the fishery was then exploiting the stock at near optimum levels.

Holts and Prescott (2001; Figure 1b) show the catch rates of striped marlin by recreational fishermen off Baja California. There was no significant trend in these catch rates ($p = 0.4$) which varied between about 0.3 and 0.8 fish per angler day from 1969 to 2000. They also show that the rates for recreational fishermen off Southern California also remained nearly constant, at less than 0.2 fish per angler day, except for rates of about 0.3 fish per angler day in 1985, and that the catch rates for fishermen in Hawaii have increased steadily from 1969 until about 1986 and that they since have remained relatively constant at about 0.1 fish per angler day.

The assessment presented in 2002 (Hinton and Bayliff 2002) was obtained using a series of ? -distribution models (Pennington, 1996) fit using general linear models (GLMs) to obtain annual abundance indices, and the Deriso-Schnute delay-difference population model (Quinn and Deriso, 1999) was used with catch and effort data for 1955-1998 from the area east of 150°W to investigate the dynamics of striped marlin stocks in the EPO. Recruitment was modeled with a Beverton-Holt recruitment curve (Ricker, 1975). . The conclusions therein indicated that the stock(s) of striped marlin in the EPO were at or near the level expected to provide landings at average maximum sustainable yield (AMSY), with an AMSY of about 4,500 mt (range: 4,300 to 4,700 mt) and a 1998 stock biomass of about 1.01 times the biomass expected at AMSY (B/B_{AMSY} ratio = 1.01).

4.2. Assessment

Standardized measures of catch per unit effort were obtained by minimizing a log-likelihood function of observed and estimated catch obtained using general linear models and using the statistical habitat-based model (statHBS: Hinton and Nakano 1996, Hinton et al 2001) with and without GLM components. Model selection followed guidelines and recommendations summarized in Hinton and Maunder (2003), with selection of the final two models for consideration in dynamics based on cross validation selection criteria of Maunder and Hinton (Submitted).

Herein standardized effort for striped marlin was obtained at 2° latitude by 5° longitude by bimonthly resolution for the 1963-2001 period for the longline fishery of Japan. The first year in the series was judged that in which the fishery was well distributed over much of the area, though more recently the fishery in the northeastern region of the EPO has experienced significant decreases in fishing effort by this fleet (Hinton and Bayliff 2002). The period from 1964-1974 has been noted to be a period with specific targeting of billfishes, particularly in the northeastern most portions of the EPO (Miyabe and Bayliff 1987), and this is addressed in the dynamics models examined in analyses presented herein by incorporating two coefficients of catchability (q), one for the 1964-1974 period, and one for all other years.

Initial analyses to help determine the constant to be added to catch to prevent problems encountered when attempting to take the natural logarithm of zero were made by examination of residuals of GLM models fitted to selections of the data using S-Plus with subsequent examination of residual and diagnostic plots. At this point outliers were identified (see section on environmental influences above). Once this preliminary step was completed, catch rate standardization models were fitted using AD-Model Builder, and the dynamics model was fitted using Solver [Microsoft Excel 2002 (SP-2)].

The final two standardization models selected were a GLM, with cross validation score (cvs) equal to 62 percent of the score achieved by fitting the nominal effort series (hereafter GLM+), and a statHBS model (Hinton et al 2001) with GLM components, which had a cvs of 63 percent of the nominal score (hereafter HBS+) Results of fitting the models, and trends in total catch and estimated total standardized effort based on GLM+ are shown in Figure 4.2.1. The lower the cvs the better the performance of the model in predicting the values of catch observed in a set of data randomly selected from the full data set available for fitting the model, but not used in model development or fitting. Standard regression diagnostics from the fitting are presented in Figures 4.2.2-4.2.4.

An analysis of the dynamics of the population using a Pella-Tomlinson model (Pella and Tomlinson 1969) using GLM+, one and two coefficients of catchability as described above, and not fitting to recruitment residuals, across a range of B_{MSY}/B_O from 0.1 to 0.5, yielded estimates of maximum sustained yield (MSY) on the range of 3,400 to 4,100, and 3,700 to 5,000 for one and two qs, respectively (Figure 4.2.5). The current depletion ratio is estimated to be about 0.33 and 0.48. The biomass level with respect to B_{MSY} is dependent on the value used for B_{MSY}/B_O. There was no significant difference ($c_1^2; p < 0.84$) in the log likelihood values observed across the range of B_{MSY}/B_O for the two q model (Table 4.2.1). Model fits were obtained using Solver [Microsoft Excel 2002 (SR-2)].

The results from an analysis of the dynamics of the population using the Deriso-Schnute delay difference population model (Quinn and Deriso, 1999) fitted to GLM+ using two qs is summarized in Table 4.2.2. The model was fit across a range of values survival and growth rates (Hinton and Bayliff 2002, Section 4.2) while controlling steepness. The results appear more sensitive to estimates of growth and survival than to steepness: there is no significant difference ($c_1^2; p < 0.58$) between fits with log likelihoods greater than 110, but the differences between these likelihoods and those with lower observed values are significant ($c_1^2; p < 0.026$). For fits with log likelihoods above 100, estimates of MSY were on the range of 8,700 to 9,200 mt, with current depletion ratios on the range of 0.68 to 0.70.

The results from these analyses are consistent with the results obtained using the Deriso-Schnute delay-difference population model using catch and effort data for 1955-1998 period as presented in Hinton and Bayliff (2002, Section 4).

5. STOCK STATUS

The results cited indicate that striped marlin in the EPO are at or above the level expected to provide landings at MSY for the Pella-Tomlinson one q model when $B_{MSY}/B_O < 0.35$ and for the two q model for all values of B_{MSY}/B_O investigated. The current production is estimated at about 3300 to 3800, which is substantially more than the current catch. The results from the Deriso-Schnute model with two qs indicated that striped marlin are above level expected to provide landings equivalent to MSY, and that the current depletion ratio is higher than indicated by the Pella-Tomlinson model.

There has been a decreasing trend in standardized fishing effort since about 1990-1991. Early indications are that the nominal fishing effort will continue for the next few years near or below levels observed in recent years. Based on the analyses and hypotheses herein, it is considered that the striped marlin stocks in the EPO are in good condition, with current and near-term anticipated fishing effort less than F_{MSY}.

6. FUTURE DIRECTIONS

6.1. Collection of new and/or updated information

In general previous recommendations made concerning data and information on striped marlin remain true.

There remain questions about the stock structure of striped marlin in the EPO. New genetic analyses are expected and collaborative effort to analyze the status of stocks of striped marlin that utilize information from those studies, as well as incorporate available biological and tagging data will continue when those genetic results are available. As a result, this analysis was restricted to updating the previously suggested model (Hinton and Bayliff 2002).

Assessment analyses would benefit significantly from improved information on the growth rates and natural mortality rates of striped marlin. This species exhibits sexual dimorphic growth, and improved estimates of sex-specific size at age, with estimates of the landings by sex, would be expected to increase confidence in the results. These improvements would require increased on-board sampling for biological data, and improvements in techniques for aging of striped marlin.

Estimates of total removals of fish from a population are critical to stock assessment. There remain undocumented and unreported landings of striped marlin from the EPO. Efforts have been undertaken to increase reporting of landings made by artisanal and small-scale commercial fisheries, and attempts are being made to obtain estimates of landings of components of the large-scale longline fisheries for which data are not now available. Though there have been improvements in these areas during the intervening period, these efforts should be pursued with diligence.

6.2. Assessment model development

Significant progress has been made during the year in developing a consistent approach to model development and selection criteria (Hinton and Maunder 2003, Maunder et al Submitted, Maunder and Hinton Submitted).

A more detailed analysis of the distribution of relative abundance, and of length-frequencies, of striped marlin on small spatial and temporal scales in the EPO should be made to determine if there exist identifiable stocks with dynamic stock boundaries in the region. If such are found, then updated analyses of stock status may be made.

A collaborative effort examining the stock structure and status of striped marlin in the Pacific Ocean initiated during 2002. Progress has been made on compiling data bases and on preparing initial analyses of parts of the data, and it is expected that this effort will continue through 2003. Hypotheses analyzed in this effort will include those developed from analyses of genetic information, as well as those with a basis in fisheries, such as those of Squire and Suzuki (1990).

6.3. General

As more data become available these analyses should be updated to ensure that, if there develop indications that the condition of the stock(s) of striped marlin has deteriorated, action could be considered and taken in a timely manner.

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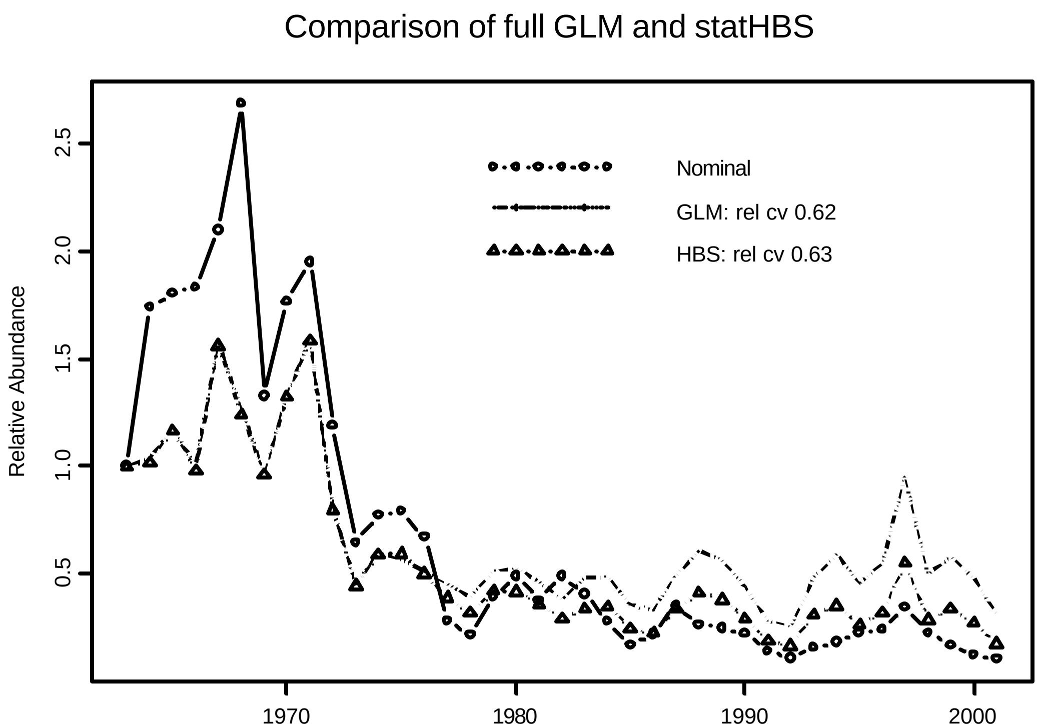

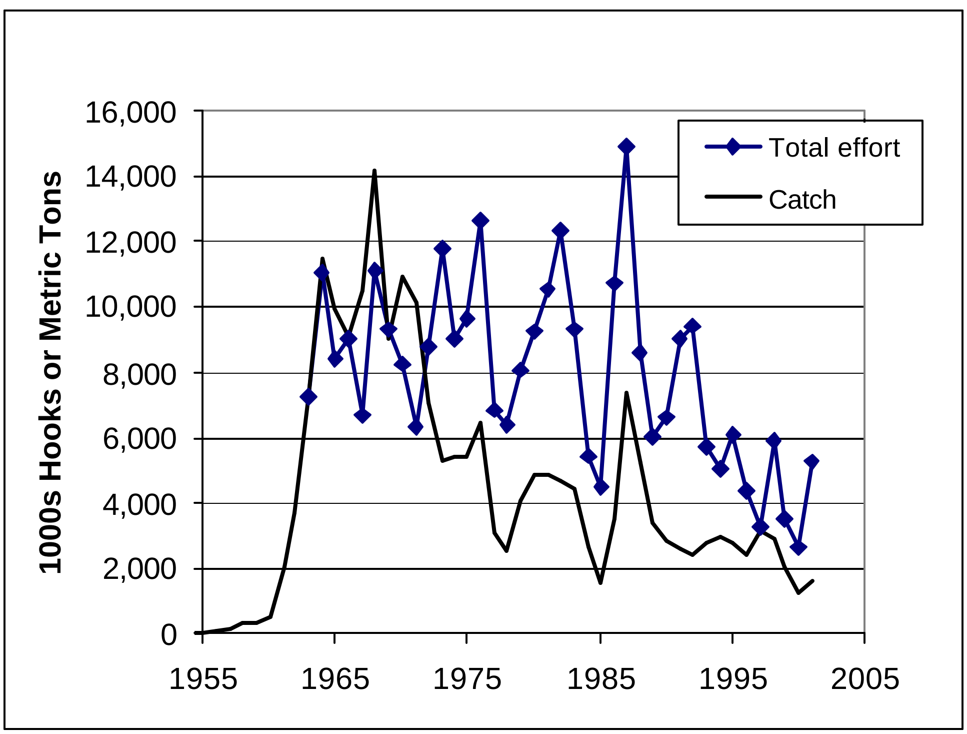

Figure 4.2.1. Upper: Fitted GLM+ and HBS+ versus nominal catch rates for striped marlin in the eastern Pacific Ocean (EPO), 1963-2001. Lower: Total catch (metric tons, 1954-2001) and estimated total standardized effort based on GLM+ (1963-2001) for striped marlin in the EPO.

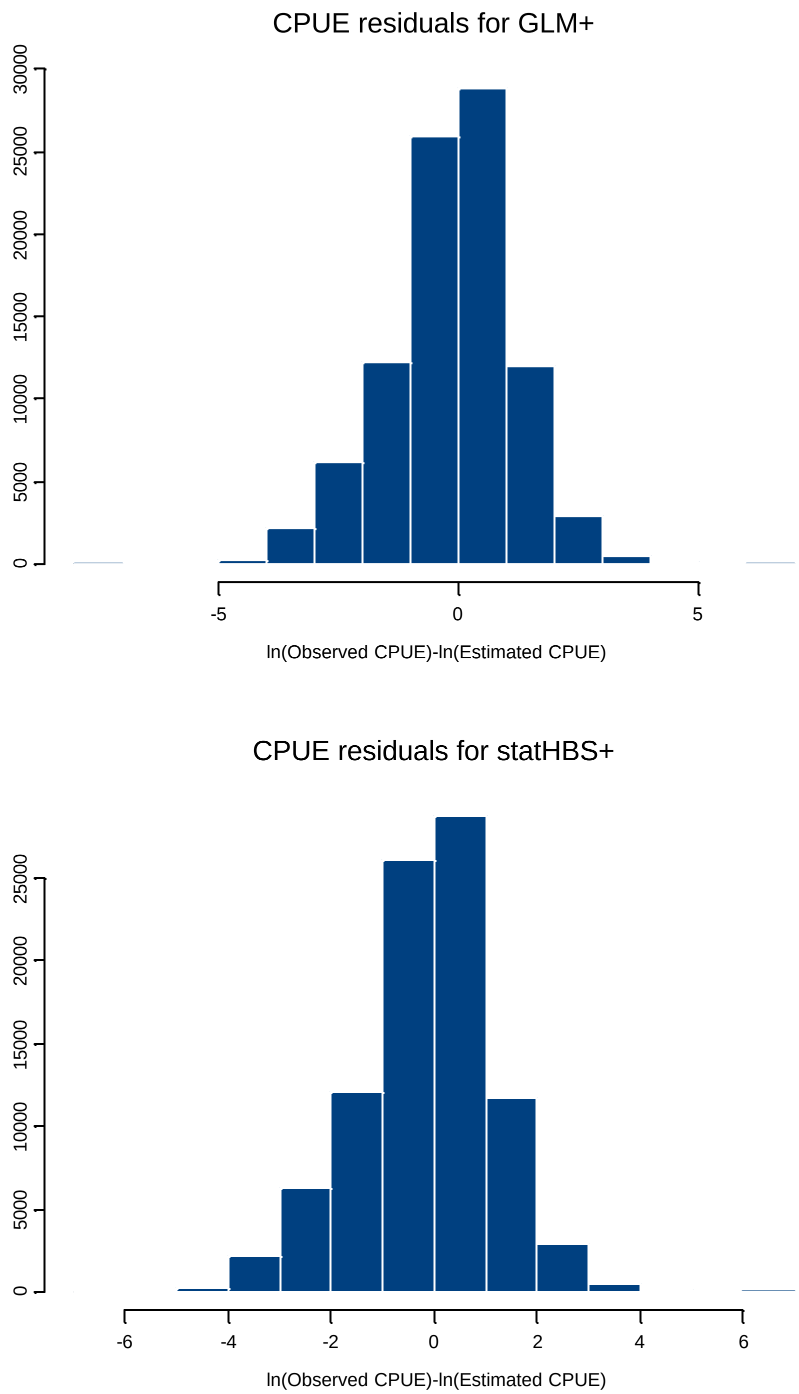

Figure 4.2.2. Frequency distribution of residuals from fitted GLM (upper) and HBS (lower) models.

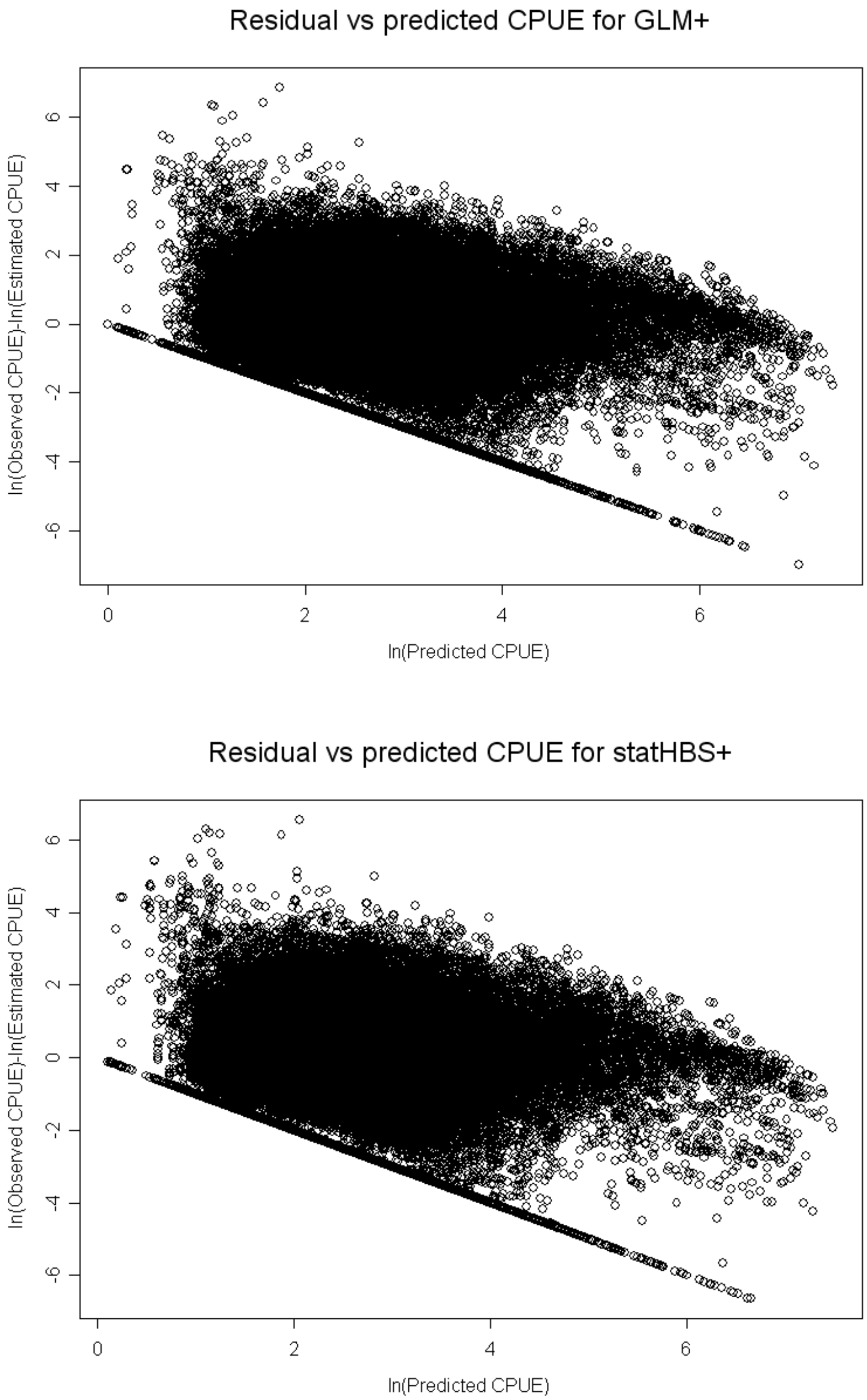

Figure 4.2.3. Deviance residuals for fitted GLM (upper) and HBS (lower) models.

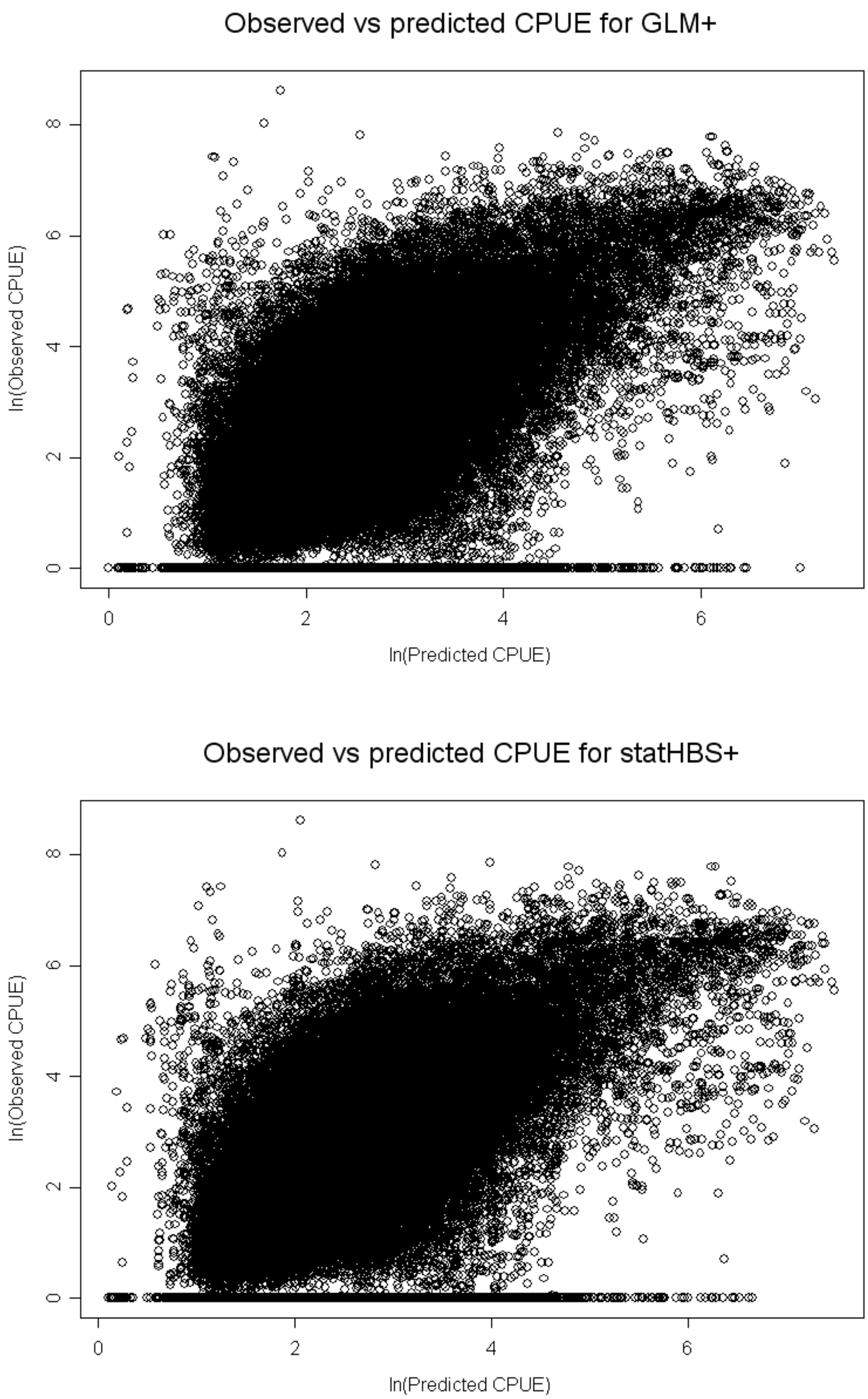

Figure 4.2.4. Fitted versus observed values for GLM (upper) and HBS (lower) models.

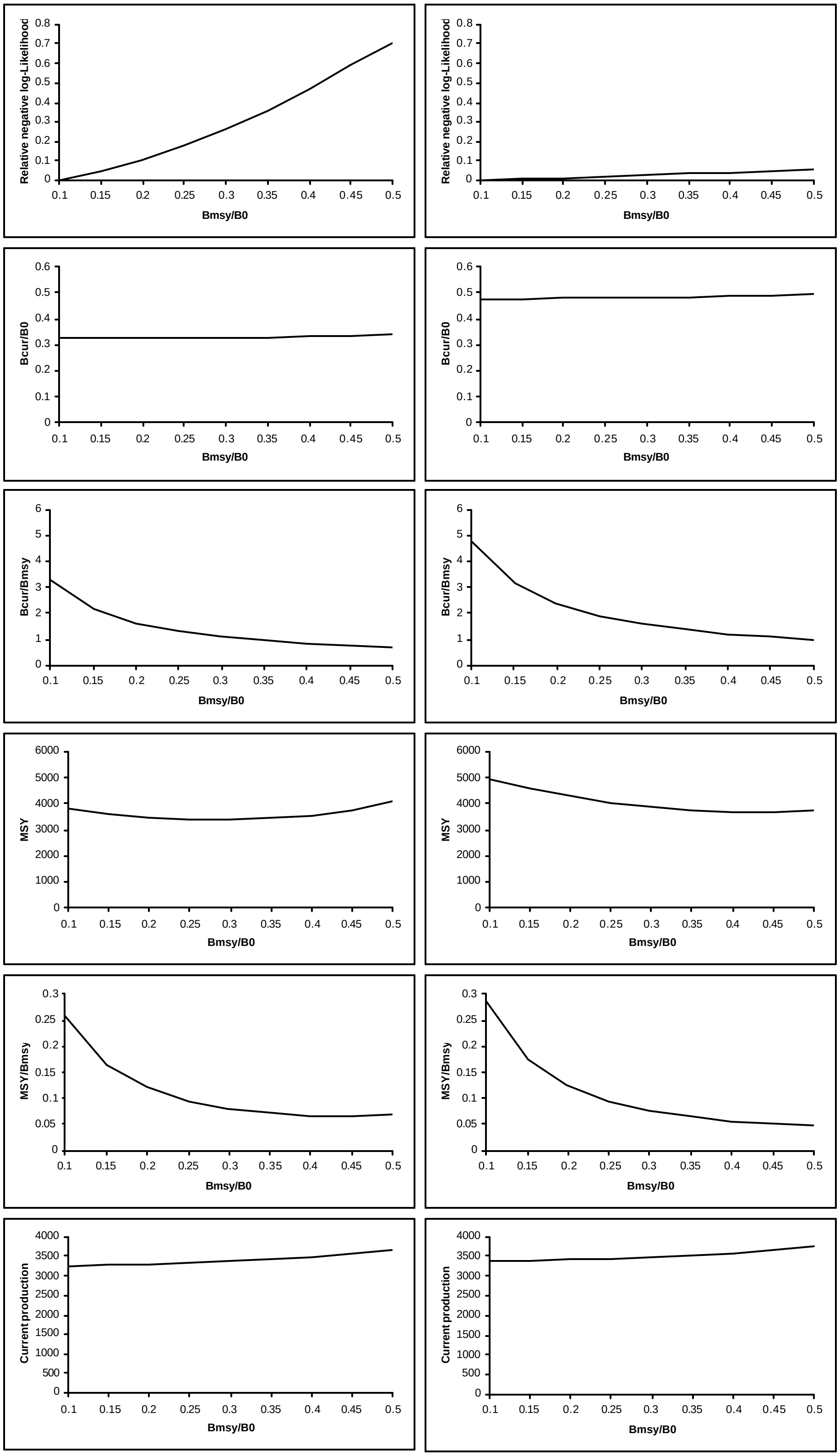

Figure 4.2.5. Results from the Pella-Tomlinson model fit to the GLM+ index of abundance with one q (Left) and two qs (Right) for different levels of B_{MSY}/B_0.

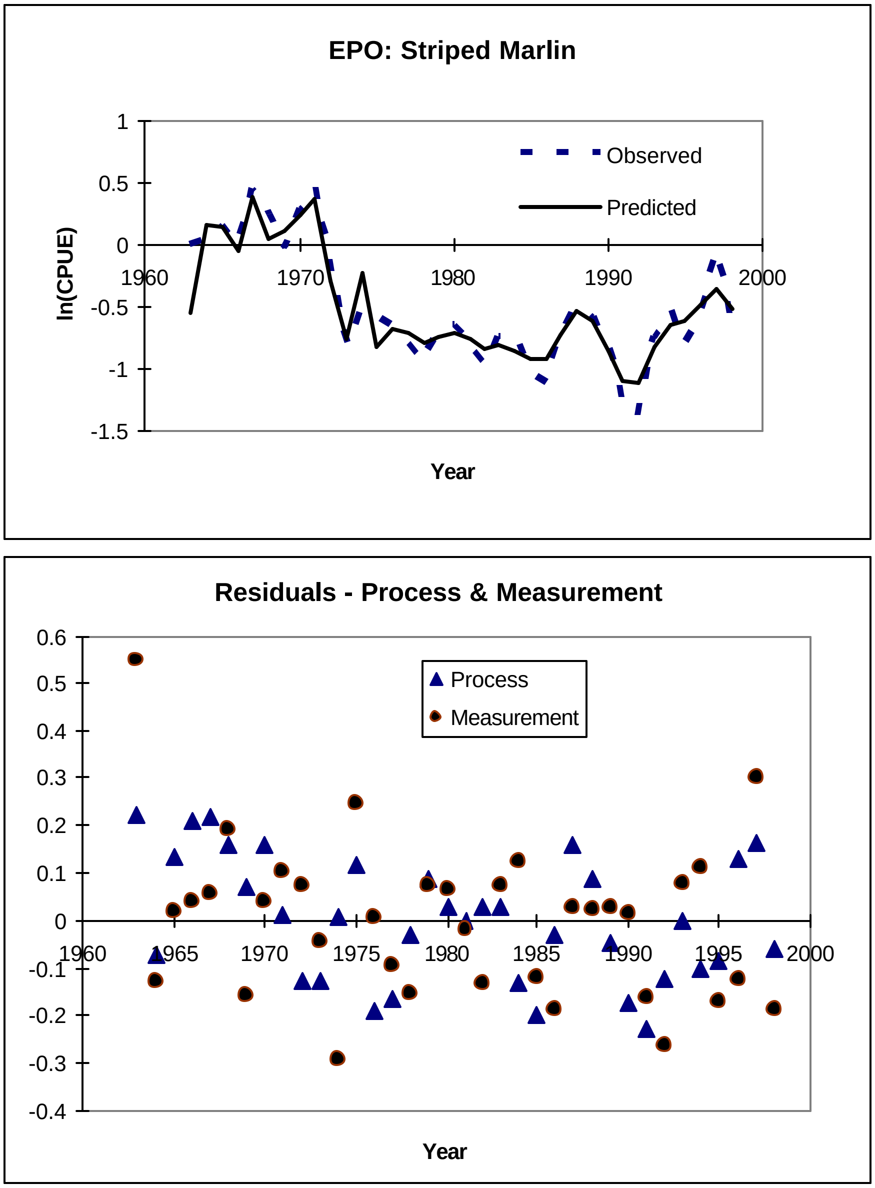

Figure 4.2.6. Observed and predicted relative abundance of striped marlin in the EPO from a Deriso-Schnute delay difference model (upper) and process and measurement residuals (lower): Steepness = 0.7, Brody growth = 0.4, Survival = 0.3.

Table 2.1.1. Preliminary estimates of retained catch (mt) of striped marlin from the eastern Pacific Ocean. 0 = more than zero but less than 0.5 mt; ... = data not available; unattainable; data not separately available but included in another category.

Year	JPN	TWN	MEX	CRI	PYF	KOR	USA	Total
1954	23	...	...	...	...	...	...	23
1955	16	...	...	...	...	...	...	16
1956	67	...	...	...	...	...	...	67
1957	150	...	...	...	...	...	...	150
1958	326	...	...	...	...	...	...	326
1959	371	...	...	...	...	...	...	371
1960	530	...	...	...	...	...	...	530
1961	2034	...	...	...	...	...	...	2034
1962	3720	...	...	...	...	...	...	3720
1963	7245	...	...	...	...	...	...	7245
1964	11467	...	...	...	...	...	...	11467
1965	9936	...	...	...	...	...	...	9936
1966	9064	...	...	...	...	...	...	9064
1967	10370	144	...	...	...	...	...	10513
1968	14138	55	...	...	...	...	...	14193
1969	9011	12	...	...	...	...	...	9022
1970	10949	27	...	...	...	...	...	10976
1971	10049	69	...	...	...	...	...	10118
1972	6981	124	...	...	...	...	...	7106
1973	5116	161	...	...	...	...	...	5277
1974	5229	174	...	...	...	...	...	5402
1975	5361	59	...	...	...	10	...	5429
1976	6410	49	...	...	...	14	...	6473
1977	3020	47	...	...	...	19	...	3086
1978	2170	34	...	...	...	292	...	2496
1979	4056	23	...	...	...	43	...	4123
1980	4771	85	0	...	...	23	...	4879
1981	4096	41	...	...	...	733	...	4870
1982	4162	38	...	...	...	482	...	4682
1983	3457	16	193	...	...	790	...	4455
1984	2306	7	...	...	...	339	...	2652
1985	1329	5	93	...	...	165	...	1592
1986	2535	24	976	...	...	...	...	3534
1987	5043	56	2184	...	...	251	...	7533
1988	3412	28	1636	...	...	178	...	5253
1989	3153	48	59	...	...	140	...	3400
1990	2812	11	...	...	...	305	...	3128
1991	2321	8	...	188		384	4	2906
1992	2006	136	...	147	16	538	12	2855
1993	2237	160	5	243	1	738	14	3398
1994	2379	129	11	270	64	475	3	3333
1995	2211	11	30	306	80	495	17	3151
1996	1961	22	0	237	90	614	10	2933
1997	2617	67	...	272	88	908	7	3959
1998	2272	21	29	281	65	640	16	3323
1999	1284	45	11	334	115	621	25	2434
2000	818	45	32	190	80	364	3	1533
2001	1132	45	5	274	73	286	3	1817

Table 4.2.1. Values of management parameters of interest obtained from fitting of a Pella-Tomlinson production model with two time periods with differing values of catchability across a range of B_{MSY}/B_0.

B_{MSY}/B_0	B_0	m	p	MSY	B_{MSY}	B/B_{MSY}	B/B_0	log likelihood
0.25	167901	0.50	0.09	3972	41975	1.86	0.47	89.88
0.30	166042	0.68	0.08	3810	49752	1.56	0.47	89.87
0.35	163683	0.91	0.06	3701	57269	1.34	0.47	89.86
0.40	160690	1.19	0.06	3650	64324	1.18	0.47	89.86
0.45	156919	1.55	0.05	3664	70635	1.05	0.47	89.86
0.50	152072	2.00	0.05	3754	76036	0.95	0.48	89.88

Table 4.2.2. Values of management parameters of interest obtained from fitting of a Deriso-Schnute delay difference model with Beverton-Holt stock recruitment and indicated values of Brody growth coefficient and annual survival rate, and with a two time periods with differing values for catchability across ranges of steepness, growth, and survival B_0 = unexploited stock biomass, MSY = maximum sustained yield, B_{MSY} = biomass at MSY.

Steepness	Brody Growth Coefficient	Survival	B_{MSY}/B_0	B/B_0	B/B_{MSY}	MSY	B_{MSY}	log likelihood
0.7	0.4	0.4	0.445	0.689	1.550	8766	8768	103.1
0.7	0.4	0.5	0.320	0.696	2.177	7990	8084	93.0
0.7	0.4	0.6	0.315	0.694	2.201	6932	9916	79.1
0.7	0.4	0.7	0.310	0.652	2.099	5866	12147	62.8
0.7	0.60	0.3	0.523	0.684	1.308	8930	8931	107.8
0.7	0.75	0.3	0.486	0.687	1.412	8860	8861	105.6
0.7	0.90	0.3	0.452	0.691	1.527	8793	8794	103.4
0.7	0.40	0.3	0.570	0.680	1.193	8980	8980	110.4
0.7	0.40	0.5	0.327	0.700	2.141	8164	8168	93.7
0.7	0.40	0.9	0.280	0.249	0.891	3387	19709	17.5
1.0	0.40	0.3	0.616	0.689	1.119	9174	9174	110.3
1.0	0.40	0.4	0.504	0.700	1.390	9159	9160	104.2
0.7	0.40	0.4	0.445	0.689	1.550	8766	8768	103.1
0.5	0.40	0.4	0.372	0.648	1.741	7276	7962	98.4