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Catch Estimates for striped marlin (*Tetrapturus audax*) in the North Pacific, 1952-2004

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Abstract

Estimates of catch are a basic requirement for most stock assessment models. This document describes how catch estimates were developed for striped marlin in the North Pacific using recorded effort in hooks and standardized CPUE values. Results indicate close agreement with nominal reported catches calculated from Japanese, Chinese Taipei, United States and Secretariat of the Pacific Community (SPC) databases. Catches peaked in the late 1960s at levels between 500,000 to 800,000 fish per annum before sharply declining to between 100,000 and 200,000 in the 1980s. Since 1998 catches are estimated at or below 50,000 fish per annum.

Introduction

This analysis is based on the following datasets:

- Logbook records from the Japanese distant water ("Enyo") and offshore ("Kinkai") longline fleets aggregated into 5x5 degree blocks. The database is comprised of two portions: records from the years 1952-1980 contain information on month/year, location, hooks fished and catch of striped marlin; records from the years 1975-2004 contain this information plus data on the number of hooks per basket (hpb, an indication of hook depth) and the number of sets represented in each data point (n=39,139 data points for the early series and n=138,837 for the late series; NRIFSF, unpub. data).
- Logbook records for longline fisheries provided by the Chinese Taipei Fisheries Agency for 1965-2003 containing information by month/year, location (by 5x5 degree block), hooks fished and catch of striped marlin (n=1,807; CTFA, unpub. data)
- Estimates of standardized catch of striped marlin by month/year and 1x1 degree block for the Hawaii-based longline fishery prepared by the Pacific Islands Fisheries Science Center (NMFS) for 1990-2004. Number of hooks are also provided for each record (n=26,554; NMFS, unpub. data).
- Public domain data on catch and effort of longline fleets in the Pacific maintained by the SPC. These records, which extend from 1952 through 2003 are aggregated

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by 5x5 degree block, and contain information on month/year, hooks fished and catch of striped marlin (n=95,634; SPC 2005).

All catch and effort data were assumed to be accurate and no adjustments were made for under- or mis-reporting. As a first step, annual and quarterly nominal catch estimates were prepared from the reported catch numbers in each database. As an alternative, catches were also estimated by taking the product of reported effort (hooks) and standardized catch per unit effort (CPUE). Since the format of the CPUE values required for this estimation is different from the CPUE model described in Yokawa and Clarke (2005), a separate CPUE standardization model was run for this analysis. The CPUE models in Yokawa and Clarke (2005) are similar in most regards and were compared to ensure basic compatibility between results (see below).

Methods

Estimation of Nominal Catches

Nominal catch estimates were calculated by converting all locational data to 5x5 degree blocks[3] and assigning a unique identifier by block, year and quarter. Japan, Chinese Taipei and Hawaii fleet catches were aligned by the unique identifier and subtracted from catch reported in the SPC database for that identifier to produce a "residual" catch. If the residual catch was negative, it was set to zero. Since there were no records available for 2004 in the Chinese Taipei and SPC databases, 2003 values were applied for 2004. The Japan, Chinese Taipei, Hawaii and residual catches were then summed to produce a catch estimate for each unique identifier, and subsequently aggregated by year and quarter to produce nominal estimates.

Estimation of Effort

Estimates of the total number of hooks by year, quarter and block were compiled in a similar manner to the nominal catches described above. However, since the purpose of the effort tallies was to estimate catches using standardized CPUE values, and since the Hawaii data already provided catches based on a standardization process, hooks from the Hawaii database were used to calculate the residual hooks but were not added to the final tally[4].

Estimation of CPUE

The data used for estimation of standardized CPUE was the Japanese longline data in its two forms: 1952-1980 and 1975-2004. All records were assigned area numbers according to the three area stratification scheme maps used in Yokawa and Clarke (2005) (Figure 1). Prior to modeling, all records for which the number of hooks was less than 10,000 were removed as such operations are expected to lie outside of the main fishing

[3] All longitudes were converted to degrees east, and all latitudes and longitudes were truncated at the nearest, lower 5 degree interval, i.e. all points were moved to the southwestern gridpoint of the block.
[4] Hawaii fleet catches were instead added to estimated catches at the last step of catch calculation.

grounds. Similarly all records for which hpb was recorded as less than 3 or greater than 22 were culled from the 1975-2004 database. The remaining records then numbered 31,456 for the early period and 83,467 for the later period.

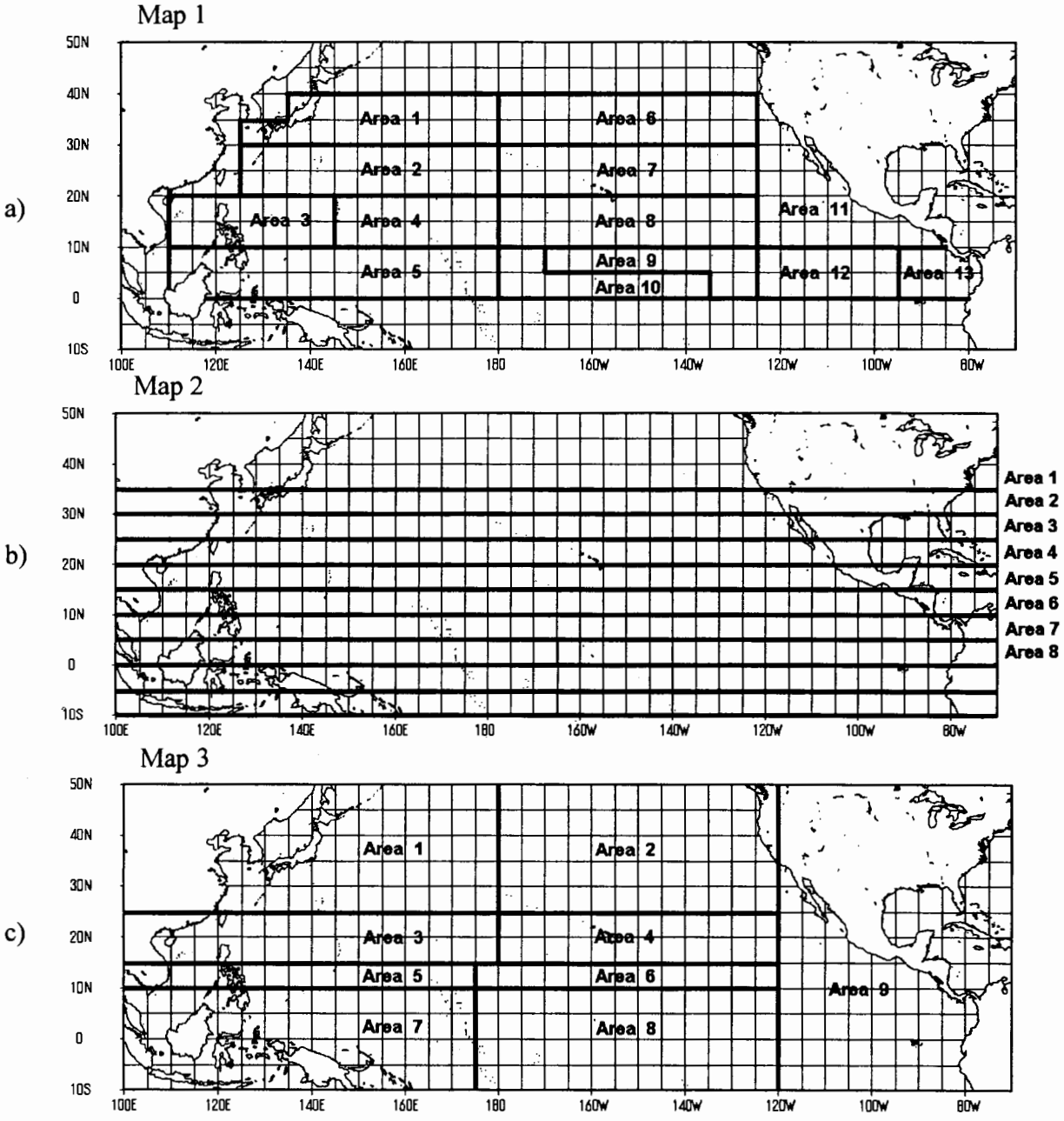

Figure 1. Three area stratification schemes based on a) expert judgment; b) the CHAID tree classification algorithm; c) the CART tree classification algorithm. All areas were limited to the area within 0° to 40° N latitude; the western boundary formed by Areas 1, 2, 3 and 5 in the top panel; and to the east by the western coast of North and South America.

Two types of generalized linear models (GLM) were applied using Splus software (Splus, 2000). The first GLM was a basic Poisson-distributed model of catch (in numbers) with hooks as an offset:

$$E(Catch) = \exp(Hooks) \times \exp\begin{pmatrix} Intercept + (Year\ Effect \times Year) + \\ (Quarter\ Effect \times Quarter) + \\ (Area\ Effect \times Area) + (hpb\ Effect \times hpb) \end{pmatrix} + \varepsilon \qquad (1)$$

The second model was a log normal model of CPUE which was defined as catch per 1,000 hooks:

$$\log(CPUE + 0.001) = Intercept + (Year\ Effect \times Year) + (Quarter\ Effect \times Quarter) + (Area\ Effect \times Area) + (hpb\ Effect \times hpb) + \varepsilon \qquad (2)$$

The terms for year (29 in the early model; 30 in the late model), quarter (4), area (13 in Map 1, 8 in Map 2 and 9 in Map 3) were designated as factors. The term hpb, which was included only in the later model as a factor, was partitioned into intervals of 3-4, 5-7, 8-9, 10-11, 12-13, 14-18, 19-22 hpb as described in Yokawa and Clarke (2005). Interactions were initially included in the models in order to maintain consistency with the models described in Yokawa and Clarke (2005). However, using the model to predict for combinations of factors for which data were scarce or non-existent produced extreme outliers and thus to avoid biased predictions, only main effects models were used. Predictions were obtained using the Splus predict.gam function with type set to response. For the Poisson model predictions, the average number of hooks per record in the modeled database (i.e. 135,328 for the early series and 32,785 for the later series) was set as a constant number of hooks per record in the predictor database. Subsequently, Poisson model predictions were divided by 135.328 and 32.785 to obtain CPUE per 1,000 hooks. For the log normal model, predictions were back-transformed from log space to produce CPUE per 1,000 hooks.

The predicted values of CPUE for each year were produced from the early database for years 1952-1974 and from the later database for years 1975-2004 for both the Poisson and log normal models and each of the three area stratification schemes. The 1952-1974 and 1975-2004 predicted values of CPUE, though based on different models (i.e. the inclusion of the hpb factor in the latter model), did not require further standardization to form a coherent series[5]. However, for the purposes of plotting, all series were centered on their mean[6] prior to plotting.

[5] A method of "stitching" together two CPUE series in which the ratio of the early series' value : late series' value is computed for overlapping years and the average of this ratio is used as a divisor for all non-overlapping early series values would be appropriate for index coefficients but is unnecessary for series of predicted CPUE values.

[6] Each value in the series was divided by the overall mean for the series.

Partitioning of Effort by Depth

Tallies of effort by year, quarter and map area were prepared from the results of aligning the Japan, Chinese Taipei, Hawaii and SPC effort databases described above. However, the later CPUE model predictions were based on depth (hpb), therefore, it was alos necessary to partition the effort into depth categories. The Japan longline database for 1975-2004 was used to generate the number and proportion of hooks in each of the seven depth (hpb) intervals for each year, quarter and map area combination (i.e. for each of the three maps). The resulting proportions were multiplied by the total number of hooks in each year, quarter and map area cell to obtain total hooks by depth as a fourth dimension to the array.

Calculation of Catch

For 1952-1974, for each year-quarter-map area combination, predicted CPUE (per 1000 hooks) was multiplied by effort (in 1000 hooks) to obtain predicted catch. For 1975-2004, effort (in 1000 hooks) for each year-quarter-map area-depth interval combination was multiplied by predicted CPUE for the same combination to obtain predicted catch. Catches were aggregated by year or year-quarter to obtain times series values. As a final step, the Hawaii fleet catch was added to the predicted catch for all time steps beginning in 1990.

Results

As described above, predictive models were limited to main effects models only (i.e. without interaction). To ensure compatibility with the approach applied in standardizing Japan longline CPUE, CPUE series based on annual values for main effects only were predicted for the Poisson and log normal models for comparison (Figure 2).

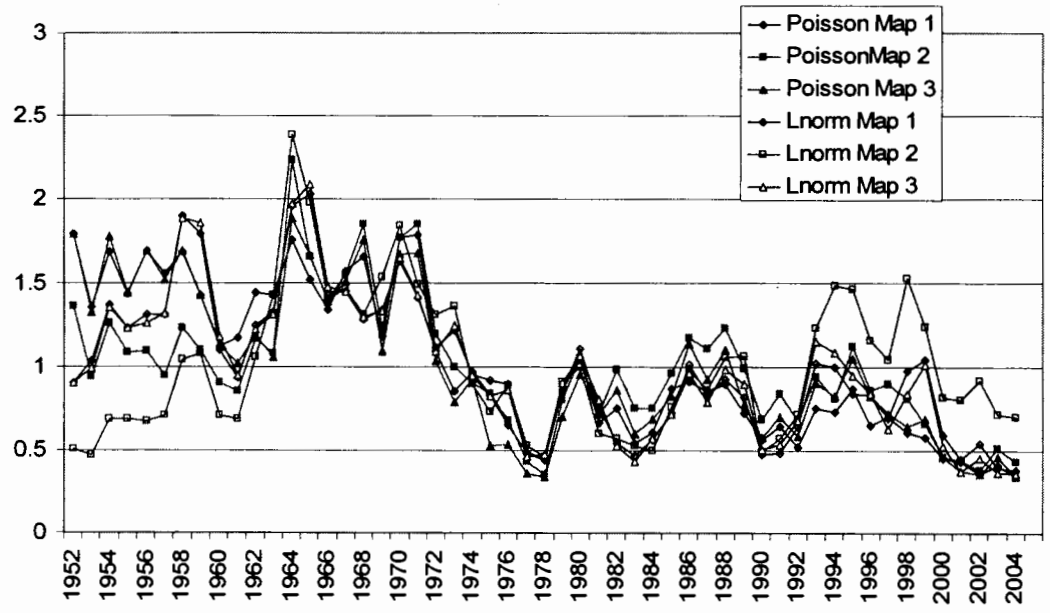

Figure 2. Annual CPUE for striped marlin in the North Pacific, 1952-2004, based on Poisson and log normal models under three area stratification schemes.

Discussion

Despite the differences in the models used to predict CPUE for this analysis and the model used to standardize data for the Japanese longline database (i.e. Poisson distribution versus log normal; omission of interaction terms), there appears to be no meaningful difference between the two methods. Catch estimates based on the four methods applied here are largely consistent with the exception of 60-100% differences between the lowest and highest estimates during an 8-year period in which catches peaked (1962-1969).

The four alternative catch estimates provided here serve as a menu of catch series to use when running base case and alternative scenarios for stock assessment models. In addition to the series presented here, it would be possible to focus on one of the estimated series and use the standard errors for the CPUE estimates to construct CPUE confidence intervals which could then be multiplied by hooks to form "high" and "low" catch scenarios for model testing. Such methods of incorporating uncertainty into the catch series are particularly recommended for models which do not account for catch uncertainty internally, e.g. the current version of the Bayesian surplus production model (Clarke and McAllister, 2005) among others.

References

Clarke, S. and McAllister, M. 2005. Application of a Bayesian surplus production model to blue shark (*Prionace glauca*) in the North Pacific. ISC Joint Session of the Marlin and Swordfish Working Groups, Shimizu, Japan.

SPC (Secretariat of the Pacific Community). 2005. Oceanic Fisheries Program Public Domain Data, 5x5 Aggregated Catch and Effort Data, accessed in November 2005 at http://www.spc.int/OceanFish/html/statistics/index.htm#Public

Splus Statistical Software. 2000. Mathsoft International, Bagshot, Surrey, United Kingdom.

Yokawa, K. and Clarke, S. 2005. Standardizations of CPUE of striped marlin caught by Japanese offshore and distant water longliners in the north Pacific. Paper submitted to the ISC Striped Marlin Assessment Workshop, Honolulu, November 2005.

Table A1. Annual and quarterly catch estimates for striped marlin in the North Pacific, 1952-2004, based nominal reported catches.

	Annual	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1952	100,790	18,831	35,137	17,422	29,400
1953	101,292	20,327	27,592	7,318	46,055
1954	268,597	26,864	60,605	41,848	139,280
1955	180,856	31,207	43,353	32,015	74,281
1956	190,985	30,802	34,918	30,618	94,647
1957	167,816	33,820	44,782	22,032	67,182
1958	251,943	33,479	48,061	42,444	127,959
1959	229,218	47,422	55,106	58,480	68,210
1960	234,950	42,095	73,307	53,795	65,753
1961	311,134	31,349	64,633	112,935	102,217
1962	408,325	78,071	116,641	107,371	106,242
1963	460,813	81,055	121,696	111,743	146,319
1964	789,324	108,008	215,987	215,361	249,968
1965	632,169	69,968	186,365	209,342	166,494
1966	483,411	67,635	104,949	155,458	155,369
1967	601,063	78,289	144,968	227,973	149,833
1968	762,892	86,887	167,613	282,331	226,061
1969	450,919	83,910	98,995	131,313	136,701
1970	494,365	56,008	92,823	101,917	243,617
1971	408,755	72,391	74,590	84,374	177,400
1972	280,052	72,202	51,152	91,205	65,493
1973	263,041	47,088	48,216	68,261	99,476
1974	262,247	44,173	41,248	96,980	79,846
1975	215,664	37,456	31,803	80,739	65,666
1976	206,420	39,807	41,288	73,284	52,041
1977	98,722	28,926	29,891	17,067	22,838
1978	98,550	20,347	22,268	15,854	40,081
1979	176,396	44,150	50,306	42,099	39,841
1980	190,297	47,326	36,639	43,280	63,052
1981	199,598	44,050	28,026	45,948	81,574
1982	234,248	49,682	47,662	67,215	69,689
1983	178,051	34,679	48,058	58,370	36,944
1984	133,736	34,248	26,346	33,461	39,681
1985	126,603	28,604	44,032	30,967	23,000
1986	182,584	46,208	57,377	33,546	45,453
1987	198,677	35,469	57,931	44,553	60,724
1988	218,995	56,838	58,333	39,858	63,966
1989	158,970	43,059	41,791	32,614	41,506
1990	89,708	28,523	22,902	16,680	21,603
1991	122,085	36,030	35,581	19,823	30,651
1992	120,557	27,823	33,727	23,159	35,848
1993	157,461	47,331	48,204	19,445	42,481
1994	135,664	42,081	39,990	19,120	34,474
1995	175,765	31,977	38,709	32,958	72,121
1996	126,269	40,705	37,405	16,786	31,373
1997	131,703	27,822	39,058	29,563	35,260
1998	90,651	19,797	27,314	17,271	26,270
1999	88,323	27,573	21,524	12,466	26,761
2000	54,767	15,248	11,077	13,903	14,540
2001	58,156	16,139	9,957	13,342	18,718
2002	51,167	15,307	11,218	9,288	15,354
2003	81,885	25,928	13,051	15,477	27,429
2004	78,082	26,089	12,731	13,771	25,491

Table A2. Annual and quarterly catch estimates for striped marlin in the North Pacific, 1952-2004, based on the Poisson Map 1 model.

	Annual	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1952	93,860	19,598	23,644	12,247	38,370
1953	80,708	20,043	18,022	17,665	24,978
1954	87,804	22,525	22,899	17,161	25,218
1955	103,445	21,057	32,924	20,923	28,541
1956	97,134	27,677	28,287	11,351	29,819
1957	149,242	28,303	28,467	39,139	53,333
1958	275,241	55,130	98,773	60,545	60,794
1959	256,221	49,207	74,209	59,134	73,672
1960	313,004	55,738	120,503	65,560	71,202
1961	364,974	61,472	105,132	106,897	91,473
1962	341,228	70,173	101,532	89,935	79,588
1963	411,567	58,607	128,681	106,343	117,936
1964	332,221	62,143	102,972	91,406	75,700
1965	478,788	78,998	145,579	132,986	121,224
1966	590,360	84,694	185,571	144,627	175,467
1967	478,906	89,677	125,544	132,020	131,665
1968	472,385	90,991	134,795	115,228	131,371
1969	624,884	91,339	148,169	192,849	192,527
1970	385,200	65,943	105,376	129,446	84,435
1971	271,233	59,360	62,338	57,421	92,115
1972	263,998	53,556	71,066	65,162	74,214
1973	378,266	68,270	119,323	101,264	89,408
1974	280,865	58,805	72,162	61,679	88,220
1975	211,352	32,373	34,966	83,693	60,321
1976	206,084	36,041	44,384	78,659	47,001
1977	99,024	22,771	30,239	25,529	20,485
1978	87,071	20,510	21,294	22,068	23,199
1979	177,834	44,942	49,452	47,375	36,065
1980	205,815	40,631	48,455	53,770	62,959
1981	176,609	39,963	39,141	50,184	47,321
1982	224,639	55,765	62,684	59,455	46,735
1983	145,339	27,305	42,475	42,294	33,265
1984	119,264	34,257	33,095	28,275	23,637
1985	121,736	31,731	36,226	23,253	30,526
1986	170,845	44,410	46,576	43,938	35,921
1987	186,966	41,780	60,345	44,067	40,774
1988	195,328	43,080	49,203	48,684	54,361
1989	147,350	36,273	41,049	28,923	41,106
1990	87,359	23,596	26,089	16,767	20,907
1991	116,635	29,400	39,517	24,361	23,356
1992	104,720	22,095	27,117	18,609	36,900
1993	141,517	33,490	39,592	25,999	42,436
1994	134,225	30,875	41,552	25,665	36,133
1995	188,527	38,397	53,307	40,856	55,967
1996	108,879	29,965	30,438	17,227	31,251
1997	113,081	23,419	30,180	27,462	32,020
1998	86,821	23,835	25,652	13,548	23,785
1999	90,108	18,490	23,592	14,543	33,483
2000	58,431	17,442	13,494	11,054	16,442
2001	65,500	15,922	16,261	12,221	21,096
2002	51,047	15,490	12,814	9,619	13,123
2003	88,228	19,635	20,566	19,404	28,624
2004	70,061	18,178	17,303	17,687	16,893

Table A3. Annual and quarterly catch estimates for striped marlin in the North Pacific, 1952-2004, based on the Poisson Map 2 model.

	Annual	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1952	171,399	21,534	44,231	40,956	64,678
1953	206,305	40,416	41,892	75,794	48,203
1954	219,829	33,367	64,030	63,148	59,284
1955	180,630	28,422	57,900	49,528	44,779
1956	182,720	36,295	49,049	34,523	62,852
1957	351,593	52,494	62,312	92,865	143,922
1958	466,171	61,257	117,101	143,960	143,853
1959	442,512	79,419	122,343	112,942	127,808
1960	454,049	61,934	109,396	127,782	154,937
1961	486,523	64,610	131,302	155,228	135,383
1962	637,623	93,797	172,249	227,758	143,819
1963	830,184	99,564	260,551	244,584	225,485
1964	736,491	89,729	232,102	230,659	184,001
1965	1,027,010	125,002	284,150	364,636	253,222
1966	1,093,532	99,258	303,905	389,567	300,802
1967	815,826	108,091	227,430	295,646	184,658
1968	798,754	112,821	237,784	284,121	164,027
1969	809,765	110,519	234,086	266,250	198,910
1970	501,721	68,502	134,405	170,356	128,458
1971	437,261	71,979	119,559	136,784	108,939
1972	405,602	64,293	111,620	145,747	83,941
1973	381,541	56,072	107,410	112,412	105,648
1974	479,172	64,173	131,035	166,325	117,639
1975	347,294	67,898	71,169	141,482	66,745
1976	267,207	49,974	83,686	80,605	52,942
1977	129,340	32,380	40,738	32,376	23,846
1978	112,441	21,819	31,704	31,416	27,501
1979	308,369	61,538	92,338	104,620	49,873
1980	353,427	70,618	86,567	129,634	66,609
1981	327,140	49,210	84,707	124,439	68,785
1982	358,563	81,119	125,864	97,766	53,814
1983	214,845	33,351	76,388	66,964	38,142
1984	193,710	37,993	74,481	48,579	32,658
1985	310,922	37,370	173,752	62,824	36,976
1986	245,683	50,510	83,275	62,067	49,830
1987	288,601	53,737	106,995	75,769	52,099
1988	337,792	59,029	123,635	88,036	67,092
1989	226,384	50,418	62,910	55,372	57,684
1990	125,574	29,117	39,312	32,070	25,075
1991	162,490	34,284	57,428	37,618	33,161
1992	133,370	28,112	41,548	25,032	38,679
1993	188,448	38,036	57,345	46,526	46,542
1994	179,323	33,807	63,531	36,674	45,310
1995	274,345	46,647	86,824	70,825	70,048
1996	147,899	37,683	43,167	31,251	35,798
1997	161,512	35,470	51,176	36,548	38,317
1998	130,605	31,672	41,742	25,136	32,055
1999	129,596	23,512	36,371	29,387	40,326
2000	80,898	17,510	22,888	19,247	21,253
2001	80,883	15,283	21,472	19,233	24,896
2002	66,535	15,675	17,030	15,734	18,096
2003	106,697	20,509	27,857	26,047	32,284
2004	89,868	19,773	22,984	23,159	23,953

Table A4. Annual and quarterly catch estimates for striped marlin in the North Pacific, 1952-2004, based on the Poisson Map 3 model.

	Annual	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1952	150,424	30,293	39,332	31,190	49,610
1953	136,238	37,815	29,091	40,224	29,109
1954	196,446	50,563	54,757	38,695	52,431
1955	138,873	36,914	41,984	24,727	35,248
1956	153,721	44,283	43,901	19,826	45,712
1957	195,124	43,374	37,091	35,304	79,356
1958	308,993	55,581	65,503	79,142	108,767
1959	355,966	67,536	79,596	94,548	114,286
1960	403,625	80,195	91,864	104,141	127,424
1961	377,863	67,813	92,434	110,456	107,160
1962	450,186	83,193	112,396	142,391	112,205
1963	537,405	85,270	161,691	132,875	157,568
1964	448,461	82,447	124,489	128,874	112,651
1965	459,964	59,940	118,330	153,785	127,910
1966	505,570	64,266	131,421	168,373	141,510
1967	477,787	84,763	129,328	137,047	126,649
1968	436,184	88,163	124,199	109,687	114,134
1969	354,206	70,673	95,499	86,895	101,139
1970	318,082	53,565	73,404	76,388	114,725
1971	255,838	50,139	55,854	58,809	91,036
1972	228,846	50,021	49,042	54,889	74,893
1973	245,473	43,107	51,263	59,510	91,593
1974	294,603	47,815	75,909	85,449	85,431
1975	223,746	38,893	38,635	78,614	67,603
1976	222,297	44,242	59,485	65,782	52,789
1977	106,377	25,246	32,833	25,776	22,521
1978	98,239	18,730	27,143	26,338	26,028
1979	207,699	47,435	66,079	52,969	41,217
1980	256,467	52,411	68,233	73,307	62,516
1981	209,273	40,995	50,969	54,237	63,072
1982	245,341	63,508	73,152	57,934	50,746
1983	150,695	29,358	56,927	33,683	30,727
1984	135,467	35,283	38,918	27,990	33,276
1985	196,011	34,996	91,723	30,968	38,324
1986	216,352	53,504	64,855	44,318	53,675
1987	207,926	48,043	69,842	46,013	44,029
1988	234,949	55,902	67,257	51,745	60,044
1989	168,678	40,249	40,432	36,511	51,486
1990	105,049	26,035	26,959	19,059	32,996
1991	133,875	35,743	45,790	24,296	28,046
1992	111,077	24,562	34,935	18,083	33,498
1993	151,670	37,658	48,937	22,850	42,225
1994	145,398	35,527	49,420	23,387	37,063
1995	201,621	43,957	62,343	39,330	55,991
1996	118,379	35,942	34,122	17,418	30,897
1997	117,849	25,945	34,634	25,441	31,829
1998	90,698	23,923	30,834	12,802	23,139
1999	95,620	21,604	27,547	15,276	31,193
2000	58,261	15,910	15,170	10,772	16,410
2001	63,112	15,845	15,648	11,183	20,436
2002	49,689	15,273	12,587	7,959	13,869
2003	85,476	21,440	20,626	16,455	26,955
2004	59,861	18,574	14,758	11,330	15,199