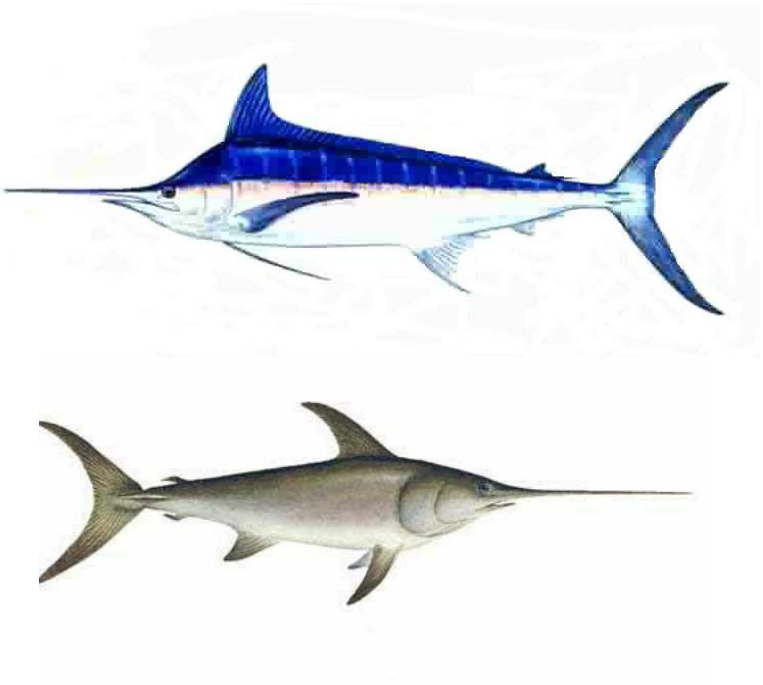
A Long-term Corrected Catch History for Striped Marlin, *Kajikia audax*, in Hawaiian Waters

William Walsh
Joint Institute for Marine and Atmospheric Research
University of Hawaii
2570 Dole St., Honolulu, Hawaii, USA, 96822

Russell Ito
NOAA NMFS PIFSC
2570 Dole St., Honolulu, Hawaii, USA, 96822



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William A. Walsh
University of Hawaii
Joint Institute for Marine and Atmospheric Research
Pelagic Fisheries Research Program
Honolulu, HI 96822

Russell Y. Ito
NOAA Fisheries Pacific Islands Fisheries Science Center
Honolulu, HI 96822

Abstract

This working paper presents a 62-year (1948–2009) catch history for striped marlin *Kajikia audax* in Hawaiian waters. These catch estimates were obtained by compiling data from several sources, including federal, state, commercial, and recreational. Known biases in the data (e.g., under-reporting; species misidentifications) were corrected using published methodologies whenever possible and on the basis of experience in this fishery in other instances. Results from recent years (1995–2009) were used to correct for discarding throughout the time series. We conclude that this corrected 62-year catch history is more accurate than an uncorrected time series with known biases. Use of this corrected catch history in the stock assessment for striped marlin in lieu of nominal catch data from Hawaiian waters is strongly recommended.

Introduction

This paper presents a multi-decade (1948–2009) catch history for striped marlin *Kajikia audax* in Hawaiian waters. The catch estimates were obtained by compiling data from several sources, including federal, state, commercial, and recreational. Known biases in the data were corrected using published methodologies to the extent possible and on the basis of experience in this fishery in other instances. Relevant caveats associated with the catch estimates for striped marlin are presented.

These data consist primarily of records of striped marlin caught by longline fishing. Other commercial and recreational striped marlin catches comprise a small fraction of the total.

This work was considered necessary and undertaken for three reasons. The first is that data reporting requirements, compliance with these requirements, and the agencies and other entities involved in data collection, archival, and provision have changed during the study period. The second is that longline gear and fishing techniques have evolved even as fleetwide effort has increased greatly in recent decades. The third is that misidentifications of billfish species (Istiophoridae) in logbook reports have been a longstanding problem in this fishery (Walsh et al. 2005; Walsh et al. 2007).

Historical Aspects of Longline Fishing in Hawaii

Deep longline fishing for pelagic species began in Hawaii in 1917 (June 1950). The target was large tunas, but billfishes and other pelagic species were also caught. Fishing was conducted with basket gear, in which segments of rope were connected to form a mainline supported by floats. Branchlines with terminal hooks were attached between floats. Monofilament mainlines largely replaced basket gear during the late 1980's (Kawamoto et al. 1989). Shallow longline fishing for swordfish *Xiphias gladius* was introduced in 1988, followed by an expansion of effort in the 1990's (Ito et al. 1998).

These gear and technology changes and the development of export markets in the United States for swordfish and tunas and in Japan for tunas contributed to this rapid fishery expansion. As a result, the longline fishery became and remains the largest commercial fishery in Hawaii.

Shallow-set longlining for swordfish was closed in early 2001 by the Western Pacific Fishery Management Council for over three years because of excessive interaction rates with protected sea turtles. This resulted in a return to deep longline fishing for tunas as the major form of activity in this fishery during this time.

History of Catch Data Sources

Striped marlin catch data were compiled from three periods in the history of this fishery. For additional details about the data sources and catch compilation, see 'Reporting of Striped Marlin Catches', below.

Catch data for the first and longest period, the years until and including 1986, were obtained primarily from Hawaii Division of Aquatic Resources (HDAR) fishermen's catch reports. No other large data set was available to check the accuracy of reported landings or species identifications for these years.

The second period (1987–1994) was characterized by the initial use of multiple data sources and involvement of trained National Marine Fisheries Service (NMFS) personnel in monitoring this fishery. Market sample data were collected five days per week (of six business days). Catch and revenues were estimated by extrapolating these samples to approximate full coverage for 1987–1991.

The federal longline logbook program was implemented in December 1990 to serve as the source of catch data. Because managing the logbook program required substantial effort, market sampling was reduced to two business days per week in 1991. By 1994, the compliance rate for logbook submission approached 100% while market coverage was ≈25–33%.

The third period (1995–2009) was characterized by development of additional sources of catch data and improved verification capabilities for fish catches. The Pacific Islands Regional Observer Program (PIROP) completed its first full year of operations in 1995. Dealer data for longline landings became available in electronic form in 2000. The Marine Recreational Fishery Statistics Survey of NOAA Fisheries (MRFSS) has been a source of recreational data since 2003.

Biases in Striped Marlin Catch Data

The uncorrected striped marlin catch data available for compilation exhibited three recognized sources of bias: species misidentifications; under-reporting; and non-reporting. Moreover, the myriad changes in the scope of the data and the fishery itself have contributed to the inherent complexity of identifying and estimating such biases.

The first source of bias usually involves misidentifications of striped marlin as blue marlin *Makaira nigricans*. This in turn causes under-reporting of the former and over-reporting of the latter species (Walsh et al. 2005; 2007). Walsh et al. (2007) demonstrated the feasibility of correcting these misidentifications with statistical methodology, which yielded improved accuracy for striped marlin longline catch data for 1994–2004. Striped marlin are also sometimes misidentified as shortbill spearfish *Tetrapturus angustirostris* or vice versa, and rarely as black marlin *Istiompax indica* or sailfish *Istiophorus platypterus* (Walsh et al. 2007).

Under-reporting can result from inadvertent undercounting of large catches, as may occur during years with strong recruitment or when fishermen concentrate primarily on target species to the detriment of data accuracy for incidentally caught species. Thus, for example, under-reporting of blue shark *Prionace glauca* catches in logbooks from tuna-targeted fishing trips occurred most commonly during the peak season for bigeye tuna *Thunnus obesus* (Walsh et al. 2002).

Non-reporting consists of seemingly deliberate failure to report fish catches. This can consist of failure to report discards, which would be expected to comprise a small fraction of the catch, or failure to report some or all of the catch, which might cause a much larger downward bias.

Objective

The objective of this working paper is to provide the most accurate long-term striped marlin catch history in Hawaiian waters as possible for use in stock assessment. To do so, we have compiled all available catch data and then relied upon both objective analytical techniques and our experience in this fishery.

Methods

Data Sources

The time series of striped marlin catches (1948–2009) was compiled from 15 data sources. The major sources are summarized in Figure 1 in terms of their coverage years, known or suspected problems with data accuracy, and corrective actions taken regarding these problems.

The principal data manipulation consisted of using both major and minor sources of catch data. If catch data were reported by multiple sources in any year, the addition from the minor sources was allotted in proportion to the quarterly totals from the major data source. It was assumed that there was no double-counting in years with multiple catch data sources.

Reporting of Striped Marlin Catches

The major data source for 1950–1986, HDAR catch reports, presumably includes most of the landed catch. Lacking an alternate data source for verification purposes, these records were accepted with one major exception. Pooley (1989) determined that the HDAR totals were implausibly low in 1987, presumably caused by non-reporting. Consequently, Boggs and Ito (1993) employed linear interpolation to correct the HDAR totals from 1979–1986. In this particular instance, the estimated annual totals were allotted as 30% to quarters 1, 2, and 4, respectively, and 10% to the third quarter. The reason was that the observed striped marlin catch from 1995–2009 has been 23–37% of the total in quarters 1, 2, and 4, but 11% in the third quarter of these years.

The two data sources for 1987–1994 were used by multiplying the number of fish reported as kept in the logbooks by the average weight per fish from the market sample. As in 1948–1986, there was no other source of data available to verify catch records so the data were accepted as submitted.

Fishery observer reports, logbook data, and commercial sales records were employed in an integrated manner in 1995–2009. The fleet-wide observer coverage rates were approximately 5% in 1995–1999, but rose to ≈10% in 2000 and have remained near 20% since 2001. Complete sales records have been available since 2000. These mutually complementary data sources

permitted detailed checks on logbook accuracy and correction of inaccuracies by a series of statistical procedures.

Statistical Procedures Applied to Longline Catch Data: 1995–2009

Longline catch data from 1995–2009 were analyzed by procedures described in Walsh et al. (2005; 2007) in order to update a time series of corrected striped marlin catch data (Walsh et al. 2007). In brief, this analysis entailed fitting a statistical model to fishery observer catch and operational data, applying the fitted coefficients to an identical suite of explanatory variables provided in the logbook reports, and then using linear regression techniques to identify likely inaccuracies. Questionable logbook data so identified were then checked against sales records. Predicted values from the model were used to replace logbook catch data deemed inaccurate.

This analysis employed a generalized additive model (GAM) fitted in R Version 2.4.1. A GAM analysis has already identified several explanatory variables that affected striped marlin catches significantly (Walsh et al. 2005; 2007). Hence, a similar GAM was re-fitted to the longer time series of fishery observer data. The explanatory variables included latitude, longitude, sea surface temperature (SST), number of hooks per float, number of hooks deployed per longline set, and a smooth function for time. The underlying probability distribution was assumed to be the Poisson because the response variable was catch (Maunder and Punt 2004). The principal difference between this GAM and the previously published model was the use of a smooth surface of latitude and longitude to express position effects. The GAM is summarized with an analysis of deviance (see Appendix, Table A2).

The GAM was used in 'predict' mode (Crawley 2007) to generate estimated catches as comparison standards for reported catches from the logbooks. The accuracy of the reported catch data was assessed by computing the log-log regression of the logbook values on the predictions and checking the studentized residuals (SR) (Draper and Smith 1981). Catch data from fishing trips with two or more sets with $SR \geq |2|$ or any sets with $SR \geq |3|$ were replaced with the corresponding GAM predictions.

Corrected catches for a 10-year period (March 1994–February 2004) were computed using data from Table B1 in Walsh et al. (2007). The corrected logbook catches in that table were added to

the observer data from those years to obtain the catch estimates herein. Mean weights have been computed from the data provided electronically by HDAR since 2000.

Discarding

Discarding of striped marlin was estimated by comparing the numbers of discards reported by observers and in logbooks on observed fishing trips in 1995–2009. For the purposes of this paper, all discards are assumed to be dead removals.

The discards reported in logbooks were arbitrarily assigned to the fourth quarter of each year from 2000–2009. This decision was predicated upon experience in this fishery. Because bigeye tuna is highly sought in the fourth quarter before the holiday season, incidentally caught species may be discarded more frequently at that time than during the remainder of the year. The other data sources were not corrected for discarding.

Recreational Catch

The MRFSS data from 2003–2009 were arbitrarily assigned to the first quarter of each year. The reason was that preliminary results from the survey suggest that most recreational catch in Hawaii is taken early in the year (i.e., January–April) (H. Ma, PIFSC, personal communication).

Results

Figure 1 depicts changes in data sources, availability, comprehensiveness, quality control and consequent accuracy for striped marlin in Hawaiian waters. The upper panel illustrates an approximately 30-year period with unknown data accuracy. The lower panel depicts the development and implementation, particularly in the last 15 years, of expanded monitoring and data management capabilities for billfish reporting in this fishery.

Figure 2 presents an annual corrected 62-year time series of striped marlin catches in Hawaiian waters as compiled from several sources in relation to the nominal series. There are four prominent features in this plot. The first is the large difference in catches between the years before and after the development of the longline fishery. The second is the very low nominal totals from *ca*. 1975–1985 caused by apparent under- or nonreporting. The third is the

substantial underreporting in the mid-1990's caused by misidentifications, and the fourth is the relatively close agreement between the nominal and corrected catches in recent years, particularly since 2005.

Nominal and corrected quarterly striped marlin catch statistics in numbers of fish caught (when available) and kilograms landed from 1948–2009 are presented in Table 1. The increases in data quality and quantity reflect transition from a system with reported weights but no catch numbers or means of verification to one with catch in numbers, total weights and detailed checking procedures.

The statistically-based corrections begun in 1994 resulted in increases in striped marlin catch estimates for every quarter except one through 1999. Since 2000, the corrected values have been less than the nominal in 22 quarters and greater in 18. One factor that probably contributed to this result was observed trips categorized as 'INVALID' during the PIROP data evaluation process. These trips had striped marlin reported during the third and fourth quarters of 2004 (1584 striped marlin), the second quarter of 2005 (427 striped marlin), and in the first quarter of 2009 (427 striped marlin), but these fish were not counted because the reliability was uncertain.

The examination of large SR from 2004–2009 detected no large-scale systematic errors in logbook data. The majority of sets with large SR were associated with large catches verified by sales records.

The average discard rate as a percentage of the number caught on observed trips in 1995–2009 was 6.2% (39535 observed longline sets). Discards were reported from 28% of the trips and 4.2% of the sets. The condition upon release was 45.3% alive and 54.7% dead. The 6.2% value was used to adjust the total catch estimate throughout the time series.

The discards reported in logbooks were arbitrarily assigned to the fourth quarter of each year from 2000–2009. This decision was predicated upon experience in this fishery. Because bigeye tuna is highly sought in the fourth quarter before the holiday season, incidentally caught species may be discarded more frequently at that time than during the remainder of the year. The other data sources were not corrected for discarding.

The MRFSS recreational catch from 2003–2009 ranged from 7–137 metric tons per year. The greatest recreational catch was taken in 2003 (137 metric tons), which represented 32% of the MRFSS catch data for these years.

Discussion

The corrections applied to the 62-year catch history for striped marlin in Hawaiian waters were based upon both circumstantial and direct evidence. The circumstantial evidence consisted of the demonstration that catch totals reported in 1987 were implausibly low (Pooley 1989). The direct evidence consisted of statistical results that identified instances of misidentifications and other biases in 1995–2009 that were subsequently verified with sales records (Walsh et al. 2007). Because both types of evidence and the actions taken on the basis of such evidence have been documented in NMFS reports (Pooley 1989) and the primary literature (Boggs and Ito 1993; Walsh et al. 2005; 2007), this corrected catch history can be considered 'transparent'.

This project entailed gathering, cross-checking, and compiling data from numerous sources of varying accuracy. However, some of the data manipulations were arbitrary, predicated upon experience in this fishery (e.g., allocation of discards and recreational to quarters). We made these decisions because our greater concern was to include all available catch data.

This work is noteworthy for inclusion of an adjustment for discarded striped marlin. Discarding of istiophorid billfishes (i.e., striped marlin, blue marlin, and shortbill spearfish *Tetrapturus angustirostris*) in this fishery generally involves small fish during years with high recruitment, and although the rates are usually low (*ca*. 5–10%), mortality associated with discarding has been documented (Walsh et al. 2007). The availability of observer data from 1995–2009 permitted calculation of an average discard rate to account for this reporting bias. Application of this correction (+6.2%) to the entire time series was considered appropriate because the apparent motivation for discarding (i.e., an excess of small fish of low economic value) has probably not changed over time. Although use of a constant as the correction is an oversimplification, this was deemed acceptable in order to include this catch

component. A detailed summary of billfish discarding patterns in this fishery is presented in Walsh et al. (2007).

The majority of discards were dead at release and some post-release mortality can also be expected. Therefore, categorization of discards as dead removals was deemed justifiable.

Finally, this catch history also includes some recreational data. Although recreational catch comprises a small fraction of the total (Pooley 1989; MRFSS), it is reasonable to assume that there has always been some. Therefore, an attempt to account for it was considered appropriate.

Conclusions

This corrected 62-year catch history is more accurate than the likely alternative, an uncorrected time series with known and suspected biases that would introduce uncertainty into the stock assessment. Therefore, use of this corrected catch history in the stock assessment for striped marlin in Hawaiian waters is strongly recommended.

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Figure 1. Timeline presenting the sources of striped marlin *Kajikia audax* catch data used to develop a corrected catch history for 1948–2009, with important characteristics of these sources and corrective actions taken with respect to known or suspected problems.

Year	1950	1955	1960	1965	1970	1975
Data Sources	Hawaii Division of Aquatic Resources Fish Catch Data					
Quantity, quality & data issues	Quantity and quality of data submitted uncertain					
Corrective actions	No addtional data available to verify source data. No corrective action taken.					

Year	1980	1985	1990	1995	2000	2005	2010
Data Sources	Hawaii Division of Aquatic Resources Fish Catch Data	NMFS Auction Sample Data	NMFS Logbook Data + NMFS Auction Sample	NMFS Logbook Data + NMFS Auction Sample + NMFS Observer Data	NMFS Logbook Data + HDAR Dealer Data + NMFS Observer Data		
Quantity, quality & data issues	Suspected underreporting of catch	Auction data less than complete ~80%.	Logbook data ~100%, Auction data 25-33%. ID problem with marlins	Logbook data ~100%, Auction data 25-33%, Observer data ~5% . ID problems with marlins	Logbook data ~100%, Dealer data ~100%, Observer data ~20%. ID problems with marlins		
Corrective actions	Linear interpolation to account for suspected underreporting	Extrapolation factor applied to sample data	NMFS personnel began to meet with fishermen to improve logbook accuracy	Stastistical models fitted to observer data used as comparison standards for the logbooks and sales records from the Dealer data to permit definitive verification of results concerning accuracy			

Figure 2. Estimated (solid black line) and nominal (HDAR, dashed red line) annual landings of striped marlin *Kajikia audax* in Hawaiian waters: 1948–2010. Estimated data are compiled from Table 1, below.

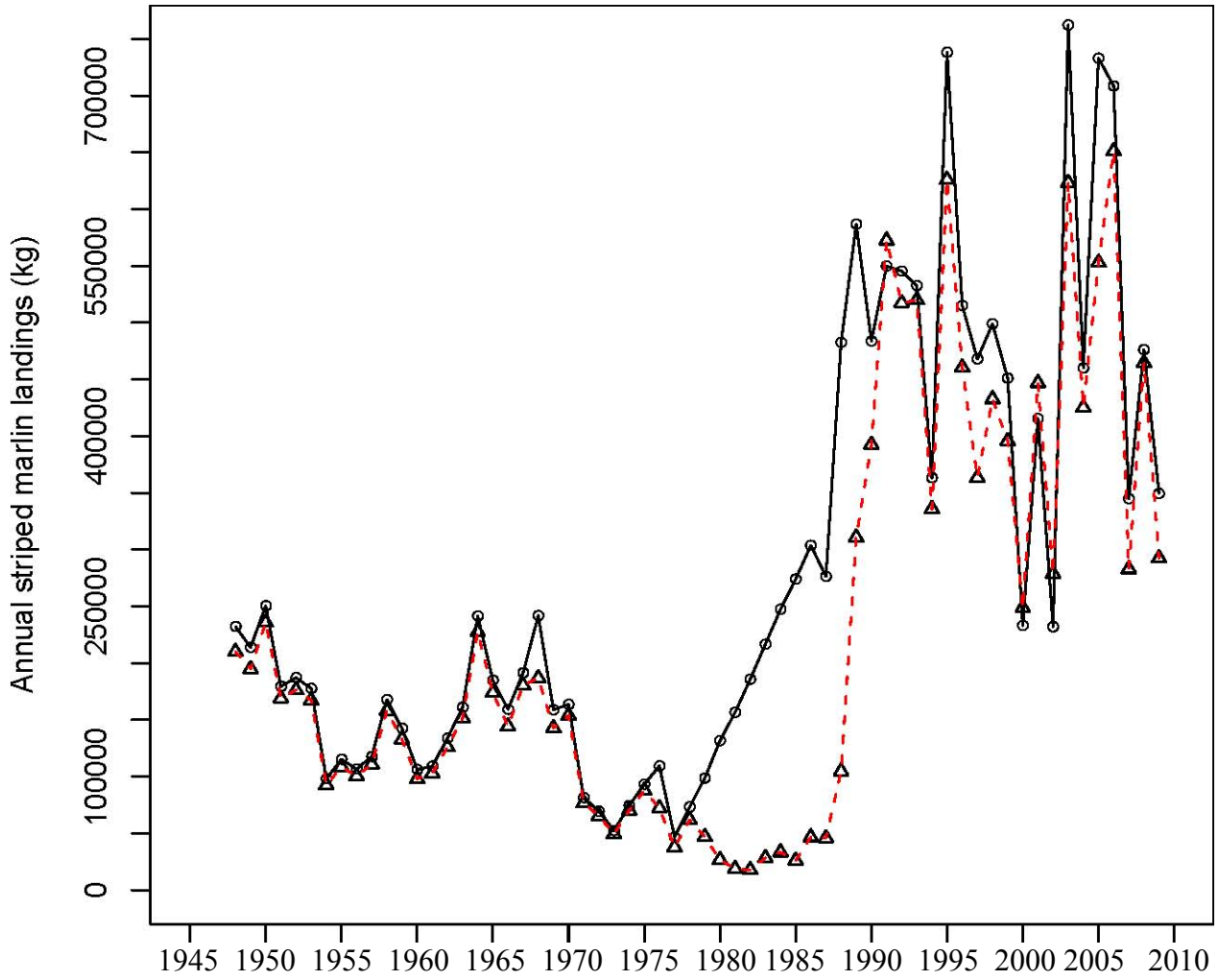

Table 1. Catch statistics for striped marlin *Kajikia audax* in Hawaiian waters at quarterly intervals in 1948–2009. Data are presented in two columns per page. Estimation of catches and landings are presented in the Appendix as Table A1. 'NA' denotes not available. The numerical insert in parentheses corresponds to the data source(s) for each year (see footnote[1]). In 1995–2009, nominal (**NMFS logbook**) and statistically corrected data are presented in standard and bold-face type, respectively.

Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)	Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)
1948 (1)	1	NA	55793	3459	**59252**	1949 (2)	1	NA	80563	4495	**85558**
	2	NA	57693	3577	**61270**		2	NA	62145	3853	**65998**
	3	NA	30133	1868	**32001**		3	NA	16797	1041	**17838**
	4	NA	75099	4656	**79755**		4	NA	41903	2598	**44501**
1950 (3)	1	NA	54204	3361	**57565**	1951 (3)	1	NA	45773	2838	**48611**
	2	NA	76479	4742	**81221**		2	NA	81282	5040	**86322**
	3	NA	28954	1795	**30749**		3	NA	19389	1202	**20591**
	4	NA	76223	4726	**80949**		4	NA	22545	1398	**23943**
1952 (3)	1	NA	62818	3895	**66713**	1953 (3)	1	NA	65106	4037	**69143**
	2	NA	42681	2646	**45327**		2	NA	52363	3247	**55610**
	3	NA	12865	798	**13663**		3	NA	22563	1399	**23962**
	4	NA	57892	3589	**61481**		4	NA	27252	1687	**28939**

[1] Data sources: 1. Otsu 1954; 2. June 1950; 3. HDAR; 4. Yoshida 1981 ; 5. Cooper 1978; 6. Cooper 1983; 7. Skillman *et al*. 1984; 8. Boggs and Ito 1993; 9. Squire 1987; 10. Ito 1991; 11. Pooley 1989; 12. Ito and Machado 2001; 13. NMFS logbooks; 14. Walsh *et al*. 2007; 15. Walsh, unpublished data.

Table 1, continued.

Year	Quarter	Catch (*N*)	Landings (kg)	Discards (*N*)	Estimated Total (kg)	Year	Quarter	Catch (*N*)	Landings (kg)	Discards (*N*)	Estimated Total (kg)
1954 (3)	1	NA	19424	1204	**20627**	1955 (3)	1	NA	20484	1292	**21776**
	2	NA	43398	2691	**46089**		2	NA	30442	1887	**32329**
	3	NA	8510	528	**9038**		3	NA	14308	887	**15195**
	4	NA	21193	1314	**22507**		4	NA	43269	2683	**45952**
1956 (3)	1	NA	39524	2450	**41974**	1957 (3)	1	NA	44437	2755	**47192**
	2	NA	23376	1449	**24825**		2	NA	26080	1617	**27697**
	3	NA	10640	660	**11300**		3	NA	9215	571	**9786**
	4	NA	26951	1671	**28622**		4	NA	31061	1926	**32987**
1958 (3)	1	NA	46509	2884	**49393**	1959 (3)	1	NA	30509	1892	**32401**
	2	NA	42443	2632	**45075**		2	NA	57239	3549	**60788**
	3	NA	12222	758	**12980**		3	NA	5458	338	**5796**
	4	NA	56886	3527	**60413**		4	NA	40981	2541	**43522**
1960 (4)	1	NA	16724	1037	**17761**	1961 (4)	1	NA	18178	1127	**19305**
	2	NA	37833	2346	**40179**		2	NA	50429	3127	**53556**
	3	NA	6632	411	**7043**		3	NA	5619	348	**5967**
	4	NA	38812	2407	**41219**		4	NA	28594	1773	**30367**

Table 1, continued.

Year	Quarter	Catch (*N*)	Landings (kg)	Discards (*N*)	Estimated Total (kg)	Year	Quarter	Catch (*N*)	Landings (kg)	Discards (*N*)	Estimated Total (kg)
1962 (3)	1	NA	21934	1360	**23294**	1963 (3)	1	NA	28918	1793	**30711**
	2	NA	67833	4206	**72039**		2	NA	60207	3733	**63940**
	3	NA	12801	794	**13595**		3	NA	7050	437	**7487**
	4	NA	23403	1451	**24854**		4	NA	55527	3443	**58970**
1964 (3)	1	NA	45314	2809	**48123**	1965 (4)	1	NA	50896	3156	**54052**
	2	NA	72746	4510	**77256**		2	NA	75267	4667	**79934**
	3	NA	7832	486	**8318**		3	NA	5390	334	**5724**
	4	NA	101506	6293	**107799**		4	NA	42693	2647	**45340**
1966 (4)	1	NA	32556	2018	**34574**	1967 (3)	1	NA	29071	1802	**30873**
	2	NA	42079	2609	**44688**		2	NA	50540	3134	**53674**
	3	NA	8337	517	**8854**		3	NA	5600	347	**5947**
	4	NA	66999	4154	**71153**		4	NA	95134	5898	**101032**
1968 (4)	1	NA	63592	3943	**67535**	1969 (4)	1	NA	53711	3330	**57041**
	2	NA	85170	5281	**90451**		2	NA	12514	776	**13290**
	3	NA	12301	763	**13064**		3	NA	41628	2581	**44209**
	4	NA	66706	4136	**70842**		4	NA	41779	2590	**44369**

Table 1, continued.

Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)	Year	Quarter	Catch (*N*)	Landings (kg)	Discards (*N*)	Estimated Total (kg)
1970 (3)	1	NA	45768	2838	**48606**	1971 (3)	1	NA	17350	1076	**18426**
	2	NA	38983	2417	**41400**		2	NA	17495	1085	**18580**
	3	NA	7236	449	**7685**		3	NA	4946	307	**5253**
	4	NA	62079	3849	**65928**		4	NA	36924	2287	**39211**
1972 (3)	1	NA	30425	1886	**32311**	1973 (3)	1	NA	5498	341	**5839**
	2	NA	23360	1448	**24808**		2	NA	7847	487	**8334**
	3	NA	2829	175	**3004**		3	NA	7077	439	**7516**
	4	NA	8769	544	**9313**		4	NA	28947	1795	**30742**
1974 (3)	1	NA	10133	628	**10761**	1975 (3)	1	NA	22750	1411	**24161**
	2	NA	13603	843	**14446**		2	NA	10323	640	**10963**
	3	NA	25637	1590	**27227**		3	NA	40310	2499	**42809**
	4	NA	20722	1285	**22007**		4	NA	14420	882	**15302**
1976 (5,7)	1	NA	14865	922	**15787**	1977 (6,7)	1	NA	7167	444	**7611**
	2	NA	21802	1352	**23154**		2	NA	15091	936	**16027**
	3	NA	40758	2527	**43285**		3	NA	4416	274	**4690**
	4	NA	25575	1586	**27161**		4	NA	17280	1071	**18351**

Table 1, continued.

Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)	Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)
1978 (5,6)	1	NA	20700	1283	**21983**	1979 (8,9)	1	NA	27900	1730	**29630**
	2	NA	20700	1283	**21983**		2	NA	27900	1730	**29630**
	3	NA	6900	428	**7328**		3	NA	9300	577	**9877**
	4	NA	20700	1283	**21983**		4	NA	27900	1730	**29630**
1980 (8,9)	1	NA	37200	2306	**39506**	1981 (8,9)	1	NA	44400	2753	**47153**
	2	NA	37200	2306	**39506**		2	NA	44400	2753	**47153**
	3	NA	12400	769	**13169**		3	NA	14800	918	**15718**
	4	NA	37200	2306	**39506**		4	NA	44400	2753	**47153**
1982 (8,9)	1	NA	52500	3255	**55755**	1983 (8,9)	1	NA	61200	3794	**64994**
	2	NA	52500	3255	**55755**		2	NA	61200	3794	**64994**
	3	NA	17500	1085	**18585**		3	NA	20400	1265	**21665**
	4	NA	52500	3255	**55755**		4	NA	61200	3795	**64994**
1984 (8,9)	1	NA	69900	4334	**74234**	1985 (8)	1	NA	77400	4799	**82199**
	2	NA	69900	4334	**74234**		2	NA	77400	4799	**82199**
	3	NA	23300	1445	**24745**		3	NA	25800	1600	**27400**
	4	NA	69900	4334	**74234**		4	NA	77400	4798.8	**82199**

Table 1, continued.

Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)	Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)
1986 (8)	1	NA	85800	5320	**91120**	1987 (10)	1	1686	33558	2081	**35639**
	2	NA	85800	5320	**91120**		2	2218	80824	5011	**85835**
	3	NA	28600	1773	**30373**		3	520	14286	886	**15172**
	4	NA	85800	5320	**91120**		4	4237	131858	8175	**140033**
1988 (11)	1	5824	122668	7605	**130273**	1989 (10)	1	8040	164528	10201	**174729**
	2	4676	166812	10342	**177154**		2	6758	242239	15019	**257258**
	3	258	8029	498	**8527**		3	442	16463	1021	**17484**
	4	6848	156894	9727	**166621**		4	4553	129348	8020	**137368**
1990 (10)	1	4805	107838	6686	**114524**	1991 (12)	1	5906	97110	6021	**103131**
	2	5021	193742	12012	**205754**		2	6262	225643	13990	**239633**
	3	993	33315	2066	**35381**		3	2046	58254	3612	**61866**
	4	5480	120569	7475	**128044**		4	5189	136753	8479	**145232**
1992 (13)	1	5272	126445	7840	**134285**	1993 (13)	1	3527	98550	6110	**104660**
	2	4220	170854	10593	**181447**		2	5101	190955	11839	**202794**
	3	2002	65700	4073	**69773**		3	1822	52084	3229	**55313**
	4	4838	150573	9336	**159909**		4	6040	159853	9911	**169764**

Table 1, continued.

Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)	Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)
1994 (13,**14**)	1	3953	102212	6337	**108549**	1995 (13,**14**)	1	4426 **4837**	86309 **99159**	6148	**105307**
	2	3221 **3236**	133501 **134123**	8316	**142439**		2	4213 **5774**	140952 **189387**	11742	**201129**
	3	985 **905**	33192 **30496**	1891	**32387**		3	2484 **3591**	64293 **90852**	5633	**96485**
	4	2817 **3165**	66969 **75242**	4665	**79907**		4	10113 **12005**	266213 **315732**	19575	**335307**
1996 (13,**14**)	1	5771 **6457**	125904 **147220**	9128	**156348**	1997 (13,**14**)	1	3171 **3759**	71815 **90216**	5593	**95809**
	2	4433 **5052**	138291 **157622**	9773	**167395**		2	5305 **6730**	184398 **232185**	14396	**246581**
	3	1983 **2360**	49768 **59944**	3717	**63661**		3	767 **885**	25106 **30267**	1877	**32144**
	4	3215 **3890**	99351 **120201**	7453	**127654**		4	2704 **3155**	70978 **88025**	5476	**93481**
1998 (13,**14**)	1	2823 **3289**	60285 **74660**	4629	**79289**	1999 (13,**14**)	1	4462 **5028**	95833 **111622**	6921	**118543**
	2	2235 **2734**	86905 **109360**	6780	**116140**		2	3907 **4119**	116768 **126041**	7815	**133856**
	3	1798 **2017**	55954 **60510**	3752	**64262**		3	1729 **1858**	47721 **65587**	4066	**69653**
	4	7260 **8345**	187599 **225315**	13970	**239285**		4	4104 **4655**	97243 **121496**	7533	**129029**

Table 1, continued.

Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)	Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)
2000 (13,**14**)	1	2856 **3238**	58023 **65731**	4075	**69806**	2001 (13,**14**)	1	3872 **3699**	70858 **67692**	4197	**71886**
	2	2392 **2450**	83221 **85260**	5286	**90546**		2	3118 **3483**	80444 **89861**	5571	**95432**
	3	619 **456**	27444 **20246**	1255	**21501**		3	1508 **1457**	30357 **29286**	1816	**31102**
	4	2061 **1583**	58255 **48282**	2994	**51276**		4	7939 **8696**	180641 **204356**	12670	**217026**
2002 (13,**14**)	1	3126 **3033**	70426 **68243**	4231	**72474**	2003 (13,**14,16**)	1	12366 **12299**	289364 **287797**	398	**288195**
	2	1861 **1570**	62822 **53066**	3290	**56356**		2	4376 **3596**	129216 **106442**	6599	**113041**
	3	589 **377**	20390 **13044**	809	**13853**		3	2406 **2237**	56497 **52570**	3259	**55829**
	4	3309 **3312**	83995 **84125**	5216	**89341**		4	12790 **12760**	266237 **284548**	17642	**302190**
2004 (13,**14,16**)	1	9673 **9369**	121763 **178011**	7193	**185204**	2005 (13,**15,16**)	1	10354 **10378**	307514 **308227**	9451	**317678**
	2	2754 **2633**	87891 **83993**	5208	**89201**		2	5177 **5450**	216032 **226138**	14021	**240159**
	3	1617 **2777**	42834 **45156**	2800	**47956**		3	1477 **1857**	51029 **64252**	3984	**68236**
	4	4383 **3868**	137192 **129578**	8034	**137612**		4	3979 **4267**	83570 **100701**	6244	**106945**

Table 1, continued.

Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)	Year	Quarter	Catch (*N*)	Landings (kg)	Discards (kg)	Estimated Total (kg)
2006 (13,**15,16**)	1	5016 **5285**	138442 **145866**	9044	**154910**	2007 (13,**15,16**)	1	5420 **5028**	142004 **131734**	8168	**139902**
	2	4338 **4349**	154082 **154390**	9572	**163962**		2	2563 **2448**	108264 **103550**	6420	**109970**
	3	5137 **4969**	134676 **130188**	8072	**138260**		3	978 **1192**	41534 **50660**	3141	**53801**
	4	8846 **8035**	247355 **232905**	14440	**247345**		4	1320 **1364**	40800 **42011**	2605	**44616**
2008 (13,**15,16**)	1	2552 **2943**	68143 **78578**	4872	83450	2009 (13,**15,16**)	1	3900 **3676**	92040 **86754**	5388	**92133**
	2	5206 **5066**	205129 **199600**	12375	**211976**		2	2809 **2671**	113203 **107641**	5754	**114315**
	3	1387 **1688**	45399 **55366**	3433	**58799**		3	1205 **1638**	45977 **62572**	3879	**66451**
	4	5532 **4747**	130691 **115352**	7152	**122504**		4	1582 **2119**	51987 **74589**	4625	**79214**

APPENDIX

Table A1. Summary of techniques used to estimate striped marlin *Kajikia audax* catches by Hawaiian fisheries, 1948–2009.

Assumption: All striped marlin were caught from 140°W longitude westward throughout the time series.
Estimation of quarterly statistics, 1948–1978: Use of data from two journal papers (1948–1949). Compilation from HDAR statistics without corrections 1950–1959. Compilation from HDAR or Yoshida (1981). In five of the six years that used data from Yoshida (1981), the total exceeded that from HDAR by 2–5%.
Estimation of quarterly statistics, 1979–1986: Use of data as estimated in Boggs and Ito (1993) and additional sources. The additional catch from the latter sources ranged from 2–8 metric tons per year.
Estimation of quarterly statistics, 1987–1991: Market sample data were used to estimate quarterly catch statistics. The sampling frequency was usually 80–90% of the business days during these years. Most (if not all) of the Hawaii-based longline fleet unloaded at the Honolulu public fish auction. The quarterly catch statistics were corrected by simple extrapolation based upon the sampling frequency.

Estimation of quarterly statistics, 1992–1999:

The federally-mandated logbook program began in 1991. Logbook data (based upon date of haul) were used to enumerate the catch and market data were used to estimate weights. Compliance with logbook submittal requirements was usually near 100%. Market coverage was ca. 33%.

Estimation of quarterly statistics, 2000–2009:

Detailed correction of striped marlin catch statistics has become feasible and recently facilitated for three primary reasons. First, compliance with logbook submittal requirements remains near 100%, and complete sales data are available as independent verification. Second, the Pacific Islands Regional Observer Program (PIROP), established in 1994, has averaged about 20% fleet-wide coverage since 2001, which has permitted direct comparisons of observer records and logbooks and statistical modeling of observer data to serve as comparison standards for the logbooks. Third, the statistical modeling has been presented in the primary literature with blue marlin (Walsh et al. 2005), while corrected catch estimates for striped marlin have also been published (Walsh et al. 2007). With established methodology, analyses can now be conducted on an ongoing basis and updated as necessary. For this reason, the residuals analyses intended to detect misidentifications concentrated on 2004–2009.

It should be noted that time did not permit the same very detailed data checks for catch data from 2005 until the present as were conducted for 1994–2004 (Walsh *et al*. 2007). Therefore, it is not possible to assess whether the seemingly close agreement between the nominal and corrected estimates from the last decade and the last five years in particular reflects improvement in logbook accuracy or undetected errors.

Catch data from the NOAA Fisheries Marine Recreational Fisheries Statistics Survey from 2003–2009. These data were assigned to the first quarter of each year (Dr. Hongguang Ma, PIFSC, personal communication). The weights were assumed to be equal to those from the longline catch and all fish caught were assumed to have been landed. The allocation to the first quarter probably introduced upward bias to the estimates.

Table A2. Summary analysis of deviance of a generalized additive model (GAM) of striped marlin *Kajikia audax* catches in Hawaiian waters, 1995–2009 (N = 39,977 observed longline sets).

Parameter	Parameter Estimate	Standard Error	t	Pr>|t|	Null deviance
Intercept	-0.57975	0.01056	-54.88	<2e-16	92069.69

Smooth term	Estimated df	Deviance reduction	F	P	Explanation of null deviance	Deviance per edf
Date of fishing (Year/quarter)	57.750	20,581.44	145.3	< 2e-16	22.35%	356.4
Sea surface temperature (C°)	8.491	6,523.98	237.6	< 2e-16	7.09%	768.3
Longitude, latitude	18.488	4,653.93	140.3	< 2e-16	5.05%	251.7
Vessel length (ft)	1.986	393.18	70.0	< 2e-16	0.43%	198.0
Hooks	1.942	147.38	111.4	< 2e-16	0.16%	75.9
Begin-set time (HST)	1.998	347.10	113.2	< 2e-16	0.38%	173.7

Residual deviance = 59422.68	*pseudo*-R^2=100*[(92069.69-59422.68)/ 92069.69] = 35.5%

The GAM explained 35.5% of the null deviance. All explanatory variables were statistically significant, but three (vessel length, hook numbers, begin-set time) explained <0.5% of the null deviance. The largest deviance reduction was from the date of fishing in quarterly intervals. The SST deviance reduction per estimated degree of freedom exceeded that for the date of fishing by 116%.