A Long-term Nominal Catch History for Blue Marlin *Makaira nigricans* in Hawaiian Waters

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Abstract

This working paper presents a 63-year (1948–2010) catch history for blue marlin *Makaira nigricans* in Hawaiian waters. The principal data source is the records from the Hawaii Division of Aquatic Resources (HDAR), which include catch data from several types of fisheries (e.g., longline, trolling). Published results from the pelagic longline fishery in recent years (1995–2004) are presented to document catch history correction methodology and results. An updated corrected catch time series for 1995–2010 data with average weights and discard rates will be provided for the full assessment. Use of corrected catch data in the stock assessment for blue marlin in lieu of nominal catch data from Hawaiian waters to the extent possible is strongly recommended.

Introduction

This paper presents a multi-decade (1948–2010) catch history for blue marlin *Makaira nigricans* in Hawaiian waters. The principal source of data is the Hawaii Division of Aquatic Resources (HDAR), which has compiled annual and monthly records of blue marlin caught with several types of gear (e.g., longline fishing, trolling, hand-lining, angling). This paper presents a re-compilation of the HDAR data so as to provide results at quarterly intervals for use in an international-scale blue marlin stock assessment to be initiated in April 2012.

In addition to the 63-year time series of nominal catches, this paper presents a shorter (10-year) series of corrected longline catch data taken from Walsh et al. (2005; 2007). These corrected results, which include estimates of numbers of caught, average weights, and numbers of discards, were obtained by fitting statistical models to data collected by the Pacific Islands Regional Observer Program (PIROP), applying model coefficients to self-reported commercial logbook data, and then comparing seemingly questionable logbook data to commercial sales records.

The data correction projects were 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

A brief summary of the historical aspects of longline fishing in Hawaii was presented in Walsh and Ito (2011). The summary described the means of data acquisition, compilation, archival of catch data for billfishes from 1948 through 2009.

Biases in Blue Marlin Catch Data

A major concern for this project and previously published studies of blue marlin catch data from the Hawaii-based pelagic longline fishery (Walsh et al. 2005; 2007) has been two known sources of bias: species misidentifications and under-reporting. The first usually involves

misidentifications of striped marlin *Kajikia audax* as blue marlin, which causes negative bias in the former and upward bias for the latter species (Walsh et al. 2005; 2007). Under-reporting of billfishes in the Hawaii-based pelagic longline fishery appears to be primarily associated with large catches, as may occur episodically during years with strong recruitment (Walsh et al. 2007). The most common sources of under-reporting are probably discarding fish without self-reporting such actions and inadvertent miscounting of large catches (Walsh et al. 2007).

Objectives

The objectives of this working paper are to provide the nominal long-term blue marlin catch history in Hawaiian waters required to begin the upcoming stock assessment and to introduce the techniques employed for and results attained by correction of longline catch data. Correction of the commercial logbooks through 2010 is planned before the final stock assessment.

Methods

Data Sources

The time series of blue marlin catches (1948–2010) **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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Table 1. Summary of blue marlin *Makaira nigricans* caught in Hawaiian waters, landed, and sold at quarterly intervals in 1948–2010. Data are presented in two columns per page. Annual totals are in boldface type.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1948	1	13.93	1949	1	13.12
	2	28.33		2	34.31
	3	16.52		3	16.57
	4	20.73		4	17.39
	Annual	**79.51**		**Annual**	**81.39**
1950	1	20.91	1951	1	11.26
	2	38.03		2	31.74
	3	30.10		3	21.01
	4	34.38		4	21.69
	Annual	**123.42**		**Annual**	**85.70**
1952	1	11.89	1953	1	13.29
	2	39.32		2	24.16
	3	18.45		3	18.99
	4	12.99		4	17.84
	Annual	**82.65**		**Annual**	**74.28**
1954	1	17.30	1955	1	14.18
	2	42.36		2	62.33
	3	27.33		3	23.07
	4	15.26		4	22.75
	Annual	**102.25**		**Annual**	**122.33**
1956	1	13.42	1957	1	9.07
	2	33.67		2	51.44
	3	19.09		3	13.21
	4	17.76		4	20.48
	Annual	**83.94**		**Annual**	**94.20**

Table 1, continued.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1956	1	13.42	1957	1	9.07
	2	33.67		2	51.44
	3	19.09		3	13.21
	4	17.76		4	20.48
	Annual	**83.94**		**Annual**	**94.20**
1958	1	11.43	1959	1	8.36
	2	34.57		2	17.22
	3	8.82		3	13.82
	4	12.34		4	13.55
	Annual	**67.16**		**Annual**	**52.95**
1960	1	3.79	1961	1	7.95
	2	14.45		2	18.10
	3	10.12		3	13.89
	4	12.06		4	12.70
	Annual	**40.42**		**Annual**	**52.64**
1962	1	6.35	1963	1	7.14
	2	16.07		2	23.03
	3	11.18		3	13.07
	4	14.55		4	12.57
	Annual	**48.15**		**Annual**	**55.81**
1964	1	7.13	1965	1	3.88
	2	14.41		2	10.79
	3	8.28		3	13.24
	4	8.07		4	12.01
	Annual	**37.89**		**Annual**	**39.92**

Table 1, continued.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1966	1	2.89	1967	1	3.87
	2	10.59		2	7.97
	3	14.32		3	13.41
	4	9.37		4	6.19
	Annual	**37.17**		**Annual**	**31.44**
1968	1	3.94	1969	1	4.11
	2	12.98		2	11.31
	3	8.77		3	34.13
	4	6.10		4	11.37
	Annual	**31.79**		**Annual**	**60.92**
1970	1	2.22	1971	1	9.81
	2	9.22		2	8.18
	3	43.80		3	2.86
	4	23.55		4	0.46
	Annual	**78.79**		**Annual**	**21.31**
1972	1	0.47	1973	1	0.31
	2	0.66		2	0.74
	3	0.08		3	8.23
	4	0.16		4	5.86
	Annual	**1.37**		**Annual**	**15.14**
1974	1	3.10	1975	1	9.11
	2	5.15		2	8.55
	3	17.29		3	9.11
	4	9.32		4	6.23
	Annual	**34.86**		**Annual**	**33.00**

Table 1, continued.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1976	1	3.59	1977	1	23.76
	2	5.17		2	23.20
	3	23.42		3	54.38
	4	27.43		4	22.69
	Annual	**59.61**		**Annual**	**124.03**
1978	1	19.44	1979	1	21.42
	2	70.00		2	55.24
	3	81.79		3	62.34
	4	23.23		4	20.24
	Annual	**194.46**		**Annual**	**159.24**
1980	1	19.73	1981	1	32.45
	2	48.22		2	48.67
	3	68.57		3	76.08
	4	37.52		4	32.93
	Annual	**174.04**		**Annual**	**190.13**
1982	1	28.52	1983	1	15.05
	2	52.39		2	35.78
	3	64.32		3	56.57
	4	34.69		4	35.14
	Annual	**179.92**		**Annual**	**142.54**
1984	1	18.85	1985	1	29.78
	2	22.18		2	38.67
	3	67.29		3	45.37
	4	28.67		4	22.54
	Annual	**136.99**		**Annual**	**136.36**

Table 1, continued.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1986	1	34.54	1987	1	34.90
	2	53.35		2	60.15
	3	74.93		3	85.84
	4	46.20		4	58.66
	Annual	**209.02**		**Annual**	**239.55**
1988	1	36.22	1989	1	70.88
	2	34.62		2	115.05
	3	102.12		3	145.96
	4	91.11		4	145.11
	Annual	**264.07**		**Annual**	**477.00**
1990	1	73.61	1991	1	50.71
	2	130.38		2	153.37
	3	215.52		3	187.83
	4	97.16		4	142.88
	Annual	**516.67**		**Annual**	**534.79**
1992	1	80.25	1993	1	27.76
	2	95.71		2	79.31
	3	131.88		3	214.35
	4	59.70		4	145.26
	Annual	**367.54**		**Annual**	**466.68**
1994	1	91.38	1995	1	27.78
	2	115.78		2	150.89
	3	247.77		3	217.57
	4	69.56		4	173.06
	Annual	**524.49**		**Annual**	**569.30**

Table 1, continued.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
1996	1	160.46	1997	1	45.20
	2	140.93		2	164.96
	3	208.51		3	279.07
	4	109.95		4	166.97
	Annual	**619.85**		**Annual**	**656.20**
1998	1	77.84	1999	1	74.86
	2	62.13		2	81.45
	3	176.38		3	210.21
	4	108.31		4	91.00
	Annual	**424.66**		**Annual**	**457.52**
2000	1	64.58	2001	1	27.68
	2	57.60		2	118.18
	3	195.00		3	274.80
	4	140.29		4	120.19
	Annual	**457.47**		**Annual**	**540.85**
2002	1	75.15	2003	1	26.35
	2	125.40		2	181.69
	3	155.35		3	130.23
	4	40.92		4	97.00
	Annual	**396.82**		**Annual**	**435.27**
2004	1	95.43	2005	1	55.93
	2	131.85		2	170.55
	3	125.88		3	141.26
	4	55.05		4	71.76
	Annual	**408.21**		**Annual**	**439.50**

Table 1, continued.

Year	Quarter	Landings (MT)	Year	Quarter	Landings (MT)
2006	1	43.20	2007	1	50.57
	2	133.42		2	112.68
	3	125.84		3	93.43
	4	126.63		4	82.52
	Annual	**429.09**		**Annual**	**339.20**
2008	1	42.76	2009	1	66.29
	2	104.59		2	156.35
	3	150.07		3	178.87
	4	120.83		4	67.06
	Annual	**418.25**		**Annual**	**468.57**
2010	1	37.17			
	2	142.12			
	3	143.68			
	4	74.57			
	Annual	397.54			

Table 2. Blue marlin landings (MT) as estimated from the HDAR data compilation from 1987 through 2010 apportioned among the Hawaii-based pelagic longline fishery, Main Hawaiian Islands troll fishery, and Main Hawaiian Islands handline fishery.

Year	Longline landings (MT)	MHI Troll landings (MT)	MHI Handline landings (MT)	Total landings (MT)
1987	50.79	252.61	8.16	311.56
1988	102.04	260.77	5.44	368.25
1989	355.56	319.27	6.35	681.18
1990	378.23	289.52	5.44	673.20
1991	296.60	339.68	6.35	642.63
1992	346.94	256.24	4.08	607.26
1993	339.23	306.30	4.99	650.52
1994	361.90	293.88	3.63	659.41
1995	570.07	310.20	4.99	885.26
1996	467.12	401.36	7.26	875.74
1997	487.07	369.34	9.07	865.49
1998	394.56	239.00	2.72	636.28
1999	356.92	287.98	4.54	649.43
2000	322.30	191.60	2.47	519.55
2001	412.35	275.96	2.23	692.59
2002	268.74	202.23	2.77	476.15
2003	352.18	176.76	2.20	533.29
2004	282.59	163.38	2.26	450.48
2005	331.68	179.26	2.73	514.82
2006	406.62	145.32	1.81	555.51
2007	261.83	119.43	0.79	383.63
2008	347.28	176.08	1.19	526.50
2009	358.14	164.96	1.12	524.90
2010	318.20	130.04	1.04	450.08

Table 3. Corrected blue marlin catch data from 1995 through 2003 from Walsh et al. (2007). Results include corrected catches (numbers of fish), weights, discards, and estimated totals.

Year	Quarter	Nominal Catch (*N*)	Corrected Catch (*N*)	Average weight (kg)	Estimated Discards (kg)	Estimated Total (kg)
1995	1		700	40.5		
	2		1928	71.8		
	3		1835	66.8		
	4		1596	74.0		
	Annual		**6059**	**67.2**		
1996	1		990	64.8		
	2		1415	67.7		
	3		1864	73.4		
	4		1016	64.8		
	Annual		**5285**	**68.6**		
1997	1		451	57.9		
	2		2451	53.8		
	3		3237	59.6		
	4		1119	69.9		
	Annual		**7258**	**59.1**		
1998	1		457	73.3		
	2		1104	67.0		
	3		1414	73.6		
	4		919	71.6		
	Annual		**3894**	**71.2**		
1999	1		483	51.9		
	2		1308	67.7		
	3		1534	82.2		
	4		555	79.2		
	Annual		**3880**	**73.1**		

Table 3, continued.

Year	Quarter	Nominal Catch (*N*)	Corrected Catch (*N*)	Average weight (kg)	Estimated Discards (kg)	Estimated Total (kg)
2000	1		176	73.3		
	2		505	67.0		
	3		1419	73.6		
	4		449	71.6		
	Annual		**2549**	**71.9**		
2001	1		101	69.6		
	2		1007	60.0		
	3		1567	64.2		
	4		518	68.4		
	Annual		**3193**	**64.4**		
2002	1		280	51.9		
	2		790	67.7		
	3		607	82.2		
	4		236	79.2		
	Annual		**1913**	**71.4**		
2003	1		334	73.3		
	2		1350	67.0		
	3		422	73.6		
	4		727	71.6		
	Annual		**2833**	**69.9**		

Figure 1. Blue marlin catches (left panel) and effort in thousands of hooks (right panel) from the Hawaii-based and American Samoa-based longline fisheries. The first pair of panels (Figure 2A) depicts catch and effort from X–2000. The second pair (Figure 2B) depicts catch and effort from 2001–2010. The third pair (Figure 2C) depicts catch and effort from 2011 (note smaller scales).

Figure 1A.

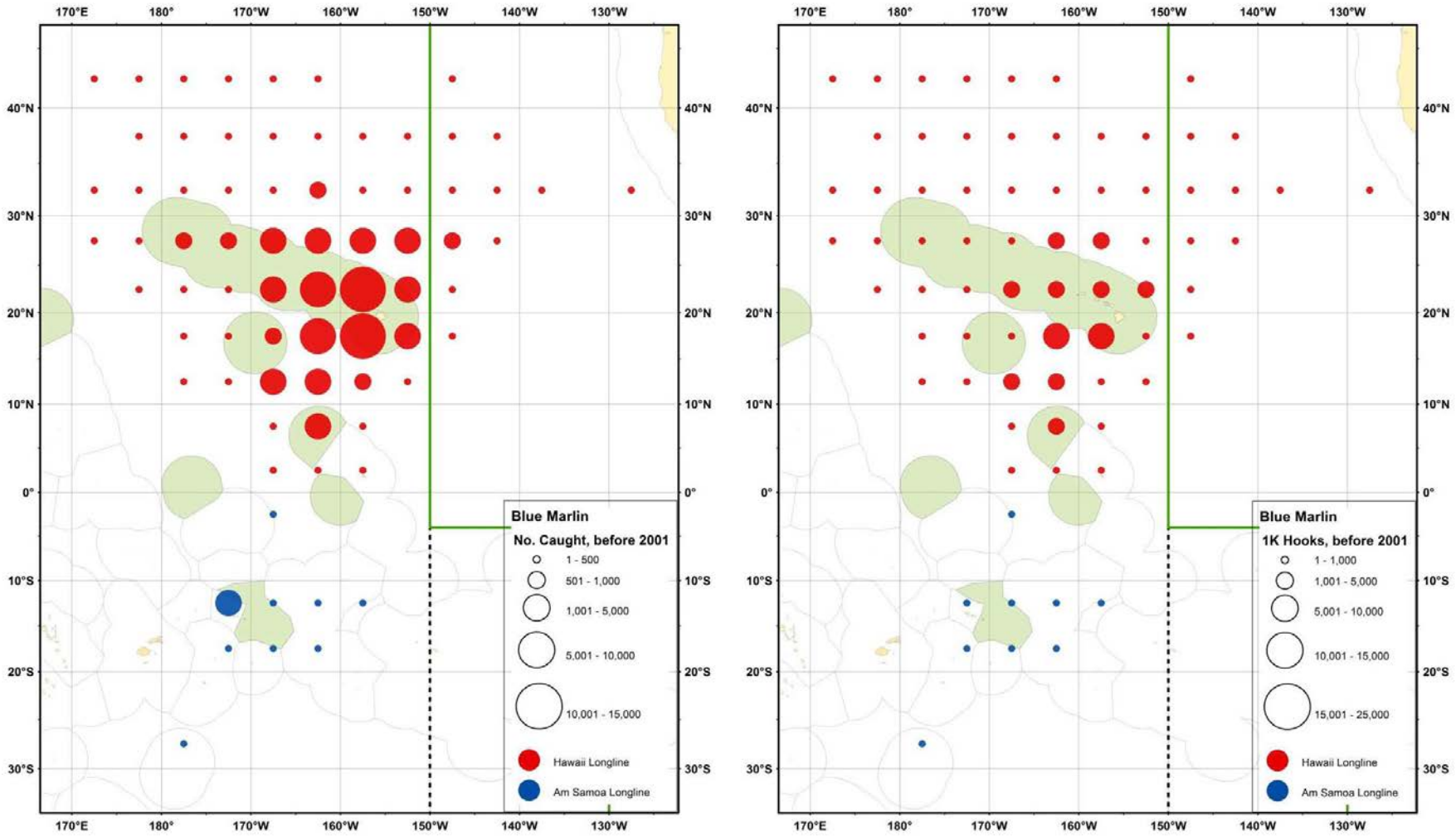


Figure 1B.

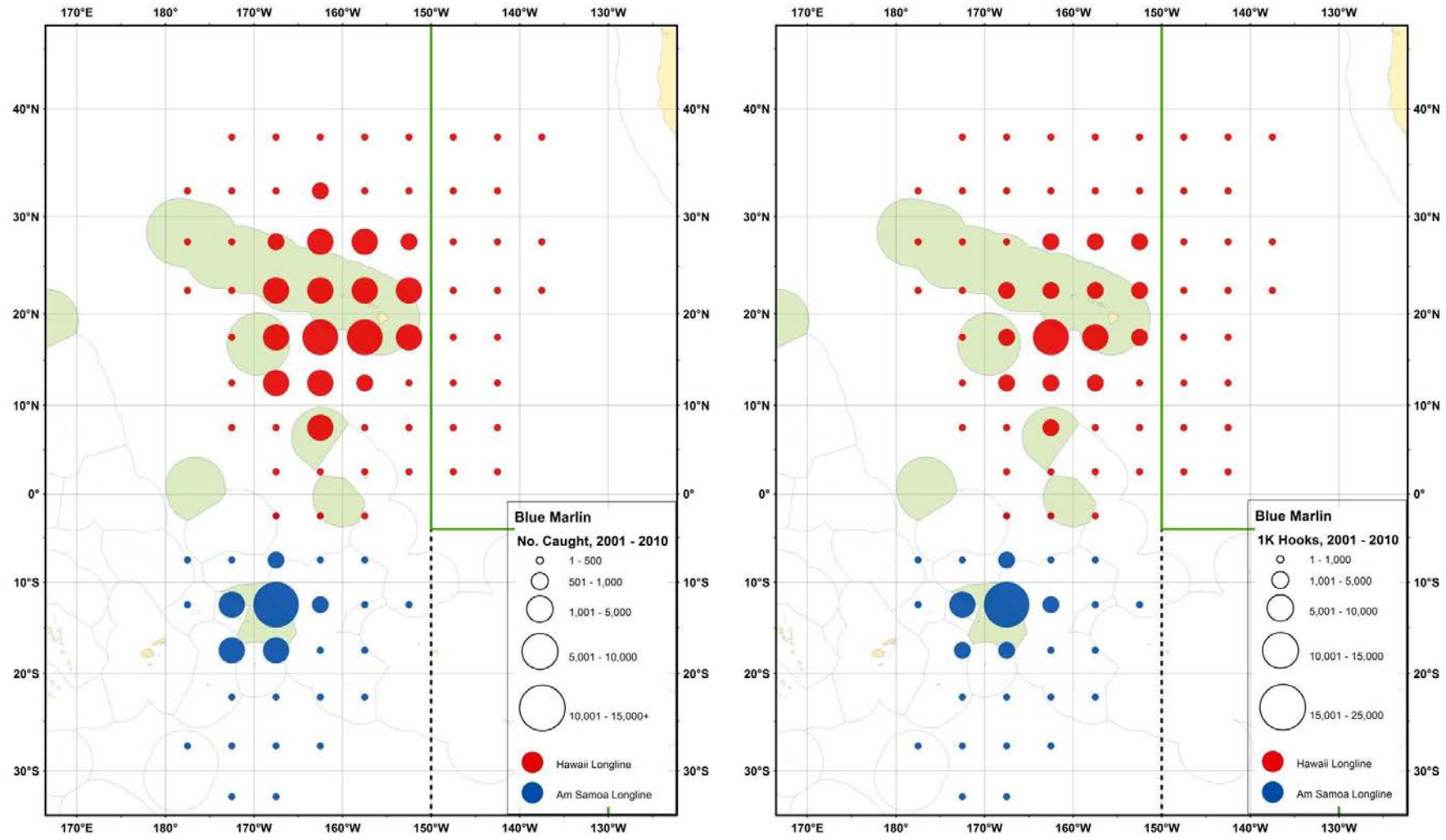
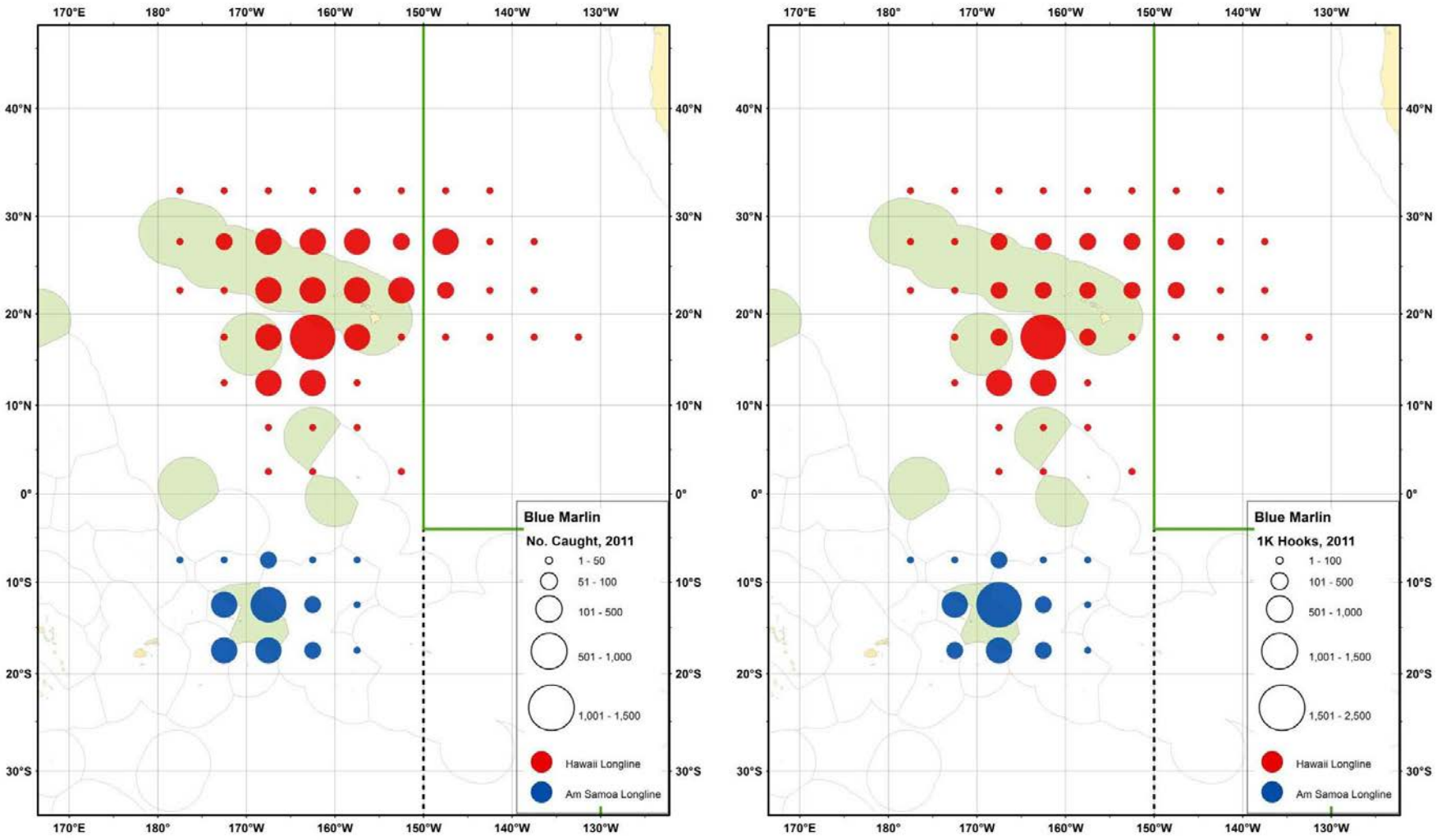

170°E
180°
170°W
160°W
150°W
140°W
130°W
40°N
30°N
20°N
10°N
0°
10°S
20°S
30°S
Blue Marlin
No. Caught, 2001 - 2010
1 - 500
501 - 1,000
1,001 - 5,000
5,001 - 10,000
10,001 - 15,000+
Hawaii Longline
Am Samoa Longline
Blue Marlin
1K Hooks, 2001 - 2010
1 - 1,000
1,001 - 5,000
5,001 - 10,000
10,001 - 15,000
15,001 - 25,000
Hawaii Longline
Am Samoa Longline

Figure 1C.


170°E
180°
170°W
160°W
150°W
140°W
130°W
40°N
30°N
20°N
10°N
0°
10°S
20°S
30°S
Blue Marlin
No. Caught, 2011
1 - 50
51 - 100
101 - 500
501 - 1,000
1,001 - 1,500
Hawaii Longline
Am Samoa Longline
Blue Marlin
1K Hooks, 2011
1 - 100
101 - 500
501 - 1,000
1,001 - 1,500
1,501 - 2,500
Hawaii Longline
Am Samoa Longline