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Preliminary analysis of length – weight relationship of swordfish (*Xiphias gladius*), black marlin (*Makaira indica*), and blue marlin (*Makaira nigricans*) caught by Indonesian longliners in the Indian Ocean

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Abstract

This paper presents several equations for converting among measures of size (length and weight) for swordfish (*Xiphias gladius*), black marlin (*Makaira indica*), and blue marlin (*Makaira nigricans*) caught by Indonesian longliners in the Indian Ocean. The equations use for transforming eye fork length and pectoral fork length to lower jaw fork length, and pectoral fork length to lower jaw fork length. The result showed that there were no significant differences existed between females and males among length measures for swordfish, blue marlin, and black marlin (ANCOVA, P> 0.05). The sex ratio (proportion of female to total of male and female) for swordfish and black marlin was 0.51 and 0.55 respectively (equal with 1:1) while for blue marlin was 0.62 where proportion of female was higher than male.

1. Introduction

Billfishes (Xiphiidae and Istiophoridae) are the second largest catch in the world after tunas, including Indonesia. About 90% of the world's landings of billfishes are taken as bycatch of the tuna longline fishery (Prager *et al*., 1995), since there is no specific fishery targeting this group of species especially in Indonesia. The estimated catch of tuna and tuna-like species of the tuna fisheries in the Indian Ocean more than doubled from 405,929 tonnes (t) in 1983 to 1,106,518t in 1995. During this same period the estimated catch of billfish nearly tripled, from 14,568t to 52,221t (IOTC 1995, 1997). Contribution of billfishes to tuna fishery in Indonesian considered significant, which up to 95,652 metric tonnes from 2004 to 2010 (DGCF, 2011).

Billfishes caught by are usually processed at sea, with heads, fins, and viscera removed and carcasses frozen (at -200^0 C to -300^0 C) for offloading months later (Su *et al*., 2005; Murniyati & Sunarman, 2000). Billfish carcasses may have been dressed in one of 10 or more ways (Prince & Miyake, 1989) before length measurements are taken. This leads to discrepancy on whole and dressed length. Because the fish are rarely weighed by fishermen

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onboard, there is also a need for conversion equations between length and weight. (Prager *et al*., 1995).

The present paper has two objectives. The first is to present equations for predicting from non-standard measurements into standard lengths (pectoral fork length; PFL & eye orbit fork length; EFL to lower jaw fork length; LJFL). Equation for predicting PFL to EFL also presented in this paper. The second objective is to present length-weight relationship based on daily monitoring data of billfishes landed in Port of Benoa, Bali. In addition, we also include sex ratio and size (length and weight) frequency distribution in our analysis.

2. Methods

Size data including LJFL, EFL and PFL which were obtained from Research Institute for Tuna Fisheries (RITF) through daily tuna and tuna-like monitoring program from 2002 – 2012 and scientific observer program from 2005 – 2013, this also include data requirement for length to length conversion which taken from March 2011 to date for swordfish, black marlin, and blue marlin. The linear regression equation (where *a* and *b* are parameters) was implemented for females and males, respectively. If there is no significant difference between them, the relationship between LJFL – EFL, LJFL – PFL, and EFL – FL was calculated again by using all data of both sexes to obtain the pooled linear regression equation. The length-weight relationship (between PFL and dressed carcass weight) was calculated using power function.

3. Results

The main fishing grounds and average CPUE (no. fish/100 hooks) by 5x5 degree square basis of billfishes from the Indonesian longliners are shown in Fig. 1. It showed that the catch of billfishes concentrated between 5^0 – 20^0 S and 105^0 – 125^0 E. The trend of CPUE for all billfishes tend to increase over the years although the nominal CPUE never exceed 0.20 (Fig. 2). All of the LJFL, EFL and PFL data consist of 19 male and 20 female of swordfish, 15 male and 5 female of black marlin; and 11 male and 10 female of blue marlin have been measured. It involved 8 trip of scientific observation from March, 2011 to date. The minimum, maximum, and average sizes by sex are shown in Table 1. It appears that average size of swordfish was smaller than both black and blue marlins. There were no significant differences existed between females and males among length measures for swordfish, blue marlin, and black marlin (ANCOVA, $P > 0.05$). LJFL, EFL and PFL data of each sex were

combined and the pooled relationships between LJFL, EFL and PFL for each species of billfish as shown in Table 2.

Length-weight (length; PFL and dressed weight, HDD) relationship of swordfish, black marlin and blue marlin are shown in Fig. 3. The data analysed comprise of 1,429 of swordfish, 390 of black marlin and 324 of blue marlin from 2002 – 2013. Knowing the length to length and length to weight equations mean we can transform non-standard length measurement into weight (total weight/dressed weight) vice versa. Both the average length and weight of swordfish, black marlin and blue marlin (Fig. 4) in general relatively stable throughout the years, even there were some sign of declining of for swordfish and black marlin and slightly ascending for blue marlin. This might be caused by the lack of data in early years of monitoring which happened because billfishes and other by-catch were not priority for sampling, therefore both daily monitoring and scientific observer data from 2002 – 2010 showing high degree of variation.

The sex ratio (proportion of female to total of male and female) for swordfish and black marlin was 0.51 and 0.55 respectively (equal with 1:1) while for blue marlin was 0.62 where proportion of female was higher than male (Fig 4). From the size frequency distribution (Fig. 5) showed that all of the billfishes caught by Indonesian longliners are likely performing a single cohort.

4. Reference

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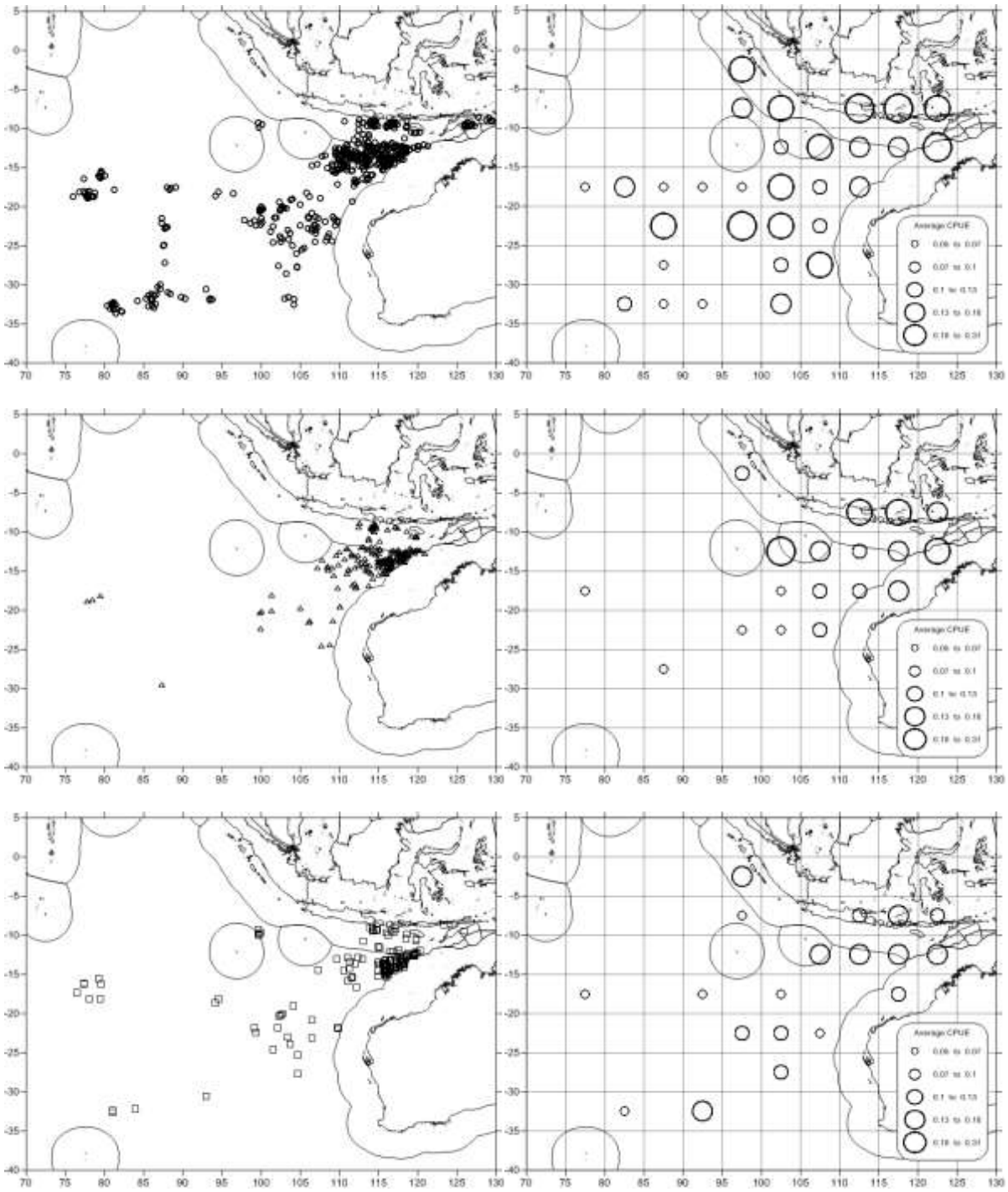


Figure 1. Fishing grounds and the average CPUE (no. fish/100 hooks) by 5x5 degree square basis of the swordfish (O), black marlin (Δ) and blue marlin (□) caught by Indonesian longliners in the Indian Ocean based on observer data during 2005 - 2013.

Table 1. The range (minimum and maximum) and average size of swordfish, black marlin and blue marlin caught by Indonesian longliners in Indian Ocean.

		Swordfish			**Black Marlin**			**Blue Marlin**		
		LJFL	EFL	PFL	LJFL	EFL	PFL	LJFL	EFL	PFL
Minimum	Male	58.0	48.0	40.0	139.0	119.0	105.0	183.0	157.0	136.0
	Female	76.0	67.0	56.0	170.0	147.0	122.0	170.0	146.0	126.0
	Pooled	**50.0**	40.0	30.0	**126.0**	106.0	91.0	**154.0**	135.0	112.0
Maximum	Male	254.0	230.0	190.0	244.0	220.0	185.0	232.0	207.0	182.0
	Female	252.0	232.0	197.0	266.0	223.0	200.0	264.0	238.0	200.0
	Pooled	**254.0**	232.0	197.0	**266.0**	223.0	200.0	**264.0**	238.0	200.0
Average	Male	156.6	137.4	116.5	195.7	171.9	147.5	201.8	175.8	152.3
	Female	158.8	143.1	115.2	206.6	179.2	154.8	203.7	175.6	151.4
	Pooled	**129.3**	113.5	94.2	**193.5**	169.2	145.8	**195.9**	170.2	147.3

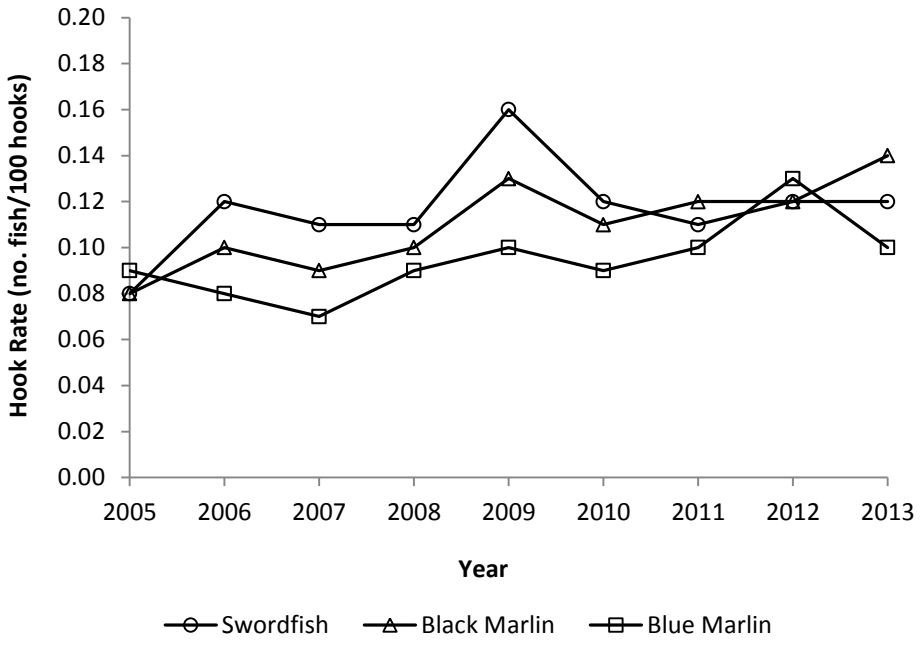


Figure 2. The trend of average CPUE of swordfish (O), black marlin (Δ) and blue marlin (□) caught by Indonesian longliners in the Indian Ocean based on observer data during 2005 - 2013.

Table 2. Regression equations for predicting from non-standard measurements into standard lengths (pectoral fork length & eye orbit fork length to lower jaw fork length) for swordfish, black marlin and blue marlin caught by Indonesian longliners in Indian Ocean.

Regression Equations	Sex(es)	Sample Size (n)	Approx. Length Range	Intercept	Slope	R^2	P
				a	b		
Swordfish (SWO)							
LJFL = a*EFL + b	M	19	58 - 254	1.082	7.908	0.997	0.000**
	F	20	76 - 252	1.059	7.206	0.996	0.000**
	M+F+U	160	50 - 254	1.060	9.027	0.988	0.000**
LJFL = a*PFL + b	M	19	59 - 254	1.243	11.863	0.991	0.000**
	F	20	77 - 252	1.289	10.21	0.988	0.000**
	M+F+U	160	51 - 254	1.241	12.44	0.977	0.000**
EFL = a*PFL + b	M	19	60 - 254	1.147	3.802	0.991	0.000**
	F	20	78 - 252	1.216	3.007	0.989	0.000**
	M+F+U	160	52 - 254	1.168	3.532	0.983	0.000**
Black Marlin (BLM)							
LJFL = a*EFL + b	M	15	139 - 244	1.059	13.686	0.988	0.000**
	F	5	170 - 266	1.183	-5.473	0.978	0.000**
	M+F+U	37	126 - 266	1.060	14.185	0.965	0.000**
LJFL = a*PFL + b	M	15	139 - 244	1.271	8.215	0.979	0.000**
	F	5	170 - 266	1.267	10.828	0.992	0.000**
	M+F+U	37	126 - 266	1.249	11.299	0.967	0.000**
EFL = a*PFL + b	M	15	139 - 244	1.195	4.367	0.982	0.000**
	F	5	170 - 266	1.054	16.073	0.986	0.000**
	M+F+U	37	126 - 266	1.195	-4.367	0.982	0.000**
Blue Marlin (BUM)							
LJFL = a*EFL + b	M	11	183 - 232	0.974	30.646	0.936	0.000**
	F	10	170 - 264	1.017	25.11	0.990	0.000**
	M+F+U	53	154 - 264	0.983	28.63	0.889	0.000**
LJFL = a*PFL + b	M	11	183 - 232	0.992	50.815	0.850	0.000**
	F	10	170 - 264	1.300	6.891	0.969	0.000**
	M+F+U	53	154 - 264	1.115	31.674	0.806	0.000**
EFL = a*PFL + b	M	11	183 - 232	1.028	19.265	0.926	0.000**
	F	10	170 - 264	1.281	-18.376	0.984	0.000**
	M+F+U	53	154 - 264	1.163	-1.019	0.952	0.000**

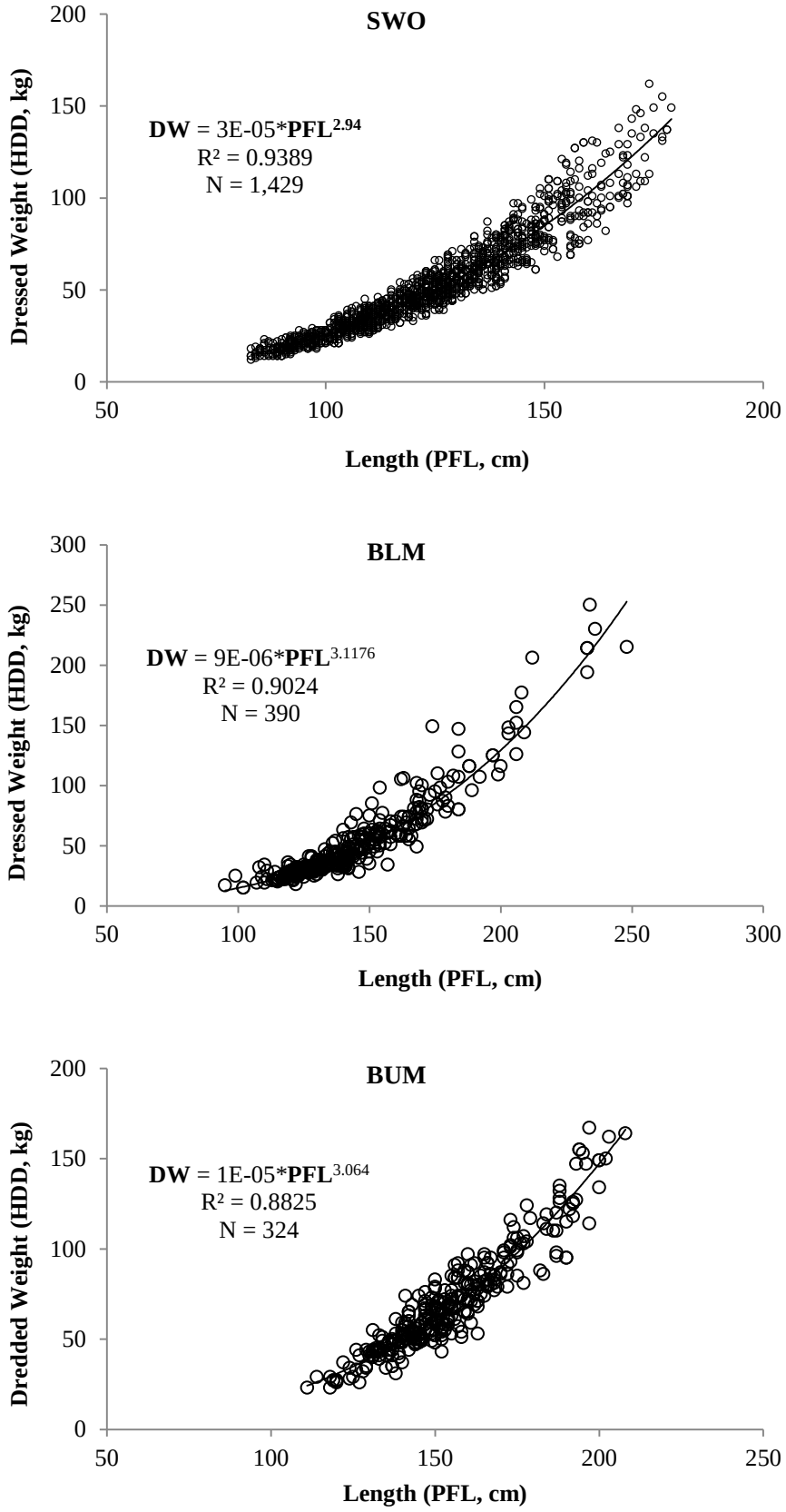


Figure 3. Length (PFL)-weight (HDD) relationship for the swordfish, black marlin and blue marlin caught by Indonesian longliners in the Indian Ocean from 2002 – 2013.

Predicting Total Weight from Non-Standard Length Measurement

1. Swordfish

from PFL to TW

$TW = 0.00001443*LJFL^{2.96267}$ (IOTC, 2013)
LJFL = 1.2410*PFL+12.440 (present study)
$TW_{est} = 0.00001443*(1.2410*PFL+12.440)^{2.96267}$

from EFL to TW

$TW = 0.00001443*LJFL^{2.96267}$ (IOTC, 2013)
LJFL = 1.0596*EFL+9.0272 (present study)
$TWest = 0.00001443*(1.0596*EFL+9.0272)^{2.96267}$

2. Black Marlin (BLM)

from PFL to TW

$TW = 0.00000096*LJFL^{3.35727}$ (IOTC, 2013)
LJFL = 1.2410*PFL+12.440 (present study)
$TW_{est} = 0.00000096*(1.2410*PFL+12.440)^{3.35727}$

from EFL to TW

$TW = 0.00000096*LJFL^{3.35727}$ (IOTC, 2013)
LJFL = 0.9825*EFL+28.63 (present study)
$TWest = 0.00000096*(0.9825*EFL+28.63)^{3.35727}$

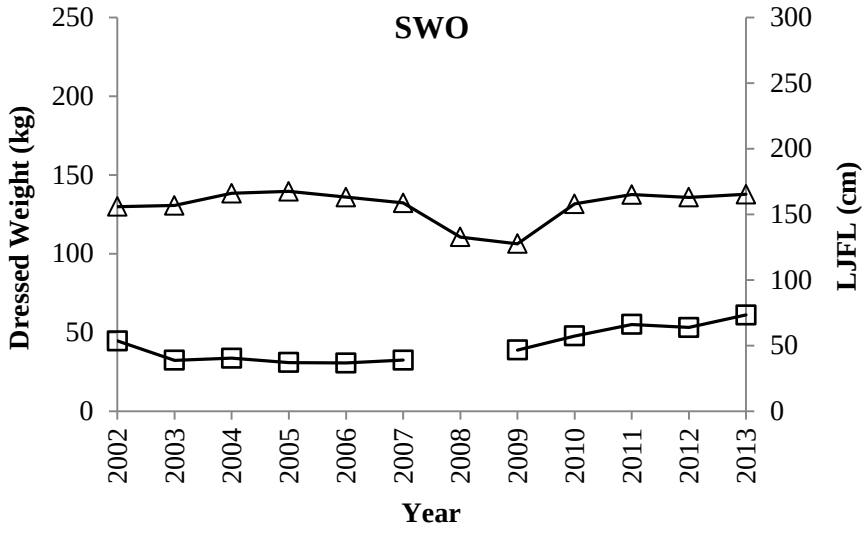
3. Blue Marlin (BUM)

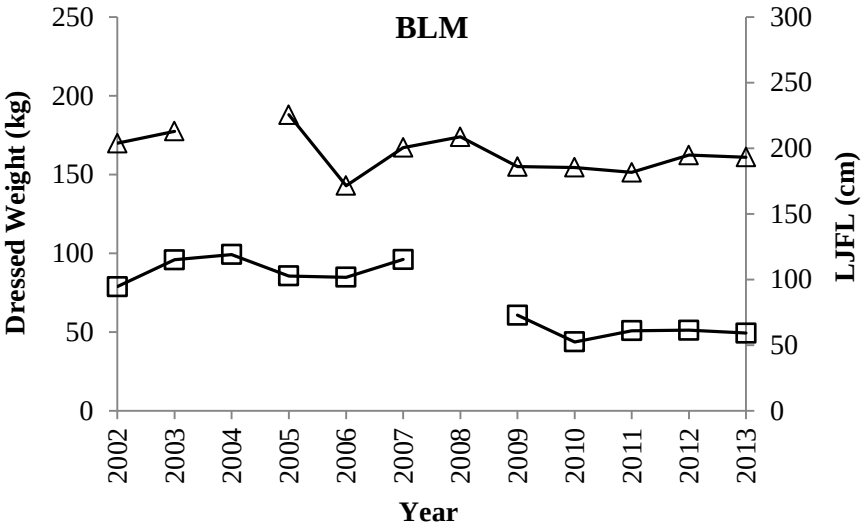
from PFL to TW

TW = 0.00000084*LJFL3.59846 (IOTC, 2013)
LJFL = 1.1151*PFL + 31.674 (present study)
$TW = 0.00000084*(1.1151*PFL + 31.674)^{3.59846}$

from EFL to TW

$TW = 0.00000084*LJFL^{3.59846}$ (IOTC, 2013)
LJFL = 0.9825*EFL + 28.63 (present study)
$TW = 0.00000084*(0.9825*EFL + 28.63)^{3.59846}$


SWO
Dressed Weight (kg)
LJFL (cm)
Year
0
50
100
150
200
250
300
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013


BLM
Dressed Weight (kg)
LJFL (cm)
Year
0
50
100
150
200
250
300
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

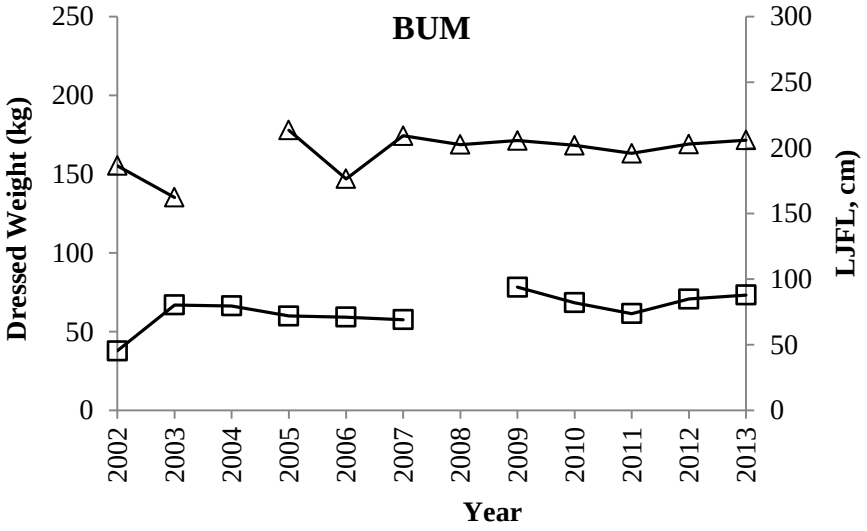
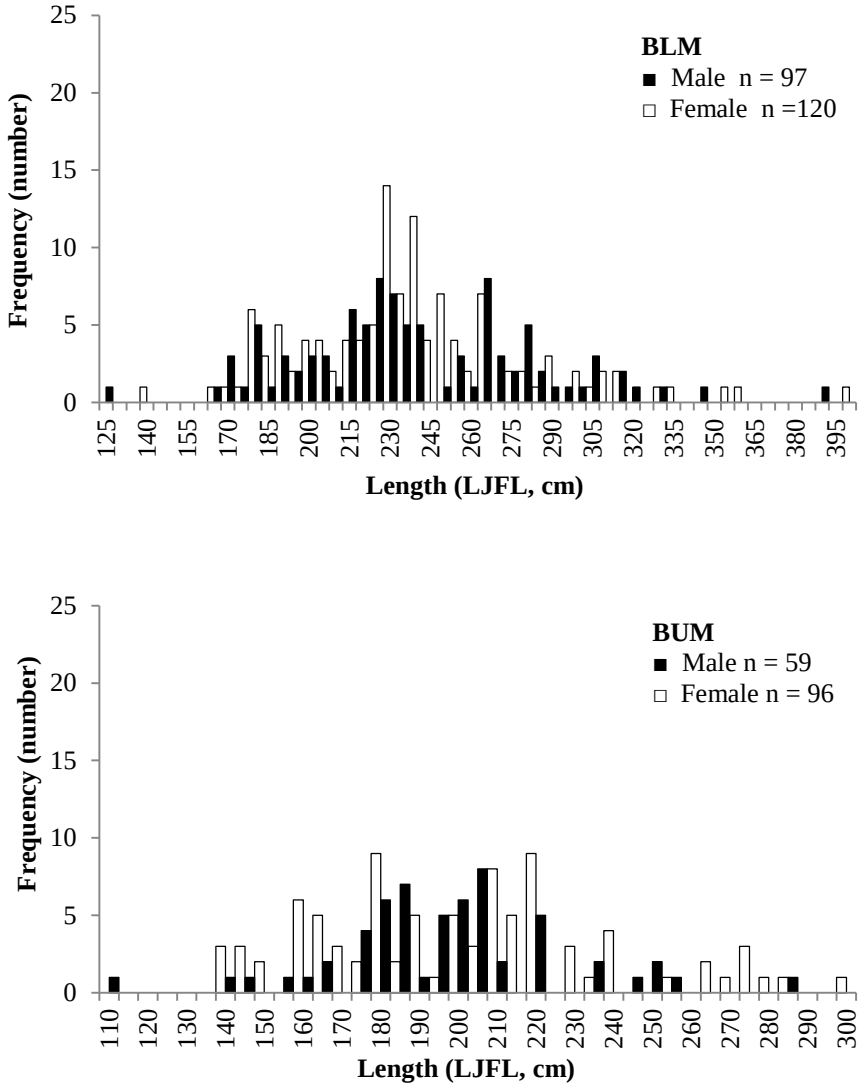

BUM
Dressed Weight (kg)
LJFL, cm)
Year
0
50
100
150
200
250
300
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

Figure 4. Average dressed weight (□) and adjusted length (Δ) of swordfish, black marlin, and blue marlin caught by Indonesian longliners in Indian Ocean from 2002 – 2013 (Note: 1) weight data from January 2008 to November 2009 was missing due to database failure; 2) No length data recorded for BLM and BUM in 2004)



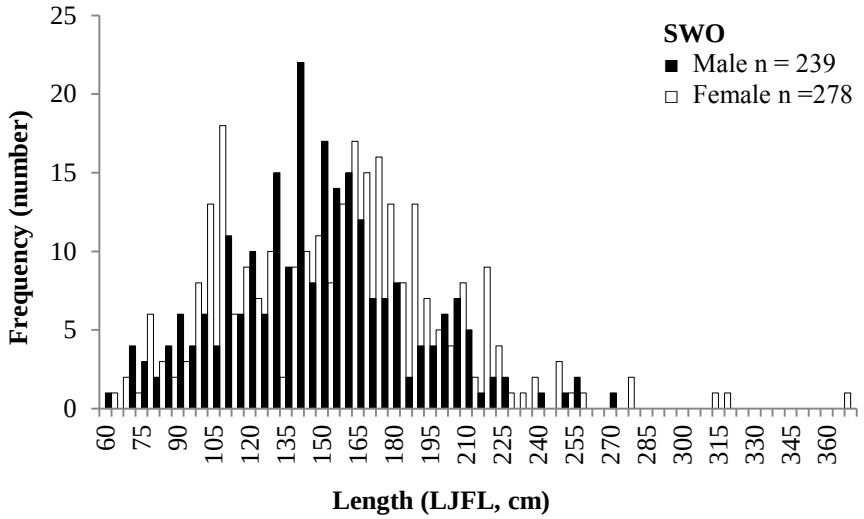
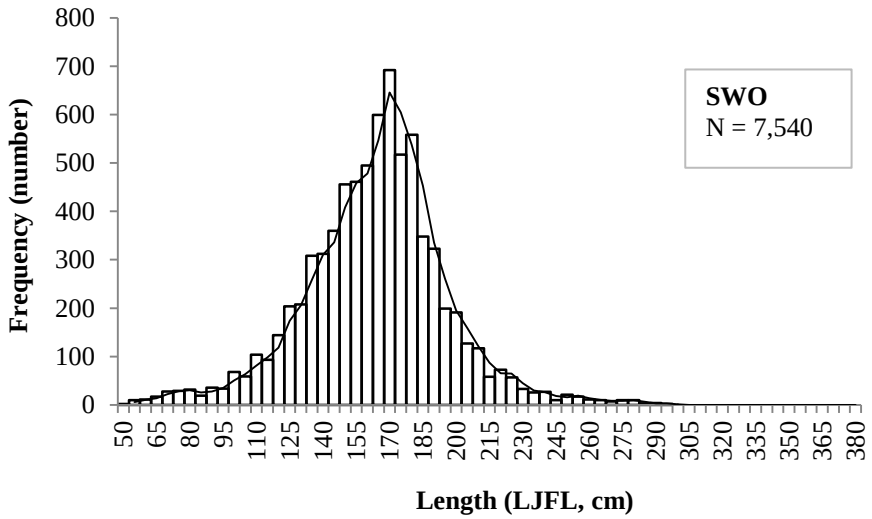
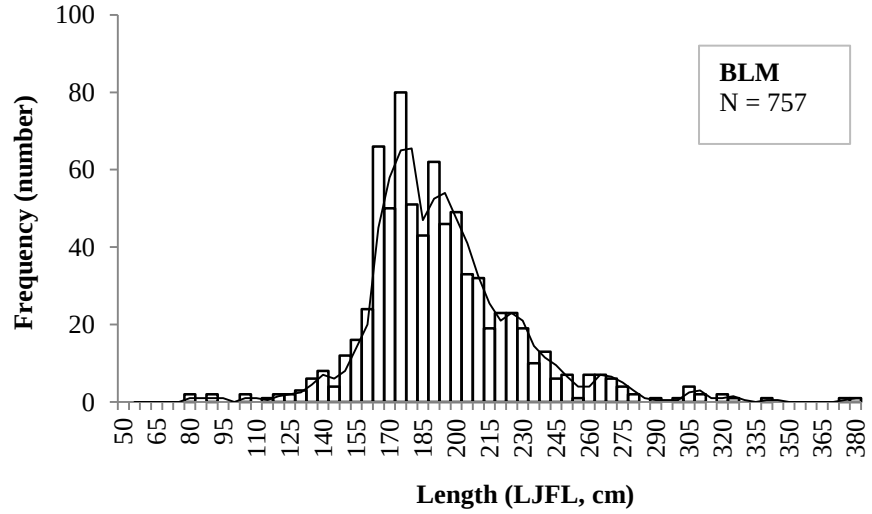


Figure 5. Size frequency distribution of black marlin, blue marlin and swordfish caught by Indonesian longliners in the Indian Ocean by sex based on observer data during 2005 – 2013 (Note: All length has been converted into LJFL)





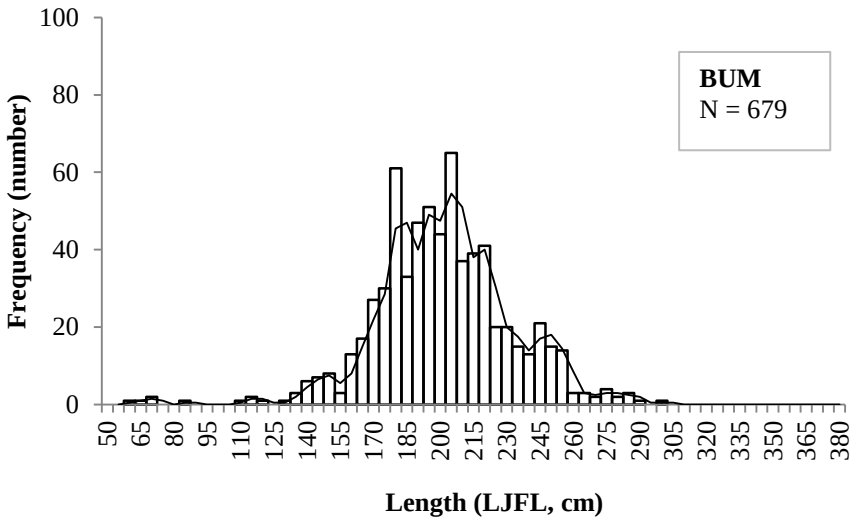


Figure 5. Size frequency distribution of black marlin, blue marlin and swordfish caught by Indonesian longliners in the Indian Ocean based on daily monitoring and observer data from 2002 – 2013 (Note: All length has been converted into LJFL)