Japanese longline CPUE for bigeye tuna in the Indian Ocean up to 2009 standardized by GLM

Hiroaki OKAMOTO and Hiroshi SHONO

National Research Institute of Far Seas Fisheries
5 chome 7-1, Orido, Shimizu-Ku, Shizuoka-City, 424-8633, Japan

Abstract

Japanese longline CPUE for bigeye tuna from 1960 to 2009 was standardized by GLM (CPUE-LogNormal error structured model). Method of standardization was as same as that used for bigeye assessment in 2009. SST (Sea Surface Temperature) was included in the model as oceanographic factor. NHF (Number of Hooks between Float) and material of main and branch lines were applied to standardize the change in catchability of longline gear.

In the tropical Indian Ocean, CPUE continuously decreased from around 9.3 (real scale) in 1960 to 3.2 in 2002 when it has increased to 4.2 - 4.7 in 2004 through 2008, about the same level as that in the late 1990's. However it has decreased again to about 3.4 in 2009 although the statistics in 2009 is still preliminary. Standardized CPUE in the south area which didn't show clear trend during the period between 1984 and 2000 (CPUE was 3.5 on average), decreased to 2.5 in 2003. It increased to 3.2 in 2004 after when it decreased to 1.3. and 1.5 in 2008 and 2009. As a result, CPUE in all Indian Ocean, which had been kept in the same level around 5 to 7 decreased to 3.0 in 2002, increased a little in 2003 and 2004 after when it decreased to about 3.0 in 2008 (2.5 in 2009 but preliminary).

1. Introduction

. Japanese longline CPUE for bigeye tuna from 1960 to 2009 was standardized by GLM (CPUE-LogNormal error structured model). Method of standardization was the same as that used for bigeye assessment in 2009 (Okamoto et al., 2009).

2. Materials and methods

Area definition:

Area definition used in this study (Fig. 1) is the same as that used in the IOTC bigeye assessment in 2006 (Okamoto and Shono, 2006) which consists of seven areas. Main fishing ground of Japanese longline fishery for bigeye was divided into seven areas and CPUE standardization was done for three cases of area combinations, Aropical (areas 1-5), South (areas 6 & 7) and ALL (areas 1-7) Indian Ocean. Area 67 in the south area was not used in this study.

Environmental factors:

As environmental factors, which are available for the analyzed period from 1960 to 2009, SST (Sea Surface Temperature) was applied. The original SST data, whose resolution is 1-degree latitude and 1-degree longitude by month from 1946 to 2009, was downloaded from NEAR-GOOS Regional Real Time Data Base of Japan Meteorological Agency (JMA).

http://goos.kishou.go.jp/rrtdb/database.html

It is necessary to get password to access the data retrieving system. The original data was recompiled into 5-degree latitude and 5-latitude longitude by month from 1960 to 2009 using

the procedures described in Okamoto et al. (2001), and used in the analyses.

Catch and effort data used:

The Japanese longline catch (in number) and effort statistics from 1960 up to 2009 were used. 2009 data is preliminary. The catch and effort data set from aggregated by month, 5-degree square, NHF (the number of hooks between floats, and main line material, was used for the analysis. Data in strata in which the number of hooks was less than 5000 were not used for analyses. As the NHF information does not available for the period from 1960 to 1974, NHF was regarded to be 5 in this period. Main line material was categorized in to two, 1 = Nylon and 2 = other. .

GLM (Generalized Linear Model):

CPUEs based on the number of catch was used;

The number of caught fish / the number of hooks * 1000

The model used for GLM analyses (CPUE-LogNormal error structured model) was as follows.

Model (CPUE-LogNormal error structured model):

$$\text{Log}(CPUE_{ijkl} + \text{const}) = \mu + YR_{(i)} + MN_{(j)} + AREA_{(k)} + NHFCL_{(l)} + SST_{(m)} + ML_{(n)} + YR(i)*AREA_{(k)} + MN(j)*AREA_{(k)} + AREA(k)*NHFCL(l) + AREA(k)*SST(m) + NHFCL(l)*ML(n) + e_{(ijkl....)}$$

Where Log : natural logarithm,

CPUE : catch in number of bigeye per 1000 hooks,

Const : 10% of overall mean of CPUE

μ : overall mean (i.e. intercept),

$YR_{(i)}$: effect of year,

$MN_{(j)}$: effect of fishing season (month),

$AREA_{(k)}$: effect of sub-area,

$NHFCL_{(l)}$: effect of gear type (class of the number of hooks between floats),

$SST_{(m)}$: effect of SST,

$ML_{(n)}$: effect of material of main line,

YR (i)*AREA (k) : interaction term between year and sub-area,

MN (j)*AREA (k) : interaction term between fishing season and sub-area,

AREA (k)*NHFCL (l) : interaction term between sub-area and gear type,

AREA(k)*SST (m) : interaction term between sub-area and SST,

NHFCL(l)*ML(n) : interaction term between sub-area and MLD,

$e_{(ijkl..)}$: error term.

The number of hooks between float (NHF) was divided into 6 classes (NHFCL 1: 5-7, NHFCL 2: 8-10, NHFCL 3: 11-13, NHFCL 4: 14-16, NHFCL 5: 17-19, NHFCL 6: 20-21) as later explanation.

Effect of year was obtained by the method used in Ogura and Shono (1999) that uses lsmean of Year-Area interaction as the following equation.

$$CPUE_i = \sum W_j * (\exp(\text{lsmean}(\text{Year } i * \text{Area } j)) - \text{constant})$$

Where $CPUE_i$ = CPUE in year i,

W_j = Area rate of Area j , ($\sum W_j = 1$),

lsmean(Year*$Area_{ij}$) = least square mean of Year-Area interaction in Year i and Area j,

constant = 10% of overall mean of CPUE.

Time period of standardization was 1960-2009 for both of annual and quarter CPUE.

3. Results and discussion

CPUE standardizations by GLM:

The bigeye CPUE (catch in number per 1000 hooks) was standardized by GLM (CPUE-LogNormal error structured model) for each of three area categories, Tropical (Areas

1 – 5), South (Areas 6 & 7) and All Indian Ocean (Areas 1 – 7) for three periods 1960-2009 as described in the materials and method section.

Trends of CPUE in each region category (Tropical, South and All Indian Ocean) were shown in Fig. 2 overlaying Nominal CPUE in real scale and relative scale. In the tropical Indian Ocean, CPUE continuously decreased from around 9.3 (real scale) in 1960 to 3.2 in 2002 when it has increased to 4.2 - 4.7 in 2004 through 2008, about the same level as that in the late 1990's. However it has decreased again to about 3.4 in 2009 although the statistics in 2009 is still preliminary. Standardized CPUE in the south area which didn't show clear trend during the period between 1984 and 2000 (CPUE was 3.5 on average), decreased to 2.5 in 2003. It increased to 3.2 in 2004 after when it decreased to 1.3. and 1.5 in 2008 and 2009. As a result, CPUE in all Indian Ocean, which had been kept in the same level around 5 to 7 decreased to 3.0 in 2002, increased a little in 2003 and 2004 after when it decreased to about 3.0 in 2008 (2.5 in 2009 but preliminary). Results of ANOVA and distributions of the standard residual in each analysis were shown in Table 1 and Fig. 3, respectively. Distributions of the standard residual did not show remarkable difference from the normal distribution. F test showed that the effects of all explanatory variables included in the model were significant in the standardization for tropical Indian Ocean, but Area and SST*AREA were not significant in the south area, and ML was not significant in the all Indian Ocean. Annual values of standardized CPUE by region were listed in Appendix Table 1.

Standardized CPUE of each month and each NHFCL by material were compared for tropical and temperate area in Fig. 4 and 5, respectively. In the temperate (south), CPUE was highest in summer (Jun–Aug) and lowest in winter (Nov-Feb). Although the seasonal trend in tropical was not so clear, that in winter was highest in winter and lowest in March. Regarding the combination of NHFCL with non-nylon main line materials, larger NHFCL shows higher CPUE in the South Indian Ocean, while smallest (NHFCL1) and largest (NHFCL 6) classes were rather low in CPUE than other NHFCL 2 – 5 which were about the same level each other in the Tropical Indian Ocean. As for the nylon mainline, CPUE in Tropical Indian Ocean was lowest for NHFCL 2 or 3, while those of other NHFCL (1, and 4-6) are the same level. Nylon material CPUE of South Indian Ocean did not show large difference between NHFCL although highest value was observed for largest NHFCL.

Finally, quarterly CPUE trend from 1960 to 2009 were shown in Fig. 6 overlaid with year trend. As described in Method section, area weighting was not done for quarterly CPUE. Nevertheless, quarterly CPUE showed very similar trend to annual CPUE. The value of quarterly CPUE from 1960 to 2009 was listed in Appendix Table 2.

4. Recerences

Shono, H. and M. Ogura, M. (1999): The standardized skipjack CPUE including the effect of searching devices, of the Japanese distant water pole and line fishery in the Western Central Pacific Ocean. ICCAT-SCRS/99/59. 18p

Okamoto, H., Miyabe, N., and Matsumoto, T. (2001): GLM analyses for standardization of Japanese longline CPUE for bigeye tuna in the Indian Ocean applying environmental factors. IOTC-2001/TTWP/21, 38p.

Okamoto, H., Miyabe, N., and Shono, H. (2006): Japanese longline CPUE for bigeye tuna in the Indian Ocean up to 2004 standardized by GLM applying gear material information in the model. IOTC-2006/WPTT/17. 16 pp.

Okamoto, H., Satoh, K., and Shono, H. (2009): Japanese longline CPUE for bigeye tuna in the Indian Ocean up to 2008 standardized by GLM. IOTC-2009/WPTT/5, 21pp.

Table 1. ANOVA table of GLM for standardization of Annual CPUE.

All Tropical **1960–2009 Year base**

Source	DF	Type III SS	Mean Square	F Value	Pr > F	R-Square=
Model	340	5202.020	15.300	48.090	<.0001	0.364067
						CV =
yr	49	587.822	11.996	37.700	<.0001	30.92348
mn	11	112.112	10.192	32.030	<.0001	
area	4	101.284	25.321	79.580	<.0001	
nhfcl	5	38.283	7.657	24.060	<.0001	
sst	1	8.946	8.946	28.120	<.0001	
ml	1	2.338	2.338	7.350	0.0067	
yr*area	196	506.157	2.582	8.120	<.0001	
mn*area	44	170.354	3.872	12.170	<.0001	
area*nhfcl	20	59.177	2.959	9.300	<.0001	
sst*area	4	93.105	23.276	73.160	<.0001	
nhfcl*ml	5	56.318	11.264	35.400	<.0001	

All South **1960–2009 Year base**

Source	DF	Type III SS	Mean Square	F Value	Pr > F	R-Square=
Model	138	4873.338	35.314	61.150	<.0001	0.361631
						CV =
yr	49	851.957	17.387	30.110	<.0001	75.07069
mn	11	631.536	57.412	99.420	<.0001	
area						
nhfcl	5	45.135	9.027	15.630	<.0001	
ml	1	3.282	3.282	5.680	0.0171	
sst	1	238.967	238.967	413.810	<.0001	
yr*area	49	225.672	4.606	7.980	<.0001	
mn*area	11	86.133	7.830	13.560	<.0001	
area*nhfcl	5	14.960	2.992	5.180	<.0001	
nhfcl*ml	5	18.700	3.740	6.480	<.0001	
sst*area						

All Indian Ocean **1960–2009 Year base**

Source	DF	Type III SS	Mean Square	F Value	Pr > F	R-Square=
Model	474	13983.786	29.502	77.040	<.0001	0.45658
						CV =
yr	49	890.514	18.174	47.460	<.0001	39.47009
mn	11	112.646	10.241	26.740	<.0001	
area	6	108.170	18.028	47.080	<.0001	
nhfcl	5	54.850	10.970	28.650	<.0001	
ml						
sst	1	2.514	2.514	6.560	0.0104	
yr*area	294	1248.552	4.247	11.090	<.0001	
mn*area	66	672.336	10.187	26.600	<.0001	
area*nhfcl	30	95.629	3.188	8.320	<.0001	
nhfcl*ml	6	52.681	8.780	22.930	<.0001	
sst*area	6	114.943	19.157	50.020	<.0001	

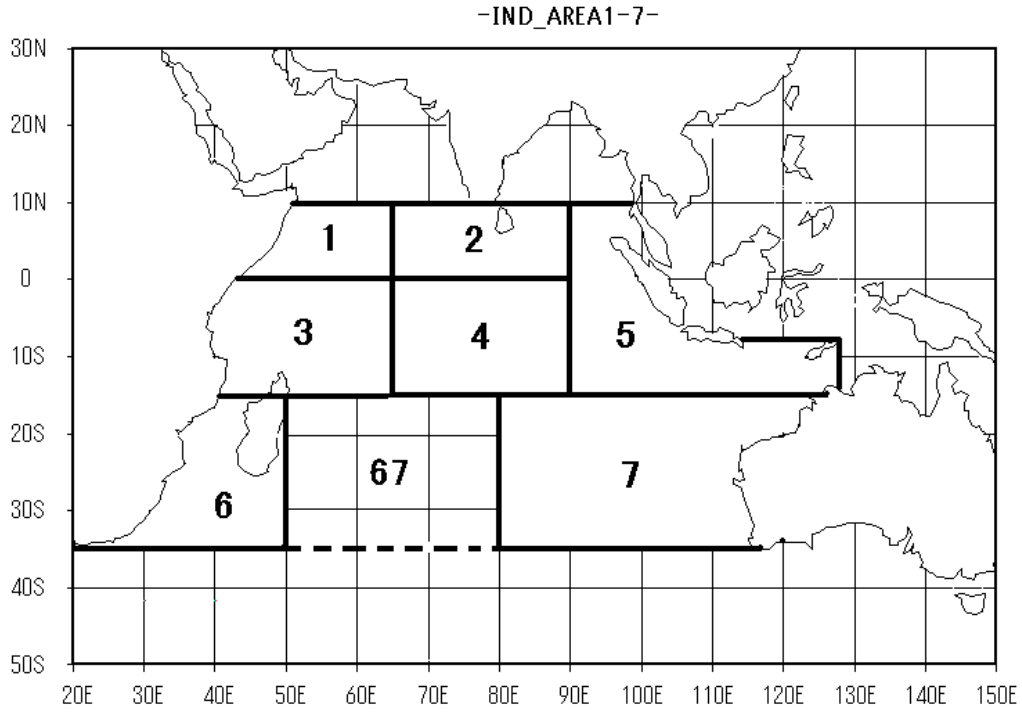

Fig. 1 Definition of sub-areas used in this study. TROPICAL, SOUTH and ALL INDIAN area categories in this paper consist of areas 1-5, areas 6-7 and areas1-7, respectively. Area67 was not used in this study.

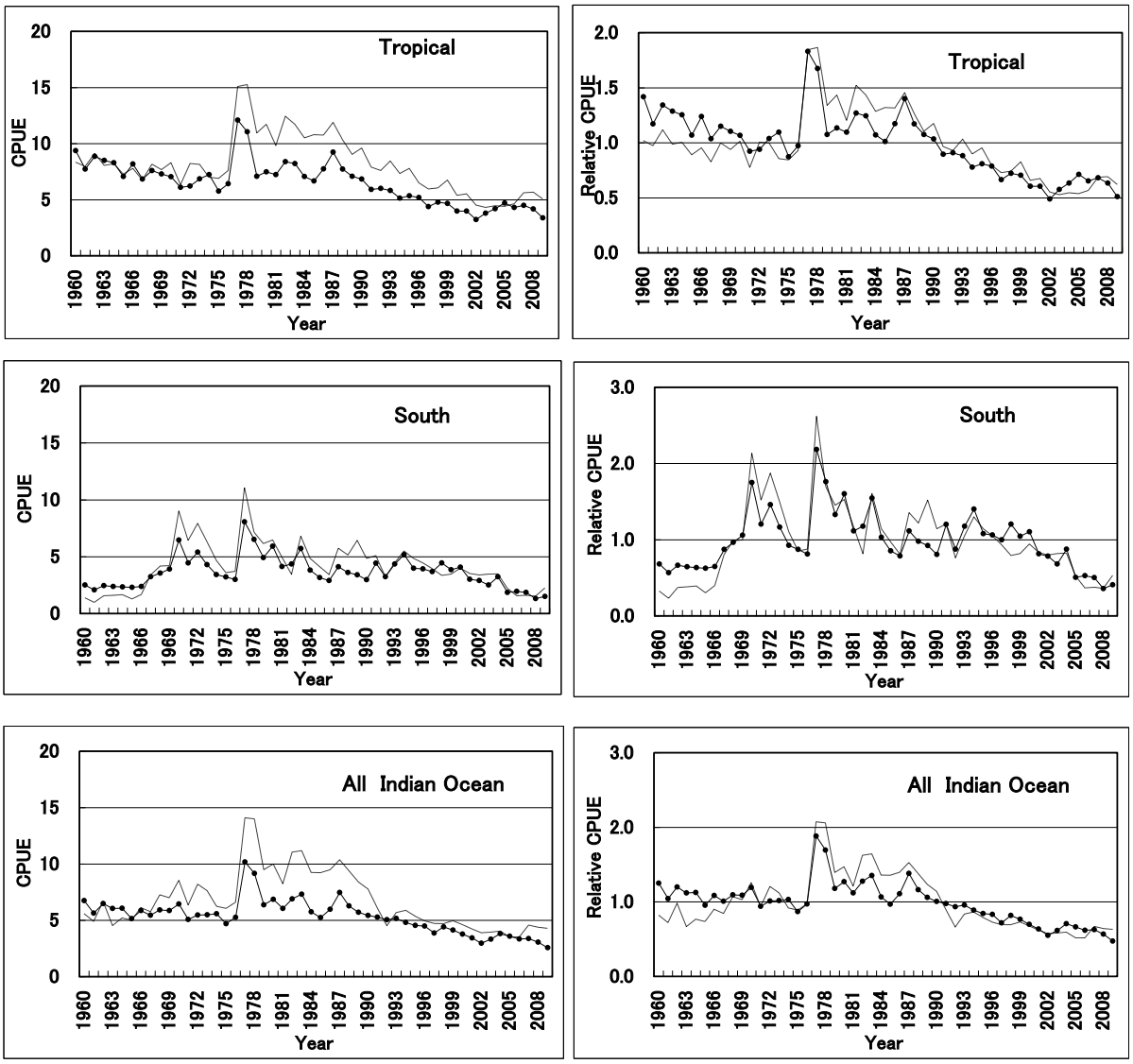

Fig. 2. Standardized CPUEs in real (left) and relative (right) scales for Tropical (top), South (middle) and ALL (bottom) Indian.

1960–2009

All Tropical

All South

All Indian

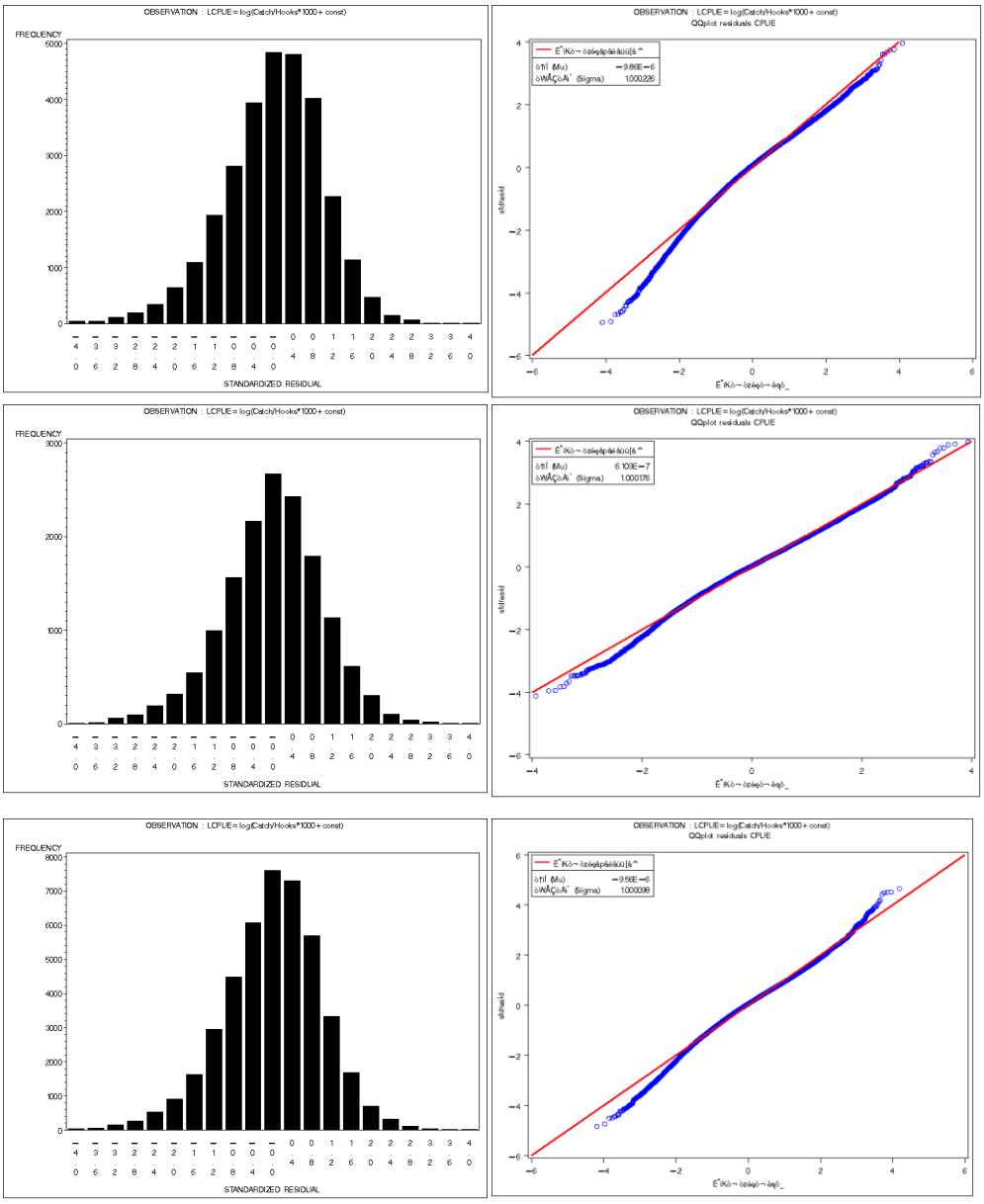

Fig. 3. Standardized residuals of year based standardization for each region expressed as histograms (upper figures) and QQ plots (bottom figures).

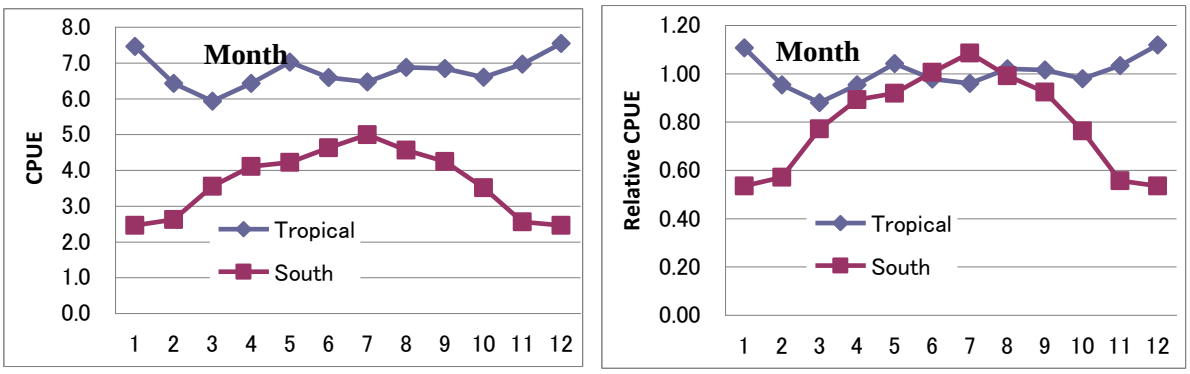

Fig. 4. Standardized CPUE in real scale by month for Tropical and Temperate Indian Ocean. Unit of CPUE is catch in number per 1000 hooks.

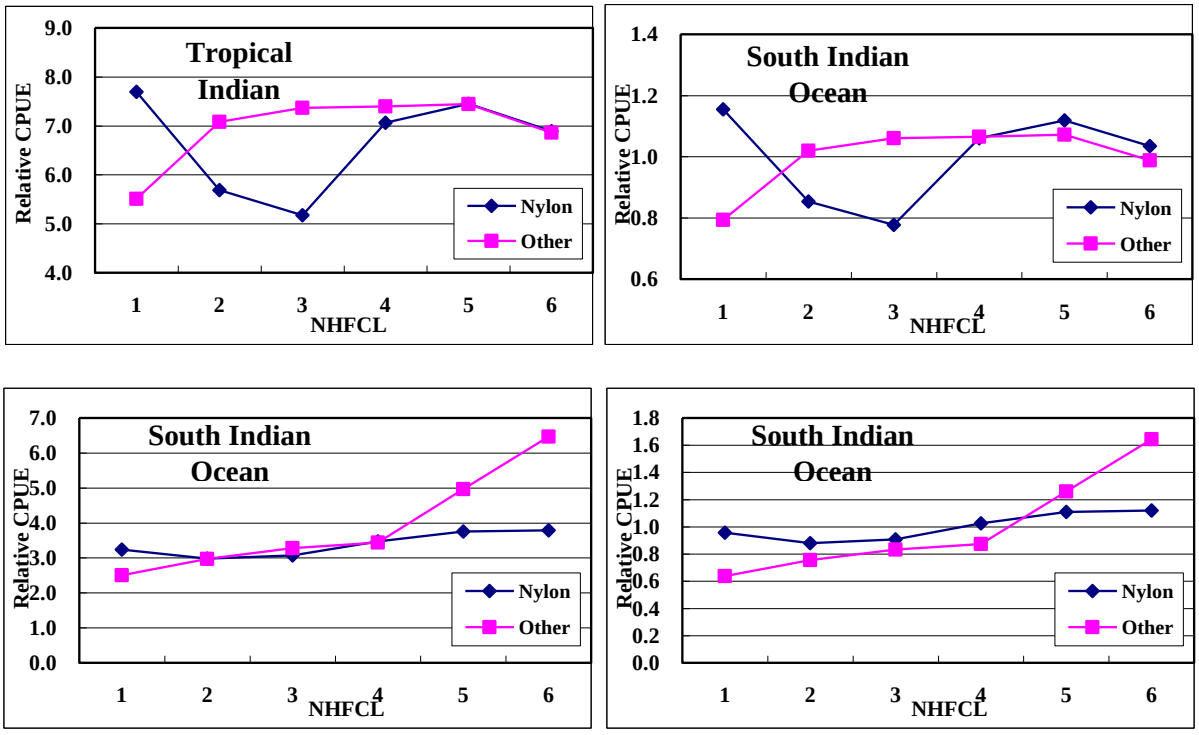

Fig. 5. Standardized CPUE expressed in real (left) and relative (right) scale by NHFCL and mainline materials for Tropical (top) and South (bottom) Indian Ocean. Unit of CPUE is catch in number per 1000 hooks.

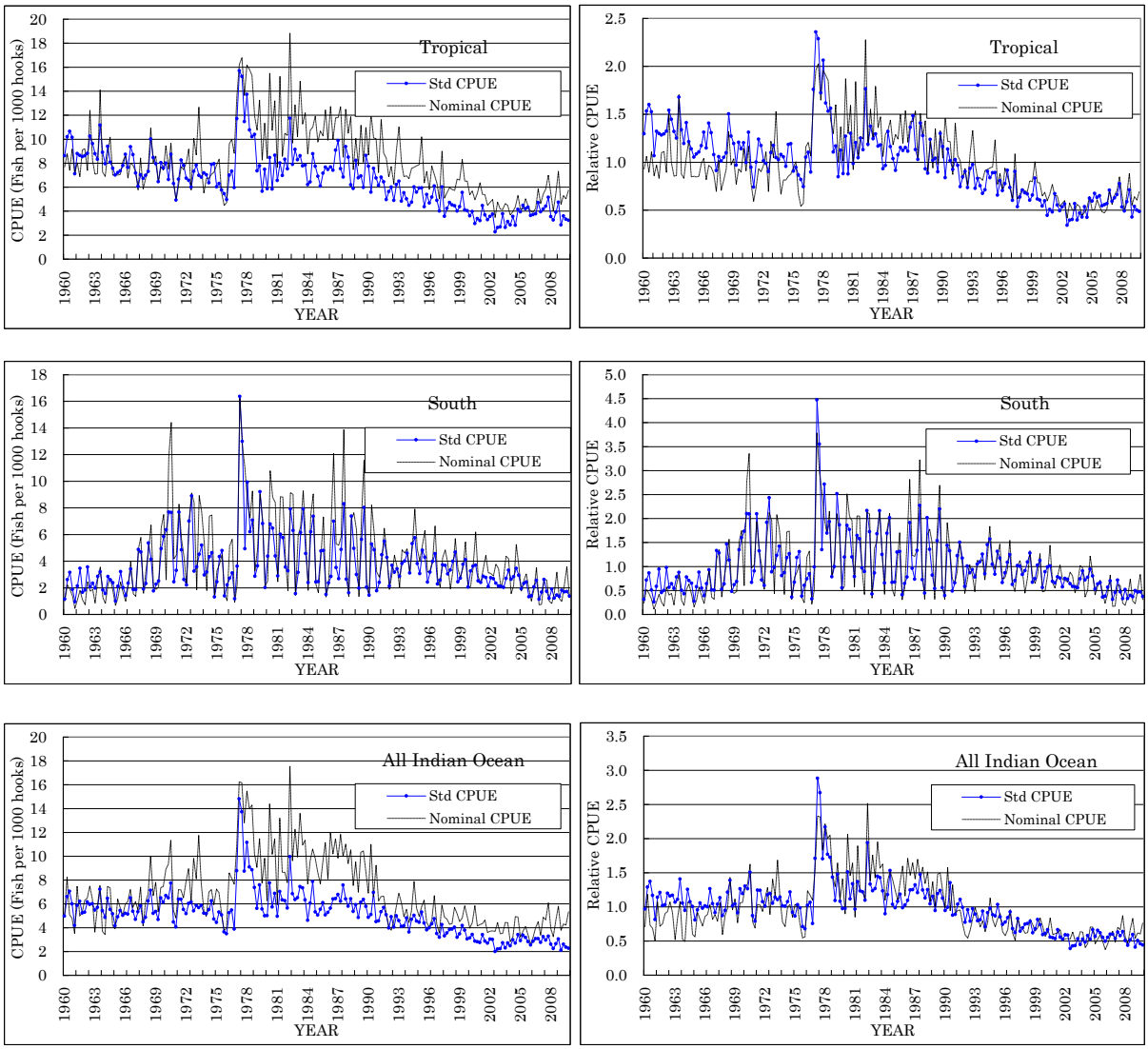

Fig. 6. Quarterly CPUE trend (blue line and dot) from 1960 to 2009 overlaid with yearly CPUE (red dot). Area weighting was not done for quarterly CPUE.

Appendix Table 1. Annual value of standardized Bigeye CPUE in Tropical, South and All Indian Ocean from 1960-2009 expressed in real and relative scale in which the average from 1960 to 2009 is 1.0, with deviation.

All tropical 1960–2009

year	CPUE	dev_t	Relative CPUE
1960	9.3702	0.0013	1.4187
1961	7.7375	0.0014	1.1715
1962	8.8644	0.0010	1.3421
1963	8.5062	0.0012	1.2879
1964	8.2908	0.0012	1.2553
1965	7.0640	0.0010	1.0695
1966	8.1773	0.0009	1.2381
1967	6.8510	0.0009	1.0373
1968	7.5926	0.0012	1.1496
1969	7.2982	0.0010	1.1050
1970	7.0540	0.0013	1.0680
1971	6.0973	0.0011	0.9232
1972	6.2130	0.0017	0.9407
1973	6.8598	0.0017	1.0386
1974	7.2467	0.0015	1.0972
1975	5.7641	0.0012	0.8727
1976	6.4211	0.0022	0.9722
1977	12.0909	0.0028	1.8307
1978	11.0649	0.0013	1.6753
1979	7.0956	0.0030	1.0743
1980	7.4900	0.0017	1.1340
1981	7.2411	0.0011	1.0964
1982	8.3852	0.0008	1.2696
1983	8.2221	0.0010	1.2449
1984	7.0761	0.0012	1.0714
1985	6.6784	0.0010	1.0112
1986	7.7468	0.0007	1.1729
1987	9.2462	0.0008	1.3999
1988	7.7388	0.0010	1.1717
1989	7.0967	0.0011	1.0745
1990	6.8381	0.0010	1.0353
1991	5.9238	0.0012	0.8969
1992	6.0114	0.0017	0.9102
1993	5.8307	0.0012	0.8828
1994	5.1362	0.0010	0.7777
1995	5.3487	0.0008	0.8098
1996	5.2077	0.0006	0.7885
1997	4.3891	0.0004	0.6645
1998	4.7738	0.0005	0.7228
1999	4.6631	0.0005	0.7060
2000	3.9921	0.0004	0.6044
2001	3.9938	0.0006	0.6047
2002	3.2375	0.0005	0.4902
2003	3.8046	0.0011	0.5760
2004	4.1907	0.0007	0.6345
2005	4.7119	0.0013	0.7134
2006	4.3104	0.0005	0.6526
2007	4.4998	0.0004	0.6813
2008	4.1859	0.0004	0.6338
2009	3.3784	0.0005	0.5115

All south 1960–2009

year	CPUE	dev_t	Relative CPUE
1960	2.5229	0.0092	0.6823
1961	2.0942	0.0067	0.5663
1962	2.4573	0.0056	0.6645
1963	2.3898	0.0052	0.6463
1964	2.3454	0.0053	0.6343
1965	2.3181	0.0046	0.6269
1966	2.3939	0.0052	0.6474
1967	3.2348	0.0032	0.8748
1968	3.5665	0.0036	0.9645
1969	3.9185	0.0042	1.0597
1970	6.4739	0.0046	1.7507
1971	4.4577	0.0045	1.2055
1972	5.4066	0.0082	1.4621
1973	4.3123	0.0068	1.1662
1974	3.4223	0.0048	0.9255
1975	3.2331	0.0045	0.8743
1976	3.0079	0.0113	0.8134
1977	8.0764	0.0171	2.1841
1978	6.5157	0.0066	1.7621
1979	4.9224	0.0064	1.3312
1980	5.9322	0.0061	1.6042
1981	4.1306	0.0046	1.1170
1982	4.3542	0.0073	1.1775
1983	5.7258	0.0057	1.5484
1984	3.8178	0.0036	1.0325
1985	3.1633	0.0039	0.8555
1986	2.9135	0.0053	0.7879
1987	4.1232	0.0046	1.1150
1988	3.6194	0.0071	0.9788
1989	3.4129	0.0072	0.9229
1990	2.9894	0.0048	0.8084
1991	4.4448	0.0024	1.2020
1992	3.2415	0.0036	0.8766
1993	4.3538	0.0023	1.1774
1994	5.1854	0.0013	1.4023
1995	3.9941	0.0009	1.0801
1996	3.9259	0.0011	1.0617
1997	3.6939	0.0013	0.9990
1998	4.4559	0.0023	1.2050
1999	3.8655	0.0020	1.0454
2000	4.0857	0.0016	1.1049
2001	3.0128	0.0012	0.8148
2002	2.9024	0.0013	0.7849
2003	2.5231	0.0028	0.6823
2004	3.2411	0.0029	0.8765
2005	1.8714	0.0031	0.5061
2006	1.9584	0.0029	0.5296
2007	1.8586	0.0028	0.5026
2007	1.3262	0.0020	0.3587
2007	1.5106	0.0020	0.4085

All Indian Ocean 1960–2009

year	CPUE	dev_t	Relative CPUE
1960	6.7631	0.0015	1.2520
1961	5.6361	0.0013	1.0433
1962	6.4880	0.0011	1.2011
1963	6.0598	0.0011	1.1218
1964	6.0776	0.0011	1.1251
1965	5.1558	0.0009	0.9544
1966	5.8732	0.0010	1.0872
1967	5.4476	0.0008	1.0085
1968	5.9192	0.0009	1.0958
1969	5.8770	0.0009	1.0879
1970	6.4582	0.0011	1.1955
1971	5.0841	0.0010	0.9412
1972	5.4663	0.0016	1.0119
1973	5.4998	0.0015	1.0181
1974	5.5806	0.0012	1.0331
1975	4.7024	0.0010	0.8705
1976	5.2595	0.0021	0.9736
1977	10.1761	0.0030	1.8838
1978	9.1556	0.0013	1.6949
1979	6.3762	0.0021	1.1804
1980	6.8685	0.0014	1.2715
1981	6.0579	0.0010	1.1214
1982	6.8995	0.0011	1.2772
1983	7.3156	0.0011	1.3543
1984	5.7579	0.0010	1.0659
1985	5.2439	0.0009	0.9707
1986	5.9837	0.0009	1.1077
1987	7.4638	0.0009	1.3817
1988	6.2835	0.0012	1.1632
1989	5.7249	0.0012	1.0598
1990	5.4345	0.0010	1.0060
1991	5.2918	0.0009	0.9796
1992	5.0519	0.0012	0.9352
1993	5.1720	0.0009	0.9574
1994	4.8079	0.0007	0.8900
1995	4.5570	0.0006	0.8436
1996	4.5010	0.0005	0.8332
1997	3.8805	0.0004	0.7184
1998	4.4247	0.0006	0.8191
1999	4.1477	0.0005	0.7678
2000	3.7772	0.0004	0.6992
2001	3.4426	0.0005	0.6373
2002	2.9820	0.0004	0.5520
2003	3.3349	0.0009	0.6174
2004	3.8284	0.0007	0.7087
2005	3.5878	0.0010	0.6642
2006	3.3540	0.0006	0.6209
2007	3.3931	0.0005	0.6281
2007	3.0700	0.0005	0.5683
2007	2.5696	0.0006	0.4757

Appendix Table 2. Quarterly value of standardized bigeye CPUE in Tropical, South and All Indian Ocean from **1960-2009** expressed in real and relative scale in which the average from 1960 to 2009 is 1.0, with deviation.

		Tropical			South			All Indian Ocean		
Year	QT	CPUE	t-dev	Relative CPUE	Tropical CPUE	t-dev	Relative CPUE	Tropical CPUE	t-dev	Relative CPUE
1960	1	8.6210	0.0036	1.2955	1.1426	0.0470	0.3124	4.9686	0.0041	0.9674
1960	2	10.2012	0.0037	1.5329	2.6137	0.0902	0.7146	6.6196	0.0046	1.2888
1960	3	10.6473	0.0063	1.6000	3.1544	0.0365	0.8624	7.0574	0.0057	1.3740
1960	4	10.1472	0.0046	1.5248	1.8617	0.0262	0.5090	5.9919	0.0042	1.1666
1961	1	7.1036	0.0039	1.0674	0.9526	0.0360	0.2604	4.1825	0.0040	0.8143
1961	2	8.7995	0.0047	1.3223	2.1334	0.0911	0.5833	5.8582	0.0053	1.1406
1961	3	8.6456	0.0071	1.2992	3.4572	0.0244	0.9452	6.2142	0.0057	1.2099
1961	4	8.5406	0.0054	1.2834	1.6571	0.0138	0.4531	5.2324	0.0040	1.0187
1962	1	8.6166	0.0032	1.2948	1.8292	0.0154	0.5001	5.2918	0.0028	1.0303
1962	2	8.8084	0.0033	1.3236	3.5657	0.0232	0.9749	6.1644	0.0032	1.2002
1962	3	10.2529	0.0054	1.5407	2.0608	0.0150	0.5634	5.9552	0.0041	1.1595
1962	4	9.6300	0.0030	1.4471	2.3447	0.0152	0.6411	6.0072	0.0027	1.1696
1963	1	8.7859	0.0030	1.3202	1.9750	0.0122	0.5400	5.4797	0.0025	1.0669
1963	2	8.3201	0.0038	1.2502	2.8490	0.0287	0.7789	5.6985	0.0037	1.1095
1963	3	11.1621	0.0068	1.6773	3.2060	0.0160	0.8765	7.2251	0.0049	1.4067
1963	4	8.8978	0.0046	1.3371	1.8350	0.0138	0.5017	5.4166	0.0036	1.0546
1964	1	7.9516	0.0043	1.1949	1.5624	0.0169	0.4272	4.8672	0.0036	0.9476
1964	2	9.3996	0.0033	1.4125	2.8464	0.0264	0.7782	6.4548	0.0032	1.2567
1964	3	8.0801	0.0047	1.2142	2.5856	0.0167	0.7069	5.5191	0.0038	1.0745
1964	4	7.5737	0.0041	1.1381	2.3760	0.0119	0.6496	5.1590	0.0032	1.0044
1965	1	7.0008	0.0027	1.0520	1.0009	0.0184	0.2737	4.1504	0.0025	0.8081
1965	2	7.2137	0.0029	1.0840	2.1149	0.0268	0.5782	4.8999	0.0030	0.9540
1965	3	7.3571	0.0036	1.1055	3.2154	0.0120	0.8791	5.4285	0.0028	1.0569
1965	4	7.8009	0.0033	1.1722	2.0079	0.0150	0.5490	5.0369	0.0028	0.9807
1966	1	8.7326	0.0028	1.3122	1.4202	0.0178	0.3883	5.2075	0.0026	1.0139
1966	2	7.6381	0.0029	1.1478	2.3431	0.0230	0.6406	5.1334	0.0029	0.9995
1966	3	9.3634	0.0034	1.4070	3.4086	0.0201	0.9319	6.4935	0.0030	1.2643
1966	4	8.7013	0.0028	1.3075	1.8650	0.0120	0.5099	5.3760	0.0024	1.0467
1967	1	7.1757	0.0025	1.0783	1.8557	0.0096	0.5074	4.6934	0.0021	0.9138
1967	2	6.0712	0.0027	0.9123	4.8672	0.0087	1.3307	5.3297	0.0022	1.0377
1967	3	7.0367	0.0032	1.0574	4.6849	0.0106	1.2809	5.8276	0.0025	1.1346
1967	4	6.7209	0.0030	1.0099	1.9046	0.0113	0.5207	4.4696	0.0025	0.8702
1968	1	6.9813	0.0033	1.0491	2.3214	0.0161	0.6347	4.8702	0.0028	0.9482
1968	2	7.3051	0.0035	1.0977	5.3613	0.0115	1.4658	6.2439	0.0029	1.2157
1968	3	10.0031	0.0048	1.5032	4.1442	0.0108	1.1330	7.1307	0.0034	1.3883
1968	4	8.4579	0.0031	1.2710	1.7605	0.0118	0.4813	5.2048	0.0026	1.0134
1969	1	7.9509	0.0027	1.1948	2.2679	0.0125	0.6201	5.3517	0.0024	1.0420
1969	2	6.4498	0.0034	0.9692	2.5083	0.0121	0.6858	4.6811	0.0028	0.9114
1969	3	8.0329	0.0038	1.2071	4.9300	0.0106	1.3479	6.4962	0.0029	1.2648
1969	4	7.5807	0.0034	1.1391	5.8479	0.0202	1.5988	6.1384	0.0032	1.1951
1970	1	8.0034	0.0034	1.2027	6.3410	0.0416	1.7337	6.6957	0.0035	1.3036
1970	2	6.6278	0.0044	0.9960	7.6819	0.0135	2.1003	6.4934	0.0036	1.2642
1970	3	8.7342	0.0060	1.3125	7.6554	0.0138	2.0930	7.7421	0.0043	1.5074
1970	4	6.2961	0.0040	0.9461	2.4429	0.0145	0.6679	4.4713	0.0033	0.8705
1971	1	4.9216	0.0029	0.7396	3.3111	0.0137	0.9053	4.0595	0.0025	0.7904
1971	2	6.6611	0.0038	1.0010	7.6761	0.0169	2.0987	6.3930	0.0034	1.2447
1971	3	8.2532	0.0047	1.2402	4.8476	0.0152	1.3254	6.3772	0.0037	1.2416
1971	4	7.8036	0.0042	1.1726	2.6245	0.0262	0.7176	5.5229	0.0039	1.0753
1972	1	6.7479	0.0045	1.0140	2.2048	0.0561	0.6028	5.1796	0.0048	1.0084
1972	2	6.5642	0.0051	0.9864	7.0107	0.0283	1.9168	6.0370	0.0048	1.1754
1972	3	5.9984	0.0050	0.9014	8.8918	0.0213	2.4311	6.1424	0.0043	1.1959
1972	4	7.3155	0.0072	1.0993	3.2439	0.0282	0.8869	5.4059	0.0061	1.0525

Appendix Table 2. Continued.

Year	QT			Relative	Tropical		Relative	Tropical		Relative
		CPUE	t-dev	CPUE	CPUE	t-dev	CPUE	CPUE	t-dev	CPUE
1973	1	7.8248	0.0056	1.1758	3.5778	0.1178	0.9782	5.8608	0.0065	1.1411
1973	2	6.9763	0.0073	1.0483	4.5067	0.0285	1.2322	5.6810	0.0062	1.1061
1973	3	6.8253	0.0052	1.0256	5.1968	0.0210	1.4208	5.8715	0.0044	1.1432
1973	4	7.1903	0.0051	1.0805	2.9575	0.0186	0.8086	5.2111	0.0042	1.0146
1974	1	7.0261	0.0040	1.0558	3.1823	0.0190	0.8701	5.1783	0.0034	1.0082
1974	2	6.3658	0.0065	0.9566	4.3302	0.0156	1.1839	5.5172	0.0047	1.0742
1974	3	7.8891	0.0042	1.1855	4.6279	0.0169	1.2653	6.2537	0.0035	1.2176
1974	4	7.9419	0.0042	1.1934	1.3144	0.0182	0.3594	4.7220	0.0036	0.9194
1975	1	6.0231	0.0035	0.9051	2.4479	0.0266	0.6693	4.4384	0.0033	0.8641
1975	2	6.2932	0.0040	0.9457	4.3421	0.0142	1.1872	5.3025	0.0033	1.0324
1975	3	5.7624	0.0032	0.8659	4.7898	0.0121	1.3096	5.0707	0.0026	0.9872
1975	4	5.4458	0.0041	0.8183	1.3903	0.0242	0.3801	3.6431	0.0038	0.7093
1976	1	4.9587	0.0043	0.7451	2.2183	0.0459	0.6065	3.4853	0.0042	0.6786
1976	2	6.9987	0.0066	1.0517	2.7138	0.0492	0.7420	5.2528	0.0064	1.0227
1976	3	7.3319	0.0099	1.1018	3.1043	0.0420	0.8487	5.4782	0.0082	1.0666
1976	4	5.9588	0.0139	0.8954	1.1728	0.3089	0.3206	3.8832	0.0153	0.7560
1977	1	11.7019	0.0096	1.7584	3.6204	0.0988	0.9898	8.7825	0.0102	1.7099
1977	2	15.6968	0.0111	2.3587	16.3667	0.0627	4.4747	14.8079	0.0103	2.8830
1977	3	15.2218	0.0092	2.2874	12.9873	0.0744	3.5508	13.7239	0.0092	2.6720
1977	4	11.4672	0.0065	1.7232	4.9335	0.0615	1.3488	8.7446	0.0071	1.7025
1978	1	13.7285	0.0031	2.0630	9.9285	0.0282	2.7145	11.1482	0.0032	2.1705
1978	2	10.7605	0.0034	1.6170	6.2036	0.0269	1.6961	9.0909	0.0034	1.7700
1978	3	10.1951	0.0035	1.5320	7.0742	0.0270	1.9341	8.8635	0.0035	1.7257
1978	4	10.3938	0.0040	1.5619	2.8694	0.0353	0.7845	7.3725	0.0041	1.4354
1979	1	7.3575	0.0052	1.1056	3.6465	0.0193	0.9970	5.6142	0.0043	1.0931
1979	2	7.7750	0.0080	1.1683	9.2072	0.0210	2.5173	7.5829	0.0061	1.4764
1979	3	5.6475	0.0058	0.8486	6.8171	0.0220	1.8638	5.5585	0.0048	1.0822
1979	4	7.4851	0.0073	1.1248	2.0221	0.0257	0.5529	4.9972	0.0060	0.9729
1980	1	5.8538	0.0044	0.8796	4.3694	0.0198	1.1946	5.0088	0.0038	0.9752
1980	2	8.4571	0.0057	1.2708	6.7859	0.0356	1.8553	7.7617	0.0054	1.5112
1980	3	5.8315	0.0068	0.8763	6.4689	0.0291	1.7686	5.7332	0.0058	1.1162
1980	4	8.6549	0.0037	1.3006	4.3854	0.0180	1.1990	6.8734	0.0033	1.3382
1981	1	6.5555	0.0026	0.9851	2.8836	0.0120	0.7884	4.9609	0.0023	0.9659
1981	2	8.0117	0.0059	1.2039	6.0175	0.0254	1.6452	7.0335	0.0052	1.3694
1981	3	6.9657	0.0053	1.0467	5.7666	0.0142	1.5766	6.3352	0.0040	1.2334
1981	4	8.3219	0.0027	1.2505	3.5515	0.0146	0.9710	6.2663	0.0025	1.2200
1982	1	7.5228	0.0023	1.1304	3.2654	0.0126	0.8928	5.6411	0.0021	1.0983
1982	2	11.7412	0.0048	1.7643	7.9135	0.0294	2.1636	9.9595	0.0047	1.9391
1982	3	7.8954	0.0033	1.1864	6.3015	0.0318	1.7229	6.8444	0.0035	1.3326
1982	4	9.1481	0.0021	1.3747	1.5537	0.0460	0.4248	6.3497	0.0025	1.2363
1983	1	8.2764	0.0017	1.2437	3.1555	0.0258	0.8627	6.5081	0.0020	1.2671
1983	2	8.6123	0.0045	1.2942	6.1500	0.0288	1.6814	7.4414	0.0044	1.4488
1983	3	7.7628	0.0028	1.1665	7.9125	0.0190	2.1633	7.3357	0.0028	1.4282
1983	4	7.8471	0.0028	1.1792	4.5702	0.0191	1.2495	6.3289	0.0027	1.2322
1984	1	6.2025	0.0024	0.9320	2.3899	0.0112	0.6534	4.6117	0.0021	0.8979
1984	2	6.4275	0.0045	0.9659	6.1894	0.0176	1.6922	6.0588	0.0039	1.1796
1984	3	8.7868	0.0035	1.3204	7.3630	0.0169	2.0131	7.8690	0.0031	1.5321
1984	4	7.7361	0.0036	1.1625	2.4394	0.0124	0.6669	5.3165	0.0029	1.0351
1985	1	6.9017	0.0020	1.0371	2.4580	0.0144	0.6720	5.0628	0.0020	0.9857
1985	2	6.0873	0.0037	0.9147	4.7544	0.0113	1.2999	5.5416	0.0030	1.0789
1985	3	7.1619	0.0028	1.0762	4.8011	0.0123	1.3126	6.0898	0.0025	1.1857
1985	4	7.6642	0.0028	1.1517	1.4928	0.0207	0.4081	5.0668	0.0028	0.9865

Appendix Table 2. Continued.

Year	QT			Relative	Tropical		Relative	Tropical		Relative
		CPUE	t-dev	CPUE	CPUE	t-dev	CPUE	CPUE	t-dev	CPUE
1986	1	7.4694	0.0013	1.1224	2.3621	0.0086	0.6458	5.2737	0.0013	1.0268
1986	2	7.6703	0.0037	1.1526	2.8521	0.0201	0.7798	5.6241	0.0035	1.0950
1986	3	7.4108	0.0037	1.1136	6.9991	0.0397	1.9136	6.4010	0.0039	1.2463
1986	4	9.0773	0.0019	1.3640	3.5118	0.0578	0.9601	6.4271	0.0024	1.2513
1987	1	9.8786	0.0014	1.4844	2.6847	0.0090	0.7340	6.7849	0.0014	1.3210
1987	2	7.5326	0.0048	1.1319	4.8749	0.0350	1.3328	6.2104	0.0049	1.2091
1987	3	6.8388	0.0091	1.0277	8.3055	0.0227	2.2708	7.5699	0.0067	1.4738
1987	4	9.3707	0.0023	1.4081	2.6455	0.0186	0.7233	6.4053	0.0024	1.2471
1988	1	8.4988	0.0016	1.2771	1.6210	0.0157	0.4432	5.8006	0.0018	1.1294
1988	2	6.1908	0.0065	0.9303	7.3725	0.0218	2.0157	6.4266	0.0053	1.2512
1988	3	5.8917	0.0056	0.8853	4.9554	0.0216	1.3548	5.3613	0.0048	1.0438
1988	4	8.2330	0.0024	1.2372	2.9922	0.0270	0.8181	5.9279	0.0026	1.1541
1989	1	6.7748	0.0019	1.0180	1.9686	0.0179	0.5382	4.8542	0.0020	0.9451
1989	2	6.9323	0.0053	1.0417	5.6230	0.0231	1.5374	6.1332	0.0047	1.1941
1989	3	5.9819	0.0089	0.8989	8.0305	0.0277	2.1956	6.3626	0.0069	1.2388
1989	4	8.6453	0.0041	1.2991	2.0416	0.0242	0.5582	5.7859	0.0039	1.1265
1990	1	7.7378	0.0022	1.1627	1.4396	0.0111	0.3936	4.8599	0.0020	0.9462
1990	2	5.5767	0.0075	0.8380	5.2728	0.0356	1.4416	5.0975	0.0068	0.9925
1990	3	7.5630	0.0078	1.1365	4.8467	0.0076	1.3251	6.9490	0.0039	1.3529
1990	4	6.7630	0.0026	1.0163	1.7802	0.0237	0.4867	4.5058	0.0028	0.8773
1991	1	6.1431	0.0021	0.9231	2.4016	0.0106	0.6566	4.5650	0.0020	0.8888
1991	2	6.8312	0.0095	1.0265	4.4777	0.0128	1.2242	5.3361	0.0054	1.0389
1991	3	6.4396	0.0091	0.9677	5.4980	0.0045	1.5032	5.6947	0.0032	1.1087
1991	4	4.9603	0.0046	0.7454	4.2841	0.0064	1.1713	5.0904	0.0027	0.9911
1992	1	5.6281	0.0037	0.8457	2.1274	0.0090	0.5816	3.9738	0.0027	0.7737
1992	2	6.0026	0.0117	0.9020	3.6866	0.0086	1.0079	4.9154	0.0048	0.9570
1992	3	4.8941	0.0191	0.7354	3.1668	0.0071	0.8658	4.0509	0.0050	0.7887
1992	4	6.2105	0.0045	0.9332	3.4198	0.0129	0.9350	4.9923	0.0035	0.9720
1993	1	6.4887	0.0037	0.9750	2.8479	0.0117	0.7786	4.5857	0.0029	0.8928
1993	2	4.8356	0.0070	0.7266	3.8276	0.0086	1.0465	4.0961	0.0039	0.7975
1993	3	5.5285	0.0064	0.8308	4.0043	0.0050	1.0948	4.1567	0.0028	0.8093
1993	4	5.0190	0.0032	0.7542	4.5906	0.0086	1.2551	4.8136	0.0025	0.9372
1994	1	4.4862	0.0022	0.6741	3.1026	0.0044	0.8483	3.6289	0.0015	0.7065
1994	2	4.7328	0.0058	0.7112	5.3143	0.0032	1.4530	4.6928	0.0022	0.9137
1994	3	6.0143	0.0085	0.9038	5.7506	0.0030	1.5722	5.0340	0.0022	0.9801
1994	4	5.5765	0.0022	0.8380	3.8143	0.0041	1.0428	4.5481	0.0015	0.8855
1995	1	5.9209	0.0023	0.8897	3.0643	0.0027	0.8378	4.4505	0.0013	0.8665
1995	2	5.9334	0.0068	0.8916	4.8095	0.0027	1.3149	5.3055	0.0021	1.0330
1995	3	4.3683	0.0062	0.6564	4.2912	0.0022	1.1732	4.3854	0.0017	0.8538
1995	4	5.3782	0.0017	0.8082	2.4228	0.0036	0.6624	3.8087	0.0012	0.7415
1996	1	4.6742	0.0016	0.7024	3.1684	0.0026	0.8663	3.9868	0.0010	0.7762
1996	2	5.1604	0.0043	0.7754	3.9729	0.0026	1.0862	4.3176	0.0017	0.8406
1996	3	6.0897	0.0038	0.9151	4.5628	0.0025	1.2475	4.7512	0.0015	0.9250
1996	4	4.8946	0.0014	0.7355	2.2825	0.0034	0.6240	3.5033	0.0010	0.6821
1997	1	4.0025	0.0010	0.6015	2.5773	0.0040	0.7046	3.1900	0.0009	0.6211
1997	2	6.0104	0.0025	0.9032	3.7231	0.0035	1.0179	4.2489	0.0016	0.8272
1997	3	3.5656	0.0026	0.5358	3.6757	0.0027	1.0050	3.3045	0.0014	0.6434
1997	4	4.2286	0.0011	0.6354	3.0365	0.0033	0.8302	3.5525	0.0010	0.6917
1998	1	4.7156	0.0009	0.7086	3.3340	0.0050	0.9115	3.8383	0.0010	0.7473
1998	2	4.5250	0.0019	0.6800	3.9904	0.0045	1.0910	3.8768	0.0016	0.7548
1998	3	4.4480	0.0027	0.6684	4.6737	0.0048	1.2778	4.0393	0.0018	0.7864
1998	4	4.0096	0.0017	0.6025	2.4517	0.0042	0.6703	3.1876	0.0013	0.6206

Appendix Table 2. Continued.

Year	QT			Relative	Tropical		Relative	Tropical		Relative
		CPUE	t-dev	CPUE	CPUE	t-dev	CPUE	CPUE	t-dev	CPUE
1999	1	4.3660	0.0015	0.6561	2.7166	0.0047	0.7427	3.4820	0.0013	0.6779
1999	2	5.5442	0.0042	0.8331	3.7634	0.0041	1.0289	4.1824	0.0021	0.8143
1999	3	4.0928	0.0025	0.6150	4.1115	0.0043	1.1241	3.7924	0.0017	0.7384
1999	4	4.0247	0.0014	0.6048	2.0502	0.0051	0.5605	3.0502	0.0012	0.5939
2000	1	3.6076	0.0011	0.5421	3.2573	0.0051	0.8906	3.1417	0.0010	0.6117
2000	2	3.9672	0.0016	0.5961	3.6166	0.0046	0.9888	3.4178	0.0014	0.6654
2000	3	2.9557	0.0028	0.4441	3.7040	0.0037	1.0127	2.8610	0.0016	0.5570
2000	4	3.3727	0.0021	0.5068	2.5199	0.0050	0.6890	2.8134	0.0016	0.5478
2001	1	3.2015	0.0017	0.4811	2.4015	0.0042	0.6566	2.7441	0.0014	0.5343
2001	2	4.4581	0.0023	0.6699	2.8676	0.0048	0.7840	3.4137	0.0017	0.6646
2001	3	3.6787	0.0030	0.5528	2.7749	0.0030	0.7587	2.8606	0.0016	0.5569
2001	4	3.2824	0.0024	0.4932	2.0925	0.0041	0.5721	2.7017	0.0016	0.5260
2002	1	3.5527	0.0016	0.5339	2.7463	0.0037	0.7509	3.0340	0.0012	0.5907
2002	2	3.7500	0.0025	0.5635	2.6766	0.0063	0.7318	3.0045	0.0020	0.5850
2002	3	2.2701	0.0022	0.3411	2.3459	0.0031	0.6414	1.9935	0.0014	0.3881
2002	4	2.6306	0.0012	0.3953	2.1360	0.0054	0.5840	2.1987	0.0011	0.4281
2003	1	2.6761	0.0023	0.4021	2.1054	0.0088	0.5756	2.2250	0.0020	0.4332
2003	2	3.7788	0.0045	0.5678	2.0296	0.0102	0.5549	2.7267	0.0035	0.5309
2003	3	2.6400	0.0051	0.3967	2.7060	0.0051	0.7398	2.2992	0.0030	0.4476
2003	4	3.1238	0.0025	0.4694	3.3171	0.0115	0.9069	2.7061	0.0022	0.5269
2004	1	2.8405	0.0018	0.4268	2.6316	0.0076	0.7195	2.4755	0.0016	0.4820
2004	2	3.5562	0.0031	0.5344	2.8336	0.0116	0.7747	2.9798	0.0027	0.5802
2004	3	2.8245	0.0025	0.4244	3.4545	0.0043	0.9445	2.6938	0.0017	0.5245
2004	4	4.1460	0.0021	0.6230	2.9323	0.0073	0.8017	3.4172	0.0018	0.6653
2005	1	3.9467	0.0020	0.5931	1.9297	0.0065	0.5276	2.9023	0.0017	0.5651
2005	2	4.4856	0.0030	0.6740	2.3224	0.0108	0.6350	3.3694	0.0026	0.6560
2005	3	4.2011	0.0032	0.6313	2.4310	0.0069	0.6646	3.1786	0.0024	0.6189
2005	4	4.3238	0.0023	0.6497	1.3229	0.0051	0.3617	2.8318	0.0018	0.5513
2006	1	3.6266	0.0012	0.5450	1.3913	0.0046	0.3804	2.5455	0.0011	0.4956
2006	2	3.7039	0.0014	0.5566	2.0769	0.0070	0.5678	2.8484	0.0014	0.5546
2006	3	3.7756	0.0020	0.5674	2.5610	0.0063	0.7002	3.0765	0.0017	0.5990
2006	4	4.7124	0.0012	0.7081	1.1394	0.0082	0.3115	3.0740	0.0012	0.5985
2007	1	3.9362	0.0008	0.5915	1.6679	0.0069	0.4560	2.7598	0.0010	0.5373
2007	2	4.1727	0.0010	0.6270	2.6181	0.0058	0.7158	3.2392	0.0011	0.6307
2007	3	4.4009	0.0019	0.6613	1.7235	0.0048	0.4712	2.9615	0.0015	0.5766
2007	4	5.1577	0.0013	0.7750	1.2021	0.0106	0.3287	3.2819	0.0014	0.6390
2008	1	3.5395	0.0013	0.5319	1.9025	0.0069	0.5202	2.6034	0.0013	0.5069
2008	2	3.2628	0.0016	0.4903	1.2179	0.0051	0.3330	2.2398	0.0015	0.4361
2008	3	3.9010	0.0021	0.5862	1.4537	0.0064	0.3974	2.6522	0.0017	0.5164
2008	4	4.7348	0.0013	0.7115	1.3444	0.0072	0.3676	3.0521	0.0013	0.5942
2009	1	2.8398	0.0012	0.4267	1.8140	0.0079	0.4960	2.1014	0.0012	0.4091
2009	2	3.5877	0.0020	0.5391	1.6960	0.0065	0.4637	2.6072	0.0018	0.5076
2009	3	3.3202	0.0034	0.4989	1.7198	0.0045	0.4702	2.3584	0.0021	0.4592
2009	4	3.2335	0.0026	0.4859	1.3636	0.0128	0.3728	2.2688	0.0024	0.4417