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STANDARDIZATION OF YELLOWFIN AND BIGEYE CPUE DATA FROM JAPANESE LONGLINERS, 1975-2004

by

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ABSTRACT

Catch-per-unit-effort data from the Japanese longline fleet between 1975 and 2005 were standardized using a generalized linear model, to provide indices of relative abundance for the IATTC bigeye and yellowfin stock assessments. A two-component (delta) model was used in order to account for zero-catch strata in the analysis. A binomial distribution was used to model the proportion of positive catch strata, and either a lognormal or a gamma distribution was used to model the catch rate in a positive catch stratum. The lognormal distribution was a better fit for the positive values than the gamma distribution used in the 2005 stock assessments. In addition to time in quarters, significant effects were a latitude-longitude interaction term and the number of hooks between floats. Including these effects gave lower relative abundance for both bigeye and yellowfin tuna in recent years than a model that included only time.

1. INTRODUCTION

Indices of abundance are very important in stock assessment. Catch and effort data are the main source for developing these indices for fisheries for tuna and many other species. Changes over time in catch rates can occur because of factors other than changes in abundance (Maunder and Punt 2004). Catch-effort standardization is used to attempt to remove the impact of these factors.

Set location can affect longline catch per unit of effort (CPUE), since oceanographic variables, such as temperature, vary with latitude as well as seasonally, and thermocline depth varies with longitude. The productivity of the ocean and ecosystem structure vary spatially with features such as upwelling zones and seamounts.

The number of hooks between floats is known to affect CPUE, through its effect on the depth distribution of hooks. Different species of tuna forage at different depths, and longliners are able to target particular species by using appropriate setting configurations. The number of hooks set between each pair of floats is a useful proxy for the set depth.

In this paper we standardize the CPUE data for yellowfin and bigeye tuna from the Japanese longline fleet in the eastern Pacific Ocean in order to provide indices of relative abundance for the IATTC bigeye and yellowfin stock assessments. We use a two-component (delta) generalized linear model (GLM). A binomial distribution was used to model the proportion of positive catch strata and either a lognormal or a gamma distribution was used to model the catch rate in a positive catch stratum. We investigate the importance of the effect of several factors on CPUE, and attempt to remove their influence from the index of relative abundance.

2. METHODS

Detailed data on catch in numbers and effort in number of hooks set, summarized by number of hooks between floats, latitude, longitude, and quarter, by the Japanese longline fleet during the 1975–2005 period were provided by Mr. Adam Langley of the Secretariat of the Pacific Community. Latitude and longitude were grouped by 5º square.

Catch and effort were omitted where there was no information on the number of hooks between floats (HBF). In some cases there were too few non-zero catch records to estimate a reliable CPUE value: the effect of omitting strata with 0, ≤2, ≤5, or ≤10 non-zero catch records at the 5º-quarter-HBF stratum level was investigated.

Data were analyzed with a delta GLM with a binomial distribution for the probability *w* of catch being zero and a probability distribution *f(y)* for non-zero catches, as in Equation (1) (E.J. Dick, NOAA Santa Cruz, personal communication; see Stefansson (1996) for a description of the method). Analyses were carried out to estimate an index for each year, which was the product of the back-transformed least-squares means for the two model components, $(1\text{-}w)\cdot E(y|y \neq 0)$. The variance of the likelihood function was weighted by effort.

$$\Pr(Y = y) = \begin{cases} w, & y = 0, \\ (1 - w)\, f\,(y) & \text{otherwise} \end{cases} \qquad (1)$$

The following combinations of explanatory variables were examined as categorical variables: latitude*longitude interaction, HBF. In the delta component, effort was also examined, since the probability of zero catch is likely to be affected by effort. Time was included as a categorical variable in all models.

$$w = g(\text{Year*quarter, latitude*longitude, HBF, effort})$$

$$f(y) = h(\text{Year*quarter, latitude*longitude, HBF})$$

Two distributions, gamma and lognormal, were examined for the non-zero data.

Models were compared using the Akaike Information Criterion (AIC). This model selection tool tends to overestimate the number of parameters when sample sizes are large (Shono 2005), so we investigated the potential effect of over-parameterization on year effects by removing one parameter at a time and comparing the indices of abundance.

3. RESULTS

The proportion of observations without catch in the unstandardized data is higher in the northern fisheries, but has much more temporal variation. The rate of zero catches appears to have declined in the northern bigeye fishery, but is little changed from its very low levels in the south (Figure 1). The average CPUE of the non-zero catches has declined in both fisheries. The proportion of zero catches in the northern yellowfin fishery has increased since the late 1990s and the average size of nonzero CPUE has declined (Figure 2). However, there was effectively no time variation in the rate of zero catches after standardization, suggesting that the observed variation is due to changes in the amount of effort applied.

Total effort and catch by species are highly seasonal in the northern fishery. The southern fishery has considerably more effort and catch (Figure 3). Effort has declined in both fisheries since a peak in the early 1990s.

We examined the effect of the values 0, 2, 5, and 10 for the data exclusion criterion ‘minpos’ – the minimum number of positive values in a stratum – on the results. Strata with fewer than or equal to minpos nonzero values were excluded from the analysis. This was most important for the northern fishery, since most strata in the southern fishery had at least 10 positive values. For both yellowfin and bigeye, there was little difference between the estimates for minpos of 5 and 10, but values 2 and particularly 0 resulted in appreciable differences (Figure 4). Since minpos of 5 resulted in estimates for more quarters than did minpos of 10, minpos of 5 was used for the analysis.

The best model for both the binomial and positive components of the data was the same for each species and fishery. The positive model included HBF and the latitude-longitude interaction. The delta component included the factors above and effort (Table 1). The lognormal distribution fitted the nonzero data better than the gamma distribution. Least-squares means were calculated for this model (Table 2). The individual fisheries show similar trends for each species (Figure 5). Standardized and unstandardized CPUE were compared to determine the extent to which standardization altered the indices (Figure 6 and Figure 7).

Each factor appears to contribute to adjusting to the overall trend. We calculated the ratio of our standardized index of abundance to the index estimated when only time is included in the model. The ratio shows a steady decline in both the northern and southern components of the southern fishery. The ratio declines at 0.73% per year for yellowfin (Figure 8) and 0.51% per year for bigeye (Figure 9). This suggests that since 1975 the Japanese fishery has increased the proportion of effort applied in locations with high catch rates and with gear configurations (in HBF) appropriate to the species targeted. Average HBF has increased over time in both regions (Figure 10).

The catch rate increased with HBF for bigeye in both north and south (Figure 11), as expected given that bigeye forage at depth, and average hook depth tends to increase with HBF. Catch rate of yellowfin declined with HBF (Figure 12).

Residuals do not show a pattern through time (Figure 13 and Figure 14). The frequency plots (Figure 15) show acceptable normality.

4. DISCUSSION

Standardization of the indices revealed several effects significantly associated with catch rate. Standardizing the data removed these effects from the indices of relative abundance, resulting in what may be considered more representative indices.

Using Akaike's information criterion with a large sample size may have led to an over-parameterized model (Shono 2005). This is unlikely to be important for the indices of abundance. However, it implies the need for caution in interpreting the significance of some effects in the analysis. It would be useful to repeat the analysis using the Bayesian information criterion (BIC) or consistent AIC (CAIC).

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TABLE 1. Akaike Information Criterion (AIC) values for alternative model configurations. Model configuration is represented by the factors yrqtr (time effect), latlong (latitude-longitude interaction), and hbf (hooks between floats).

Fishery	Model	Distribution	AIC binomial	AIC positive	AIC total	Rank
BET N	yrqtr.latlong.hbf	lognormal	932.5	32961.1	33893.5	1
BET N	yrqtr.latlong	lognormal	925.6	33085.7	34011.3	2
BET N	yrqtr.hbf	lognormal	2009.0	37964.4	39973.4	3
BET S	yrqtr.latlong.hbf	lognormal	5330.8	210615.3	215946.1	1
BET S	yrqtr.latlong	lognormal	5361.0	211401.6	216762.6	2
BET S	yrqtr.hbf	lognormal	7321.4	222199.5	229520.8	3
BET S	yrqtr.latlong.hbf	gamma	5330.8	305207.1	310537.9	4
YFT N	yrqtr.latlong.hbf	lognormal	4064.8	13623.0	17687.8	1
YFT N	yrqtr.latlong.	lognormal	4071.0	13646.6	17717.6	2
YFT N	yrqtr.hbf	lognormal	4335.2	14590.0	18925.1	3
YFT N	yrqtr.latlong.hbf	gamma	4064.8	32368.0	36432.8	4
YFT S	yrqtr.latlong.hbf	lognormal	16200.5	157953.4	174153.9	1
YFT S	yrqtr.latlong	lognormal	16244.2	158246.1	174490.3	2
YFT S	yrqtr.hbf	lognormal	20478.9	186610.9	207089.7	3
YFT S	yrqtr.latlong.hbf	gamma	16200.5	294736.9	310937.4	4

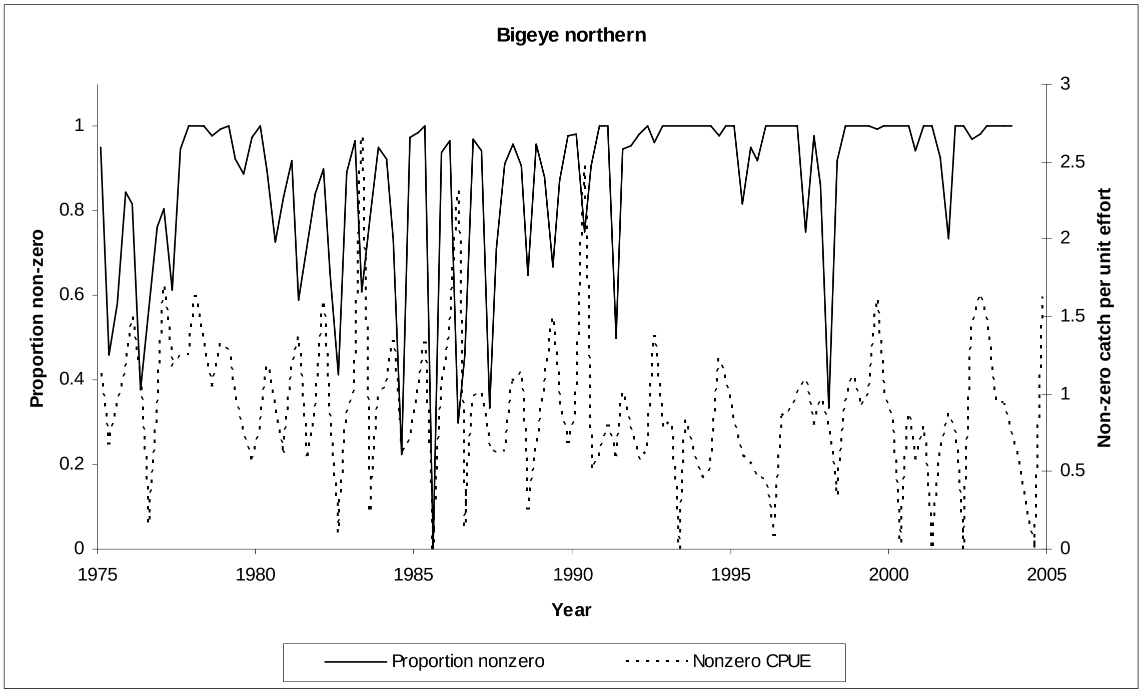
TABLE 2. Indices of abundance for the four fisheries based on the model that included effects for time (year-quarter), latitude-longitude interaction, and HBF.

Time	YFT N	YFT S	BET N	BET S
1975.1	1.8906	0.5689	1.4826	1.1214
1975.2	0.9092	2.0850	0.8738	1.2478
1975.3	1.0574	2.5342	1.3250	1.3737
1975.4	0.5989	1.8485	1.3518	1.2707
1976.1	1.6530	0.7039	1.8429	1.1730
1976.2	0.6180	0.9911	1.2047	1.0593
1976.3	1.6611	1.4800	0.1200	1.2057
1976.4	1.0575	1.3232	0.8886	1.3164
1977.1	1.1864	0.7190	1.7691	1.5182
1977.2	0.7929	0.8096	1.2879	1.4014
1977.3	0.0991	0.9073	1.5867	1.2333
1977.4	0.4385	0.7532	1.5879	1.1746
1978.1	0.7237	0.5150	1.8795	1.3614
1978.2	0.3149	0.7277	1.4745	1.2019
1978.3	0.1638	0.4992	1.2534	1.0592
1978.4	0.7631	0.6280	1.5468	1.0117
1979.1	1.6395	0.4879	1.4906	1.2569
1979.2	1.5205	0.4664	0.9735	1.1756
1979.3	1.2060	0.5402	0.7542	1.2136
1979.4	2.0448	0.6853	0.6426	1.1084
1980.1	2.2354	0.4187	1.0304	1.3519
1980.2	0.8396	0.3732	1.2319	1.0647
1980.3	0.5139	0.6570	0.9460	1.0617
1980.4	0.7167	0.6357	0.5780	1.0382
1981.1	1.0983	0.5398	0.8359	1.1243
1981.2	0.7554	0.4061	1.2957	1.0517
1981.3	0.4711	0.5085	0.5482	1.0039
1981.4	0.6003	0.4752	0.8984	0.9473
1982.1	0.7914	0.4774	1.2943	1.1282
1982.2	0.4325	0.6112	1.0280	1.1225
1982.3	0.6640	0.7633	0.1030	1.2684

Time	YFT N	YFT S	BET N	BET S
1982.4	0.4727	1.0303	1.4593	1.2945
1983.1	0.7796	0.6849	1.3847	1.3691
1983.2	0.6185	0.5371	1.2347	1.2400
1983.3	0.6976	0.8836	0.4136	1.2138
1983.4	0.8810	1.1144	1.4139	0.9881
1984.1	0.7536	0.4315	1.3040	1.0720
1984.2	0.4323	0.6993	0.8900	1.0732
1984.3	1.5941	0.7497		1.1516
1984.4	0.8869	1.0894	1.1200	1.0890
1985.1	1.2271	0.8663	1.2652	1.3578
1985.2	1.3039	0.7092	1.1580	1.6434
1985.3		1.1182		1.8059
1985.4	0.5343	1.0994	1.3859	1.7451
1986.1	1.2629	0.8998	1.4413	1.7360
1986.2	0.2369	0.8571		1.5581
1986.3	2.7771	0.9757	0.3531	1.4741
1986.4	0.8363	0.8713	0.8447	1.2859
1987.1	0.5719	0.7285	1.0455	1.5138
1987.2	0.6067	0.6644		1.2226
1987.3	1.7632	0.7596	0.5109	1.0928
1987.4	1.0998	0.4986	0.9472	0.9795
1988.1	0.7320	0.2748	1.2557	1.1159
1988.2	0.6616	0.6352	1.3399	0.8421
1988.3	1.1349	0.7281	0.5206	0.6666
1988.4	1.2921	0.5248	0.6649	0.7349
1989.1	2.3708	0.3488	0.9938	0.8824
1989.2	0.7295	0.7998	1.1119	0.8689
1989.3	0.6562	1.3355	0.8944	1.0322
1989.4	0.8207	1.3470	0.6296	0.9140
1990.1	1.1827	1.1629	0.8161	1.0755
1990.2		1.6846		1.1470

Time	YFT N	YFT S	BET N	BET S
1990.3	0.8927	1.6602	2.4498	1.3591
1990.4	0.2542	1.0651	0.6971	1.1203
1991.1	0.3205	0.9391	1.0043	1.0980
1991.2		1.1127		0.9640
1991.3	0.2330	0.8666	0.9688	1.0710
1991.4	0.5290	0.9439	0.6676	0.9175
1992.1	0.4710	0.7870	0.6174	0.9563
1992.2		0.7672		0.8109
1992.3	0.1735	0.8977	1.2926	0.8456
1992.4	1.7945	0.5886	0.7578	0.7886
1993.1	1.4994	0.5135	0.9005	0.8441
1993.2		1.0204		0.8840
1993.3	0.4995	1.4527	0.7795	0.8506
1993.4	2.1004	1.1289	0.6084	0.7659
1994.1	1.5393	0.6368	0.4555	0.8274
1994.2		0.8363		0.7655
1994.3	0.1962	1.5267	1.1066	0.7496
1994.4	1.0703	2.0130	1.0260	0.7244
1995.1	1.9374	1.1994	0.8712	0.8615
1995.2	1.4091	1.1410	0.5893	0.7557
1995.3	1.4619	1.3216	0.4934	0.7760
1995.4	3.2158	0.8036	0.3931	0.7765
1996.1	2.4967	0.7346	0.4024	0.8641
1996.2		0.9862		0.5885
1996.3	0.7993	1.4782	0.7046	0.7903
1996.4	1.1782	1.0594	0.9022	0.7574
1997.1	1.4590	1.2353	1.3871	0.7824
1997.2		1.7655		0.6693
1997.3	0.6489	1.9460	0.7085	0.7703
1997.4	1.5438	1.8704	0.9492	0.8158
1998.1	3.5128	1.3972	0.7050	0.9206

Time	YFT N	YFT S	BET N	BET S
1998.2		0.8139		0.7765
1998.3	3.0889	1.0173	0.9013	0.8004
1998.4	1.4674	1.2367	1.0067	0.6870
1999.1	0.6729	0.5415	0.8333	0.6030
1999.2		1.0699		0.6481
1999.3	0.6146	1.4491	1.5217	0.6736
1999.4	0.5050	1.6516	0.8658	0.5852
2000.1	0.4371	1.4783	0.6938	0.8086
2000.2		1.6232		0.8373
2000.3	1.4940	2.0439	0.7590	1.0516
2000.4	1.3031	2.9803	0.5043	1.0406
2001.1	0.7171	1.3321	0.6994	0.8658
2001.2		1.2911		0.8428
2001.3		1.3866		0.9406
2001.4	0.5329	1.4066	0.8176	0.8846
2002.1	0.3828	0.7358	0.7494	0.6722
2002.2		0.5501		0.5704
2002.3	0.0781	0.8137	1.0739	0.7623
2002.4	0.1962	0.7922	1.6001	0.8189
2003.1	0.6233	0.7150	1.4136	0.6297
2003.2	0.6647	0.9859	0.8541	0.4277
2003.3	0.1085	1.6220	0.9385	0.4340
2003.4	0.3531	0.7949	0.6599	0.5554
2004.1	0.4283	0.4269	0.5333	0.5570
2004.2		0.5461		0.5975
2004.3		1.9648		0.7844
2004.4	0.7213	1.7860	1.6116	0.8411



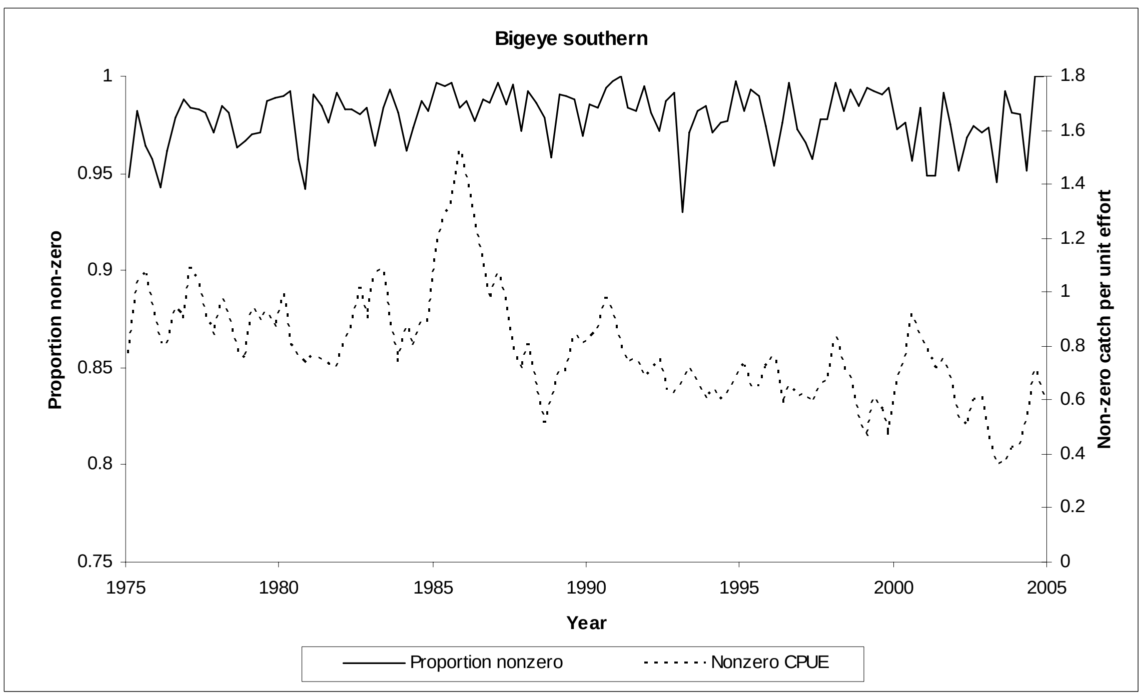


FIGURE 1: The proportion of non-zero observations (time/latlong/hbf strata) by quarter (solid line) and the unstandardized CPUE of positive observations (dotted line) for bigeye in the northern and southern fisheries.

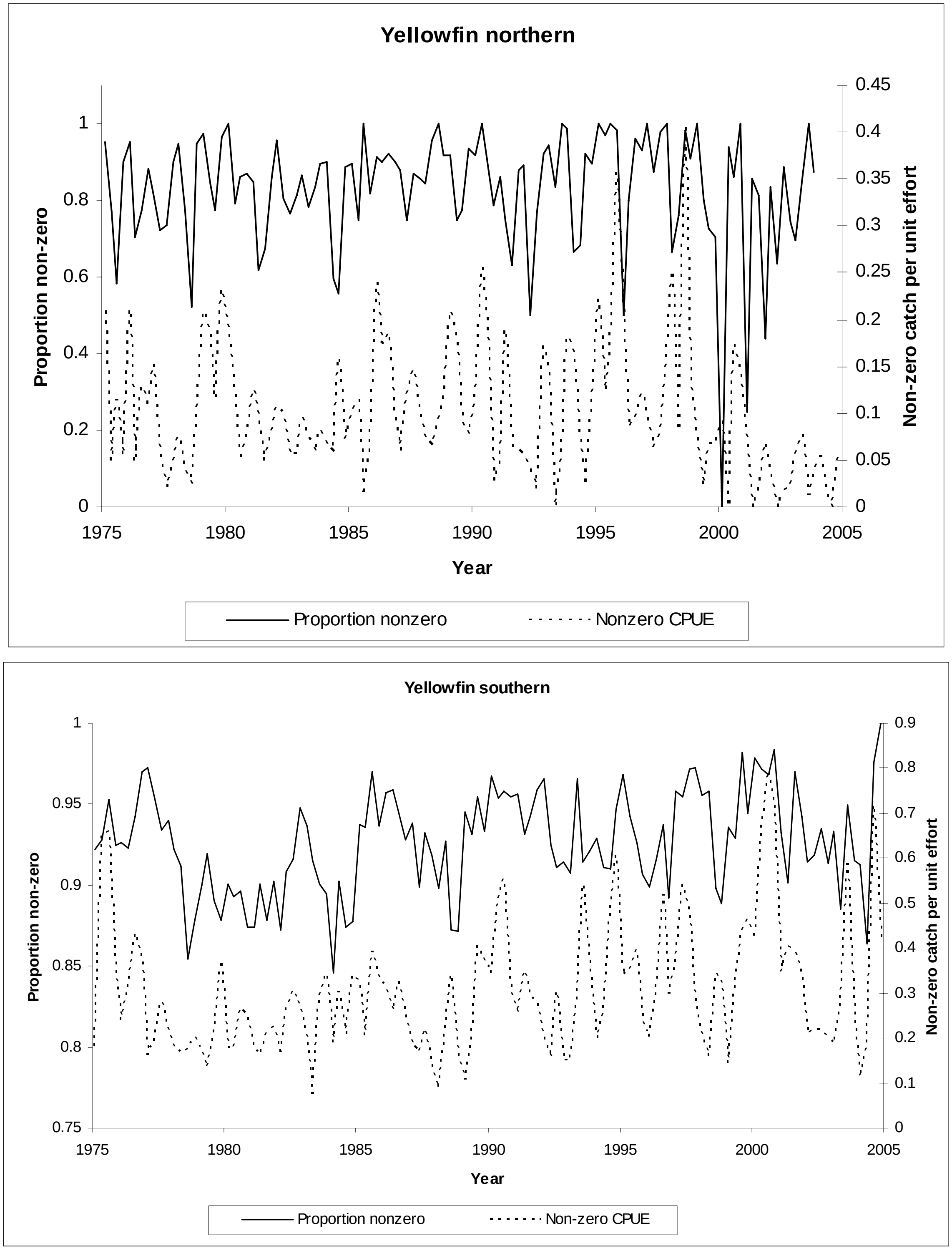
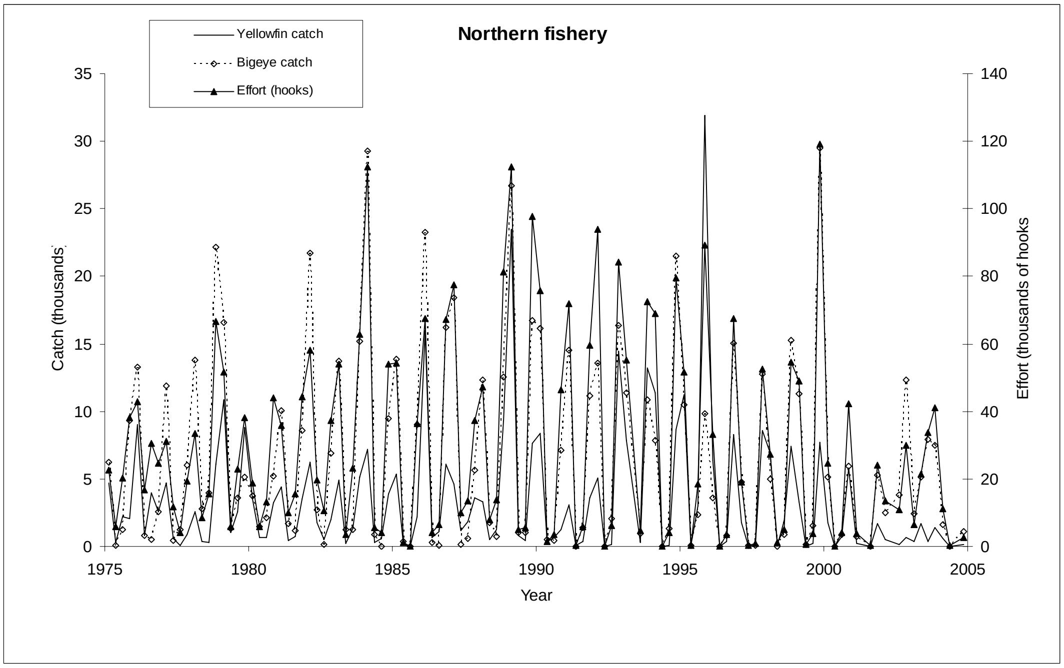


FIGURE 2: The proportion of non-zero observations (time/lat/long/hbf strata) by quarter (solid line) and the unstandardized CPUE of positive observations (dotted line) for yellowfin in the northern and southern fisheries.



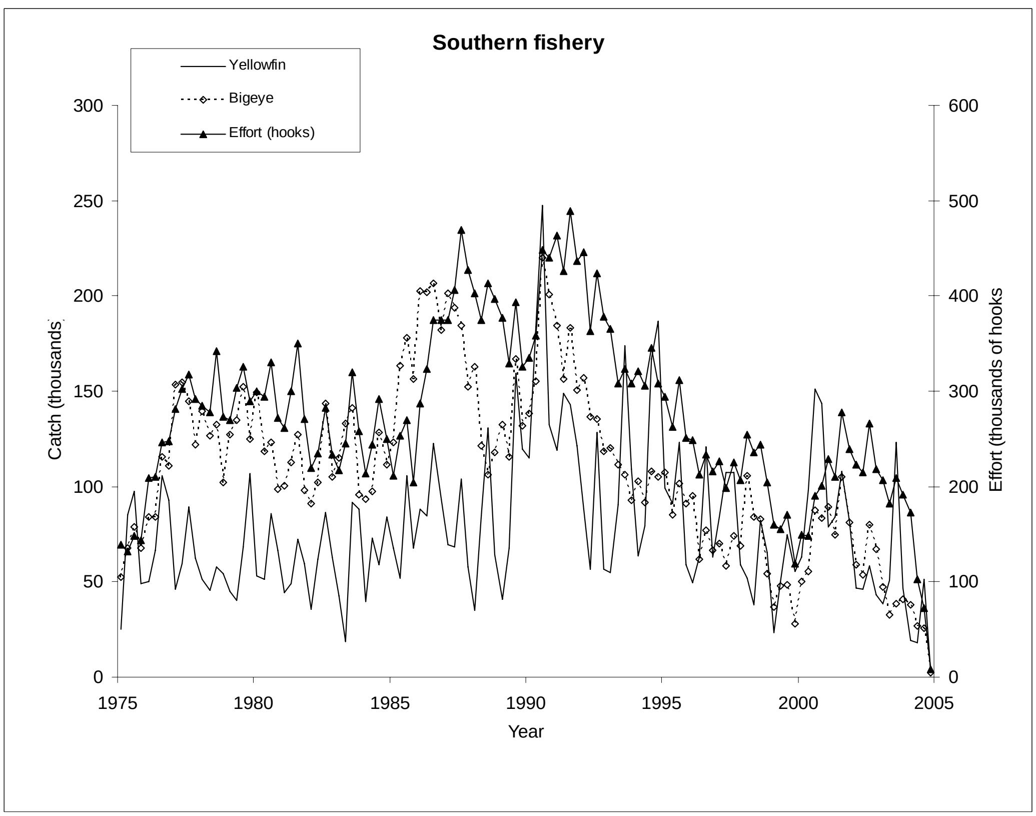
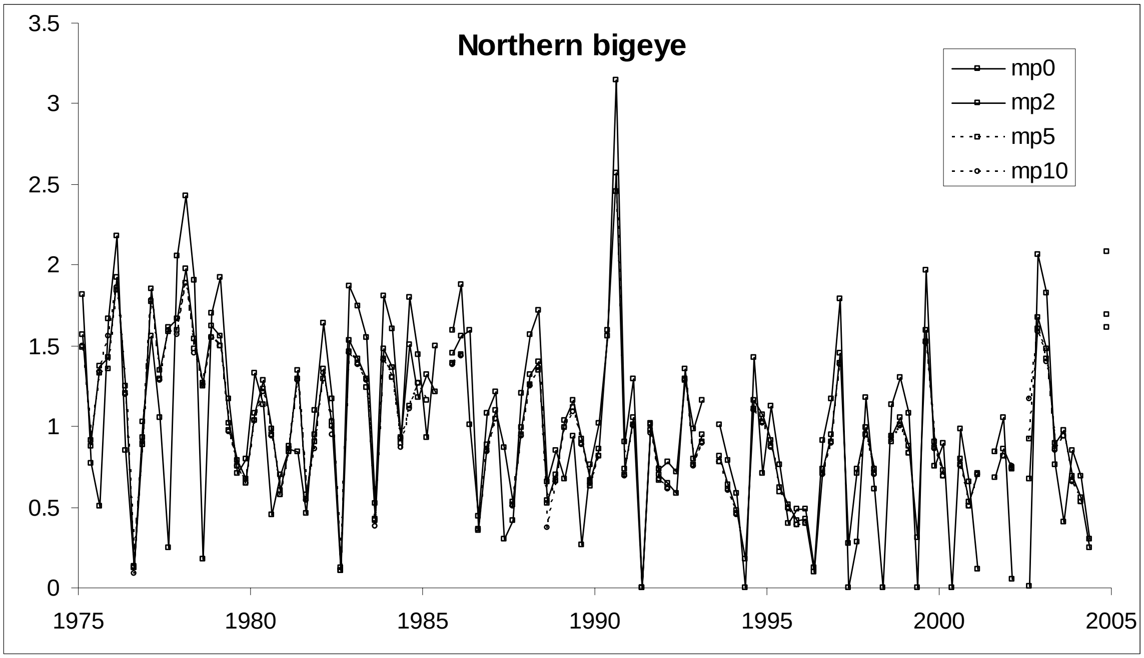


FIGURE 3: Effort and catch by species in the northern and southern components of the Japanese longline fishery



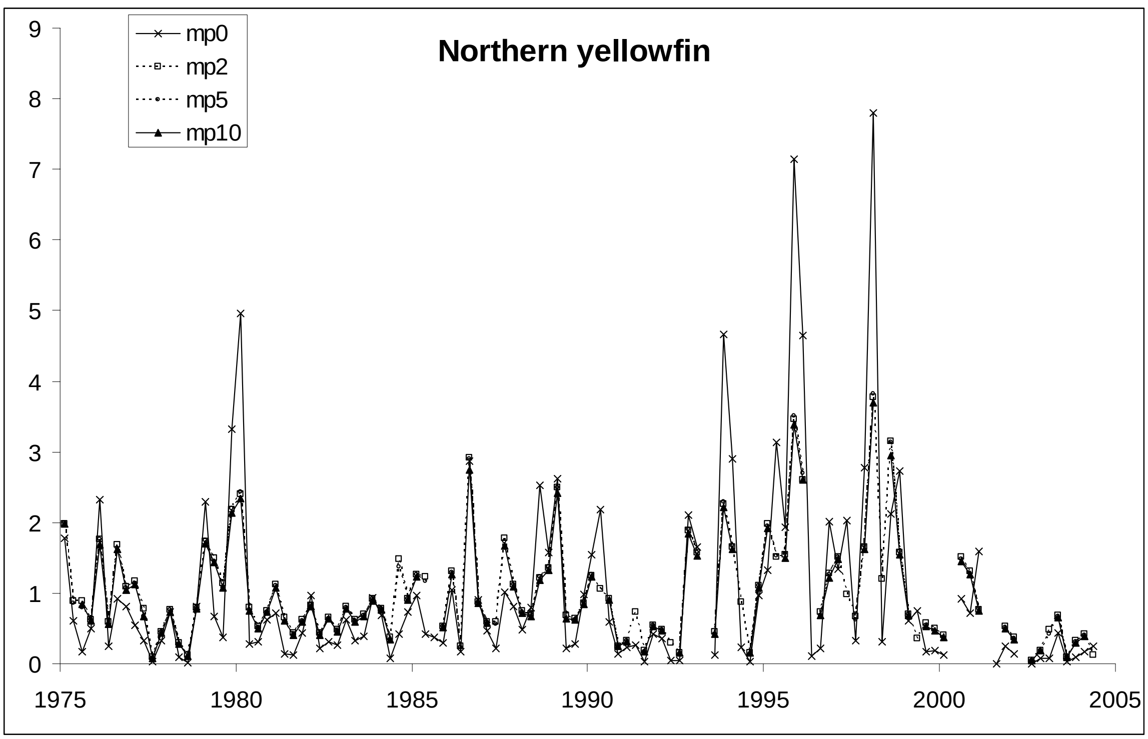
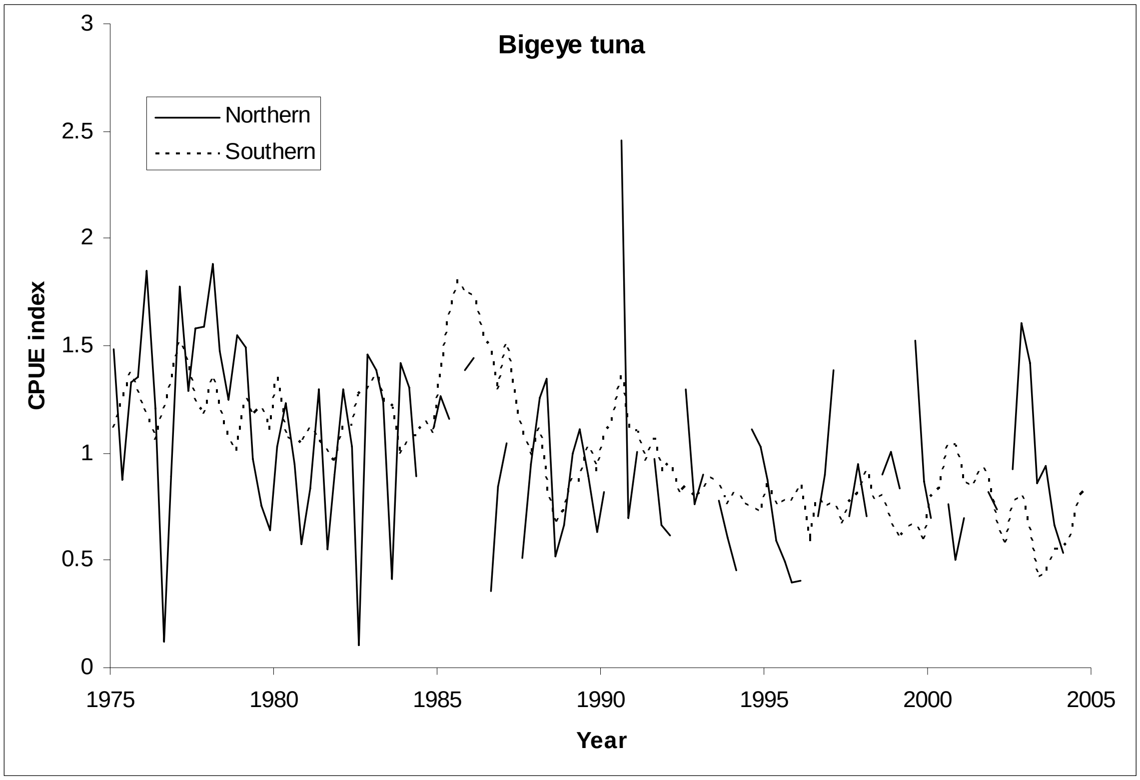


FIGURE 4: Comparison of standardized indices of abundance estimated while varying the minimum number of positive values (minpos = 0, 2, 5, or 10). Strata with fewer than the minimum were excluded from the analysis. The indices are rescaled so that each index averages 1.



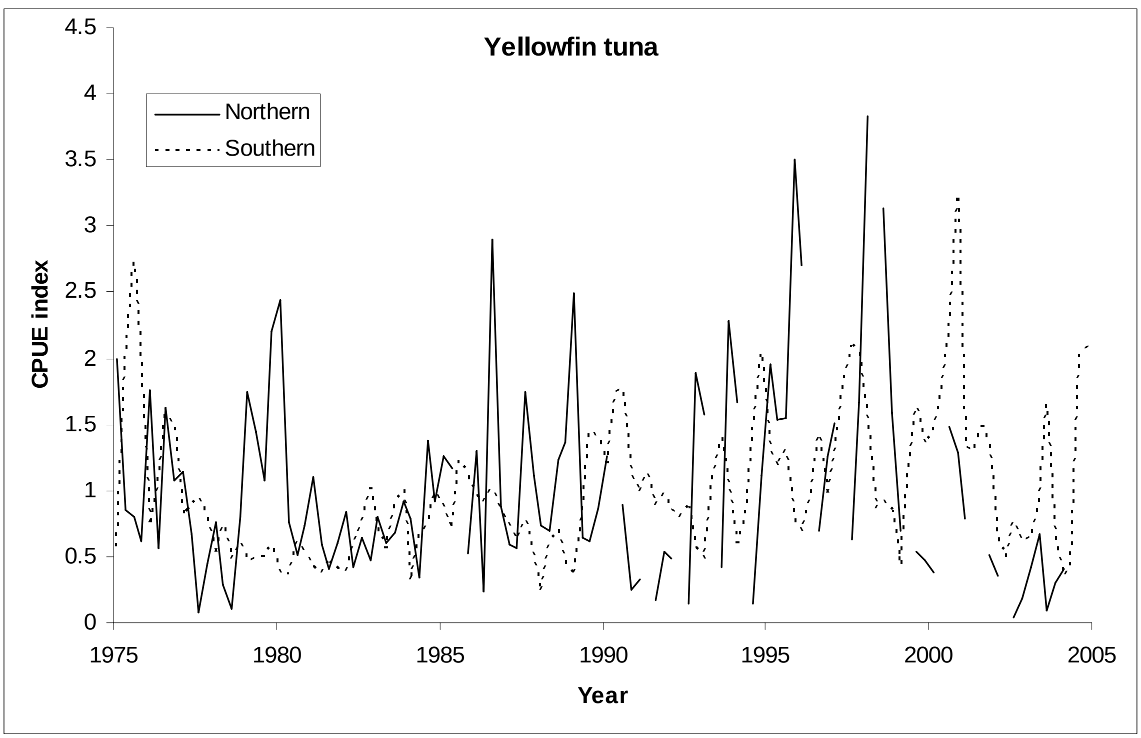
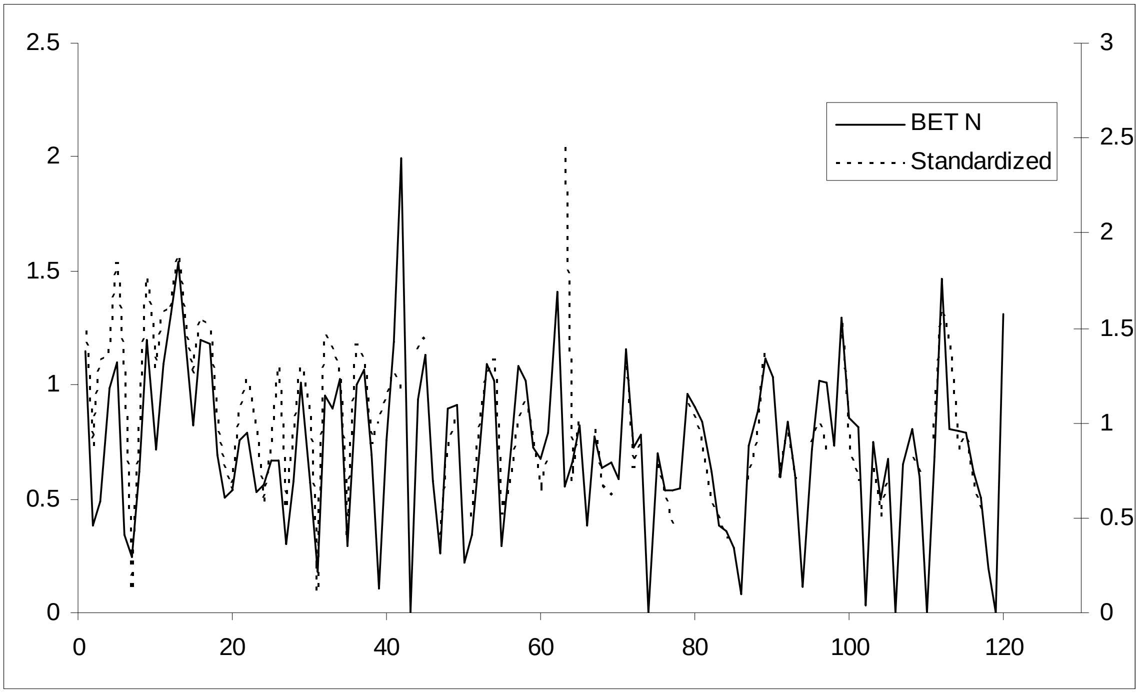


FIGURE 5: Indices of abundance for bigeye and yellowfin tuna in both northern and southern fisheries, based on a delta lognormal model that includes latitude, longitude, and HBF.



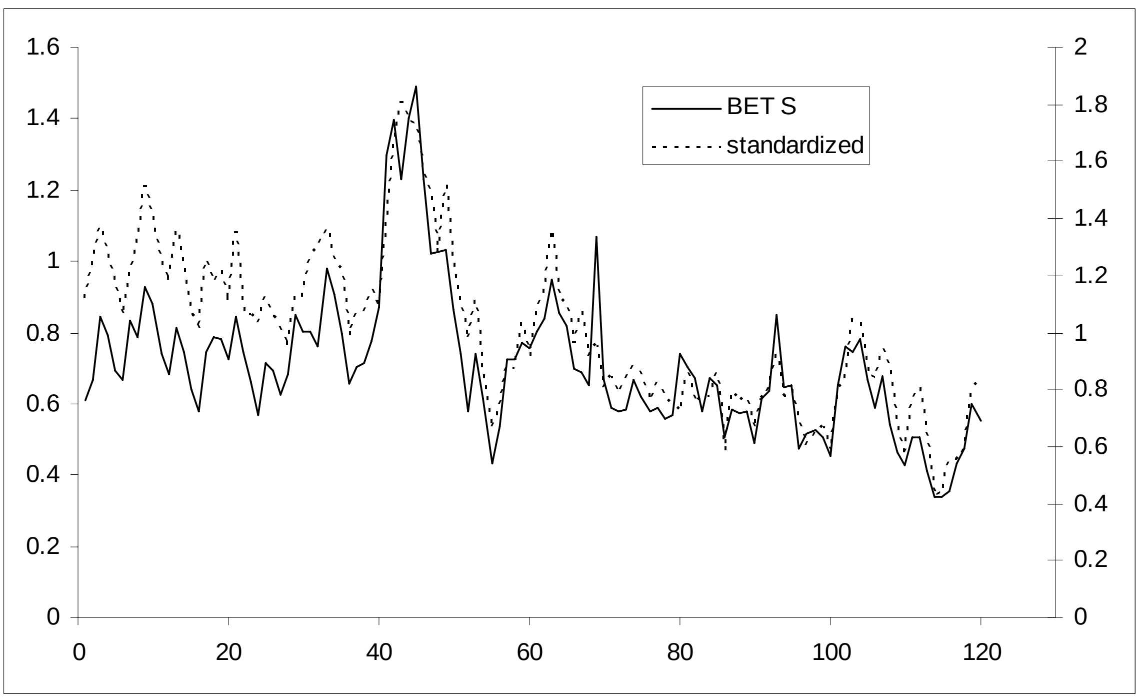
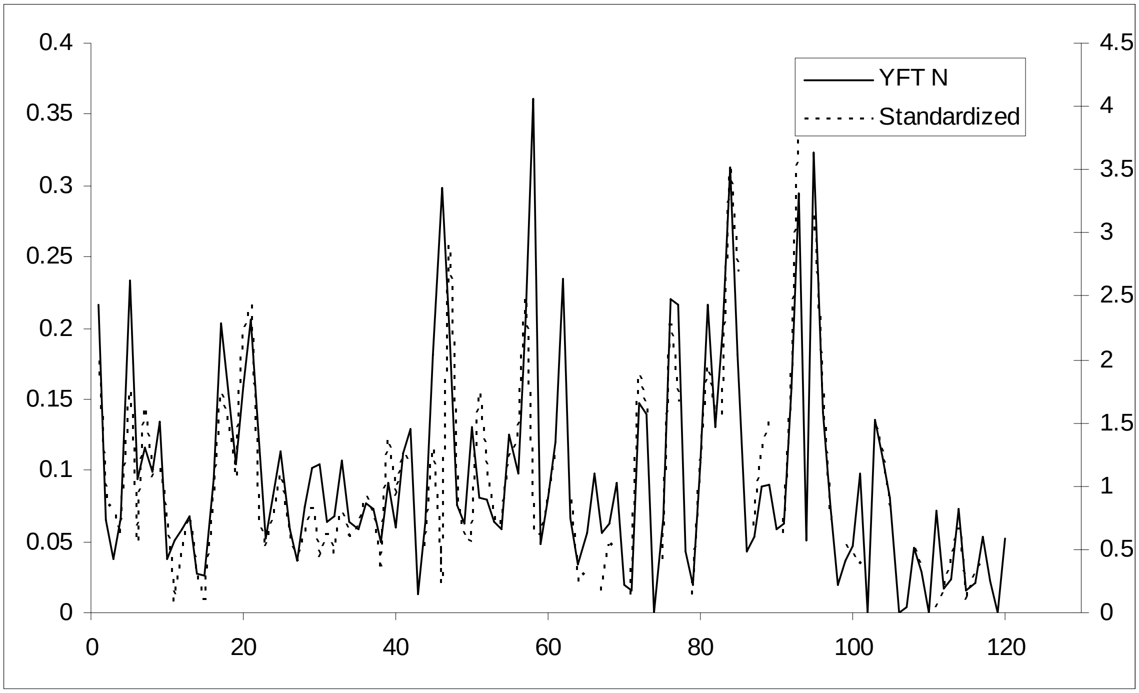


FIGURE 6: Unstandardized and standardized CPUE for bigeye in the northern and southern fisheries.



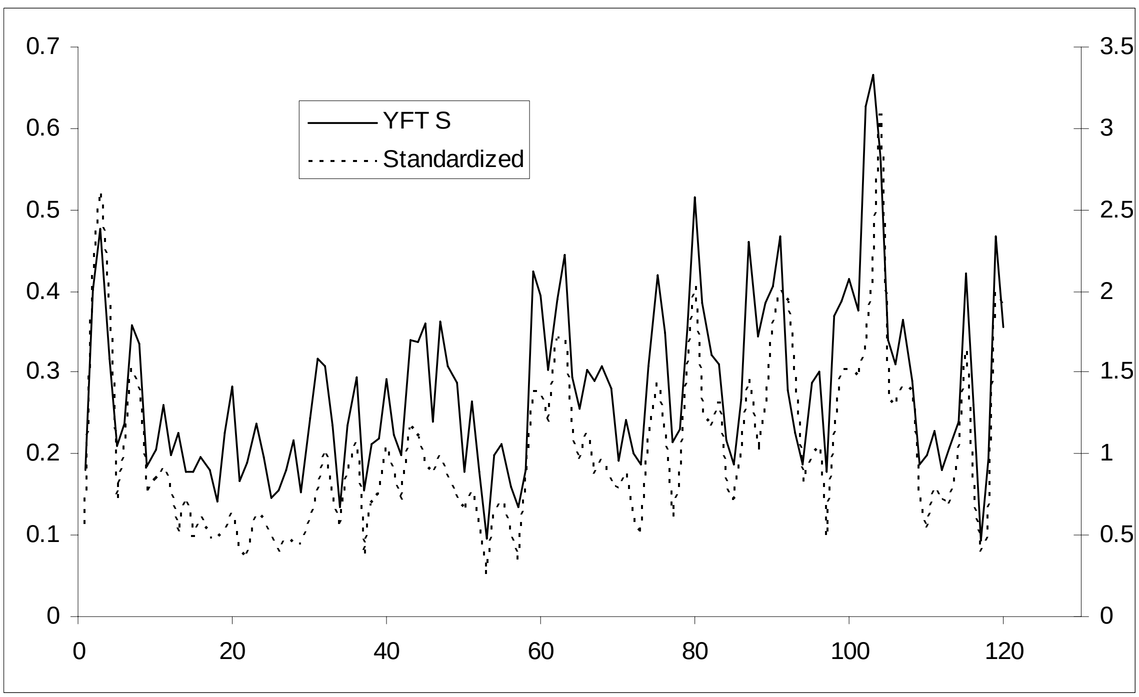


FIGURE 7: Unstandardized and standardized CPUE for yellowfin in the northern and southern fisheries.

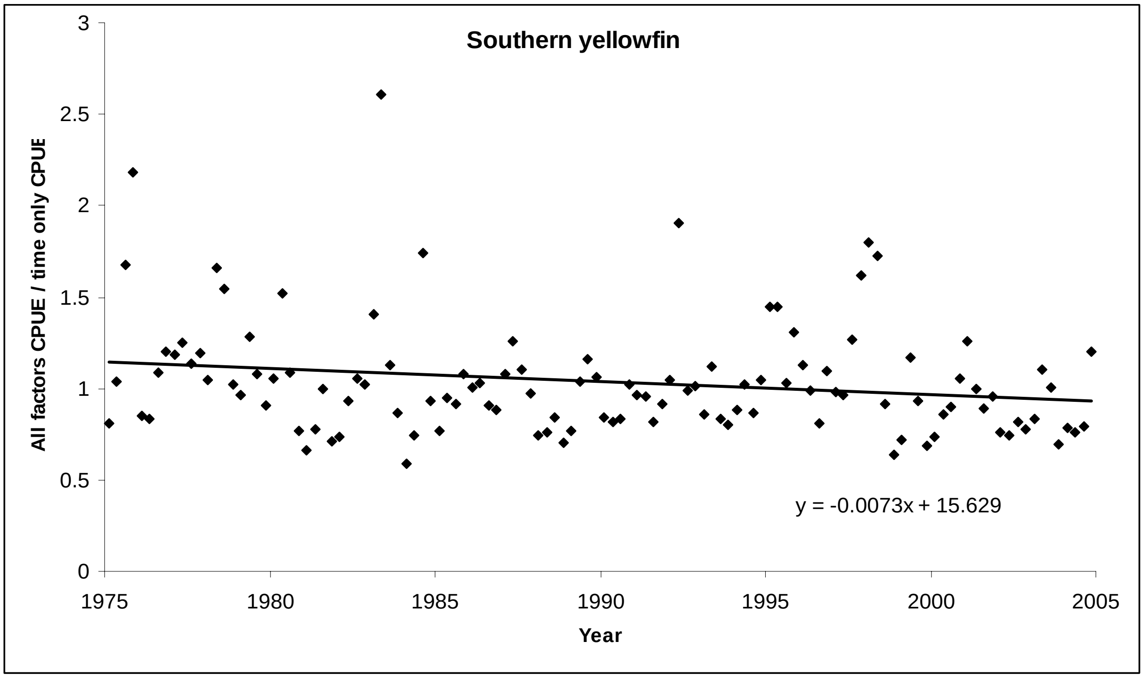


FIGURE 8: Ratio of CPUE standardized by all factors to CPUE standardized by time only for yellowfin tuna in the southern fishery

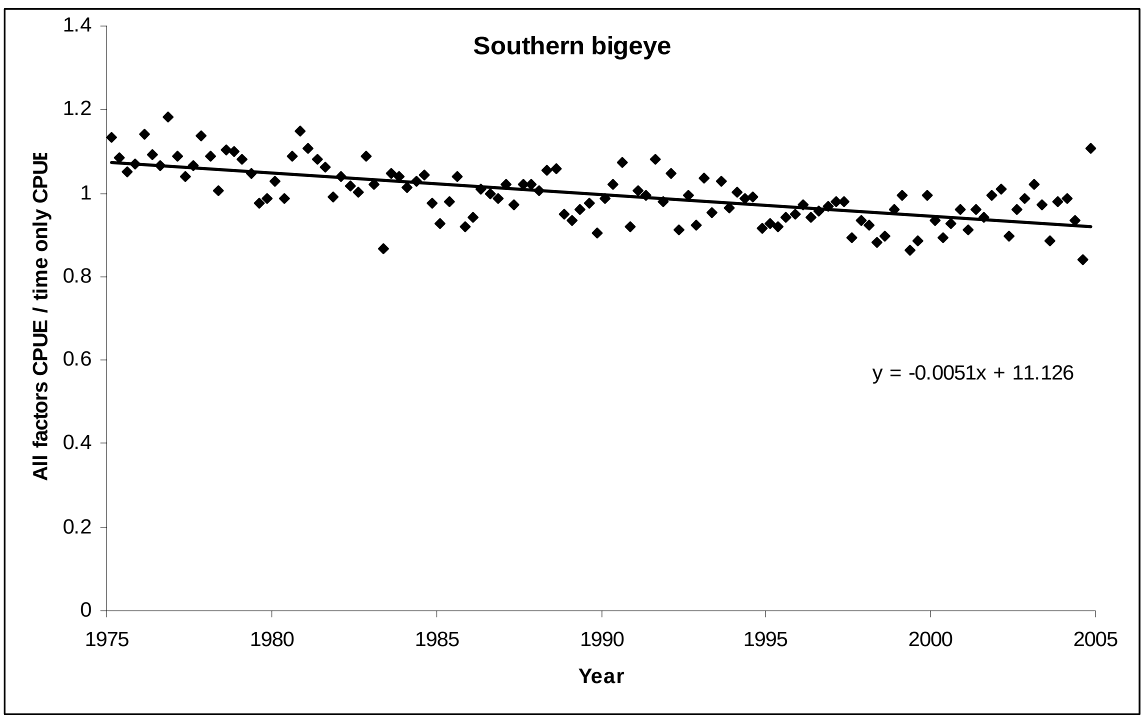


FIGURE 9: Ratio of CPUE standardized by all factors to CPUE standardized by time only for bigeye tuna in the southern fishery.

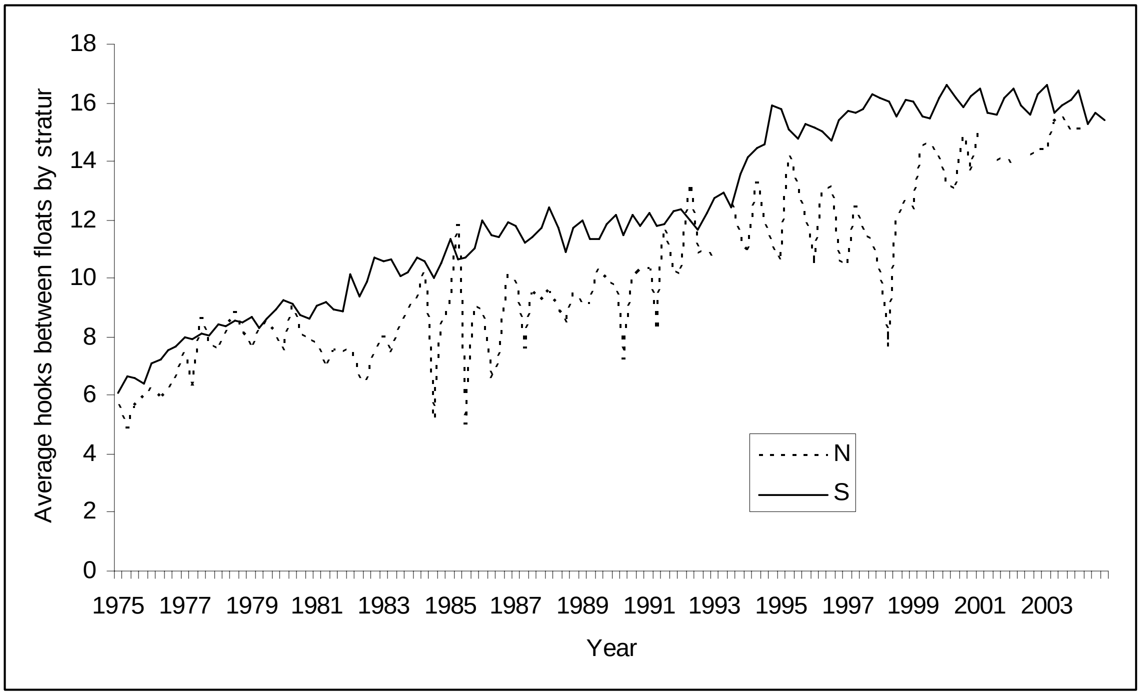


FIGURE 10: Average HBF by region through time.

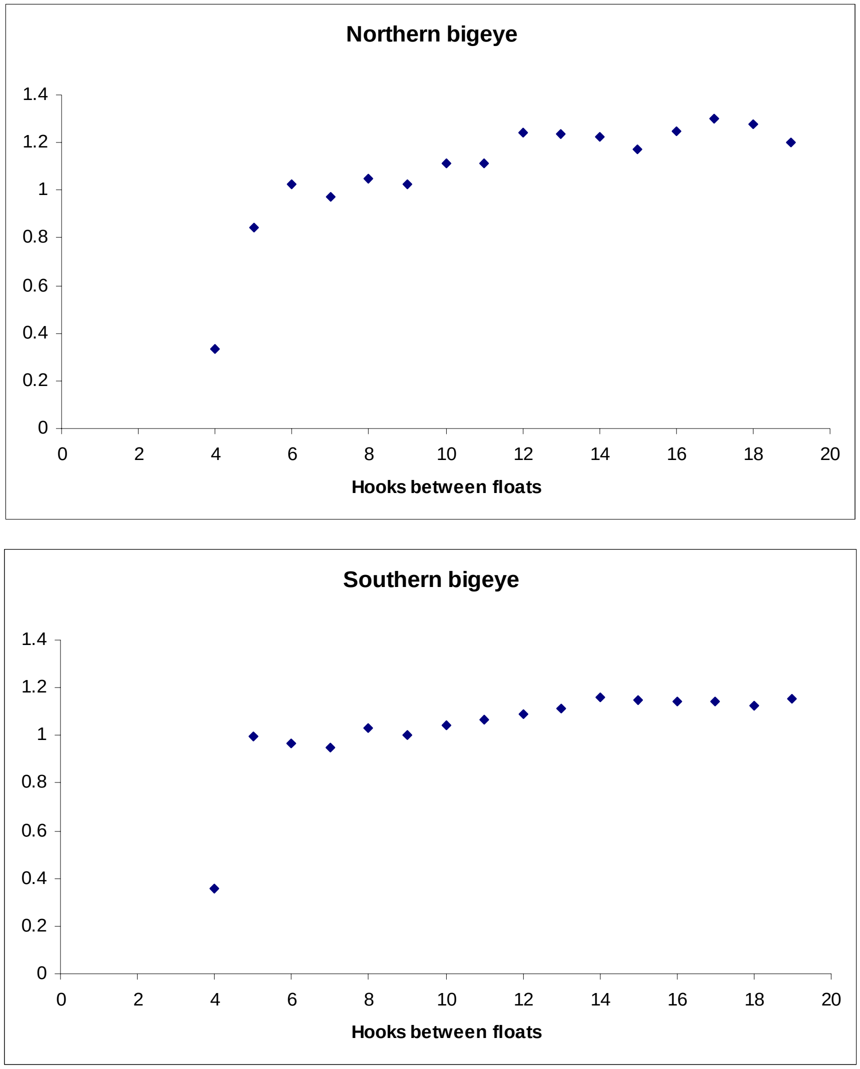
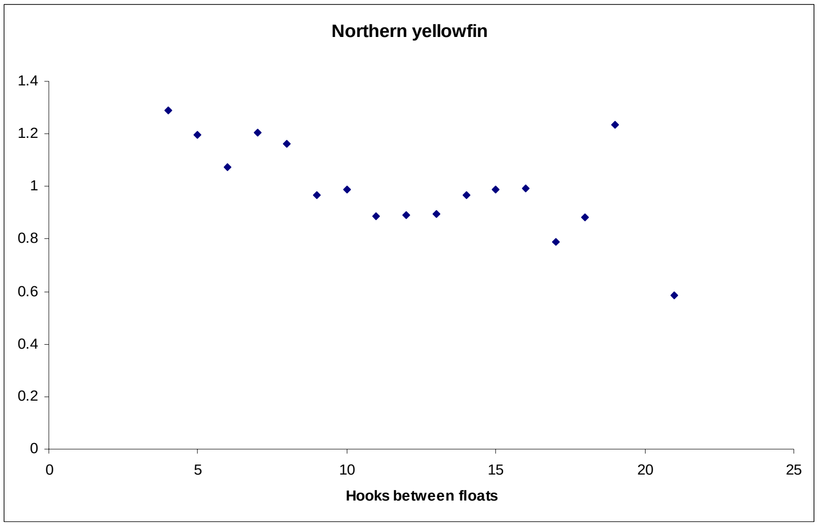


FIGURE 11: Relationship between the HBF and CPUE for bigeye in the northern and southern fisheries.



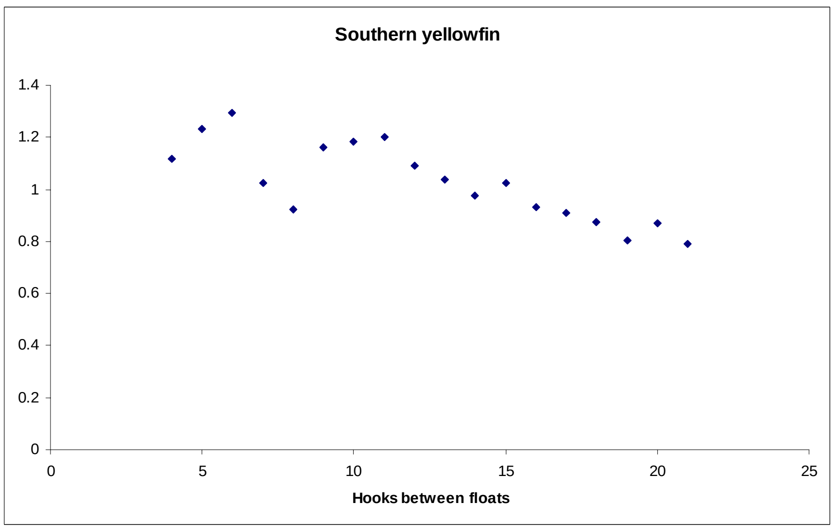


FIGURE 12: Relationship between the number of HBF and CPUE for yellowfin in the northern and southern fisheries.

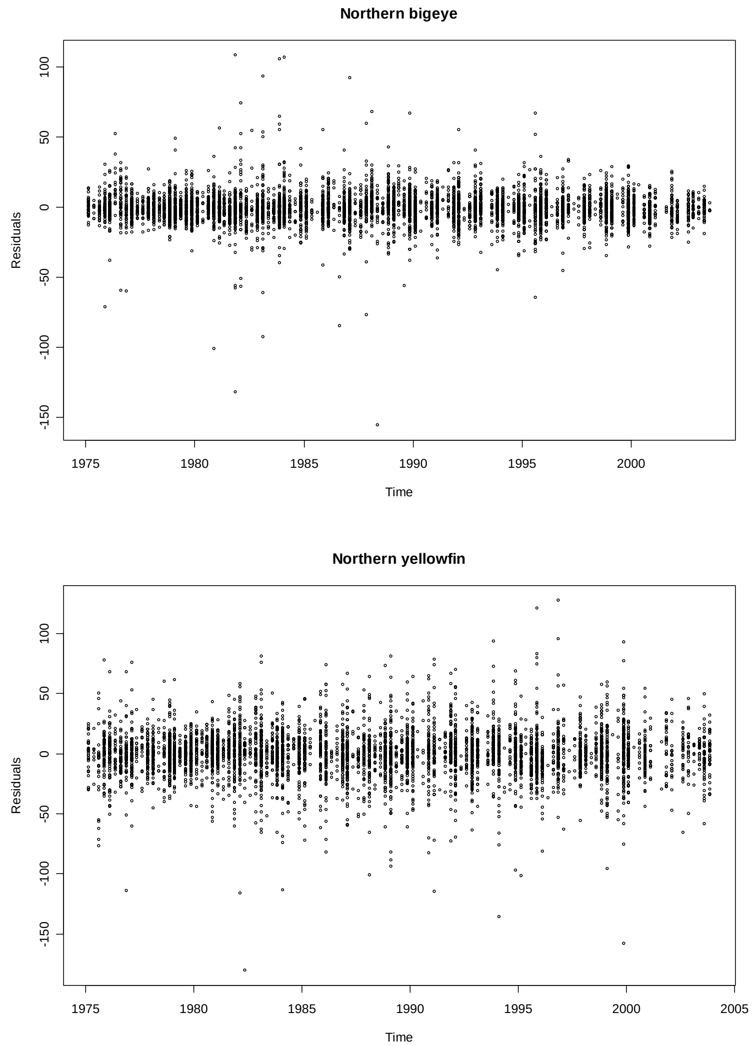


FIGURE 13: Residuals for nonzero values through time for the northern fisheries for bigeye and yellowfin..

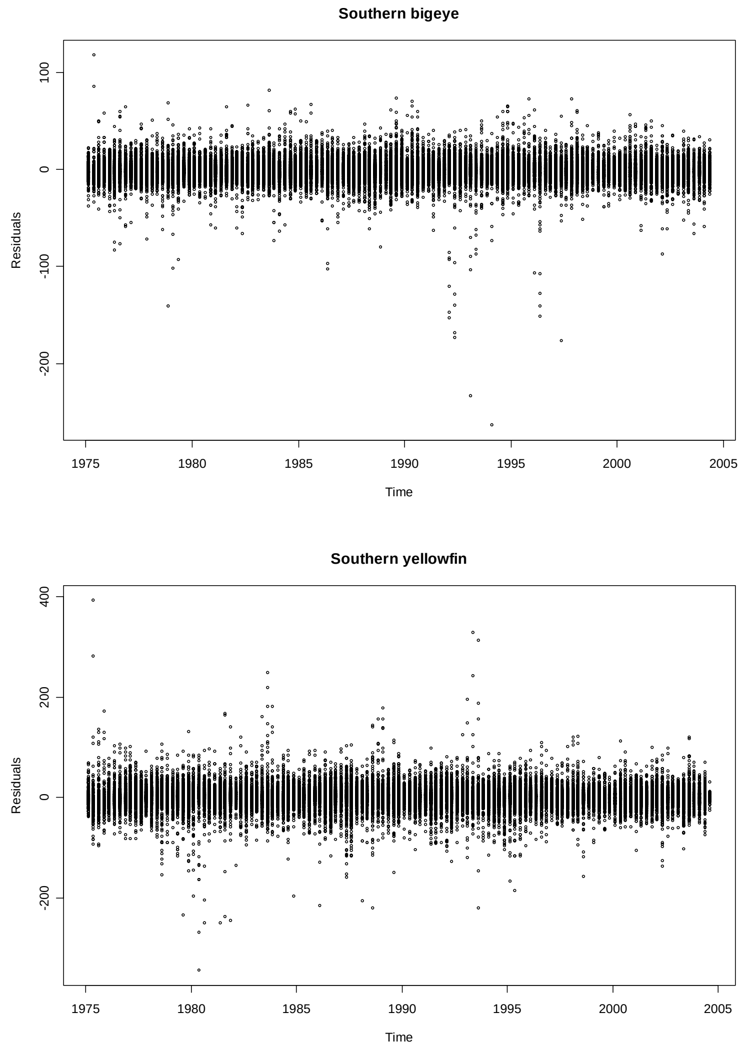


FIGURE 14: Residuals for nonzero values through time for the southern fisheries for bigeye and yellowfin.

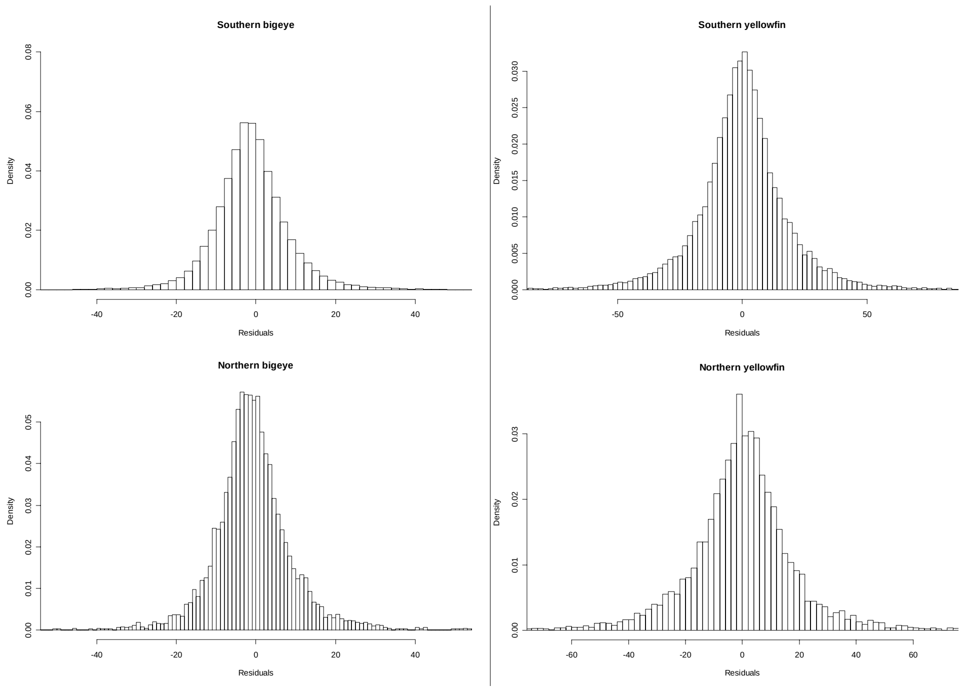


FIGURE 15: Frequency histogram of residuals for all nonzero catches.