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STANDARDIZED CPUE OF BLUEFIN TUNA (*THUNNUS THYNNUS*) CAUGHT BY SPANISH TRAPS FOR THE PERIOD 1981-2004

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SUMMARY

Catch rates from the Spanish traps in the Atlantic have been traditionally standardized using a GLM approach with a lognormal error assumption. Nevertheless, some concerns have been expressed regarding the current unit of effort used for standardization purposes as well as the model error assumption. This document explores the adequacy of current effort unit and proposes alternative model error assumptions for the standardization of the CPUE index.

RESUME

Les taux de captures des madragues espagnols étaient habituellement standardisés par des modèles linéaires de type log-normal. Cependant, la manière dont l'effort était quantifié, ainsi que la structure log-normale du modèle ont été sujet à débat. Ce document vise donc à explorer l'adéquation de cette quantification et propose d'autres types de modèles GLM pour la standardisation de cet indice de CPUE.

RESUMEN

Las tasas de captura de las almadrabas españolas en el Atlántico se han estandarizado tradicionalmente mediante técnicas de GLM asumiendo un error de tipo lognormal. No obstante, se ha manifestado cierta preocupación relacionada con la unidad de esfuerzo utilizada durante la estandarización así como con la asunción del tipo de error del modelo. En este documento se estudia la idoneidad de la unidad actual de esfuerzo y se proponen asunciones alternativas de error del modelo durante el proceso de estandarización de índices de CPUE.

KEYWORDS

Effort, CPUE, trap fishery, bluefin tuna, east Atlantic

1. Introduction

The Spanish trap abundance index has been traditionally used for VPA calibrating purposes at Bluefin Tuna Eastern Stock Assessment Sessions (ICCAT, 1999, 2003). Nevertheless, some objections have been raised regarding the adequacy of the effort unit as well as the model error assumption used for standardization.

Therefore, this document aims to examine more deeply this quantification of the trap effort as well as alternative model error assumptions for standardization purposes in order to propose more adequate standardized CPUE indices. This work is a follow up to analyses conducted by de la Serna *et al.* (2004) under the FAO- COPEMED project.

2. Material and methods

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Traps are fixed and passive gears that intercept bluefin tuna when swimming towards spawning grounds (*derecho*) or feeding grounds (*revés*). Traps have been subjected to few technical modifications over decades or even centuries, but their catchability has probably changed during the 1960s, because of the development of purse seines and long line fisheries in the East Atlantic and Mediterranean Sea (Ravier and Fromentin, 2001).

Traps are equipped with large guiding panels made from netting to lead the fish into the catching chamber or *copo* (**Figure 1**).

When there is a sufficiently large number of fish, which is decided daily by the trap Captain and verified by a scuba diver, the net at the bottom of the *copo* is lifted and the *matanza* starts thus resulting in a catch. During the most intense period of the fishing season, consistently during the month of May, there is pratically a daily *matanza.*

At present there are four traps operating along the southern Spanish coast, close to the Straits of Gibraltar (i.e. Barbate, Conil, Tarifa and Zahara). These traps have remained stable for decades as regards to their configuration and the way they are operated. They are set from mid April to mid July*)*, being May the most intense period of the fishing season.

Information on catch in number of individuals, size composition, days of fishing, and trap characteristics was collected from 1981 to 2004 by the IEO (C.O. Malaga); a period for which catchability is assumed to have been more stable than during the 1960s or the 1970s. During that period, traps caught from 741 to 2723 tonnes of bluefin tuna annually. Note that the last two years, i.e. 2003 and 2004, displayed the lowest catches in the series, with 741 and 862 tonnes, respectively.

3. Results

3.1 Catch and effort

Figure 2 shows the total catch (in number of fish) against the total number of *matanzas* (number of annual net liftings) per year and by trap and for all the traps. In general, there is a linear positive relationship between both variables, but, for some of the traps (and for all traps), catch seems to reach an asymptote as the number of *matanzas* increases, which might be related to gear saturation processes.

In previous studies (e.g. Ortiz de Urbina & de la Serna 2003), trap effort was defined as the number of days elapsed during two consecutive net lifting operations (or *matanza*). **Figure 3** shows catch in number against effort, as defined by the number of days between two consecutive *matanzas* for the whole data series. These two variables do not display any clear relationship with each other. For instance catch corresponding to small "effort" (i.e. 1 to 7 days) tends to be higher than that with higher "effort" (8 to 11 days), but high catch also occurs at very high "effort" (12, 16 or 17 days).

Figure 4 shows catch in number against effort as defined by number of days between two consecutive *matanzas* for the whole data series by trap and by year; the observed pattern is similar to the abovementioned one.

Another problem with using the number of days between *matanzas* is not necessarily precise nor free of subjectivity. The database shows a large number of cases with only one or a very small number of fish caught in a day. It is likely that these are fish that died in the trap and were retrieved by the diver, but there is nothing in the database that would allow one to distinguish an individual's death from a *matanza*. On the other hand, it is plausible that under some conditions a Captain will order a *matanza* for just a few fish; for example, towards the beginning and end of the fishing season. Besides, Captains of different traps may have different subjective thresholds for deciding when to order a *matanza* depending on the number of fish in the trap.

As this quantification of effort is not satisfactory, we also investigated an alternative, simply defined as the number the days during which the trap is set and operative during a given year. Such simple quantification is reasonable because we know that traps are passive, having been set in the same season and locations for decades and it is deemed that they did not support any significant technical modifications since the early 20th century.

3.2 Length distribution

Figure 5 shows length distribution for the whole study period (1981- 2004) and by month. Length seems to vary between months (de la Serna *et al* 1992), with bluefin tuna mean length becoming smaller as the fishing season moves forward. On average, mean length (FL, cm) ranges from 200 cm to 230 cm, which corresponds to ages 10 to 13 (Cort, 1991). This is consistent with the results obtained by Restrepo *et al* (2007) and Fromentin *et al* (2007) that also suggest that on average bluefin are fully selected by traps after age 10; considerably older than the age 6+ assumed by the SCRS in the past.

3.3 Models for abundance indices standardization

In order to explore alternative models for the standardization of abundance indices and based on the nature of the available data, we firstly examined the relationship between mean catch and variance computed over 10 days (**Figure 6**). As expected with such data, the variance is not constant (even when transformed logarithmically), but increases non-linearly with the mean; it is roughly proportional to the mean squared. Therefore, the following error distributions that allow for over-dispersion were used: negative binomial, quasi likelihood with logarithmic link and quasi likelihood with variance function inverse to the squared mean (McCullagh and Nelder 1989).

The models were fitted to the data for the whole trap season (i.e. mid April to mid-June) and for the month of May (i.e. the major fishing period). The response variable (catch rate) was defined in two ways: (i) the number of fish divided by the numbers of days elapsed during two successive *matanzas* and (ii) nominal catch (as the number of fishing days remain the same over the whole series).

Figures 7 to 10 show the corresponding outputs of the models considering: (i) a negative binomial model with a log-link fitted to nominal catch in May **(Figure 7)**, (ii) a negative binomial with a log-link for number of fish between *matanzas* in May **(Figure 8)**, (iii) a negative binomial with a log-link for nominal catch for the whole season **(Figure 9)** and (iv) a negative binomial with a log-link for number of fish between *matanzas* during the whole season **(Figure 10)**. In general, models fitted on nominal catches display much better fits (both in terms of prediction and residuals) than those fitted on number of fish between *matanzas*. This result is not unexpected, as the binomial catch data sets are highly aggregated compared to the other data set.

Fitted values for the ‘year effect’ of the four above models are provided in **Table 1** and shown in **Figure 11**. Although the goodness of fit and performances of the models are quite different when considering nominal catch or catch between *matanza*, the corresponding fitted ‘year effects’ (i.e. the standardized CPUE series) are surprisingly quite similar.

Figures 12 to **15** show goodness of fit analyses for quasilikelihood model with a log-link fitted to nominal catch in May **(Figure 12)** and nominal catch during the whole season **(Figure 13)** and quasilikelihood model with an inverse squared mean variance link for nominal catch in May **(Figure 14)** and nominal catch during the whole season **(Figure 15)**. In general, the goodness of fit, both in terms of prediction and residuals, appear to be close to those obtained with a negative binomial distribution (i.e. **Figures 7 and 9**).

Fitted values for the ‘year effect’ of the four above models are shown in **Table 2** and **Figure 16**. The two models with a log-link display again similar outputs than the negative binomial models, but these with the inverse link function appear to be more smoothed (probably because the inverse link assumes a greater variance in the data than the log-link).

Fitted values for the ‘year effect’ of the four models based on data for the month of May are shown in **Figure 17.**

4. Discussion and conclusions

As regards length distribution analysis, our examination is consistent with the results obtained by Restrepo et al (2007) and Fromentin *et al* (2007) that suggests that on average bluefin are fully selected by traps after age 10; considerably older than the age 6+ discussed by SCRS in the past.

Trap effort quantified as the number of days elapsed during two consecutive net lifting operations (or *matanza*) does not appear to be satisfactory because the catch level is not related to it (there is indeed no clear increasing relationship between catch and effort being so defined).

As expected from the above results, the models fitted on nominal catches display better fits (both in terms of prediction and residuals) than those fitted on number of fish between *matanzas*. Nonetheless, the corresponding fitted ‘year effects’ (i.e. the standardized CPUE series) are surprisingly quite similar between different models and effort. Choosing another link function than the log-link, such as the inverse squared mean variance, change, however, quite substantially the fitted ‘year effects’.

More detailed investigation on trap data should be done in near future, for instance by incorporating environmental information, but models fitted on nominal catch in May appear to display already satisfactory goodness of fit.

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Table 1. Predicted abundance indices and corresponding standard error. Negative binomial error distribution.

	Negbin-May_mat-	*CV*	*Negbin-May_nom*	*CV*	*Negbin-Tot_mat*	*CV*	*Negbin-Tot_nom*	*CV*
1981	1.000000	0.3600	1.000000	0.3765	1.000000	0.3027	1.000000	0.2962
1982	1.135034	0.1734	1.332309	0.2170	1.091878	0.1430	1.326886	0.1695
1983	0.899350	0.1812	0.999646	0.2171	1.411511	0.1607	1.403636	0.1697
1984	1.997414	0.2011	1.767612	0.2169	2.104190	0.1845	1.546456	0.1697
1985	0.850561	0.1738	1.011621	0.2171	0.861087	0.1448	1.048037	0.1697
1986	0.433025	0.1877	0.331047	0.1928	0.421078	0.1503	0.372591	0.1506
1987	0.569720	0.1750	0.526412	0.1924	0.541994	0.1501	0.496013	0.1504
1988	1.052648	0.1649	1.107516	0.1920	1.007849	0.1353	1.133410	0.1501
1989	0.650288	0.1795	0.579598	0.1923	0.682197	0.1520	0.605596	0.1502
1990	1.312287	0.1720	1.264030	0.1920	1.087118	0.1352	1.251722	0.1498
1991	0.590740	0.1816	0.520032	0.1924	0.628848	0.1431	0.662421	0.1502
1992	0.587693	0.1719	0.567635	0.1924	0.611577	0.1439	0.603759	0.1502
1993	0.699934	0.1783	0.617858	0.1923	0.659945	0.1521	0.565665	0.1503
1994	0.611141	0.1747	0.569232	0.1923	0.643840	0.1544	0.537542	0.1505
1995	0.374668	0.1961	0.270499	0.1930	0.522301	0.1649	0.387570	0.1506
1996	0.742507	0.1869	0.624914	0.1923	0.752778	0.1623	0.593744	0.1507
1997	0.931953	0.1527	1.198293	0.1920	1.120385	0.1232	1.600477	0.1499
1998	1.146410	0.1724	1.112862	0.1920	1.083124	0.1443	1.092257	0.1501
1999	1.540241	0.1638	1.674037	0.1920	1.603477	0.1327	1.940913	0.1499
2000	0.860159	0.1754	0.781674	0.1922	0.910047	0.1457	0.874783	0.1501
2001	0.499056	0.1842	0.433620	0.1925	0.574217	0.1348	0.701749	0.1503
2002	1.052455	0.1893	0.837310	0.1921	1.249031	0.1609	0.990695	0.1502
2003	0.843597	0.2732	0.377975	0.2178	0.944835	0.2244	0.392422	0.1343
2004	0.722338	0.2183	0.429489	0.1925	0.672901	0.1749	0.500211	0.1949

Table 2. Predicted abundance indices and corresponding standard error. Quasi- likelihood error distribution.

	Quasi-log-May	*CV*	*Quasi-log-Tot*	*CV*	*Quasi-1/mu^2-May*	*CV*	*Quasi-1/mu^2-Tot*	*CV*
1981	1.000000	0.4833	1.000000	0.4212	1.000000	0.4436	1.000000	0.3770
1982	1.496624	0.1532	1.562803	0.1274	1.078063	0.1403	1.258080	0.1086
1983	0.929022	0.1979	1.371382	0.1367	1.009179	0.1258	1.224015	0.1034
1984	1.508941	0.1526	1.444179	0.1328	1.066081	0.1374	1.224577	0.1035
1985	0.992104	0.1898	1.062601	0.1607	1.022727	0.1281	1.162445	0.0967
1986	0.292422	0.4314	0.341459	0.3568	0.528636	0.3165	0.563661	0.2690
1987	0.449862	0.2951	0.451105	0.2768	0.734577	0.1638	0.714906	0.1808
1988	0.912401	0.1790	0.983684	0.1510	0.984093	0.1202	1.099525	0.0901
1989	0.556631	0.2488	0.582797	0.2220	0.834552	0.1255	0.864358	0.1224
1990	1.237153	0.1551	1.261728	0.1311	1.053986	0.1343	1.203362	0.1000
1991	0.433094	0.3046	0.568216	0.2267	0.726150	0.1682	0.858236	0.1243
1992	0.520753	0.2620	0.574651	0.2246	0.807057	0.1335	0.857714	0.1245
1993	0.482516	0.2778	0.482863	0.2603	0.777109	0.1439	0.768679	0.1566
1994	0.432037	0.3049	0.444431	0.2803	0.719342	0.1712	0.715125	0.1805
1995	0.249892	0.5003	0.334793	0.3634	0.448408	0.4082	0.565003	0.2680
1996	0.345868	0.3687	0.407698	0.3028	0.640684	0.2208	0.684432	0.1956
1997	1.005572	0.1702	1.414755	0.1241	1.010207	0.1247	1.208572	0.1008
1998	0.868586	0.1840	0.883303	0.1619	0.968040	0.1180	1.055961	0.0898
1999	1.448134	0.1464	1.733472	0.1144	1.059137	0.1356	1.244323	0.1062
2000	0.740771	0.2031	0.789874	0.1752	0.945855	0.1160	1.025425	0.0913
2001	0.324005	0.3928	0.569935	0.2261	0.597991	0.2533	0.859759	0.1238
2002	0.580920	0.2403	0.741884	0.1833	0.843557	0.1227	0.976498	0.0966
2003	0.377111	0.4106	0.464491	0.3185	0.614236	0.2918	0.707974	0.2224
2004	0.252870	0.4924	0.321157	0.3776	0.512996	0.3297	0.561901	0.2701

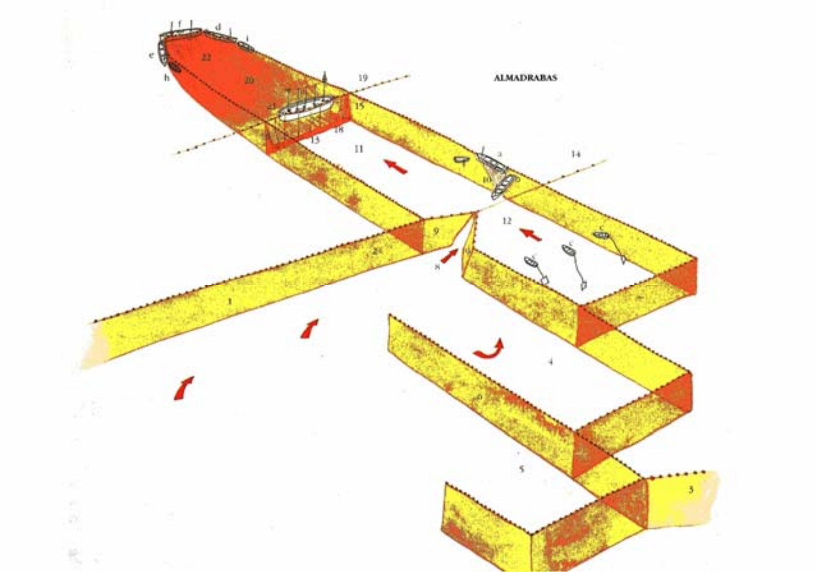

Figure 1. Trap sketch.

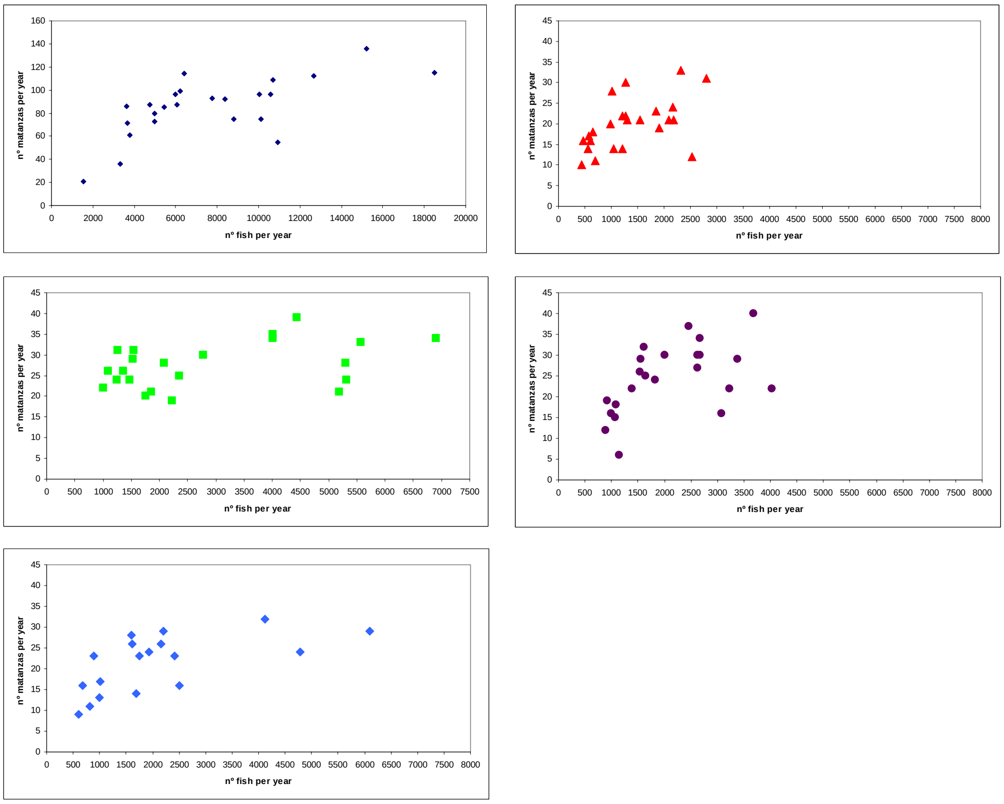

Figure 2. Total annual catch (number of fish) against total annual number of *matanzas* for the four traps and by trap (from top to bottom and from left to right). Spanish traps. 1981- 2004.

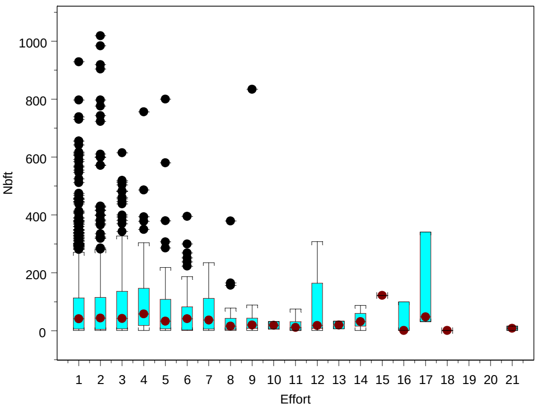

Figure 3. Catch (number of fish) against effort as defined by the number of days between two consecutive *matanzas* for the 1981- 2004 period.

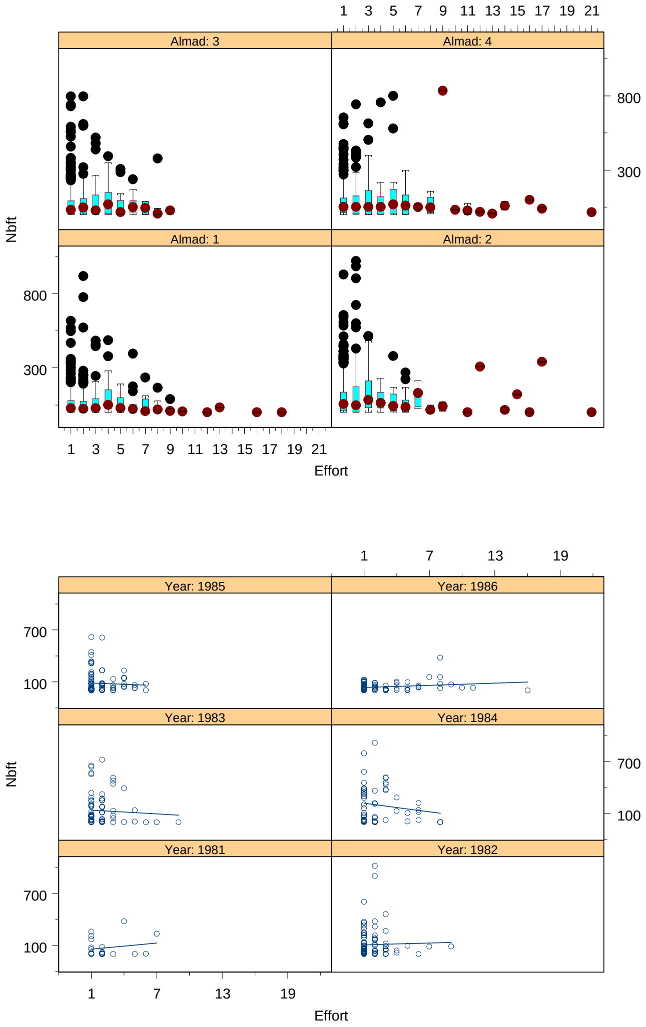

Figure 4. Catch (number of fish) against effort as defined by the number of days between two consecutive *matanzas* by trap (upper panel) and by year (lower panel, for selected years). Spanish traps. 1981- 2004.

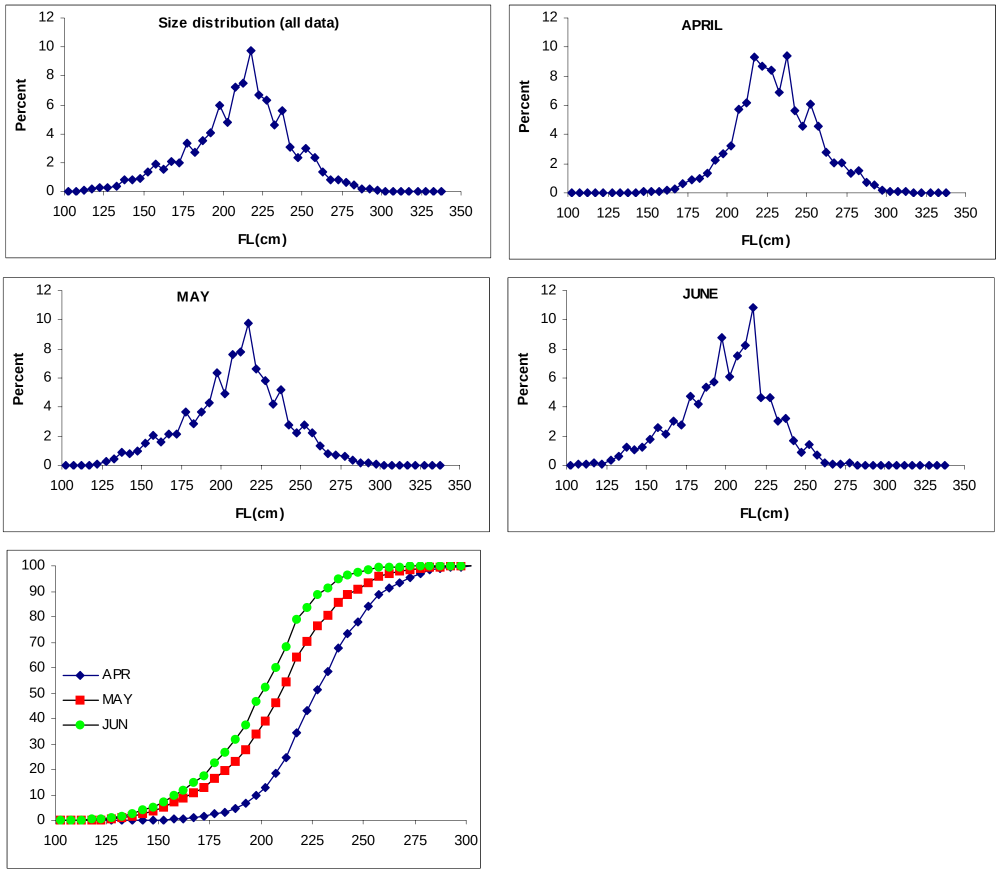

Figure 5. Total annual catch (number of fish) and total annual number of *matanzas* for the four traps and by trap (from top to bottom and from left to right). Spanish traps, 1981-2004.

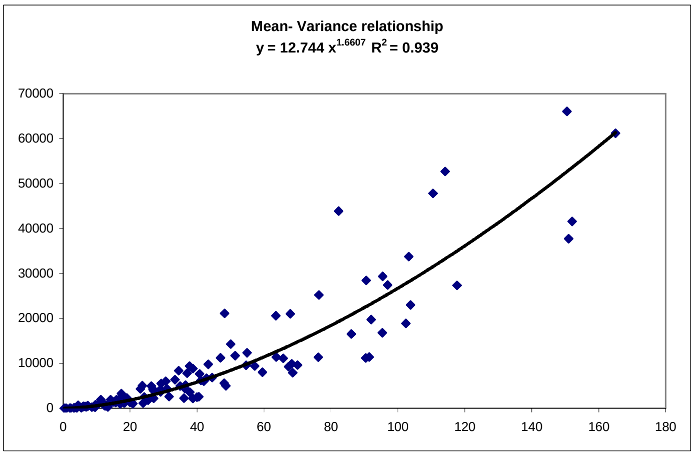

Figure 6. Mean-variance relationship for the 1981-2004 period, computed at 10-day intervals.

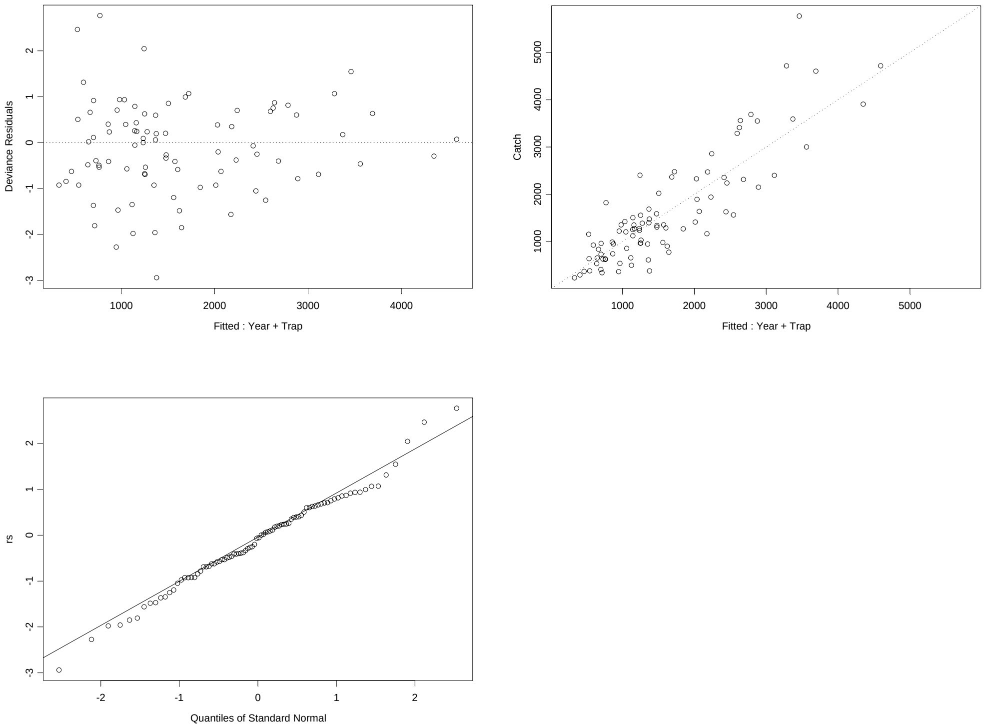

Figure 7. Negative binomial. Nominal BFTASX catch during May, 1981-2004.

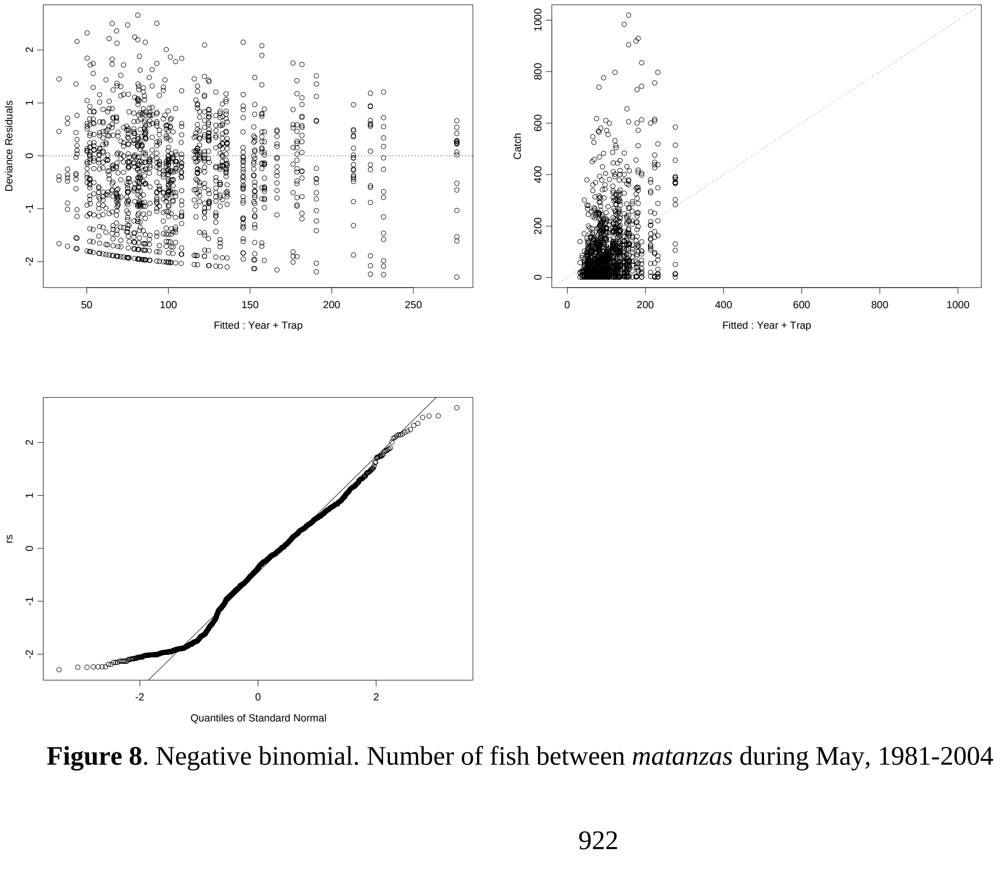

Figure 8. Negative binomial. Number of fish between *matanzas* during May, 1981-2004.

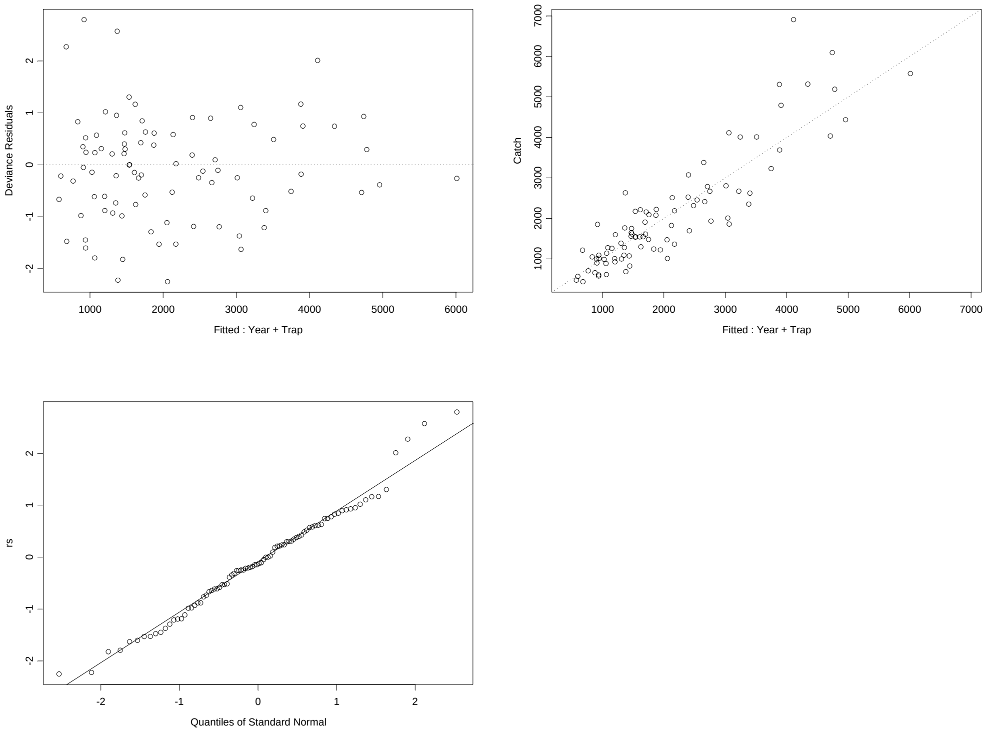

Figure 9. Negative binomial. Nominal catch for the whole trap season, 1981-2004.

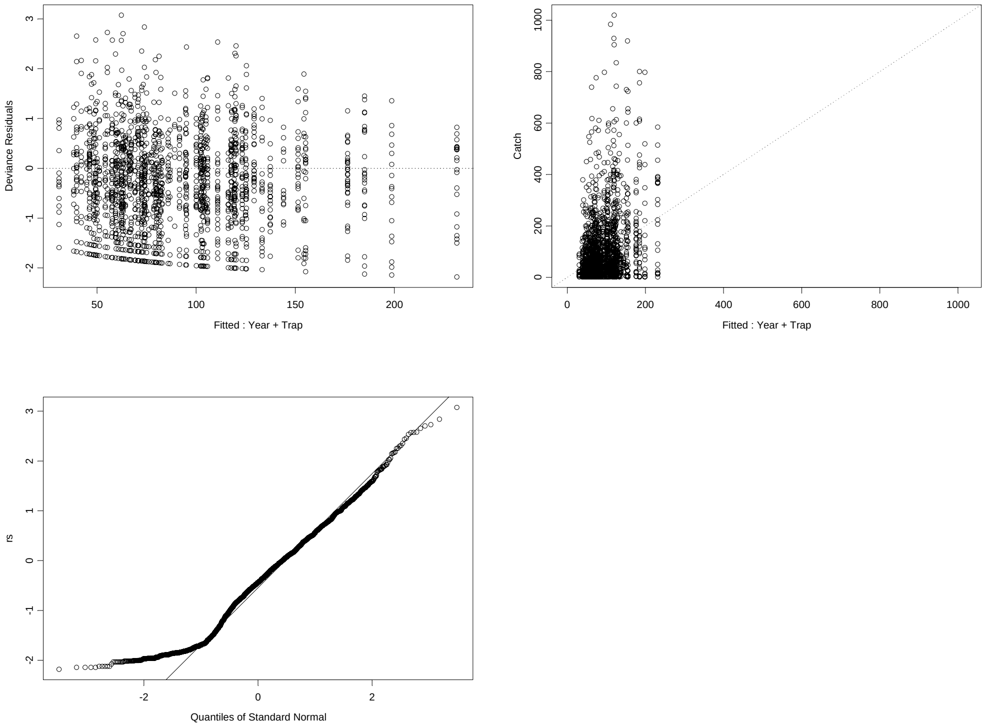

Figure 10. Negative binomial. Number of fish between *matanzas* for the whole trap season, 1981-2004.

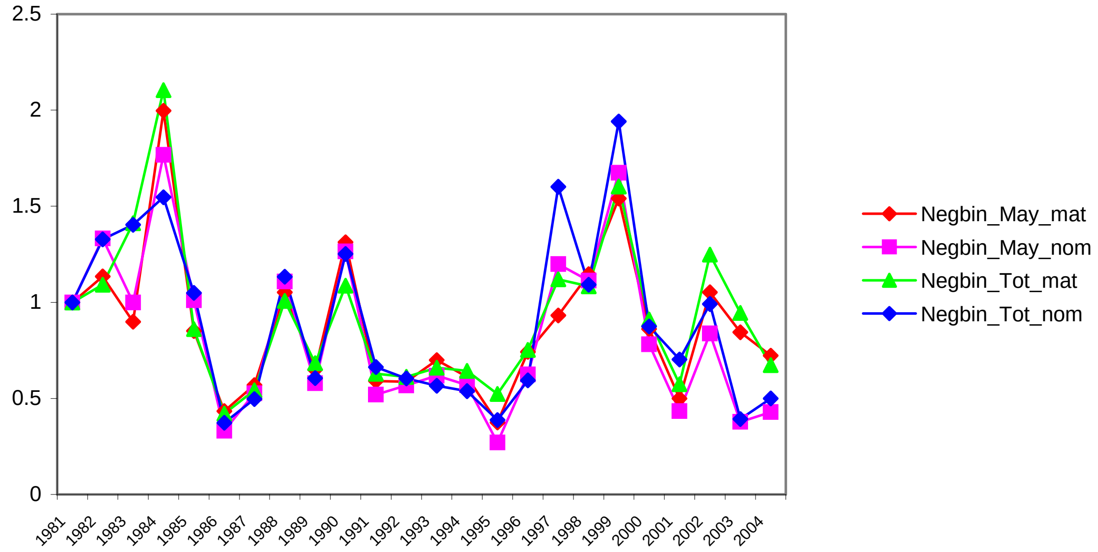

Figure 11. Predicted abundance indices. Negative binomial error distribution.

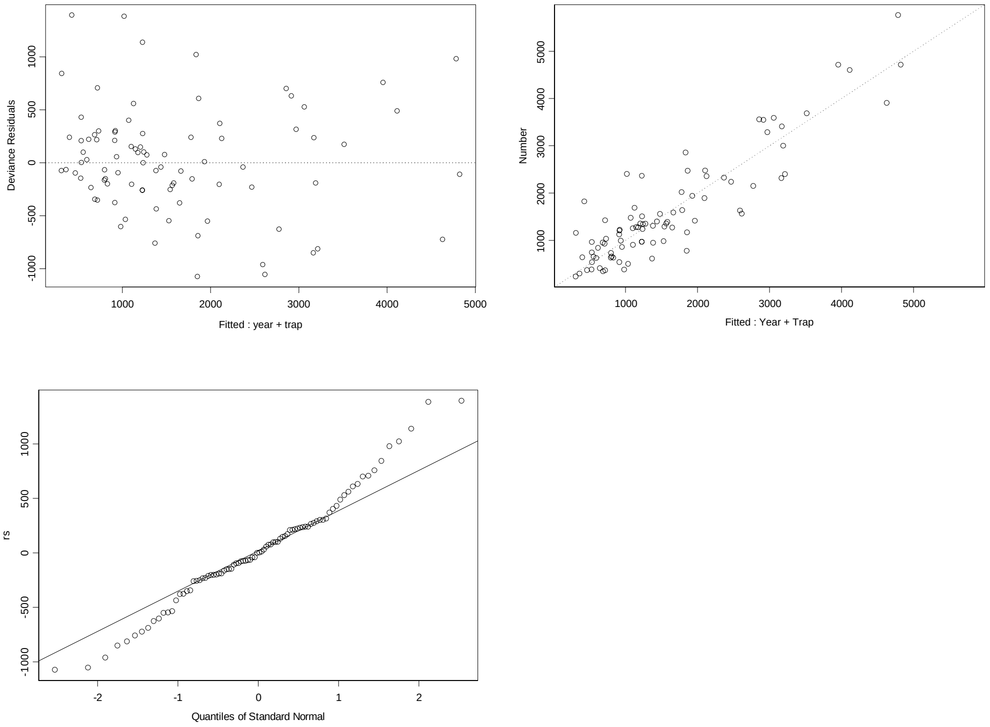

Figure 12. Quasi likelihood. Log link. Number of fish in May, 1981-2004.

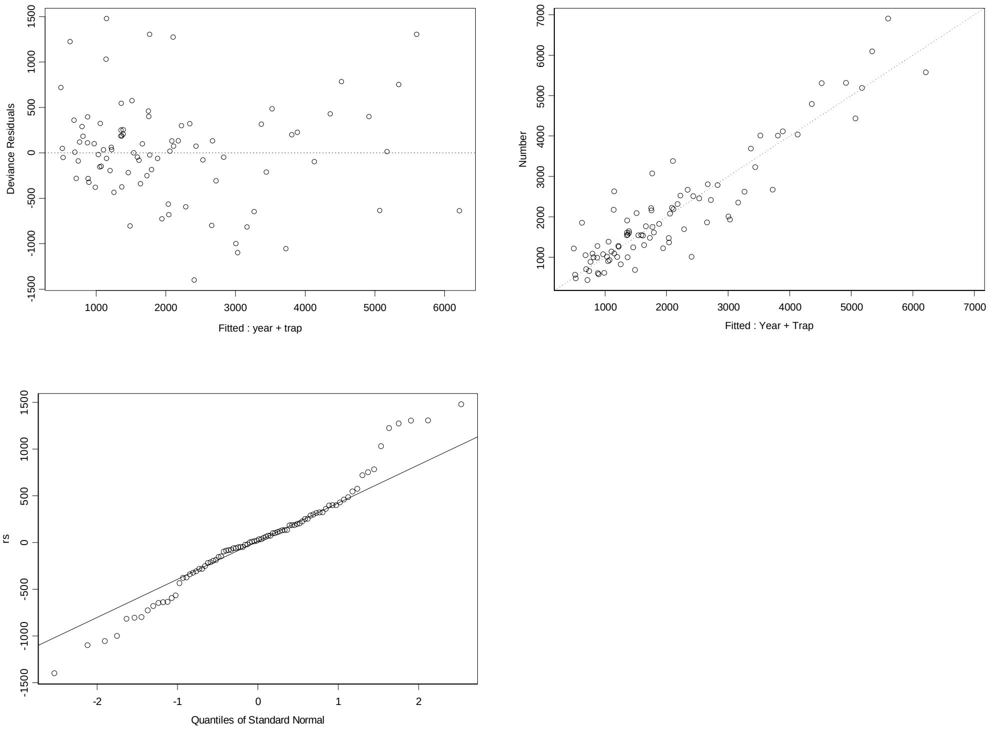

Figure 13. Quasi likelihood. Log link. Number of fish for the whole trap season, 1981-2004.

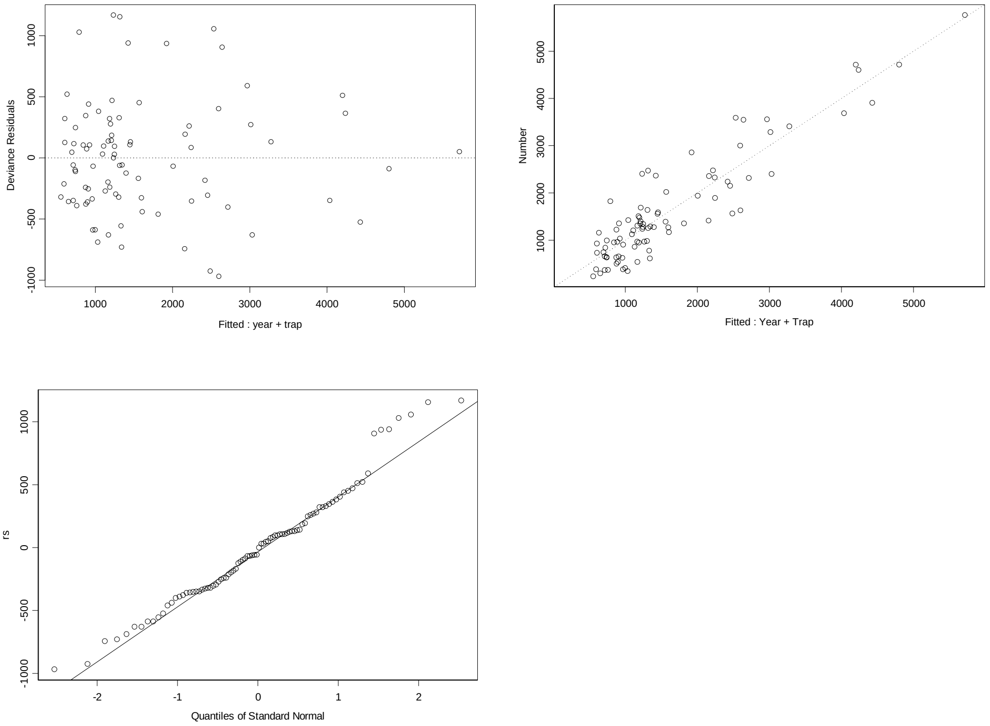

Figure 14. Quasi likelihood. Inverse squared mean link. Number of fish in May, 1981-2004.

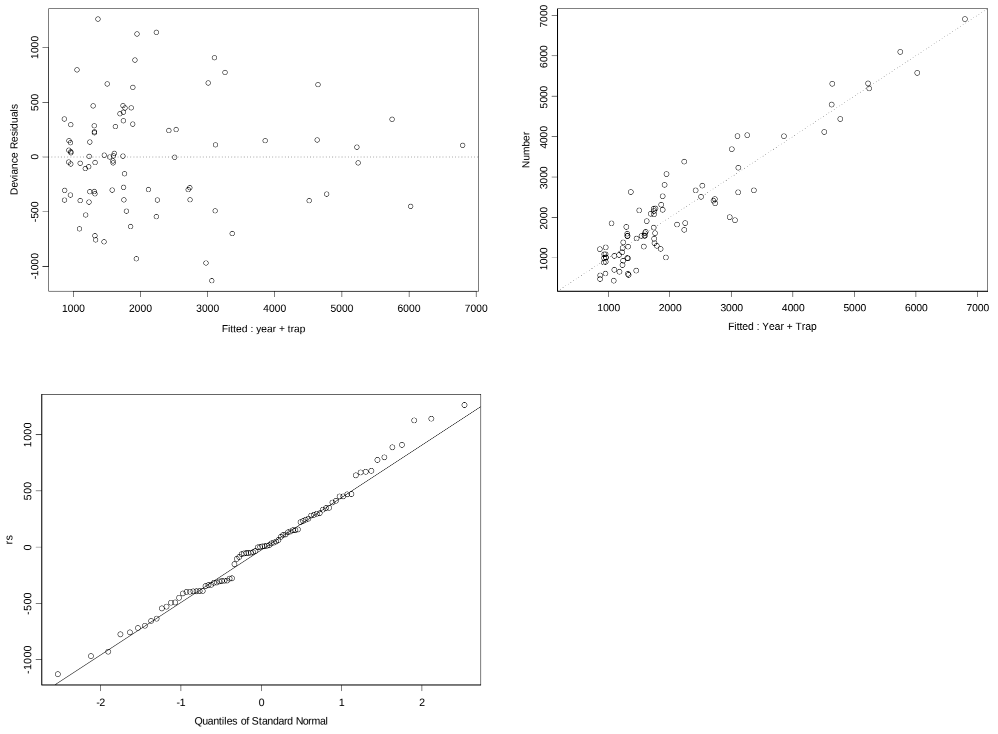

Figure 15. Quasi likelihood. Inverse squared mean link. Number of fish for the whole trap season, 1981-2004.

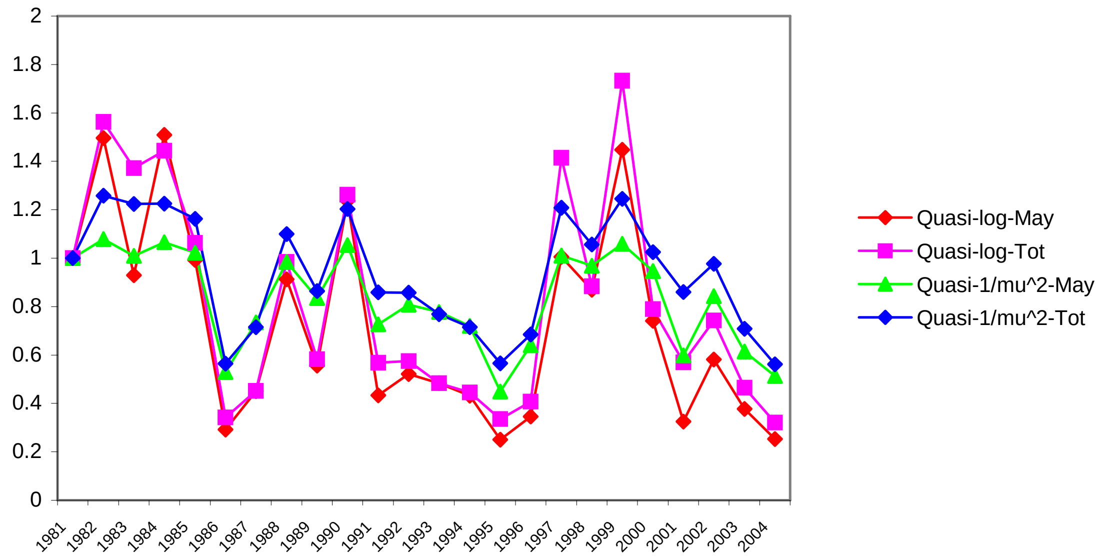

Figure 16. Predicted abundance indices. Quasi- likelihood error distribution.

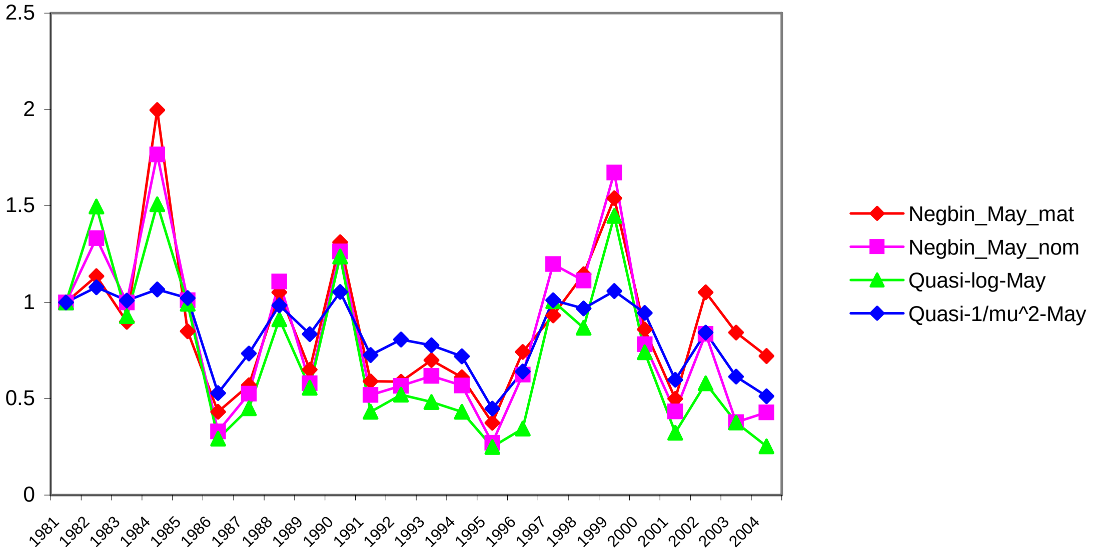

Figure 17. Predicted abundance indices. May data. Negative binomial and quasi- likelihood error distributions.