An updated assessment of the South African Monkfish resource, *Lophius vomerinus*.

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Introduction

An assessment of the South African monkfish resource was initially undertaken by Booth (2004) and comprised a simple replacement yield model given that the application of a modified version of hybrid age-structured surplus production models failed to converge due to the uninformative nature of the data. Furthermore, the data for the West and South Coasts were modeled separately. The analysis was updated by Glazer (2008) and a further update given additional data is presented in this paper. Indications are that replacement yields of around 6900 tons on the West Coast and 1400 tons on the South Coast would maintain biomasses at current levels.

Maximum likelihood estimation

Appendix A provides specifications of the replacement yield model. The analyses of Glazer (2008) incorporated catch data for the period 1991-2006 and survey indices for the period 1991-2007. Additional data are now available (catches to 2010 and survey indices to 2011) and have been included in the updated analyses. Tables 1 and 2 indicate the annual catches and survey estimates respectively for the period under review. It should be noted that surveys utilizing the old and new gear are currently not treated as separate indices in the models. For the West Coast analysis, only the summer survey index is used since no winter surveys have taken place since 1990. For the South Coast analysis only the autumn survey index is used since it covers a greater depth range than does the spring survey (limited to 200m), and hence provides greater coverage of the distribution of monkfish on the South Coast.

Sensitivity to the replacement yield estimates for each Coast is tested for different time periods, initiating from 1991 to 1994 respectively, as well as for three different catchability coefficients (q), namely 0.7, 1.0 and 1.3. A q of 1.0 assumes that the survey biomass estimates equals resource biomass, whereas a q of 0.7 assumes that the survey underestimates the biomass by 30%, and a q of 1.3 assumes that the survey over-estimates the biomass by 30%. Booth (2004) indicated that it is quite possible that the biomass estimates from the surveys are unbiased estimators of absolute abundance given that monkfish are sluggish-swimming demersal fish that do not evade the net vertically; hence the choice of q=1.0. He conceded that there may be some loss under the net, but said that this is likely to be offset by a small increase in catchability by fish being herded into the net by the trawl doors.

AD-Model Builder (Otter Research Ltd. 2000) was used to perform the analyses, with the 90% confidence intervals and coefficients of variation obtained from the inverse Hessian.

Bayesian estimation

Bayesian analysis, to take full account of estimation uncertainty, was employed for two of the twenty four datasets analyzed, namely:

- West Coast, 1991-2011, q=1.0
- South Coast, 1991-2011, q=1.0

The reasons for the choices of these datasets is that a longer time series is expected to produce less variable estimates than a shorter time series, and, as suggested above, the survey estimates of abundance are likely to be unbiased given that monkfish are sluggish-swimming fish that do not evade the net vertically.

The Bayesian analysis was implemented by means of the MCMC (Markov Chain Monte Carlo) method (Gelman *et al*. 1995), and convergence was tested using the Bayesian Output Analysis (BOA) package (Smith, 2004). The diagnostics from the tests of Geweke (1992), Raftery and Lewis (1992) and Heidelberger and Welch (1983) were monitored for instances of non-convergence (these tests are used to show when convergence has not occurred rather than to prove that convergence to the posterior mode has occurred (Gamerman (1997)).

Results and discussion

Maximum likelihood estimates

Observed and estimated indices of abundance are shown in Figure 1 for the various assumptions of catchability, *q*. Figure 2 compares the estimated indices of abundance from the updated assessment with those from the 2008 assessment for the *q*=1 scenario.

Model predicted replacement yield estimates are summarized in Table 3, and Table 4 presents the negative log-likelihood values obtained from each model fit.

An examination of the results in Table 3 reveals that the replacement yield estimates are fairly insensitive to the choice of *q* for each dataset analyzed, and that as the time period analyzed decreases, so the variability in the replacement yield estimate increases. It is evident that a lower *q* yields higher replacement yield estimates on both West and South Coasts. Replacement yield is more poorly estimated on the South Coast, with CVs between 6% and 15%, compared to those on the West Coast with CVs of between 1% and 3%.

For the scenario of *q*=1 replacement yield estimates ranged between 6906 - 6995 tons on the West Coast and 1423 - 1508 on the South Coast. Overall it appears that a replacement yield of ~6900t on the West Coast and ~1400t on the South Coast (for a *q* of 1.0) will maintain biomass at current levels on each Coast respectively (the 2008 model estimated replacement yields were ~6500t on the West Coast and ~800t on the South Coast). The West Coast RY exceeds the annual monkfish catches for 2008-2010 by 11-23%, while on the South Coast the RY is approximately 88-100% of the annual catches for 2008-2010.

Bayesian estimates

For the West Coast dataset a chain of 1 million samples was run with a burn-in of 100 000 discarded and thinning by 100 to reduce any autocorrelation. The estimable parameters for this model passed all of the diagnostic tests. A chain of the same length, burn-in and thinning was applied to the South Coast dataset, but the diagnostic tests indicated that a longer chain was required. A chain of 1.5 million samples with a burn-in of 200 000 discarded and thinning of 100 subsequently passed all the diagnostic tests. Allowing for burn-in and thinning, 9000 and 13 000 model-estimated indices of abundance were generated for the West and South Coast datasets respectively.

Slope statistics were obtained by regressing the natural logarithm of the model estimated biomass against time for the period 2003-2007 to compare with the trends reported for that period in the 2008 assessment. Slope statistics for the most recent 5 years (2007-2011) from the updated assessment were also determined. For each, the posterior mean, median and 90% probability intervals are reported in Table 5. Although the posterior median for the trend for the South Coast remains negative for this updated assessment, trends for both coasts are increased (upward trends larger, downward trends less negative) compared to the earlier analysis in 2008, in part as a result of the decrease in catches over the most recent three years (see Table 1). On the West Coast most of the change in trend comes from considering a period moved on by four years (i.e. 2007-2011 *vs* 2003-2007), whereas for the South Coast this is less clear.

The median annual estimates of abundance and associated 90% probability intervals for the period 2007-2011 are shown in Figure 3.

Table 6 reports the posterior mean, median and 90% probability intervals for RY and B_0 for each coast. Note that these mean and median values for RY are effectively identical to the corresponding MLEs in Table 3.

References

Booth, T. 2004. South African monkfish (*Lophius vomerinus*) stock assessment. Unpublished MCM Demersal Working Group document, WG/05/04/D:A:07. 18pp.

Butterworth, D. and H. Geromont. 1996. Replacement yield calculations for the South coast rock lobster. MCM working group document, WG/07/96/SCL10. 7pp.

Gamerman, D. 1997. Markov Chain Monte Carlo. Chapman and Hall, London. 245pp.

Gelman, A., Carlin, J.B., Stern, H.S. & Rubin, D.B. 1995. Bayesian Data Analysis. Chapman and Hall. 552pp.

Geweke, J. 1992. Evaluating the Accuracy of Sampling-Based Approaches to the Calculation of Posterior moments. *In* Bayesian Statistics 4. pp169-193. *Edited by* Bernardo, J.M., Berger, J.O., Dawid, A.P. and Smith, A.F.M. Oxford University Press, Oxford.

Glazer, J. 2008. Updated replacement yield estimates for the South African Monkfish resource, Lophius vomerinus, and analyses of trends in abundance. Unpublished DAFF (Branch Fisheries) Working Group Document, 2008:WG-Dem:A:01. 10pp.

Heidelberger, P. and Welch, P.D. 1983. Simulation Run Length Control in the Presence of an Initial Transient. Operations Research. 31: 1109-1144.

Otter Research Ltd. 2000. An introduction to AD Model Builder Version 4: For use in non-linear Modeling and Statistics. Otter Research Ltd. (http://www.otter-rsch.com/)

Raftery, A.E. and Lewis, S.M. 1992. How many Iterations in the Gibbs Sampler? *In* Bayesian Statistics 4. pp763-773. *Edited by* Bernardo, J.M., Berger, J.O., Dawid, A.P. and Smith, A.F.M. Oxford University Press, Oxford.

Smith, B.J. 2004. Bayesian Output Analysis Program (BOA) Version 1.1 Users Manual.

Table 1 – South African monkfish catches, disaggregated by coast. (Source: pre-2000: Booth (2004), 2000-2006: R.W. Leslie, DAFF, *pers commn*, 2007-2010: R. Cooper, DAFF, *pers commn*).

Year	West coast (t)	South coast (t)
1991	4637	1246
1992	3860	998
1993	3390	859
1994	3053	1036
1995	5082	1164
1996	4720	1419
1997	6077	881
1998	7210	693
1999	6119	831
2000	7623	1048
2001	9196	1058
2002	7589	1292
2003	5665	1712
2004	7282	1538
2005	7408	1194
2006	5175	2154
2007	5592	2184
2008	6212	1587
2009	5606	1404
2010	6221	1595

Table 2 – Summary of the research cruise data[1] collected onboard the *RV Africana* between 1991 and 2011. Italicized bold values indicate biomass estimates from surveys utilizing the new gear.

Year	Biomass estimate (t)	SE (t)
	West Coast – summer index	
1991	10960	1314
1992	16178	2081
1993	15588	1785
1994	23888	3090
1995	22634	2274
1996	21310	2951
1997	25024	3715
1998	No survey	
1999	28811	3108
2000	No survey	
2001	No survey	
2002	25188	2854
2003	22711	2801
2004	***27235***	***2846***
2005	***28242***	***3347***
2006	21015	2379
2007	***28695***	***3823***
2008	***31595***	***3929***
2009	***27846***	***2909***
2010	39065	7133
2011	***33000***	***4361***
	South Coast – autumn index	
1991	10558	4633
1992	9493	1179
1993	9793	1041
1994	11912	2268
1995	10697	1409
1996	10723	1800
1997	6813	1091
1998	No survey	
1999	14015	2253
2000	No survey	
2001	No survey	
2002	No survey	
2003	6817	1040
2004	***9479***	***1939***
2005	***6974***	***1216***
2006	14487	2143
2007	***8545***	***1519***
2008	***19131***	***2530***
2009	***17574***	***2231***
2010	18100	4642
2011	***10105***	***1655***

[1] These indices differ slightly from the ones used in the assessment conducted in 2008 as a result of a recent validation exercise conducted by Tracey Fairweather (DAFF) on the research data.

Table 3 – Maximum likelihood estimates of replacement yield (t) for the South African monkfish resource for different datasets and assumed values of *q*. Asymptotic normal 90% confidence intervals and the CV corresponding to each MLE are also shown.

Data analysed	West coast	South coast
	q=1.3	
1991-2011	6683.2 [6536.1, 6820.6] (1.1%)	1388.6 [1201.5; 1563.3] (6.5%)
1992-2011	6701.3 [6539.1, 6874.9] (1.4%)	1415.9 [1211.1; 1607.2] (7.6%)
1993-2011	6824.7 [6659.7, 7001.3] (1.4%)	1437.7 [1208.6; 1651.8] (8.3%)
1994-2011	6867.8 [6668.3, 7081.0] (1.6%)	1465.0 [1223.8; 1723.1] (9.2%)
	q=1.0	
1991-2011	6906.1 [6733.9, 7066.9] (1.3%)	1423.3 [1186.5; 1644.5] (8.7%)
1992-2011	6888.7 [6686.5, 7077.7] (1.5%)	1455.5 [1195.8; 1698.2] (9.3%)
1993-2011	6993.8 [6789.1, 7212.9] (1.6%)	1478.6 [1187.8; 1750.3] (10.3%)
1994-2011	6995.3 [6747.5, 7260.6] (2.0%)	1508.3 [1201.8; 1836.3] (11.4%)
	q=0.7	
1991-2011	7309.3 [7060.5, 7541.8] (1.8%)	1488.8 [1159.0, 1796.9] (11.6%)
1992-2011	7222.5 [6944.7, 7482.0] (2.0%)	1530.2 [1167.8, 1868.7] (12.4%)
1993-2011	7294.5 [6997.0, 7612.9] (2.3%)	1555.6 [1149.6, 1934.9] (13.7%)
1994-2011	7225.1 [6876.3, 7598.4] (2.7%)	1589.8 [1161.7, 2048.0] (15.1%)

Table 4: Negative log likelihood values from assessments of the South African monkfish resource for different datasets and assumed values of *q*.

Data analysed	West coast	South coast
	q=1.3	
1991-2011	-26.90	-8.88
1992-2011	-25.00	-8.09
1993-2011	-25.65	-7.20
1994-2011	-23.81	-6.35
	q=1.0	
1991-2011	-29.45	-9.61
1992-2011	-27.39	-8.75
1993-2011	-26.75	-7.79
1994-2011	-24.59	-6.87
	q=0.7	
1991-2011	-29.97	-10.33
1992-2011	-28.60	-9.40
1993-2011	-26.82	-8.37
1994-2011	-24.92	-7.39

Table 5 – Mean, median and 90% probability intervals associated with the slope statistic (the average percentage change in abundance per annum for select 5-year periods) derived from Bayesian analyses of select datasets from the West and South Coasts respectively. The slope statistics derived from the assessment conducted in 2008 (related to the period 2003-2007), are also shown for comparison with the updated assessment model.

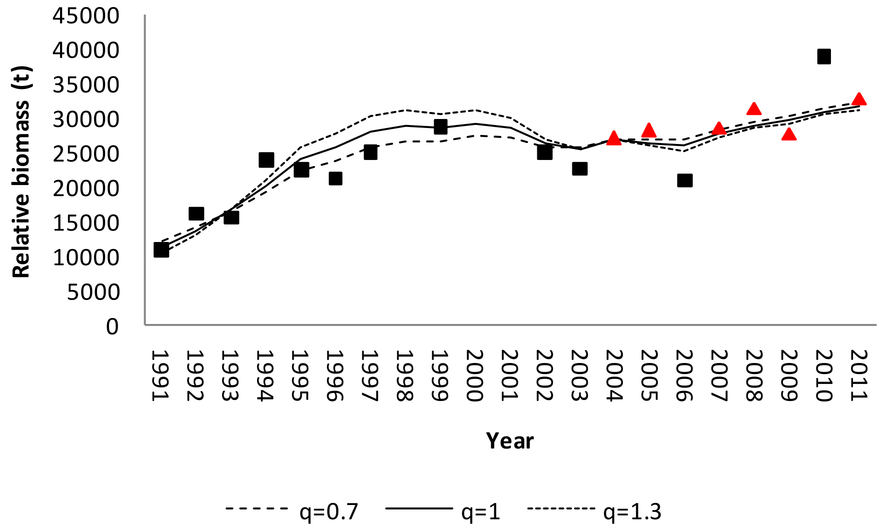
Model	Statistic	West Coast	South Coast
2008 assessment	**Mean**	0.76	-5.56
(2003-2007)	**Median**	0.78	-5.42
	90% PI	-0.09; 1.53	-9.0; -2.55
2011 assessment	**Mean**	1.23	-1.35
(2003-2007)	**Median**	1.24	-1.30
	90% PI	0.63; 1.78	-3.33; 0.47
2011 assessment	**Mean**	3.34	-2.05
(2007-2011)	**Median**	3.35	-1.91
	90% PI	2.96; 3.69	-4.6; 0.07

Table 6: Mean, median and 90% probability intervals for B_0 and RY derived from the Bayesian analyses of select datasets from the West and South Coasts respectively.

Coast	Parameter	mean	median	90% PI
West	B_0	11389.1	11366.5	9897.6; 12992.3
	RY	6906.0	6906.0	6738.4; 7074.8
South	B_0	9000.2	8864.8	6526.6; 11936.3
	RY	1425.7	1424.4	1193.4; 1661.9

Figure 1: Observed (squares represent the old gear and triangles the new gear) and model predicted indices of abundance for the period 1991-2011 for various assumptions of *q*.

a) West Coast



b) South Coast

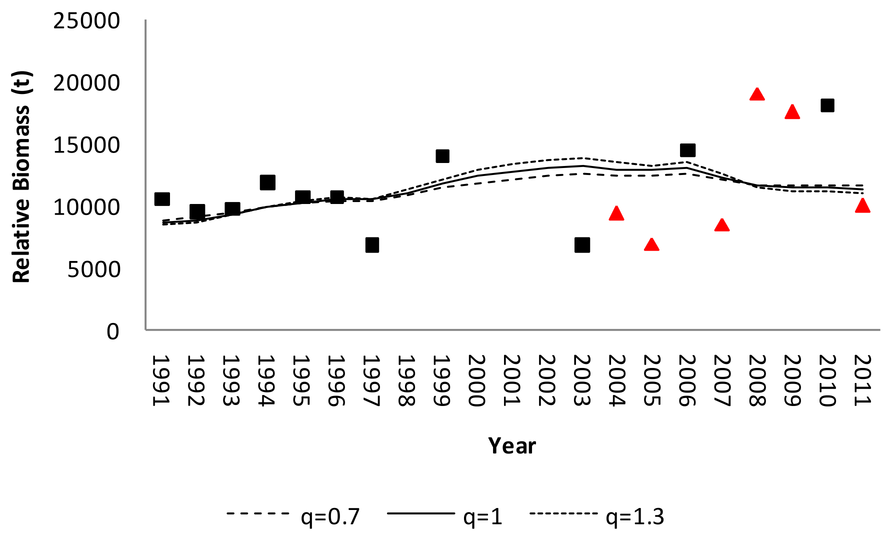
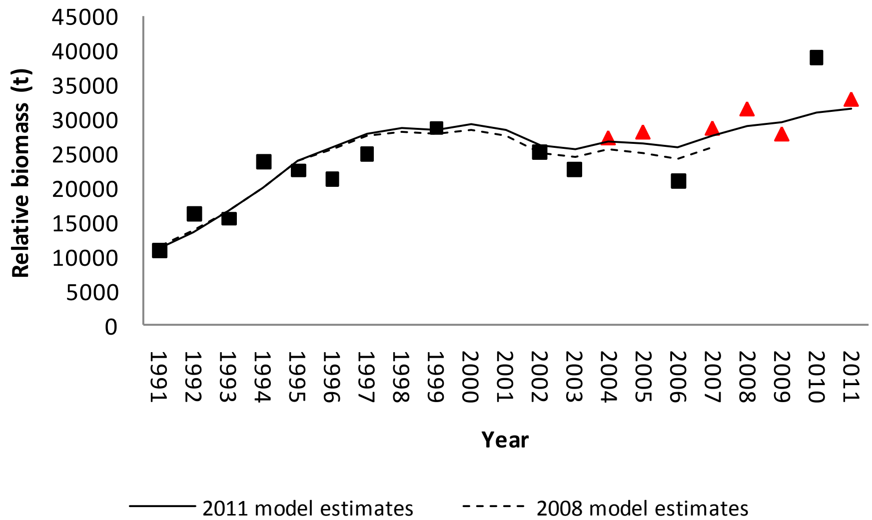


Figure 2: Observed (squares represent the old gear and triangles the new gear) and model predicted indices of abundance for *q*=1 as derived from the 2008 and 2011 assessments respectively.

a) West Coast



b) South Coast

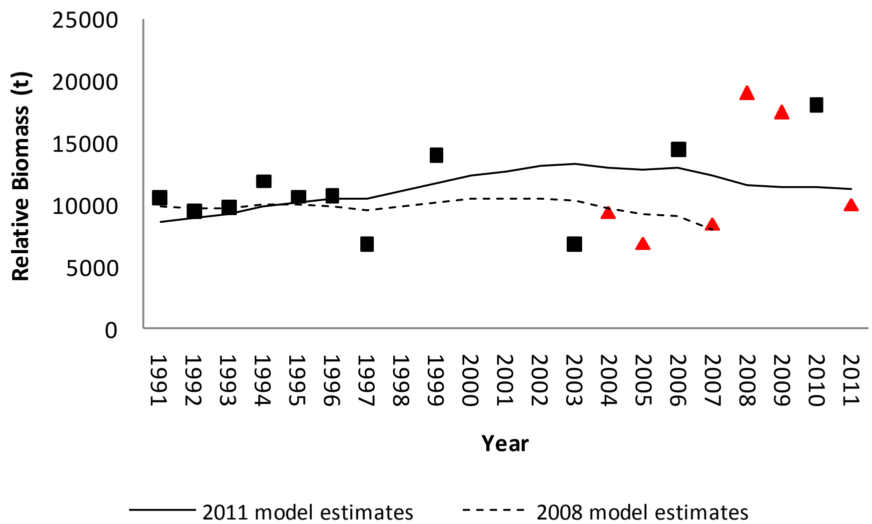
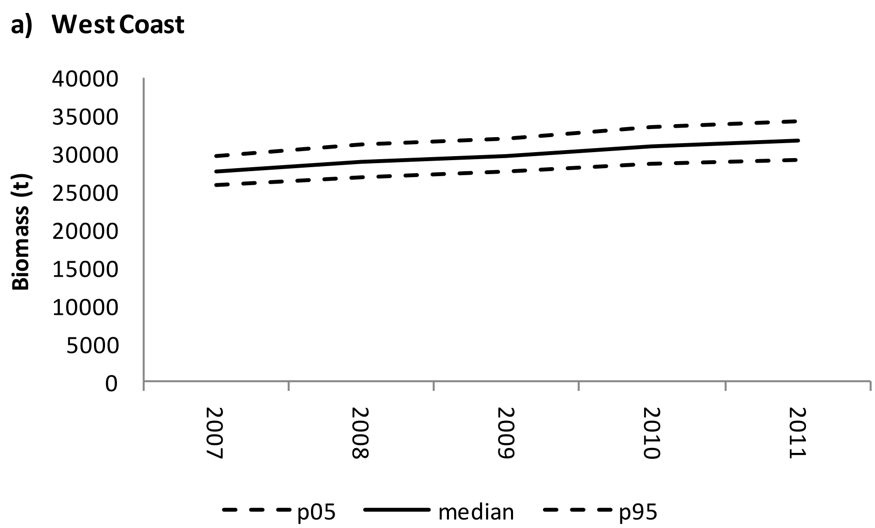
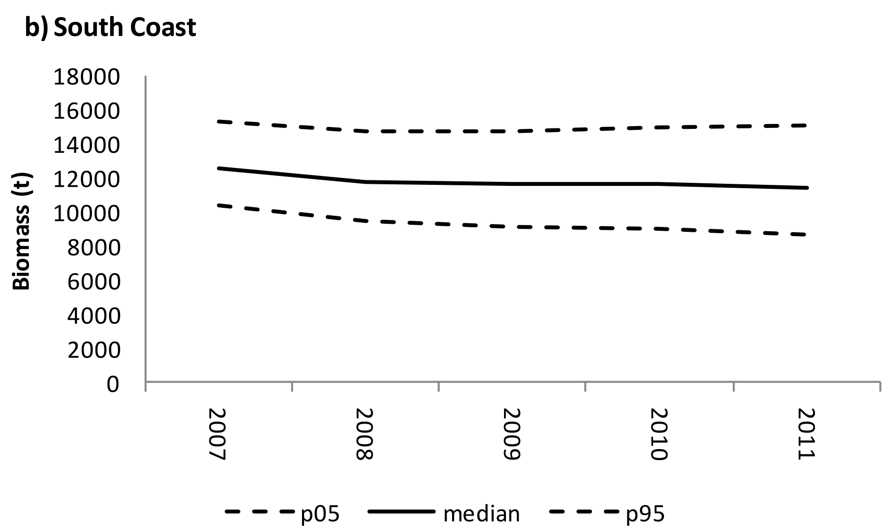


Figure 3: Median annual estimates of abundance and associated 90% probability intervals for the most recent 5 years derived from Bayesian analyses of select datasets (*q*=1.0 and period=1991-2011) from the West and South Coasts respectively.





Appendix 1 – Estimating replacement yield

Within a production modeling framework, biomass, B, is calculated from biomass in the previous year, and the net difference in surplus production, $g(B)$, and catch, C, from the previous year such that

$$B_{y+1} = B_y + g(B_y) - C_y$$

For biomass to remain stable, then the harvest (and consequently the replacement yield) equals the annual surplus production of the population such that $RY_y = g(B_y \mid \theta)$ where θ is the parameter vector that describes surplus production. If θ cannot be adequately estimated, annual surplus production can be set to a value equal to that of the average replacement yield (Butterworth and Geromont, 1996) such that

$$B_{y+1} = B_y + RY - C_y$$

The likelihood is calculated assuming that the abundance indices are log-normally distributed about their expected values:

$$I_y^i = q_i B_y e^{\varepsilon_y^i}$$

where I_y^i is the abundance index for year *y* and series *i*, $q_i B_y$ is the corresponding model estimate, and ε_y^i is the observation error, $\sim N(0, \sigma_i^2)$, corresponding to series *i* in year *y*.

The estimate of average replacement yield (over some suitable time period) and the initial biomass in the first year of the time period can be estimated by maximizing a likelihood of the form:

$$L = \prod_{i=1}^{n_t} \prod_{y=1}^{n_y} \left[\frac{1}{\sqrt{2\pi\sigma_i^2}} e^{-\frac{1}{2\sigma_i^2}\left(\ln(I_y^i) - \ln(q_i B_y)\right)^2} \right]$$

The contribution of each abundance index to the negative log-likelihood function (after the removal of constants) is given by:

$$-\ell n L_i = n_i \ell n(\hat{\sigma}_i) + \frac{n_i}{2}$$

<u>Bayesian estimation</u>

For a Bayesian implementation, the following priors were specified for the estimable parameters with the intent that they be uninformative:

RY ~ U[0, 1000000]
B_0 ~ U[5,1000000]