Preliminary results from an assessment of the South African *P. delagoae* rock lobster resource to investigate the recovery of the resource between two periods of experimental trap-fishing.

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ABSTRACT

Data from two trap-fishing experiments carried out on the east coast of South Africa targeting the *P.delagoae* rock lobster, along with trawl-catch information for the years 1985-2009, are used to develop a population assessment for this species. The assessment aims to investigate the extent, if any, of the recovery of the rock lobster between the two periods of fishing, as well as assess the current stock level and potential future sustainable catch. The model is an age-structured model and includes age-to-length conversions in order to assess the fit of the model-predicted catches to length data available from the trap experiments.

KEYWORDS: *P. DELAGOAE* ROCK LOBSTER, TRAP FISHERY, BARANOV, GLM

INTRODUCTION

The rock lobster *P.delagoae* occur on rocky substrata as well as trawlable softer substrata of mud or sand off the east coast of South Africa and Mozambique. Pre 1994, the species was fished exclusively through trawling, starting in 1920 with exploratory trawling by the S.S "Pickle" on the KZN coast. After the 1960s, lobster-directed trawl fishery progressively diversified to catch other species (Groeneveld, 2000). An experimental survey was started in 1994 to investigate the potential of trap-fishing for *P. delagoae* on the rocky substrata off South Africa. This resulted in a sharp decline in catch rates and hence the experiment was terminated in 1997 (Groeneveld, 2000). A second experiment was run 10 years later from 2004-2007 to determine if the stock had recovered and could sustain a trap fishery (Boucher, 2007). Details of these two experiments are given in Groeneveld (2000), Boucher (2007) and the reports of these experiments.

This assessment aims to investigate the extent of the recovery of the *P.delagoae* rock lobster between the two periods of experimental trap-fishing and to assess the current stock levels as well as potential future sustainable catch. The age-structured model allows model-predicted catch-at-length proportions to be computed and fit to the length data available from the trap experiments.

DATA

Catch data

Catch numbers from both experimental trap fisheries are known and have been provided by Fisheries, Department of Agriculture, Forestry and Fisheries (DAFF). Exploratory trawling first started in 1920, but quantities taken are unknown. A trawl catch series for the years 1985 to 2009 has been provided by Fisheries, DAFF, but information on the catches of *P. delagoae* and other crustaceans by the trawl fishery is sketchy for the period 1961-1970 and completely absent for the period between 1971 and 1984 (Groeneveld, 2000). *P.delagoae* straddles the border between South Africa and Mozambique and is managed according to two completely separate management approaches. An unknown proportion of the catches reported for 1961-1970 emanated from outside South African waters, from international waters off Mozambique (Berry, 1972). In this first preliminary assessment, the pre-1985 catches have not been taken into account. The post-1985 catches are given in Table 1 and the 1961-1970 catch series is given in Table 2.

Trend information

Incomplete catch data for the first experiment prevented the running of an independent GLM. However, a GLM was run on the data from the second experiment to obtain a standardised CPUE series for the years 2004-2007, and an approach was devised to produce a comparable CPUE series for the first experiment based on the GLM results given in Groeneveld (2000). The GLM approach is given in the Appendix and the results are reported in Table 3.

Tag-recapture data

Tag-recapture data are available from the first experiment and these were used to verify the von Bertalanffy growth curve parameters obtained from Groeneveld (2000).

Length data
Catch-at-length data are available from the trap experiments for 1994-1997 and for the years 2004 and 2007. These data were incorporated in the model to inform selectivity. The reliability of these data is questionable, as they were taken from excel files that did not give descriptions or explanations of the data. Data for the years 2005-2006 were not provided.

Assumptions made
The following assumptions were made on parameter values and relations needed for the assessment:

Growth curve parameters: ℓ_∞ = 130mm, κ = 0.13, ℓ_0 = 1.5mm (growth curve is shown in Figure 12)

Weight-length relation: $w(a) = 0.0018\ell^{2.77}$ (Boucher, 2007)

METHODS

Population Dynamics:
Note that difficulties arising from the use of the simpler Pope equations in an initial assessment attempt led to the use of the Baranov equations given below.

The population dynamics are given by:

$$N_{y+1,0} = R\left(B_{y+1}^{sp}\right) \tag{1}$$

$$N_{y+1,a+1} = N_{y,a}e^{-(M+S_aF_y)} \qquad 0 \le a \le m-2 \tag{2}$$

$$N_{y+1,m} = N_{y,m}e^{-(M+S_aF_y)} + N_{y,m-1}e^{-(M+S_aF_y)} \tag{3}$$

where

$N_{y,a}$ is the number of rock lobsters of age *a* at the start of year *y*,

M is the natural mortality for *P. delagoae* rock lobster,

F_y is the instantaneous fishing mortality for year *y*

$R\left(B_{y+1}^{sp}\right)$ is the recruitment for year *y+1* given by the Beverton-Holt stock recruitment relationship (see equation (6)),

B_y^{sp} is the spawning biomass at the start of the year *y*,

m is maximum age considered, and

S_a is the selectivity function, assumed here to be a logistic curve given by

$$S_a = \frac{1}{1-e^{-(a-a_s)/\delta}} \tag{4}$$

where a_s and δ are estimatable parameters.

Stock-recruitment Relationship
The spawning biomass in year *y* is given by:

$$B_y^{sp} = \sum_{a=1}^{m} w_{a+0.5}f_aN_{y,a} = \sum_{a=a_m}^{m} w_{a+0.5}N_{y,a} \tag{5}$$

where

f_a is the proportion of lobsters of age *a* that are mature (assumed knife-edge at age a_m, taken to be 5 years in this assessment), and

$w_{a+0.5}$ is the mass of a fish at age *a*+½, as catches are modelled as spread uniformly over the year.

The Beverton-Holt stock recruitment relationship relates the number of recruits at the start of year *y* to the mature population sector, and is given by:

$$R(B_y^{sp}) = \frac{\alpha B_y^{sp}}{\beta + B_y^{sp}} \qquad (6)$$

with

$$\alpha = \frac{0.8hR_0}{h-0.2} \qquad (7)$$

$$\beta = \frac{0.2K^{sp}(1-h)}{h-0.2} \qquad (8)$$

where

$R_0 = K(1-e^{-M})$ is the recruitment at pristine population level K (in numbers),

K^{sp} is the pristine spawning biomass at pristine levels, and

h is the steepness of the recruitment curve. It is the ratio of recruitment when the mature population is 20% of its pristine level to that when it is pristine, and is taken in this assessment to be 0.75.

The likelihood function

CPUE contribution

The model treats the CPUE estimates from the GLM output as relative indices of abundance. It is assumed that the observed relative abundance index is log-normally distributed about its expected value:

$$I_y = qN_y^{\exp} e^{\varepsilon_y} \qquad (9)$$

where

I_y is the relative abundance (CPUE index) from the GLM assessment for year *y*,

q is the catchability coefficient,

ε_y is from $N(0,\sigma^2)$, and

$N_y^{\exp}$ is the model estimate of observed exploitable population size at the start of year *y*, given by:

$$N_y^{\exp} = \sum_a S_a N_{y,a} \qquad (10)$$

The σ parameter is the residual standard deviation which is estimated in the fitting procedure by its maximum likelihood value:

$$\hat{\sigma} = \sqrt{1/\bar{n}\sum_y \left(\ln I_y - \ln q - \ln N_y^{\exp}\right)^2} \qquad (11)$$

where

$\bar{n}$ is the number of data points in the CPUE series, and

q is the multiplicative bias, estimated by its maximum likelihood value:

$$\ln \hat{q} = 1/\bar{n}\sum_y \left(\ln I_y - \ln N_y^{\exp}\right) \qquad (12)$$

Length data contribution

The model provides estimates of the catch-at-age ($C_{y,a}$) by number. These can be converted into proportions of the catch of age *a*:

$$p_{y,a} = C_{y,a} / \sum_{a'} C_{y,a'} \tag{13}$$

Using the von Bertalanffy growth curve, these proportions at age can be converted to proportions at length, under the assumption that the length-at-age distributions remain constant over time:

$$p_{y,\ell} = \sum_{a} p_{y,a} A_{a,\ell} \tag{14}$$

where $A_{a,\ell}$ is the proportion of animals of age *a* that fall into length group ℓ. The *A* matrix has been calculated under the assumption for each age *a*, the length-at-age is normally distributed about the mean length given by the growth curves. The standard deviation used for this normal distribution is a function of age and proportional to the mean length:

$$\sigma_a = 0.01\bar{\ell}_a \tag{15}$$

where $\bar{\ell}_a$ is the mean length for age *a* obtained from the growth curve.

To compute the likelihood contribution, suppose in year *y*, $r_{y,l}^{obs}$ rock lobsters of length *l* are caught. The model gives $p_{y,l}^{\text{mod}}$, the predicted proportion of the total catch that corresponds to animals of length *l*. Under the assumption that these proportions follow a multinomial distribution, the probability that r_{y,l_1}^{obs} catches are observed for length l_1, r_{y,l_2}^{obs} catches are observed for length l_2, … and r_{y,l_n}^{obs} catches are observed for length l_n, is given by

$$\frac{\sum_{i=1}^{i=n} r_{y,l_i}^{obs}}{r_{y,l_1}^{obs}!\, r_{y,l_2}^{obs}! \ldots r_{y,\ln}^{obs}!} p_{y,l_1}^{\text{mod}} p_{y,l_2}^{\text{mod}} \ldots p_{y,\ln}^{\text{mod}} \tag{16}$$

Fishing mortality

The catch of animals of age *a* taken in year *y* is given by:

$$C_{y,a} = S_a F_y N_{y,a} \frac{1 - e^{-(M + S_a F_y)}}{M + S_a F_y} \tag{17}$$

The total catch by weight is then given by

$$C_y^w = \sum_{a=0}^{m} w_a C_{y,a} \tag{18}$$

Thus given S_a, $N_{y,a}$ and *M*, an instantaneous fishing mortality has to be found such that the right hand side of equation 14 equals C_y^w from the catch history. In other words, the roots of the equation

$$g(F_y) = C_y^w - \sum_{a} w_a S_a F_y N_{y,a} \frac{1 - e^{-(M + S_a F_y)}}{M + S_a F_y} \tag{19}$$

have to be found.

The F_y values have been estimated by adding $\sum_{y} (g(F_y))^2$ to the negative log likelihood

The final (penalised) negative log likelihood is thus given by:

$$-\ln L = n \ln \sigma + \frac{1}{2\sigma^2} \sum_{y} \left(\ln I_y - \ln q - \ln \ln N_y^{\exp}\right)^2 - \sum_{Y} \sum_{\ell} r_{y,\ell}^{obs} \ln p_{y,\ell}^{\text{mod}} + w \sum_{y} (g(F_y))^2$$

The negative log likelihood is then converted into a likelihood value (L), and both a simplex method and the built-in ADMB minimiser were used to minimise $-lnL$ and therefore find the maximum likelihood estimates for the estimatable parameters.

RESULTS

Table 4 gives the model-estimated parameter values and their approximate 95% confidence intervals. Current population levels as fractions of the initial levels are also given. Figure 1 shows the trajectory of the exploitable population (in numbers), as well as the fit to the CPUE trend data. Figure 2 shows the exploitable biomass, and Figure 3 shows this same quantity as a fraction of initial biomass. Figure 4 shows projections into the future under the assumption of different catch levels. Figures 5a and b show the reported catch in tons and the model estimated numbers caught. Figure 6 shows the estimated instantaneous fishing mortality for each year. Figures 7 and 8 illustrate the reported catch series from three different sources. Figures 9 and 10 demonstrate the fit to length data, and Figure 11 splits the 2004 catch-at-length data into the three experimental regions. Lastly Figure 12 shows the von Bertalanffy growth curve that was assumed for this model.

DISCUSSION

A major issue in this assessment is the uncertainty about the catch data. Berry (1972) reports that exploratory trawling started as early as 1920. Although quantities caught are unknown, it is mentioned that catches of over 10 000 lobsters were taken in a 1.5 hour drag, suggesting that the catches were not insignificant. Berry (1972) gives a table of catches for the years 1961-1970, but states that these are unreliable as they include an unknown proportion of Mozambique catches. This preliminary assessment does not take pre-1985 catches into account and assumes that the population was at its pristine level in 1985, but this is clearly not the case. As such this is an issue which needs to be addressed in future work. Figures 7 and 8 show reported catch series from various sources. There is a slight discrepancy between the data series provided by Fisheries, DAFF and that found in Groeneveld (2000) for the overlapping years 1995-1998 (see Figure 7). While this should not have an appreciable impact on this assessment, it may be worth investigating. One last concern regarding treatment of catches in this assessment is that trap and trawl catches have been treated identically. One would assume that the selectivity for animals taken by these two methods would not be the same, and thus future assessments should possibly try to take this into account.

A concerted effort has been made to obtain a comparable CPUE series for the two trap fishing experiments (see Appendix). As a first attempt, a single q value (the catchability coefficient, see equation (9)) was computed for both series. It was found, however, that a much better fit to the data was obtained when allowing a different q value to be computed for each of the two series. A restriction was imposed that the q_2/q_1 should not be greater than 2. The assessment seemed to favour a ratio of close to 2, suggesting that the catchability of the lobsters doubled from the first experiment to the second. The feasibility of this result still needs to be explored. There is some concern about the validity of the CPUE series. While best efforts were made to obtain a comparable series, missing and incomplete data made this difficult, and as such the results should be taken as preliminary. That said, the assessment does indicate that the lobster numbers did not increase substantially in the 10 years between the two experimental trap fisheries (see Figure 1). However, for some reason, it seems that the animals were more catchable in the second experiment than in the first. As a next step, a second model could be implemented which splits the stock into a fished and unfished sector. This may better explain the trends shown by the data. The question of the validity of the CPUE series as an index of abundance should be considered when assessing the reliability of these results.

This assessment allowed the natural mortality to be estimated. Exploration of the likelihood profile showed that there was a definite maximum likelihood associated with a particular M value. Groeneveld (2000) gives 0.09-0.15y^{-1} as a reasonable range, so the M value supported by the data in this assessment seems rather low (0.067yr^{-1}). This last value suggests that the species is longer lived than previously thought.

One aspect of the assessment was to determine sustainable future catches. Figure 4 shows projections into the future under different catch assumptions. Based on this figure, current stock levels (estimated at 3.5% of initial biomass, see Table 4) would be able to sustain an annual catch of at most 4 tons, at which catch rate the stock levels would not show any substantial growth in the future.

The logistic form of the selectivity function prevented an MSY value from being computed explicitly. A crude method for overcoming this is to set the catch at a constant and run the population dynamics for a long period of time. If the catch is at or below MSY, then the population will settle at a non-zero value. As soon as the catch exceeds MSY, the population will die out. This catch value can thus be adjusted until the maximum value is found for which the population does not go into decline. Using this simple method, an MSY of 10tons was estimated.

The extension to the model to include length data proved to be challenging. Catch-at-length data for 1994-1997 shows a peak at the 130^{+}mm length group, where as the years 2004 and 2007 both show a peak at ~65mm (see Figure 9). Closer inspection of the data, as well as the graphic displays given in the experimental reports, revealed that for the second experiment, large numbers of smaller animals were caught in the South region, and this is responsible for the above-mentioned peak at lower lengths (see Figure 11). This trend is not visible in the data for the first experiment, but lack of information about the available data files has made it impossible to explore this further. The implication for the assessments is that the model battles to fit both these peaks. The model is age-structured and conversions from age to length involve the von Bertalanffy growth curve (see Figure 12), as well as a σ value which determines the size of the uncertainty about the mean length-at-age value given by the von Bertalanffy equation (see equation (15)). The value of σ was fixed rather than estimated in the model, and it was found that low values favour the peak at lower lengths, whereas higher values of σ provide a better fit to the 130^+mm peak. A possible explanation of this is that a large value of σ allows the modelled lobsters to reach larger sizes, whereas a small value enforces a stricter adherence to ℓ_∞=130mm, thus not providing sufficient large animals to fit the 130^+mm peak. It was decided to set σ at an intermediate value of 0.1. The fit to the length data can be seen in Figure 9. The length data were used to inform the selectivity function (equation (4)) and the data seemed to support an almost knife-edge selectivity with age-at-selectivity a_s=4.34, and δ=0.049 (see Figure 13).

Lastly, the growth parameter values need some verification. Tag-recapture data from the first experiment was used to check the von Bertalanffy growth curve parameters obtained from Groeneveld (2000), but yielded an ℓ_∞ that seems low (ℓ_∞*=120mm*, κ*=0.13*) . Groeneveld (2000) quotes an ℓ_∞ that ranges from 129.3-161.2mm and a κ value from 0.0691-0.0714. The values used in this assessment are given at the beginning of this document, and model sensitivity to these values should be investigated.

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Table 1: Historic catch series for *P. delagoae* rock lobster

Year	Trawl fishery Catch (tons)		Trap fishery Catch (tons)	Trap fishery Catch (numbers)	Total Catch (tons)
1985	27.2	*	0	0	27.2
1986	59.9	*	0	0	59.9
1987	36.8	*	0	0	36.8
1988	30.5	*	0	0	30.5
1989	16.3	*	0	0	16.3
1990	13.7	*	0	0	13.7
1991	22.2	*	0	0	22.2
1992	37.3	*	0	0	37.3
1993	37.8	*	0	0	37.8
1994	24.4	*	89.5 *	24532 °	113.9
1995	10.826	**	50.0 *	21354 °	60.826
1996	10.194	**	39.5 *	23071 °	49.694
1997	10.108	**	7.4 *	6000 °	17.508
1998	5.881	**	0	0	5.881
1999	7.824	**	0	0	7.824
2000	11.113	**	0	0	11.113
2001	8.824	**	0	0	8.824
2002	9.079	**	0	0	9.079
2003	5.372	**	0	0	5.372
2004	4.021	**	25.97 °°	46849 °°	29.991
2005	4.497	**	15.5 °°	29591 °°	19.997
2006	4.604	**	13.62 °°	30567 °°	18.224
2007	5.136	**	11.09 °°	33904 °°	16.226
2008	4.712	**	0	0	4.712
2009	3.912	**	0	0	3.912

* Groeneveld (2000)
** Fisheries, DAFF data (Neil van den Heever, pers. commn)
° Fisheries, DAFF data (Excel spreadsheet, "Pdsize comp data, 94-97.xls"), possibly incomplete
°° Scientific reports on experiments for 2004-2007

Table 2: Pre-1985 catches as reported in Berry (1972). Note that an unknown proportion of these catches emanate from Mozambique.

Year	Catch (tons)
1961	300
1962	200
1963	100
1964	200
1965	200
1966	100
1967	*
1968	*
1969	100
1970	100

*Unspecified but more than nil.

Table 3: Relative abundance trend data: CPUE series from the GLM assessment (see Appendix).

Year	CPUE
1994	416.92
1995	436.06
1996	176.82
1997	125.13
2004	282.32
2005	319.91
2006	266.94
2007	97.71

Table 4: Model parameter estimates. The approximate 95% confidence interval (taken to be ± twice the standard deviation) is shown in the parenthesis.

Parameter	**Estimate**
K	879 400 [623 200, 1 135 600]
M	0.067 [0.022, 0.112]
N_{2010}/K	0.145 [0.101, 0.190]
B_{2010}/B_0	0.035 [0.018, 0.052]
N_{2010}^{exp}/K^{exp}	0.078 [0.044, 0.113]
B_{2010}^{exp}/B_0^{exp}	0.026 [0.007, 0.045]

Figure 1: Estimated trajectory for exploitable population in numbers. The CPUE fit is shown. The dashed lines indicate a probability envelope corresponding to the approximate 95% confidence interval. Values to the right of the vertical dashed line show projections into the future, under the assumption of zero catch.

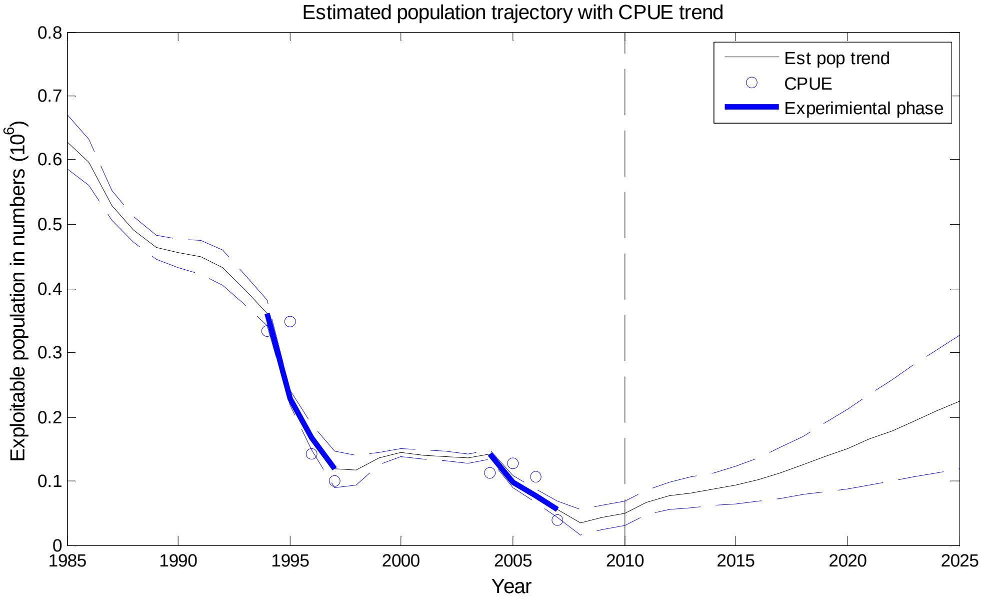


Figure 2: Estimated trajectory for exploitable biomass in tons under the assumption of zero future catch.

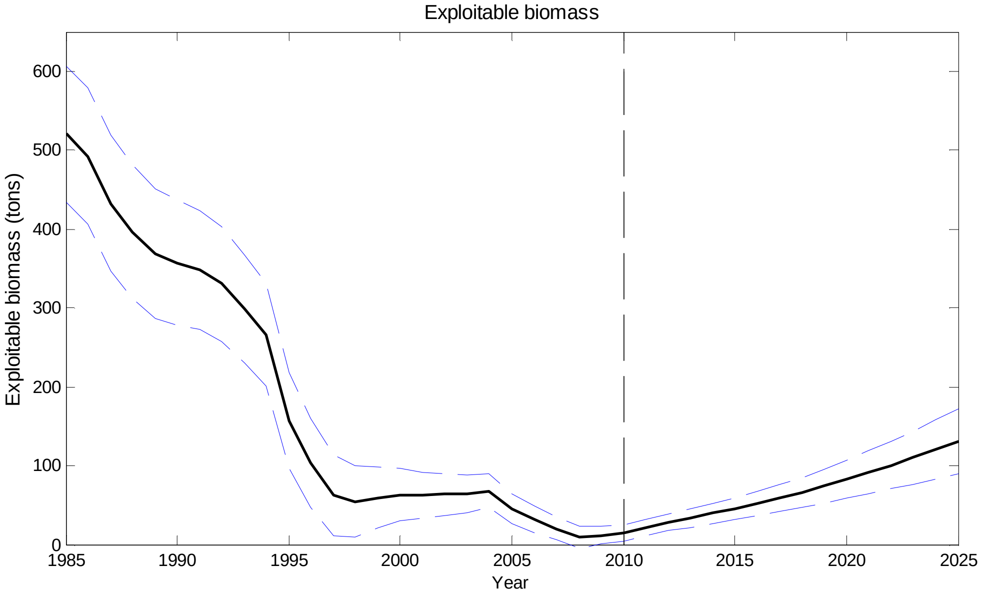


Figure 3: Exploitable biomass as a fraction of initial biomass. The values to the right of the dashed line show projections into the future under the assumption of zero future catch.

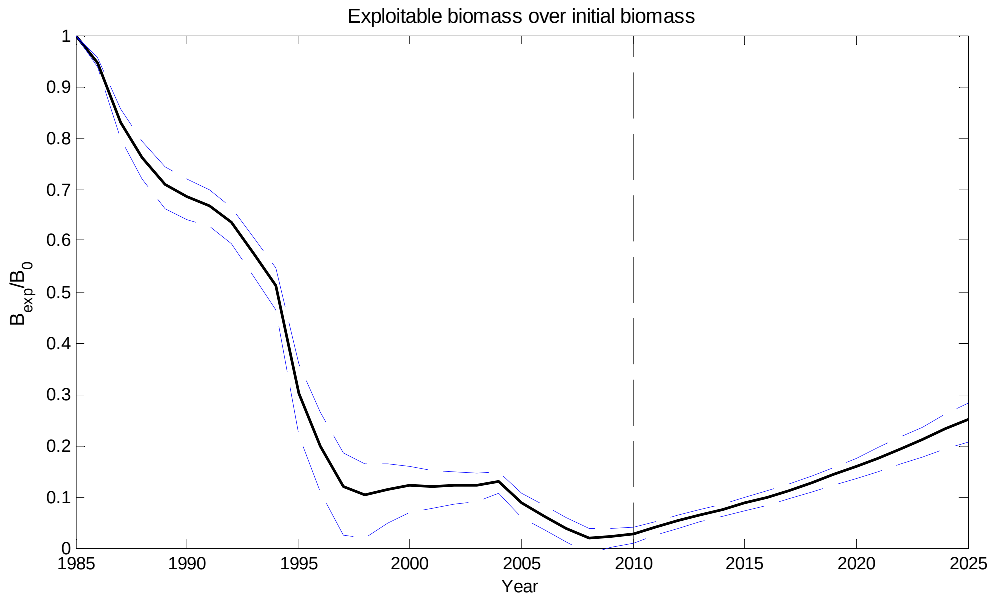


Figure 4: Population trajectories for four different future catch scenarios. The values to the right of the dashed line show projections into the future.

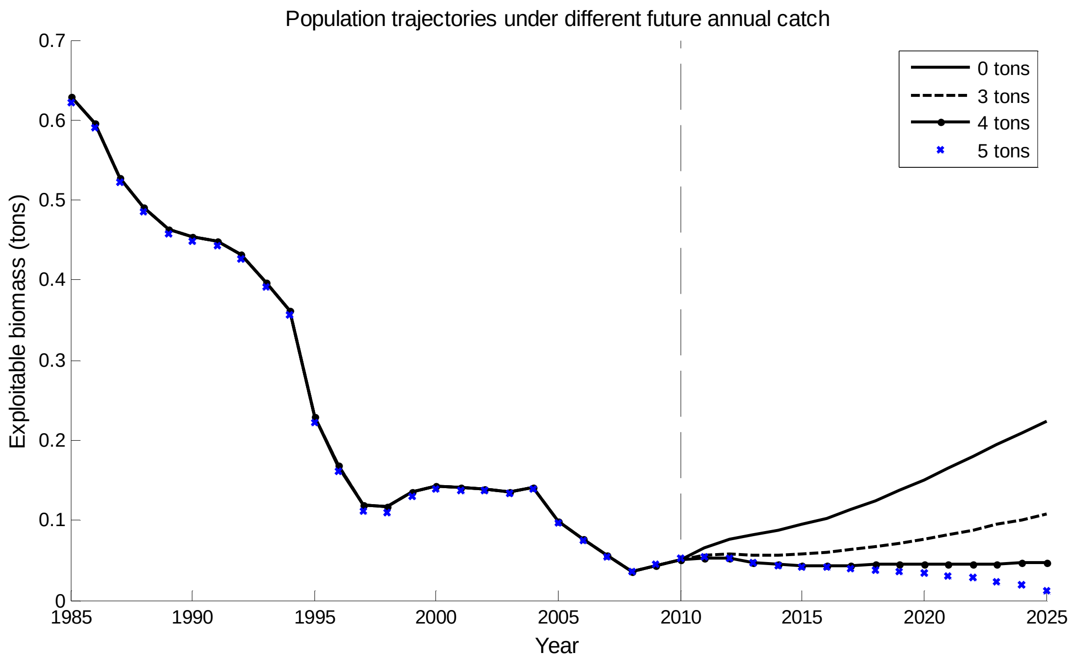


Figure 5: The annual the model-predicted catch in numbers is shown in (a), while (b) shows corresponding reported catch in tons.

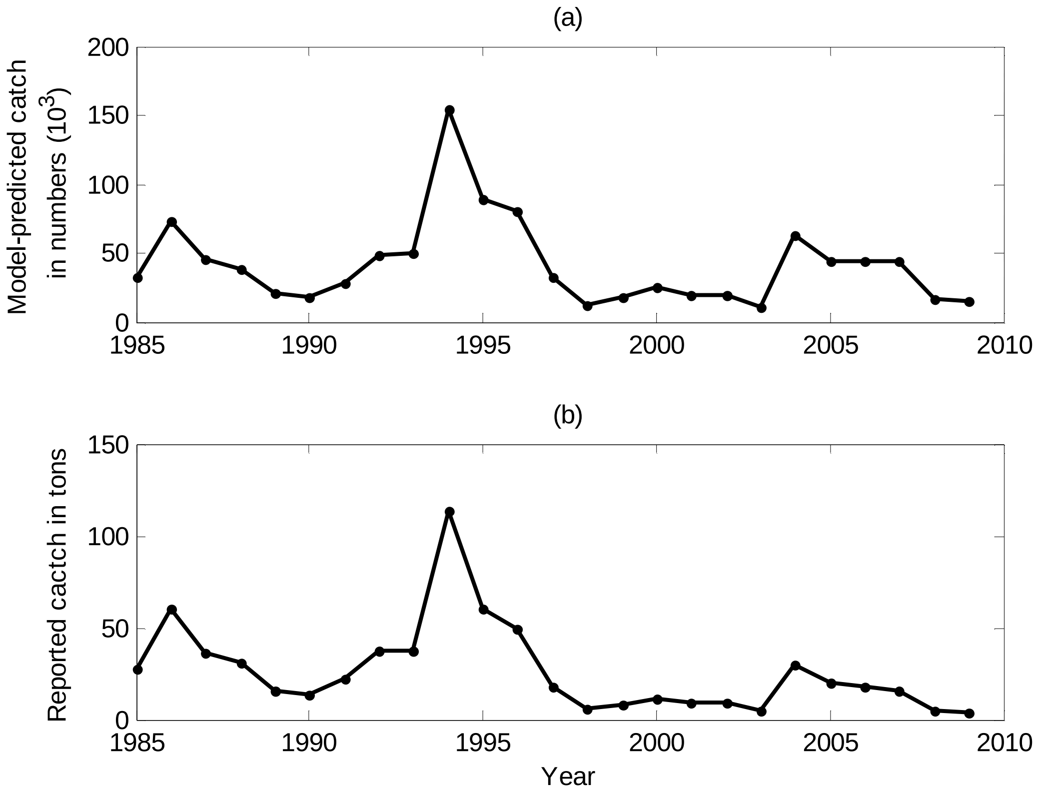


Figure 6: Estimated annual instantaneous fishing mortality.

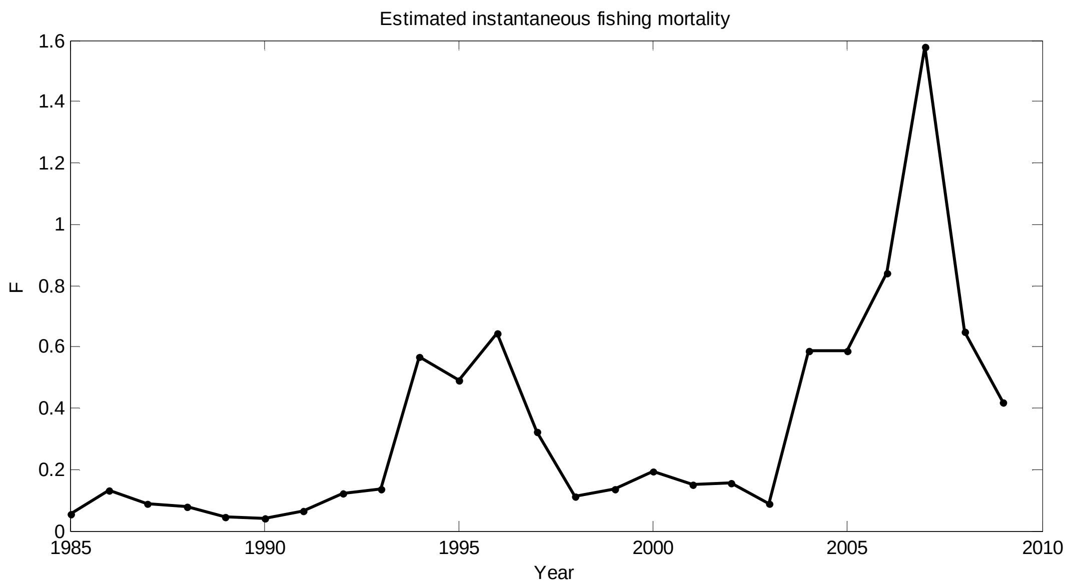


Figure 7: Catch series for the year 1985-2009 from two different sources, Fisheries, DAFF (Neil van den Heever, pers. commn) and Groeneveld (2000).

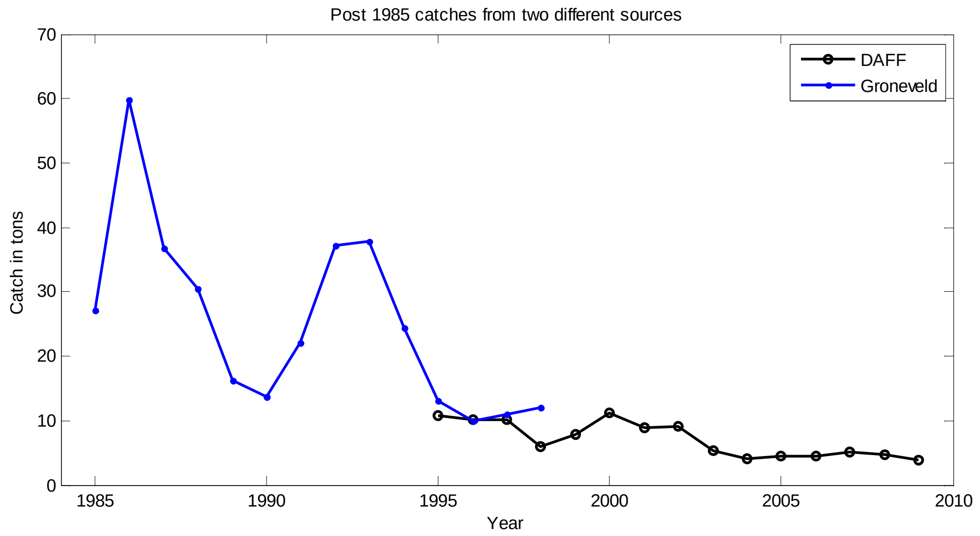


Figure 8: Reported catches including those given in Table 1 of Berry (1972). These catches are considered to be unreliable as they include an unknown proportion of Mozambique catches.

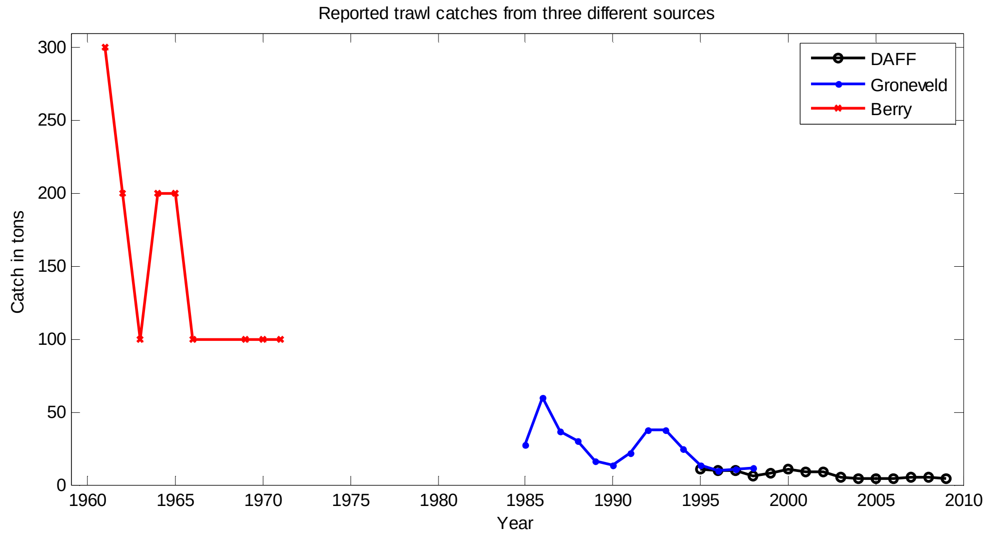


Figure 9: Fit to length data for 1994-1997, and for the years 2004 and 2007. The white bars show the observed data and the black line shows the model-predicted proportions. The 2005 and 2006 data were not available.

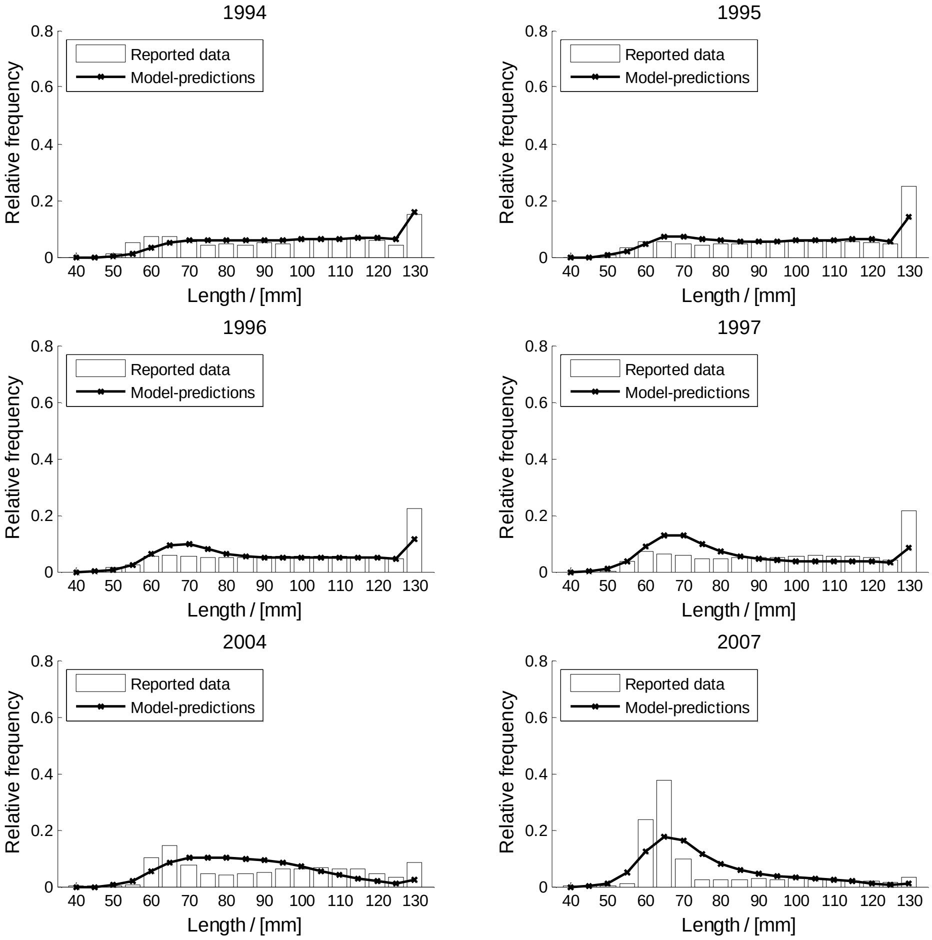


Figure 10: Bubble plot showing fit to length data. The size (radius) of the bubble is proportional to the corresponding standardised residual ($\varepsilon_{y,\ell} = (p_{y,\ell}^{obs} - p_{y,\ell}^{\mathrm{mod}}) / \sqrt{p_{y,\ell}^{\mathrm{mod}}}$, where $p_{y,l}^{obs}$ and $p_{y,l}^{\mathrm{mod}}$ are the observed and model-predicted catch-at-length proportions respectively) . For positive residuals, the bubbles are white and for negative residuals, the bubbles are grey.

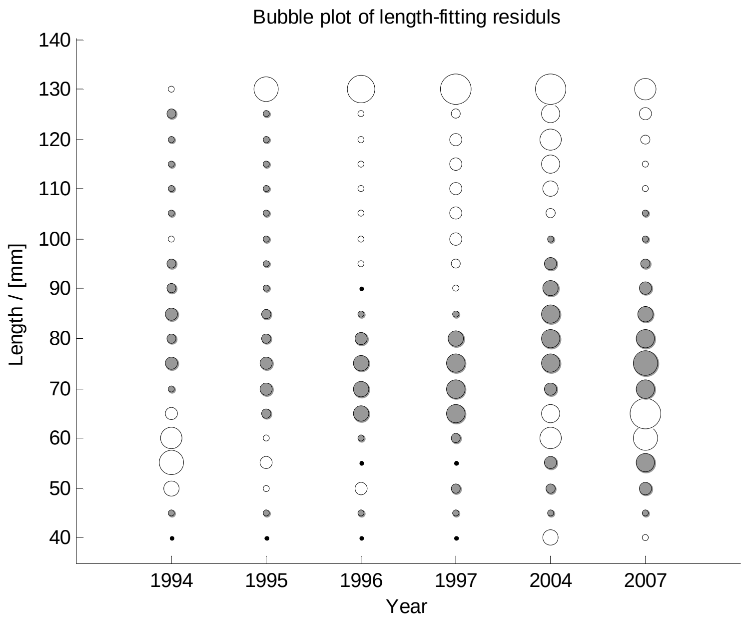


Figure 11: Catch-at-length distributions for 2004 split according to the three different sampling regions, showing the peak at 65mm for region South.

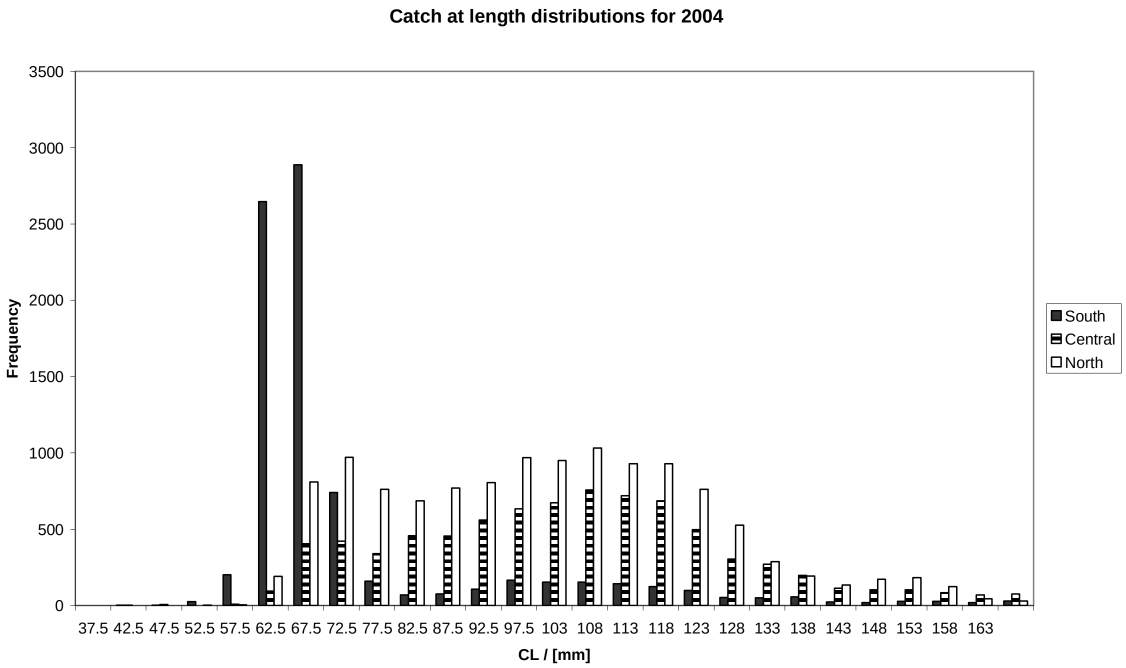


Figure 12: Von Bertalanffy length-age relationship for the parameter values given in the data section.

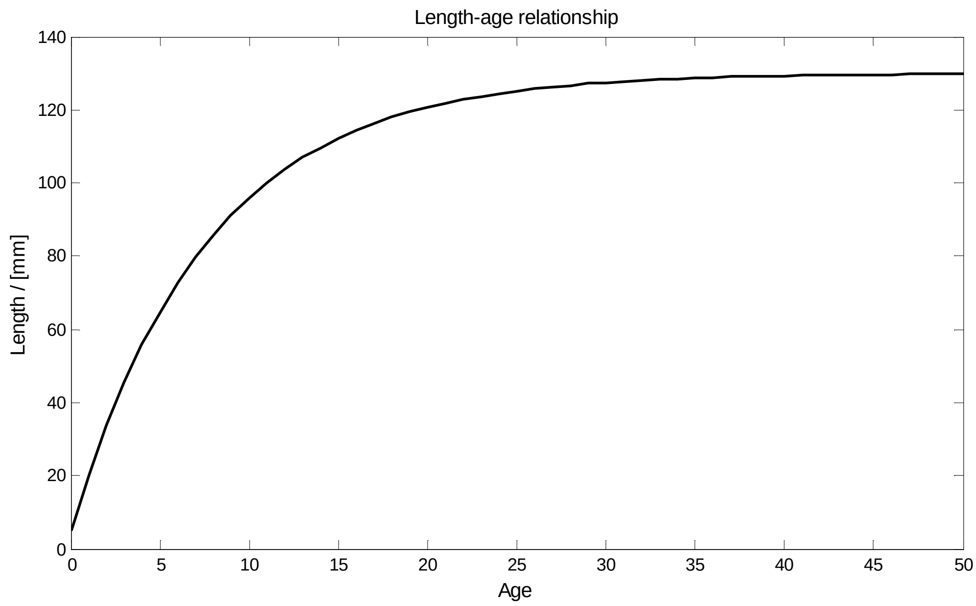
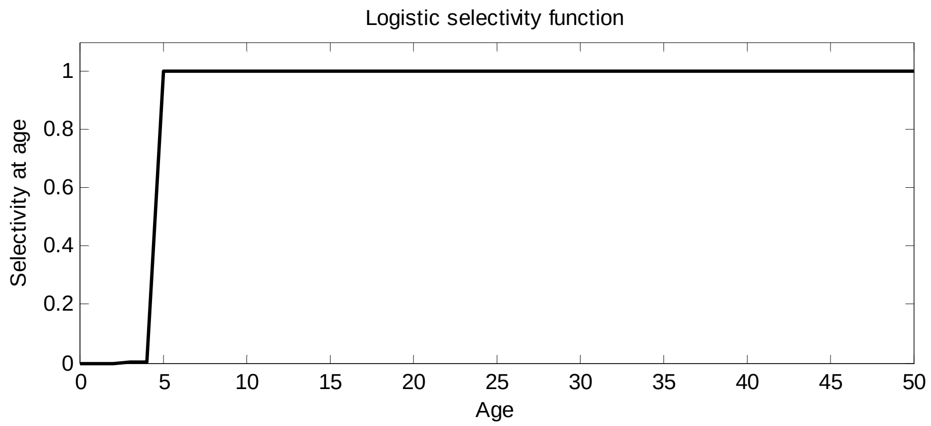


Figure 13: Logistic selectivity function for estimated values a_s=4.34, and δ=0.049.



APPENDIX

An approach for using general linear models (GLMs) to obtain a comparable CPUE series for the two trap-fishing experiments (1994-1997 and 2004-2007)

A full data set is available for the second experiment, thus GLMs can be run on these data. The available data for the first experiment, however, are incomplete thus preventing GLM's from being run. Standardised CPUE data are available from the first experiment in Groeneveld (2000). In an effort to obtain comparable CPUE data for the two experiments, the GLM described in the Groeneveld thesis (see below) has been repeated for the data from the second experiment. The resulting CPUE series is assumed to be comparable to that given in Groeneveld (2000). A different GLM (as was deemed appropriate) was run on the data from the second experiment and a calibration factor was computed between these two GLM results for the second experiment. This calibration factor was applied to the CPUE data from Groeneveld (2000) for the first experiment to obtain a comparable series for the two experiments.

GLM specifications for the first experiment from Groeneveld (2000):

Model used: $$\ln(CPUE + \delta) = \mu + \alpha_{year} + \beta_{month} + \gamma_{region} + \lambda_{soaktime} + \varphi_{phase} + \varepsilon \qquad \text{(A1)}$$

The constant δ (0.05 of the mean CPUE) was added to allow for the occurrence of zero CPUE values. The error term ε is assumed to follow a normal distribution.

Reference points are the generic first points in the set, i.e. year (1994), month (May), area (North), soaktime (0-35 hours), phase (experimental).

The standardised CPUE is given by:

$$CPUE_{year} = \sum_{region}[\exp(\mu + \alpha_{year} + \beta_{month} + \gamma_{region} + \lambda_{soaktime} + \varphi_{phase}) - \delta] * A_{region} \qquad \text{(A2)}$$

where the area of each region, A_{region}, given in Table A1 below.

Table A1: Areas for the three sampling regions

Region	**Area**
South	414.4km^2
Central	340 km^2
North	92.2 km^2

The standard set of factors were selected to be sampling phase (commercial), month (July), soak time (36-72 hours), corresponding to the categories with the most data points.

Table A2: GLM parameters from Groeneveld (2000)

Parameter	**Estimate**
Intercept	-1.0117
1995	0.0435
1996	-0.8153
1997	-1.1317
south	-0.3605
central	0.1925
June	0.2421
July	-0.091
August	-0.0688
September	-0.9206
36-72	0.1317
>72	0.1539
commercial	0.6317

Table A3: CPUE series derived by applying the parameter values given in Table A2 to equation (A2), where $\beta_{month}, \gamma_{region}, \lambda_{soaktime}$ and φ_{phase} are parameter values corresponding to the standard conditions described above.

Year	Standardised CPUE	Proportional change	Mean CPUE
1994	547.4	100	374.3
1995	572.6	105	
1996	232.2	42	
1997	164.3	30	

Table A4: Results from the GLM run on data from the second experiment according to the above specifications:

Year	CPUE	Proportional change	Mean CPUE
2004	443.5	100	317.4
2005	301.1	68	
2006	282.4	64	
2007	242.6	55	

Independent GLM assessment on data from second experiment:

Model**:** $C = Te^{L}$ (Poisson model)

where C is number of lobsters caught, T is the number of traps, and L is given by:

$$L = \mu + \alpha_{year} + \beta_{month} + \gamma_{region} + \eta_{trap-type} + \lambda_{soaktime} + \theta_{depth} \qquad \text{(A3)}$$

where:

μ	is the intercept,
year	is a factor with 4 levels associated with the years (i.e. the Season-Years: 2004-2007),
month	is a factor with levels associated with the fishing month (months 5-12),
region	is a factor with levels associated with groupings of fishing regions (South, Central and North),
trap type	is a factor with levels associated with the trap type (plastic or bee-hive),
soak time	is a factor with 3 levels associated with the soak time period (“1” <35 hours, “2”= 36-71 hours and “3” is >72 hours, and
depth	is a factor with 5 levels associated with fishing depth ranges (“1” for depths < 200m, “2” for 200–274m, “3” for 275-324, “4” for 325-375 and “5” for depths ≥ 375 m).
phase	is a factor with two levels for commercial and experimental phase
line	is a factor with four levels associated with line condition (good, tangled, broken and missing, where missing corresponds to a set of data points for which the line condition is missing, all for area South in the year 2007)

In this application the CPUE has been standardised on the year 2004, month September (9), region Central, trap-type plastic, soak time “2” and depth “5”. The data used were those resulting from the experimental phase only, and only data points for which line condition was good have been used (i.e. those data points for which no line-condition data were available have been excluded).

The standardised CPUE series is obtained from:

$$CPUE_{year} = \sum_{region} \left(\left(\exp\left(\mu + \alpha_{year} + \gamma_{region} \right) \right) * A_{region} \right) \qquad \text{(A4)}$$

where:

A_{region} is the surface size of the region concerned, given in Table A** below.

Region	Area
South	414.4km^2
Central	340 km^2
North	152 km^2

Table A5: CPUE series for the second experiment resulting from the GLM assessment

Year	CPUE	Proportional change	Mean CPUE
2004	282.2	100	241.7
2005	319.9	113	
2006	267.0	95	
2007	97.7	35	

Calibration

The calibration factor is the mean CPUE series from the independent GLM run on the data from the second experiment (see Table A5) divided by the mean CPUE from the GLM run done according to the specifications in Groeneveld (see Table A4). Results given below:

Table A6: Scaled CPUE series for the first experiment

μ_1 (from Table A4)	317.4		
μ_2 (from Table A5)	241.7		
Year	**CPUE (Table A3)**	**Scaled CPUE (CPUE* μ_2/μ_1)**	**Proportional change**
1994	547.4	416.9	100
1995	572.6	436.0	105
1996	232.2	176.8	42
1997	164.3	125.1	30

Figure A1: Re-scaled CPUE series. In this plot, '1' corresponds to the independent GLM applied to the second experiment's data (Table A5), '2' corresponds to the GLM applied to the second experiment's data according to the Groeneveld (2000) specifications (Table A4), '3' corresponds to the GLM results for the first experiment from Groeneveld (2000) (Table A3), and '4' corresponds to the CPUE series rescaled using the calibration factor (Table A6). Series '1' and '4' are taken to be comparable.