Updated investigation of the orange roughy south of *Johnies* given further data

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Abstract

The biomass of orange roughy for the region south of *Johnies* is estimated coarsely by treating the product of standardised CPUE and area as an index of abundance, and then calibrating against population model based estimates of abundance from the recognised aggregations. For the intermittent aggregation model estimates of abundance, for *Frankies* and *Rix*, this suggests that cumulative catches from *South Johnies* would not have appreciably reduced abundance in the region. However, one of two model options to estimate the *Johnies* abundance yields more pessimistic results, and the decline in the standardised CPUE for the region over the last three years also raises concerns. Results from the ASPM assessment of the *Johnies* and *South Johnies* aggregations combined suggest a resource at 48% of its pre-exploitation level. Projections based upon this ASPM suggest that the medium term sustainable yield for the combined aggregation is in the vicinity of 750 t.

Introduction

Over the past few years an increasing quantity of orange roughy has been taken from outside the existing quota management areas that correspond to the four recognised aggregations (*Hotspot*, *Rix*, *Frankies* and *Johnies*). Recently most of this additional catch has come from the area south of *Johnies* (see Table 1).

Brandão and Butterworth (2004) attempted to relate the size of this catch to the likely biomass of orange roughy in this region and the probable sustainable yield therefrom. Brandão and Butterworth (2005) carried out an assessment using the approach of an Age-Structured Production Model which allowed intermittent aggregation, where the various *South Johnies* “sub-aggregations” were combined with the *Johnies* aggregation. This paper updates both these assessments using further data that are now available.

Comparative Abundance Indices

The definition of the sub-aggregations *South 26*, *South 27*, *South 28* and *South 29* that comprise the *South Johnies* “aggregation” is described in Brandão and Butterworth (2005). The areas for these sub-aggregations are given in Table 2.

A GLM-standardisation of the CPUE data including those for the *South Johnies* sub-aggregations was then conducted as in Brandão and Butterworth (2006a). The “zero” method of Brandão and Butterworth (2002) of combining the standardised CPUE indices from each individual sub-aggregation to obtain a standardised CPUE index for the South Johnies aggregation was used to deal with empty cells, i.e., it is assumed that empty cells mean that there was no orange roughy in those areas for those years. The results of this analysis (for the four recognised aggregations as well as for *South Johnies*) are given in Table 3, where the CPUE predicted for a chosen vessel and month has been multiplied by sub-aggregation area and added over the constituent sub-aggregations of each aggregation to provide an index of abundance (of the form density×area). Brandão and Butterworth (2005) apply a restriction on the number of tows needed in each year of each sub-aggregations for it to be included in the GLM analyses ($\geq$ 20). This restriction was also applied in the present GLM analyses. This implies that there are no 1997 and 2000 standardised CPUE indices for *South Johnies* (Table 3).

Calibrating the CPUE-based indices

Table 4 lists population model-based estimates of abundance for the various recognised aggregations from Brandão and Butterworth (2006b). Two options are given for Johnies, for reasons detailed in Brandão and Butterworth (2006b). The averages over time for each aggregation can then be used to calibrate the averaged abundance indices in Table 3 to provide estimates of biomass in *South Johnies*:

$$\text{Biomass } \textit{South Johnies} = \text{Average Biomass for recognised aggregn} \times \frac{(\text{Average CPUE} \times \text{Area}) \text{ for } \textit{South Johnies}}{(\text{Average CPUE} \times \text{Area}) \text{ for recognised aggregn}}$$

The averages were calculated for common years only. The results are shown in Table 5 (from which *Hotspot* was excluded as it is dissimilar to the other larger aggregations), and range from some 8 000 to 90 000 tons.

Age-Structured Production Model

Table 6 shows the index of abundance provided by the delta-lognormal model assuming binomial errors for the proportion positive for the *South Johnies* combined to the *Johnies* aggregation. The "zero" method of Brandão and Butterworth (2002) for combining the standardised CPUE indices from each individual sub-aggregation to obtain a standardised CPUE index for the combined aggregation was used to deal with empty cells. The overall standardised index for the combined aggregation is obtained by summing the standardised CPUE for each sub-aggregation multiplied by its associated geographical area. The standardised CUPE index for the *South Johnies* aggregation on its own is also given in Table 6. Figure 1 shows the index of abundance for *South Johnies* provided by the delta-lognormal model assuming binomial errors for the proportion positive for each aggregation. For comparison purposes, the nominal CPUE series is also shown in Figure 1. Differences between the series are most marked for the last few years, with the standardised series showing a lesser decline.

Table 7 provides results for the population model fitting exercise as conducted by Brandão and Butterworth (2006b) when the *South Johnies* aggregation is combined to the *Johnies* aggregation forming a mega-aggregation that runs from the original *Johnies* all the way to latitude 29° south. Note that this involves combining the *Johnies* and *South Johnies* catches, while maintaining use of the same abundance indices as for the assessment of *Johnies* alone (this is not internally inconsistent, as within the paradigm of the intermittent aggregation model, the abundance indices reflect only a part of the whole population). For comparison purposes, the results obtained by Brandão and Butterworth (2006b) for two options for the *Johnies* aggregation alone are also given.

Allowing for intermittent aggregation of the resource, the stock depletion at the beginning of the fishing year 2005 for the combined aggregation is estimated at 48% of the pre-exploitation abundance (Table 6). The proportion of the stock present is highest in 1997 (95%) and lowest in 2003 (6%). Results are intermediate between those for *Johnies* aggregation in isolation for q^{AC} estimated and q^{AC} = 1.07, being closer to the latter.

Figure 2 shows 35-year deterministic projections of the orange roughy stock for the combined aggregation of *Johnies* and *South Johnies* aggregation under the intermittent model for the baseline CPUE interpretation and σ^{CPUE} estimated. For the combined aggregation a 500 t constant catch improves the stock depletion from 48% to 54% whereas a constant catch of 1000 t reduces the stock depletion after 35-years to 24% of the pre-exploitation abundance.

What level of *South Johnies* catch might be sustainable?

The total catch from the *South Johnies* region advised to date is only 2 959 tons (Table 1). Compared to the biomass estimates in Table 5 based upon *Frankies* and *Rix*, this is relatively small, suggesting that this cumulative catch would not have depleted abundance in the *South Johnies* region substantially. If *South Johnies* is to be regarded as comprising an independent population, these two Table 5 estimates would then correspond closely to the pristine population abundance (*K*).

Two factors do, however, suggest greater caution than this conclusion might suggest. The first is that one of the two *Johnies*-based estimates in Table 5 indicates an appreciably lower abundance for *South Johnies*. The second is the downward trend over the last three years in the GLM-standardised CPUE for the region (Fig. 1).

Projections using the intermittent aggregation ASPM model suggest an appropriate overall annual catch in the medium term to be in the vicinity of 750 tons for the combined mega-aggregation of *Johnies* and *South Johnies*.

Future work

Brandão and Butterworth (2004) addressed the possibility that orange roughy south of *Johnies* are merely the fish that normally aggregate during the July – August spawning period at *Johnies*, which then arguably disperse to the south in other months. The similar trends of the month factor estimated in the GLM analyses for the recognised and for the

South Johnies aggregations (Fig. 2 of Brandão and Butterworth 2004) suggested that the *South Johnies* roughy are not the same fish as aggregate at *Johnies*. (Furthermore, the fish from *South Johnies* tend to be smaller, R. Morrison, pers. commn.).

Brandão and Butterworth (2005) re-iterated a previous recommendation to examine the length structure of orange roughy from *South Johnies* more closely. The sustainable yield estimates for *Johnies* assume that juvenile orange roughy from that population are not present on the aggregation, and are not subject to harvest. It is therefore desirable to verify that the *South Johnies* fish are not sufficiently small in size to possibly constitute the juvenile component of the population associated with *Johnies*. Before such work can proceed, however, clarification is needed regarding which length distribution data are available for this region.

As indicated above, the recent CPUE trend for the *South Johnies* region raises cause for some concern. However to date, only one of the methods (the “zero” method) for dealing with empty cells in CPUE standardisation has been implemented, and sensitivity to the associated assumption need to be checked.

Acknowledgements

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References

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Table 1. Yearly (fishing year) catches of orange roughy (in tons) taken from the aggregations considered in this paper. The notation of, for example, "1996" for year refers to the period July 1996 to June 1997. The year 2005 is incomplete as data were available only until July. The catches for the *South Johnies* sub-aggregations were obtained from the commercial fishing database and are therefore based on the captains' estimated catches as were those for 2004 and 2005 for the other aggregations.

Year	*Johnies*	*Frankies*	*Rix*	*Hotspot*	*South Johnies*
1994	1 145	—	—	2 169	68
1995	3 773	2 291	323	897	23
1996	2 062	8 736	1 861	477	—
1997	7 539	4 817	3 836	482	5
1998	1 917	650	3 921	358	69
1999	1 367	40†	444	226	35
2000	667	11†	307	224	11
2001	452	214†	183	106	132
2002	376	155††	350	336	570
2003	430	158	124	129	1 776
2004	87	54	13†††	42	270
2005	10	1	0†††	0	0
Total	19 825	17 127	11 362	5 446	2 959

† Closed to normal commercial fishing

†† Fishery partially reopened since September 2002

††† Closed to normal commercial fishing on 1st August 2004

Table 2. Geographical area for each sub-aggregation of orange roughy off Namibia, including sub-aggregations south of *Johnies*.

Aggregation	Sub-aggregation	Area (km^2)
Johnies	***Johnies1***	82.8
	Johnies2	457.2
	Johnies3	198.2
	Johnies4	587.1
Frankies	***21 Jump Street***	39.2
	Frankies Flats	17.8
	Frankies Outer	1 255.0
	Three Sisters	39.6
	Smifton	15.8
Rix	***Rix Inner***	99.4
	Rix Outer	685.6
Hotspot	***Hotspot Inner***	97.3
	Hotspot Outer*	89.0
South Johnies	***South 26***	181.8
	South 27	1 917.0
	South 28	1 510.0
	South 29	1 037.0

Table 3. Abundance indices for Namibian orange roughy aggregations obtained by standardising the CPUE using the delta-lognormal model assuming binomial errors for the proportion positive, and then multiplying this index of density by the area of the sub-aggregation in question. The “zero” method is applied for years in which there are no data for sub-aggregations.

Year	Aggregation				
	Johnies	***Frankies***	***Rix***	***Hotspot***	***South Johnies***
1998	65.98	58.63	153.01	15.36	48.34
1999	31.81	29.41	30.35	8.72	38.61
2000	26.91	—	30.33	3.42	—
2001	15.36	35.30	22.62	5.52	99.04
2002	19.34	12.85	22.60	11.82	188.94
2003	15.66	32.39	13.02	3.67	91.61
2004	5.45	1.17	—	3.44	55.19
Average	25.79	28.29	45.32	7.42	86.96

Table 4. Biomass estimates (in tons) obtained by Brandão and Butterworth (2006b) for orange roughy aggregations for the intermittent aggregation models.

Year	**Aggregation**			
	Johnies	***Johnies*** **(q^{AC} = 1.07)**	***Frankies***	***Rix***
1998	4 401	26 949	19 969	15 177
1999	2 871	25 548	19 869	11 577
2000	1 918	24 734	20 372	11 466
2001	1 674	24 633	20 895	11 496
2002	1 650	24 751	21 211	11 651
2003	1 704	24 947	21 580	11 643
2004	1 706	25 091	21 938	11 859
2005	2 050	25 569	22 389	12 180
Average	2 247	25 278	21 028	12 131

Table 5. Estimates of biomass in the *South Johnies* aggregation obtained by calibrating against a CPUE×Area index of abundance for other aggregations, and the model estimates of average biomass in Table 4.

Calibrated against	**Average biomass in *South Johnies* aggregation**
Johnies	8 220
Johnies **(q^{AC} = 1.07)**	89 168
Frankies	60 651
Rix	24 931

Table 6. Abundance indices for orange roughy obtained from standardised commercial CPUE series, based on a delta-lognormal model, for the *South Johnies* aggregation and when the *South Johnies* aggregation is combined to the *Johnies* aggregation. The "zero" method (see Brandão and Butterworth (2002) for a description of the methods) of dealing with cells (sub-aggregations) without data in particular years is considered.

Year	***South Johnies***	***South Johnies* combined with *Johnies***
1994	0.190	4.103
1995		0.630
1996		0.891
1997		1.091
1998	0.631	0.698
1999	0.504	0.430
2000		0.164
2001	1.293	0.698
2002	2.466	1.271
2003	1.196	0.655
2004	0.720	0.370

Table 7. Estimates obtained when the intermittent model is fitted to the available indices of Namibian orange roughy for the *South Johnies* aggregation combined to the *Johnies* aggregation taking account also of the catches removed from *South Johnies*. For comparison, the results obtained by Brandão and Butterworth (2006b) for *Johnies* are also given. The estimates shown are for the pre-exploitation orange roughy (recruited=mature) abundance (B_0), the natural mortality (M), the current stock biomass (B_{2005}) and stock depletion (B_{2005}/B_0) at the beginning of the year 2005, the acoustic estimate multiplicative bias (q^{AC}), the research swept area index multiplicative bias (q^{SA}) and the commercial CPUE index catchability coefficient (q^{CPUE}), the standard deviation for the standardised CPUE series (σ^{CPUE}), the estimated proportion of the stock present each year ($x_{1994}, \dots, x_{2005}$), the maximum sustainable yield (MSY), the maximum sustainable yield level (MSYL) and the negative of the log likelihood (as well as its different components). Biomass units are tons.

Parameter estimates	*Johnies*	*Johnies* (q^{AC} = 1.07)	*South Johnies* combined with *Johnies*
B_0	18 259	40591	34 047
M	0.035	0.045	0.044
B_{2005}	2 050	25569	16 217
B_{2005}/B_0	0.112	0.630	0.476
q^{AC}	1.882	**1.070**	1.244
q^{SA}	3.624	0.906	1.016
q^{CPUE} ($\times 10^5$)	17.780	4.090	8.470
σ^{CPUE}	0.515	0.902	0.783
x_{1994}	0.829	0.792	0.752
x_{1995}	0.405	0.641	0.459
x_{1996}	0.590	0.690	0.561
x_{1997}	0.950	0.947	0.949
x_{1998}	0.543	0.301	0.345
x_{1999}	0.336	0.139	0.168
x_{2000}	0.646	0.237	0.248
x_{2001}	0.791	0.466	0.620
x_{2002}	0.754	0.442	0.659
x_{2003}	0.180	0.046	0.063
x_{2004}	0.414	0.244	0.447
x_{2005}	0.460	0.190	0.255
MSY	291	838	693
MSYL	0.249	0.247	0.247
-ln *L*: Total	11.741	14.312	11.990
-ln *L*: CPUE	-1.790	4.363	2.811
-ln *L*: Acoustic survey	6.486	1.708	2.128
-ln *L*: Sweptarea	6.171	4.720	5.784
ln *L*: year bias *x*	-1.705	6.285	3.415
-ln *L*: prior on *M*	-2.183	-2.879	-2.860
-ln *L*: prior on q^{AC}	4.762	0.115	0.712

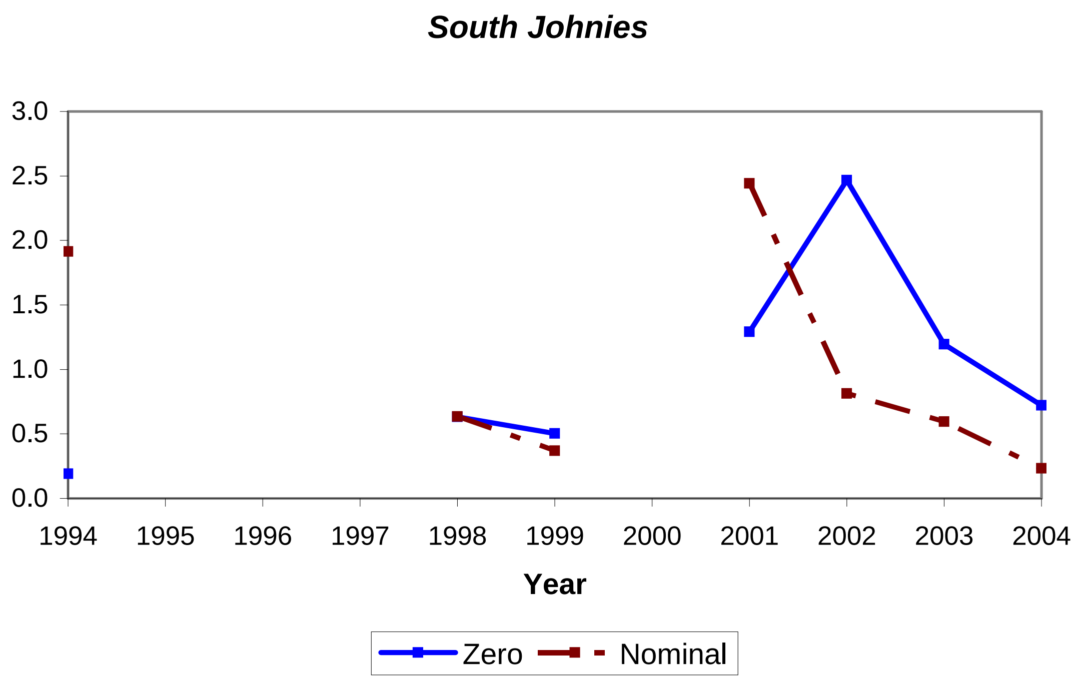

Figure 1. Index of abundance for the *South Johnies* aggregation (normalised to its mean over the eleven year period) for Namibian orange roughy obtained from fitting the delta-lognormal model to catch and effort data assuming binomial errors for the proportion positive. Results are shown for the "zero" method of dealing with empty cells when combining the indices from sub-aggregations. For comparison, the nominal CPUE series is also shown.

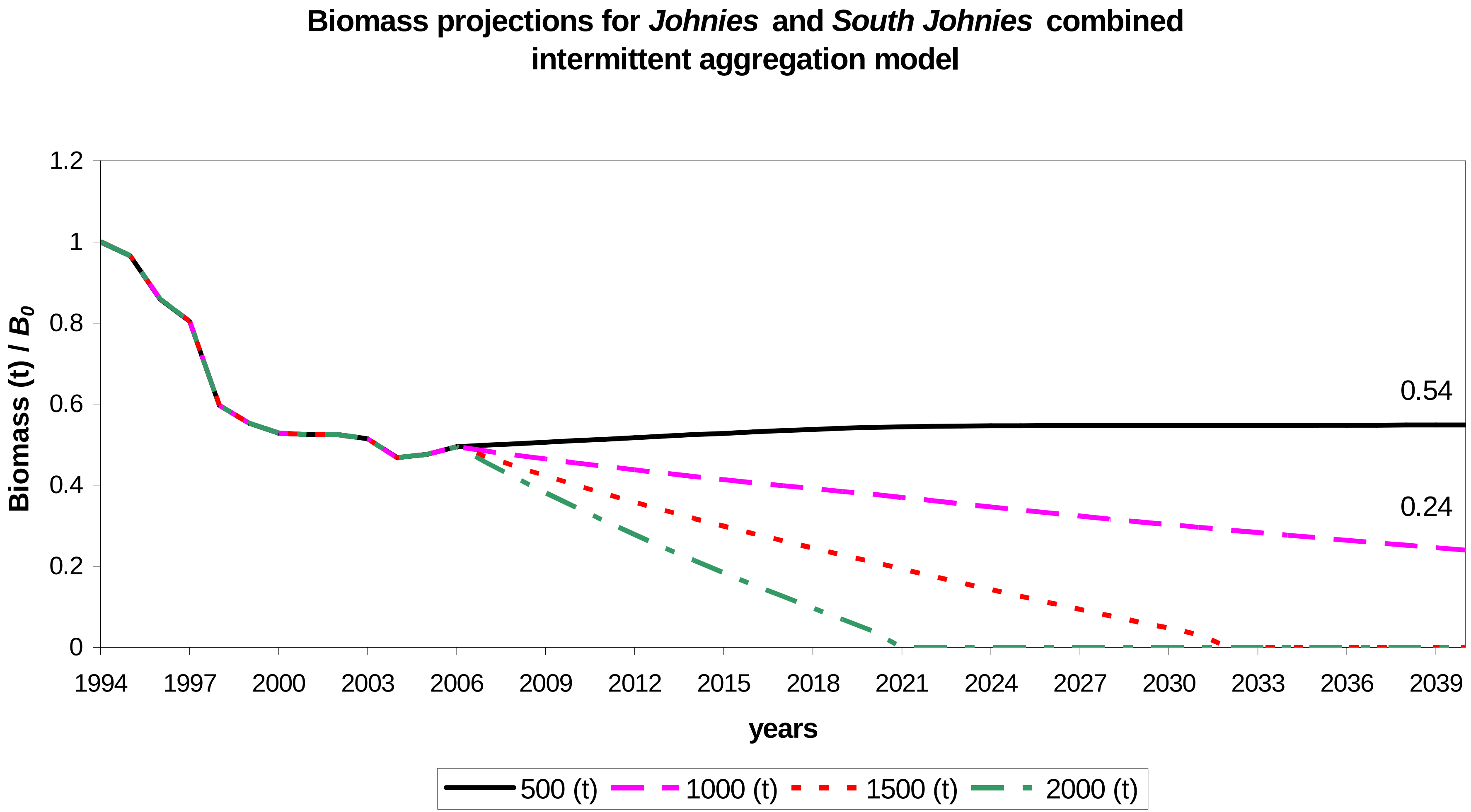

Figure 2. Thirty five year projections of the orange roughy stock for the *Johnies* and *South Johnies* aggregations combined under the scenario of the intermittent aggregation model, the "zero" method CPUE scenario and σ^{CPUE} estimated. Results for various levels of future constant catch are shown. The figure at the right end of a trajectory is the stock depletion after 35 years.