Preliminary results for a photo-identification-based assessment of southern right whales in South African waters

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INTRODUCTION

This working paper presents preliminary results of a photo-id based assessment of southern right whales in South African waters using the three-mature-stages (receptive, calving, resting) model of Cooke *et al.* (2003). The application of the approach is near-identical to that of Cooke *et al.* (2003), except that here the starting population is not assumed to reflect a steady age-structure corresponding to the Leslie matrix model describing the population dynamics. The photo-id data for grey-blazed female calves, which are identifiable when giving birth themselves, are used to link the dynamics of the mature females with the output of their reproduction by allowing for estimation of parameters for first-year mortality and the maturity ogive.

NOTATION

The notation used in providing results is as follows:

α	probability that a mature whale that calves becomes receptive the next year
β	probability that a resting mature whale rests for a further year
γ	probability that a receptive mature whale rests rather than calves the next year
S	post-first-year annual survival rate
S_j	first year survival rate
ρ	probability that a grey-blazed female calf is identifiable when itself calving
a_m, δ	parameters of the logistic function of age for the probability that a whale of that age becomes mature that year
r	annual (instantaneous) mature female growth rate.

Note that the basic model allows for a three-year reproductive cycle: receptive to calve to rest. In simple terms the α parameter allows for the possibility of a two-year cycle, the β a four-year cycle, and the γ a five-year-cycle.

RESULTS

Table 1 gives results for the three model variants run: time invariant β and γ parameters, followed by separately allowing first β only and then γ only to be time dependent. Note that the mature female increase rate r is estimated externally to the main assessment model by fitting a log-linear regression to the annual total number of mature females estimated by the

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model. Furthermore the "likelihood" includes penalty terms from the random effects associated with estimation of time dependence in β and γ.

Plots for a number of the model outputs are shown in Figs 1-5.

For the time-invariant model the current (2008) estimate of the mature female population is 1120, and of the total population (including calves and assuming a 50:50) sex ratio is 3612.

DISCUSSION

The estimate of α at 2% (Table 1) is similar to that of Cooke *et al*. (2003) for the right whales off Argentina. The β estimate of 11% is slightly greater than the 9.5% for the Argentine population, whereas γ at 7% is much less than the 14% for the Argentine whales. Unlike the Argentinian case, it is possible to estimate time dependence in the β parameter, though there are no obvious trends. In contrast, if such dependence is allowed for γ, there is an indication that the 1980s were a good period for reproduction, with the early 1990s the reverse (Fig. 4).

The estimate for annual post-first-year survival S of 0.987 (Table 1) is slightly less than the corresponding estimate of 0.990 from the simpler model of Brandão *et al.* (2011). There is a corresponding increase in the first year survival rate S_j estimate from 0.74 in Brandão *et al.* (2011) to 0.90. The detectability of mothers with calves has decreased slightly over the monitoring period (Fig. 2).

The annual instantaneous growth rate of the mature female population (see also Fig. 5) is 6.8% (Table 1), though there is an indication that this was slightly less over the first ten years of the series. Estimates of the initial age structure in 1979 do not suggest that this growth rate applied to the years immediately preceding 1979, but instead that the population was closer to stable over that period. In qualitative terms this is what might be expected from the impact of (illegal) Soviet catches, which are estimated to have totalled some 306[3] whales between 0 and 32°E over the period from 1961/62 to 1966/67 (Tormosov *et al*., 1998).

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Tormosov, D.D., Mikhaliev, Y.A., Best, P.B., Zemsky, V.A., Sekiguchi, K., and Brownell, R.L., Jr. 1998. Soviet catches of southern right whales, *Eubalaena australis*, 1951 - 1971; Biological data and conservation implications. *Biological Conservation* 86: 185-197

[3] This number is not tabulated in Tormosov *et al.* (2008), but extracted directly from the raw data used for their analyses.

Table 1. Estimates of various demographic parameters for right whales off South Africa for the time invariant model as well as when the probabilities β or γ vary with time (see text for explanation of symbols).

Parameter	Estimates		
	Time invariant	Time variant β	Time variant γ
α	0.020	0.020	0.020
β *(time invariant)*	0.110	—	0.111
γ*(time invariant)*	0.072	0.073	—
S	0.987	0.987	0.987
S_j	0.903	0.906	0.907
ρ	0.887	0.887	0.888
a_m	6.758	6.937	7.045
δ	1.493	1.593	1.683
r	0.068	0.070	0.070
β_{1979}/ γ_{1979}	—	0.018	0.038
β_{1980}/ γ_{1980}	—	0.126	0.015
β_{1981}/ γ_{1981}	—	0.095	0.205
β_{1982}/ γ_{1982}	—	0.001	0.028
β_{1983}/ γ_{1983}	—	0.122	0.044
β_{1984}/ γ_{1984}	—	0.182	0.049
β_{1985}/ γ_{1985}	—	0.105	0.019
β_{1986}/ γ_{1986}	—	0.070	0.018
β_{1987}/ γ_{1987}	—	0.107	0.047
β_{1988}/ γ_{1988}	—	0.090	0.058
β_{1989}/ γ_{1989}	—	0.068	0.047
β_{1990}/ γ_{1990}	—	0.138	0.080
β_{1991}/ γ_{1991}	—	0.017	0.138
β_{1992}/ γ_{1992}	—	0.119	0.046
β_{1993}/ γ_{1993}	—	0.194	0.173
β_{1994}/ γ_{1994}	—	0.099	0.064
β_{1995}/ γ_{1995}	—	0.056	0.068
β_{1996}/ γ_{1996}	—	0.090	0.075
β_{1997}/ γ_{1997}	—	0.100	0.059
β_{1998}/ γ_{1998}	—	0.133	0.091
β_{1999}/ γ_{1999}	—	0.127	0.083
β_{2000}/ γ_{2000}	—	0.096	0.122
β_{2001}/ γ_{2001}	—	0.066	0.071
β_{2002}/ γ_{2002}	—	0.092	0.021
β_{2003}/ γ_{2003}	—	0.237	0.068
β_{2004}/ γ_{2004}	—	0.160	0.096
β_{2005}/ γ_{2005}	—	0.089	0.082
β_{2006}/ γ_{2006}	—	0.049	0.071
β_{2007}/ γ_{2007}	—	0.081	0.061
β_{2008}/ γ_{2008}	—	0.081	0.059
-"Log-likelihood"	-9000	-8957	-8957

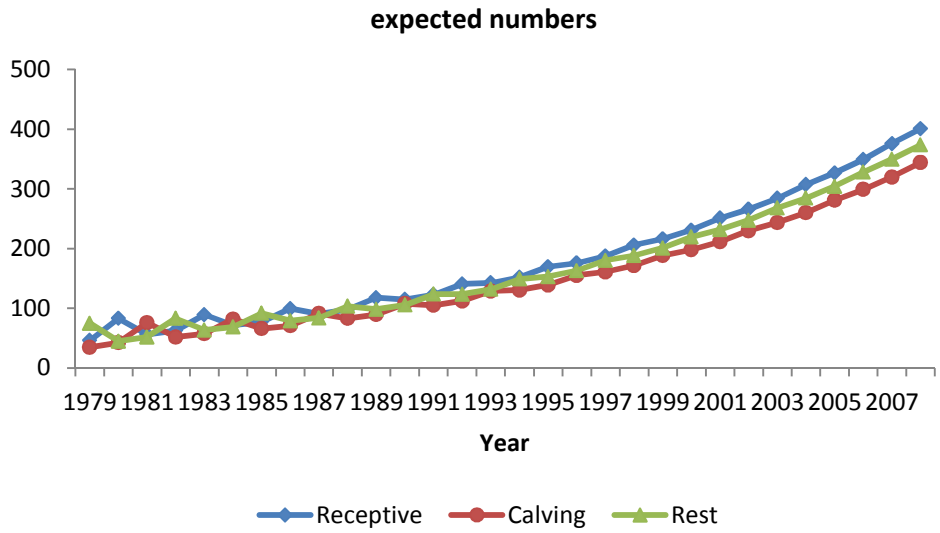

Figure 1. Expected number of mature female southern right whales that are in the calving, receptive or resting stages under the time invariant model.

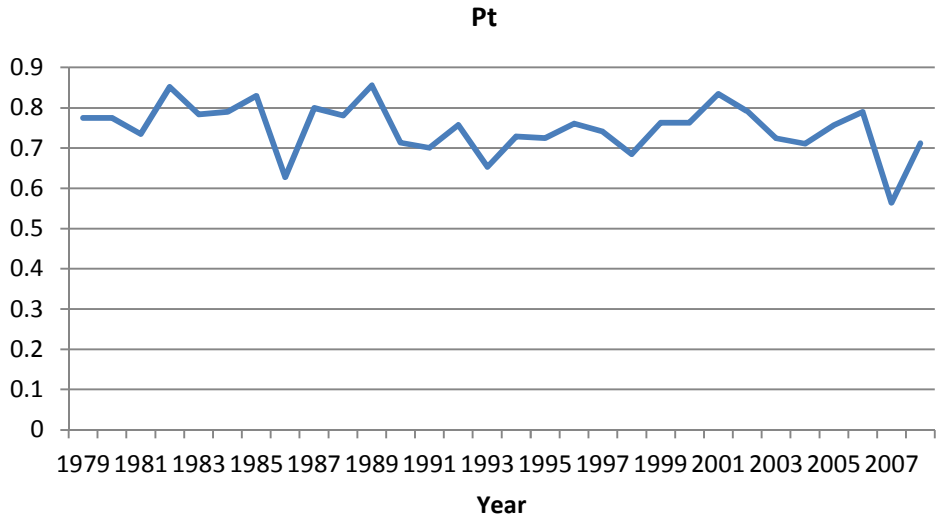

Figure 2. Estimated probabilities of observing a female whale with its calf on aerial surveys under the time invariant model.

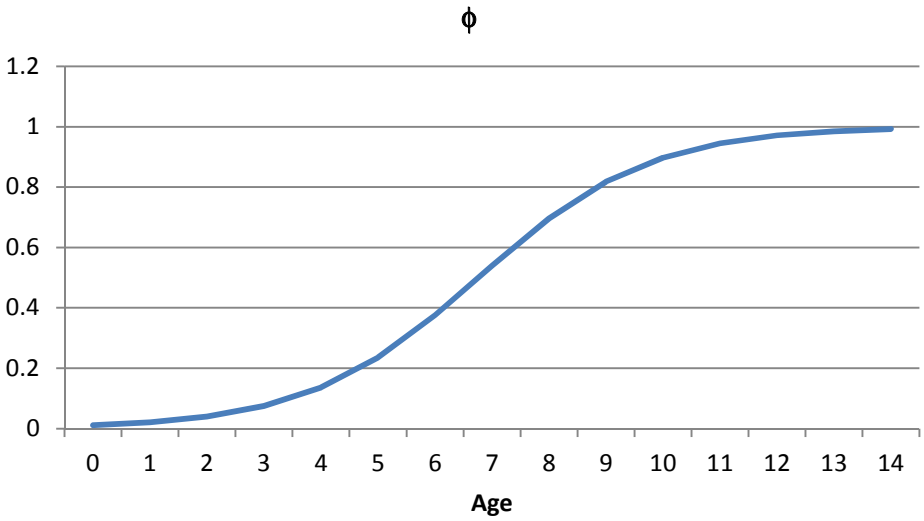

Figure 3. Estimated probabilities of an immature whale of age *a* becoming receptive the following year under the time invariant model. In implementation the model permits this transition only from age 4 and above.

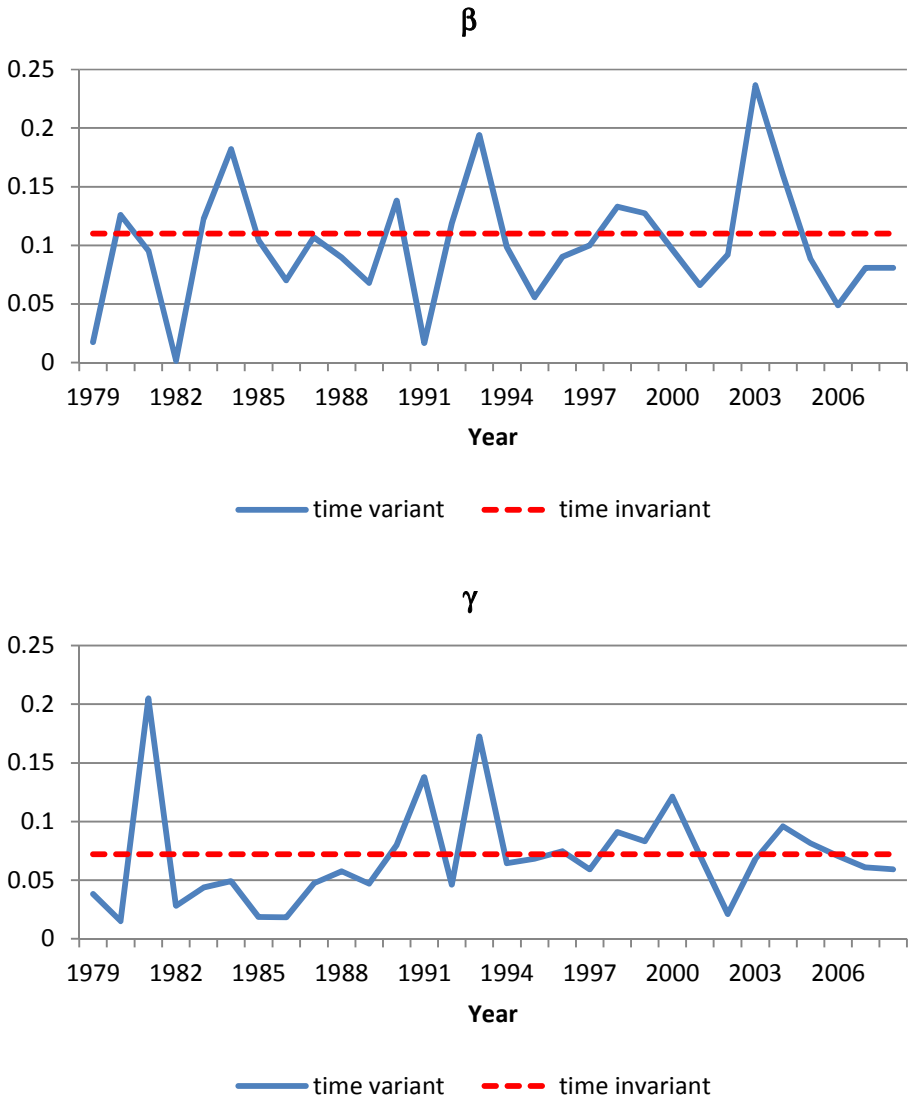

Figure 4. Time variant estimates of the probabilities that a resting whale will rest in the following year (top) and of the probabilities that a receptive whale will rest the following year (bottom).

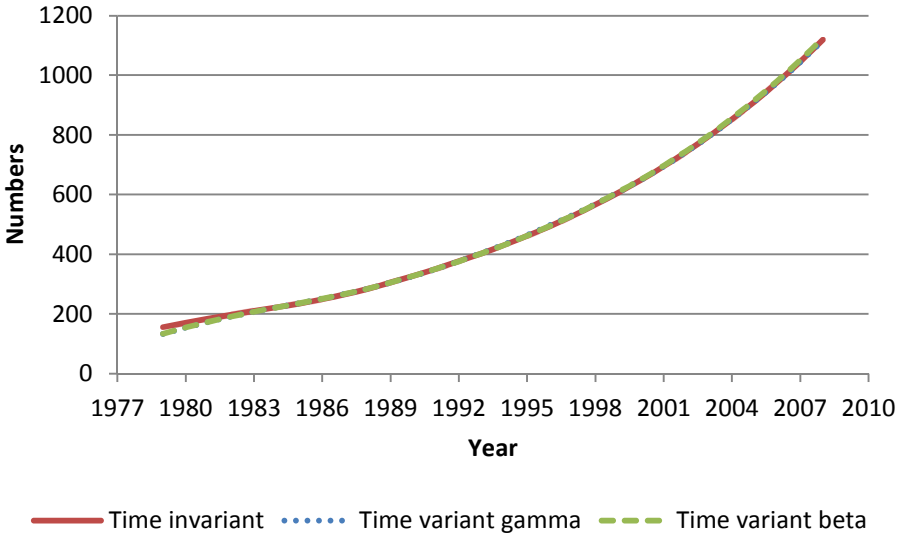

Figure 5. Estimated total number of mature females for the three models considered.