Evaluation of potential bias in abundance estimates for seasonal gray whales in the Pacific Northwest

(SC/64/AWMP10)

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Abstract

SC/M12/AWMP2-Rev provided abundance estimates for gray whales in the Pacific Coast Feeding Group (PCFG) that are being used in the current AWMP implementation trials. Some of the implementation trials propose that the increasing trend in the abundance estimates from 1998-2002 is bias and there is no trend at all in the abundance. I evaluate the plausibility of those trials by expanding the range of simulations conducted in SC/M12/AWMP2-Rev with a scenario of an underlying population with no trend and another scenario of a population with a trend that matches the PCFG estimates. I also evaluate the bias proposition by several additional analyses of the data that include additional data from 1996-1997 and that sequentially exclude data from 1998 to 2001 to examine the affect on the estimates. This evaluation is limited to the JS1 abundance estimator described in SC/M12/AWMP2-Rev, which is based on the open Jolly-Seber population model with an adjustment to handle the transient whales that are only present in a single year. Based on this evaluation I believe the bias is limited to the 1998 estimate and the remainder of the increase from 1999-2002 is real.

1 Introduction

For the implementation trials, PCFG whales are defined as whales seen in the area between 41-52N during 1 June - 30 November. That area is part of the migratory corridor of the whales that migrate further north into Alaska and while most migration will have ended prior to 1 June some whales may continue to migrate north through the PCFG after 1 June or south earlier than 30 November. Thus, it is not surprising that some whales identified in the PCFG are only seen in one year. Transient animals are a problem for capture-recapture models and a true robust design was not possible with these data. SC/-M12/AWMP2-Rev provided abundance estimates for gray whales in the Pacific Coast Feeding Group (PCFG) using 4 different approaches and recommended using the JS1 abundance estimates which are based on the open Jolly-Seber population model with an adjustment to "remove" the transient whales that are only seen in a single year. Those JS1 abundance estimates are being used in the trials.

To evaluate a range of conditions, some of the implementation trials are based on the assumption that the increasing trend in the abundance estimates from 1998-2002 is solely bias and there is no trend at all in the abundance. In 1999-2000 conditions in the Bering were poor and there were large numbers of gray whales stranding during the migration. With whales migrating through the PCFG region, it is reasonable to expect that some whales may have chosen to forage in the PCFG and not travel further north. Calambokidis et al. (2004) proposed that passing through the PCFG during the migration was a natural mechanism for external recruitment into the PCFG and they suggested that the relationship between the length of stay in their first year and their continued return ("survival") to the PCFG provided evidence that foraging success was the determinant for recruitment. Subsequently, Calambokidis et al. (2010) documented internal recruitment through return of calves seen initially with their mothers and argued that internal recruitment is likely to be higher than the documented level because many of the calves would be weaned prior to most of the survey effort in the PCFG.

There are two unanswered questions that are relevant to the treatment of the PCFG as a stock. First, what is the magnitude of recruitment into the PCFG especially during the period between 1999-2002 when the JS1 abundance estimates increased. Second, how much of the recruitment is internal versus external. I only consider the first question and in particular I evaluate the plausibility of the bias trials by expanding the range of simulations conducted in SC/M12/AWMP2-Rev with a scenario of an underlying population with no trend and another scenario of a population with a trend that matches the PCFG estimates. I also evaluate the bias hypothesis by several additional analyses of the data that include additional data from 1996-1997 and that sequentially exclude data from 1998 to 2001 to examine the affect on the estimates.

2 Methods

2.1 Abundance estimation

Transient behavior in which an animal is seen only once can be modeled by including a different "first year" survival (Pradel et al. 1997) for the newly seen animals. Survival in the time interval after being first seen is dominated by permanent emigration rather than true mortality. Survival in subsequent time intervals represents true survival under the assumption that animals do not permanently emigrate except in their first year. Pradel et al. (1997)were working with release-recapture data (Cormack-Jolly-Seber) where modeling this transient effect on survival is straightforward because the initial capture event is not modelled. For a Jolly-Seber (JS) type analysis where the first capture event is also modeled, the inclusion of a transient effect is less easily accommodated because some of the whales may not be seen in their first year. The JS1 approach assumes that all newly entering whales are seen and divides the whales into cohorts based on the year in which they were first seen ("newly seen"). With the POPAN (Schwarz and Arnason (1996)) formulation of the JS model, the JS1 estimator is constructed by fixing probability of entry and capture probability to 1 for the first occasion which effectively nullifies modelling the initial capture event with the strong assumption that all new whales are seen.

The JS1 estimator of abundance is a modification of the typical Jolly-Seber estimator which for any year the estimator can be expressed as:

$$\hat{N} = n/\hat{p} = (u+m)/\hat{p} \quad (1)$$

where $n = u+m$, n is the number seen in a year being composed of new animals (u=unmarked) and previously seen animals (m=marked), and $\hat{p}$ is the capture probability estimate. For the PCFG we are assuming that any new whale is sighted ($p = 1$) and we are only interested in estimating the abundance of whales that will remain part of the PCFG (non-transient). We can modify the JS estimator for year j as follows to get the JS1 estimator:

$$\hat{N}_j = u_j\hat{\phi}_j + m_j/\hat{p}_j \quad (2)$$

where ϕ_j is the first year survival rate of "new" whales. When ϕ and p contain whale specific covariates like minimum tenure (MT) the estimator becomes:

$$\hat{N}_j = \sum_{i=1}^{u_j} \hat{\phi}_{ij} + \sum_{i=1}^{m_j} 1/\hat{p}_{ij}. \quad (3)$$

To obtain an abundance estimate for 2010, we assumed that the parameter for first year survival intercept in that year was the same as in 2009. A variance-covariance matrix for the abundance estimates was constructed using the variance estimator in Borchers et al. (1998) for a Horvitz-Thompson type estimator with an adaptation for the first component of the abundance estimator for prediction of number of new whales that do not permanently emigrate.

SC/M12/AWMP2-Rev provides the details of the models for survival (ϕ) and capture probability (p) that were fitted using the RMark interface (Laake and Rexstad 2008) to program MARK (White and Burnham 1999) for the 1998-2010 PCFG photo-identification data set. I use the same set of models here for additional analysis of an extended data set from 1996-2010 and from subsets of the original data including 1999 to 2010, 2000 to 2010 and 2001 to 2010. Extending the data set to include 1996 and 1997 data allows estimation of p for 1998 and inclusion of whales seen prior to 1998 but not seen in 1998. Reducing the original data set provides an empirical evaluation of the bias by comparing the estimates for years greater than y when y is included and excluded from the data (e.g., compare estimates for 1999 and 2000 when 1998 is included/excluded from the analysis).

2.2 Simulation

SC/M12/AWMP2-Rev contained a simulation study to investigate the properties of the various estimators of abundance. I expanded that simulation to include a constant capture probability of p=0.5 and 0.6 in addition to 0.7 and 0.8 used in SC/M12/AWMP2-Rev. I have limited the presentation to the JS1 estimator being used in the implentation trials. As in SC/M12/AWMP2-Rev, the simulation considered 2 scenarios with constant ϕ=0.95 for non-transient whales and ϕ=0.0 for transient whales which are assumed to permanently emigrate and never return. In the first scenario, the population is at equilibrium in which the number of new non-transients and transients match the expected number of mortalities of non-transient whales ($N(1-\phi)$). In the second scenario, I used the observed number of transients (seen only in one year) and recruits to the non-transients from the PCFG gray whale data from NCA-NBC area (41-52N) and a initial population size of 120 non-transients from previous years still alive in 1998. A single population entry structure was constructed for each scenario from which 100 replicates of the survival and capture process were simulated. Even though p was constant in the simulated data, a time varying p model was fitted to make it similar to the real data analysis. I summarized the abundance time series for the 100 replicates for each estimator to examine bias in abundance $\hat{N} - N$ and bias in sequential estimates of trend $(\hat{N}_{t+1} - \hat{N}_t)/\hat{N}_t - (N_{t+1} - N_t)/N_t$.

3 Results

3.1 Simulation

The simulation results (Figure 1-2) clearly shows that abundance is under-estimated for the initial years and the magnitude of the problem is worse for smaller p as expected. However, if $p \geq 0.7$ and the initial estimate in 1998 is excluded, the bias in the trend for the increasing scenario is less than 4% and for the stable scenario it is less than 11% (Table 1). While there is still some bias for higher p an assesment of population growth would not be altered substantially. A fitted generalized logistic growth model would have bias for RMax, the maximum rate of increase, and z, the exponent that controls the location of the inflection point but it would not affect the conclusion that the population is above MNPL for the increasing trend scenario.

3.2 Analysis of different data subsets

The abundance estimate for 1998 using the 1996-2010 data is 7% higher than the same estimate using 1998-2010 (Table 2) and the changes in the remainder of the estimates for 1999-2010 were minor. Even the change in the 1998 estimate was not as large as might be expected from the simulation results. This can be explained by the high estimated detection probability for 1998 (0.92). Likewise, when the data were truncated at the beginnng of the sequence, the abundance estimate at the beginning of the sequence was influenced the most and for the 1999-2010 and 2000-2010 data sets, the negative bias carried over to the second estimate in the sequence. This can be explained by examining the estimates of p for 1999-2002 with an MT value of 30 days which were 0.92, 0.69, 0.69, 0.74, 0.87. The two lowest estimates were for 1999 and 2000 so the impact was larger.

The estimated values of p from the data provide a reference point for the simulation results. However, it is important to understand that p is the probability of recapturing (resighting) a whale that was previously seen and that a whale that was seen in a previous year may or may not have returned in each year and may have instead spent the summer/fall north or south of the PCFG. Thus, p combines both the chances of seeing a whale that is present in the PCFG and the probability that it is in the PCFG that year. SC/M12/AWMP2-Rev demonstrated that the best model for p included variation across years and the covariate MT, minimum tenure from the previous year. The parameter for MT was positive, meaning that if a whale was seen in the prior year for a longer period of time that it would be more likely to be seen the following year. MT could be incorporating both heterogeneity in capture probability based on the whale's location and fidelity as well as the possibility that MT represents a whale's foraging success in one year that impacts the whales probability of return the following year in the same way that it influences the chances of permanent emigration for newly seen whales. The simulation bias is a function of p for the new immigrants which by definition are in the population; thus, the estimates of p from the real data are likely lower than the probability of sighting a whale that is present in the PCFG. With the very high value of p in 1998, the bias in the estimates beyond 1998 should be minimal. However, this conclusion needs to be tempered by the possibility of heterogeneity in p that may have resulted from the lack of widespread survey coverage in 1996-1997.

4 Discussion

Obviously we will never know the extent of bias in the JS1 sequence of abundance estimates for non-transient PCFG gray whales; however, based on these results it seems very unlikely that the trend in the true sequence was flat which means that the B implementation trials are not plausible. The I trials which allow for some bias with a pulse of recruitment during the 1999-2000 stranding event seem far more reasonable. The increase in the abundance estimates during 1999-2002 seems quite plausible. We may never be able to assess how much of the increase was due to internal (calves) versus external (immigration) recruitment although continued biopsy and genetics work may provide some answers (Lang and Martien 2011). Regardless, it is hard to imagine that there is not some level of external recruitment into the PCFG with the entire ENP stock of whales migrating through the area each year.

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Table 1: Bias in trend using sequential pairs of abundance esimates and true abundance for the trend and no-trend simulation scenarios with p=0.5 to 0.8.

	p = 0.5	p = 0.6	p = 0.7	p = 0.8
Trend				
1998	0.59	0.47	0.36	0.24
1999	0.07	0.06	0.02	0.01
2000	0.09	0.06	0.04	0.02
2001	0.02	0.02	0.01	-0.00
2002	0.04	0.03	0.02	0.02
2003	0.04	0.03	0.02	0.01
2004	0.02	0.01	0.01	0.00
2005	0.03	0.02	0.02	0.01
2006	0.01	-0.00	-0.00	-0.00
2007	0.01	0.00	0.00	-0.00
2008	0.00	0.00	-0.00	-0.00
2009	-0.00	-0.01	-0.01	-0.01
No Trend				
1998	0.49	0.37	0.28	0.18
1999	0.20	0.15	0.11	0.08
2000	0.08	0.05	0.03	0.02
2001	0.03	0.02	0.01	0.00
2002	0.01	0.01	0.01	-0.00
2003	0.01	0.00	0.00	-0.00
2004	0.01	0.00	-0.00	0.00
2005	0.00	0.01	0.00	-0.00
2006	-0.00	-0.00	-0.00	0.00
2007	0.01	0.00	0.00	0.00
2008	0.00	0.00	0.00	-0.00
2009	0.01	0.00	0.01	0.00

Table 2: Annual estimates of abundance using JS1 with different ranges of data used in the analysis from 1996-2010 to 2001-2010.

	1996-2010	1998-2010	1999-2010	2000-2010	2001-2010
1996	26				
1997	38				
1998	108	101			
1999	133	135	90		
2000	143	141	126	115	
2001	170	172	167	158	130
2002	191	189	190	188	193
2003	202	200	202	201	202
2004	206	206	209	208	219
2005	206	206	208	206	196
2006	190	190	192	191	191
2007	183	183	187	185	174
2008	189	191	198	197	211
2009	184	185	192	189	177
2010	185	186	195	192	198

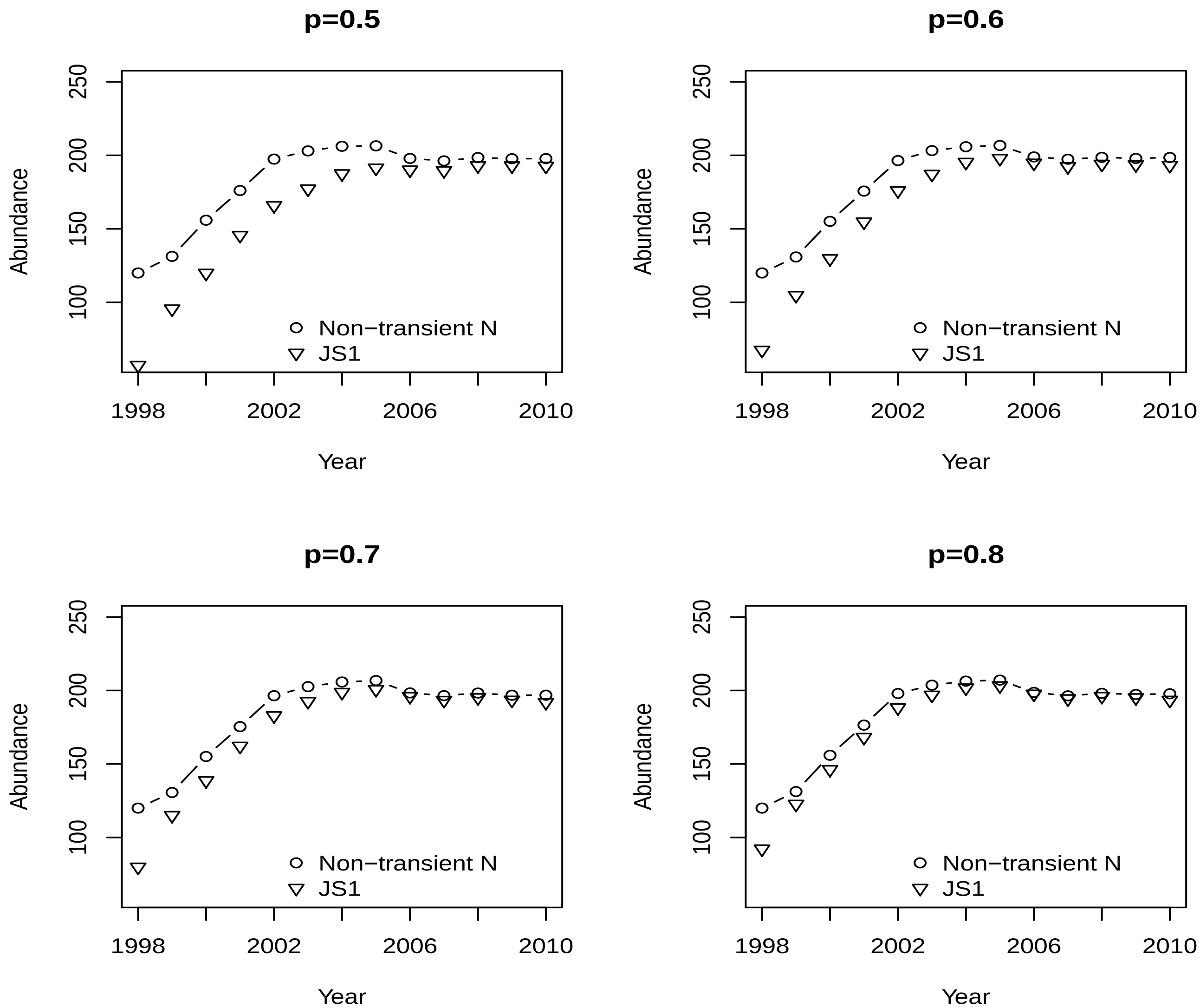

Figure 1: Simulation results for JS1 estimators with p=0.5, 0.6, 0.7 and 0.8 with an increasing trend and leveling in true abundance that mimics the pattern in the gray whale abundance estimates. The true average simulated non-transient N is shown with a line and the average estimates for JS1 is shown with symbols.

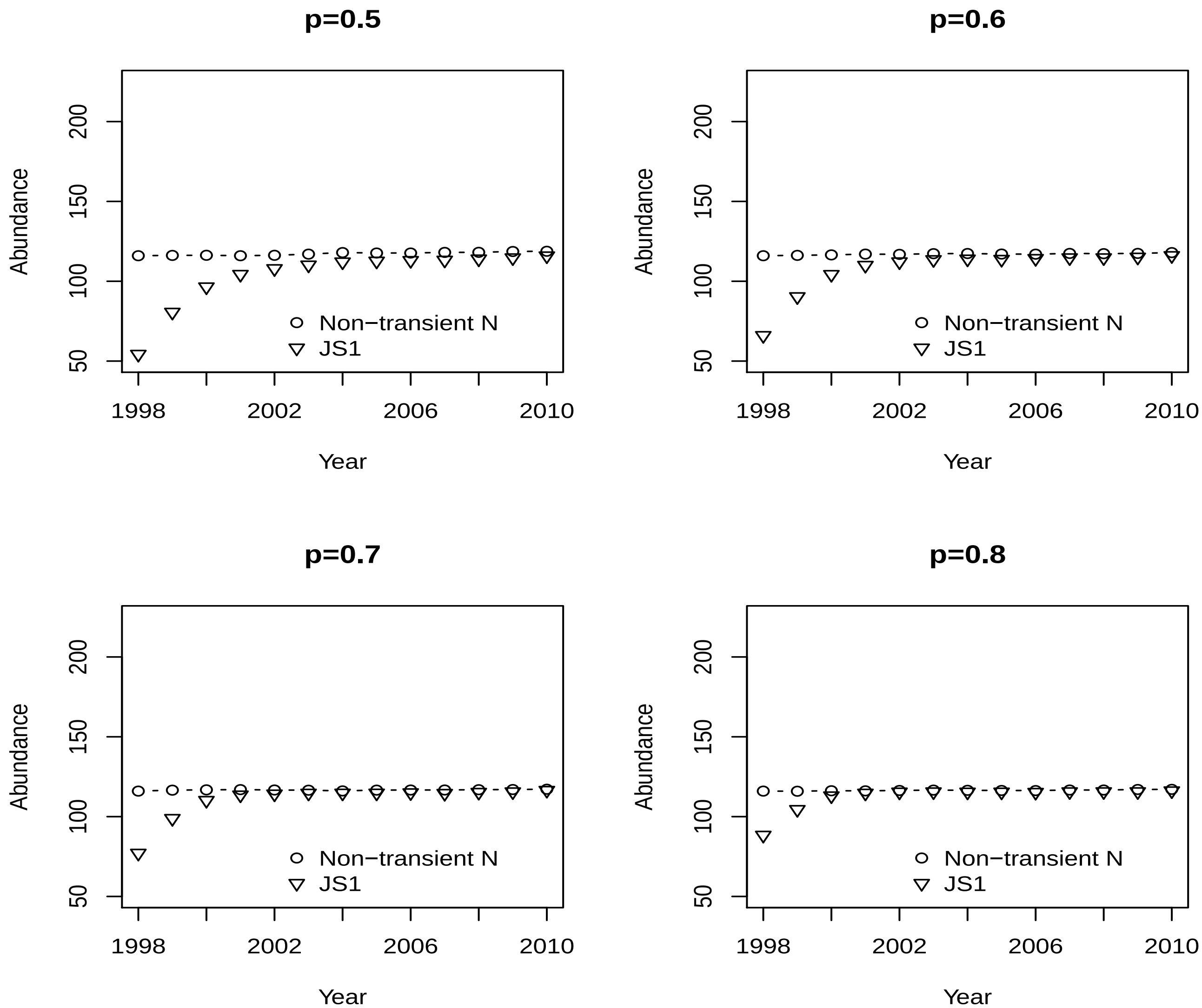

Figure 2: Simulation results for JS1 estimators with p=0.5, 0.6, 0.7 and 0.8 with no trend in true abundance. The true average simulated non-transient N is shown with a line and the average estimates for JS1 is shown with symbols.