

Health of North Atlantic right whales *Eubalaena glacialis* over three decades: from individual health to demographic and population health trends

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Supplement 1.

Visual depiction of the calving cycle of an adult female right whale.

Right whale calving cycles

In years of good health and sufficient food resources, North Atlantic right whales calve approximately every 3+ years (Fig. S1; Knowlton et al. 1994, Browning et al. 2010, Kraus et al. 2007) with an estimated 12-13 mos gestation (Best 1994). Body condition fluctuates with the female reproductive cycle in baleen whales from resting to pregnant to lactating (Lockyer 1986, Miller et al. 2011, Miller et al. 2012, Williams et al. 2013), and this change in body condition can be detected visually (Pettis et al. 2004, Bradford et al. 2012). Because this is a normal process and not an indication of declining health, reproductive females were considered separately from other demographic groups. Below is an illustration of the typical calving cycle for a female right whale (EG#1004) showing the different phases of the cycle corresponding to the groups used for reproductive females in the main text.

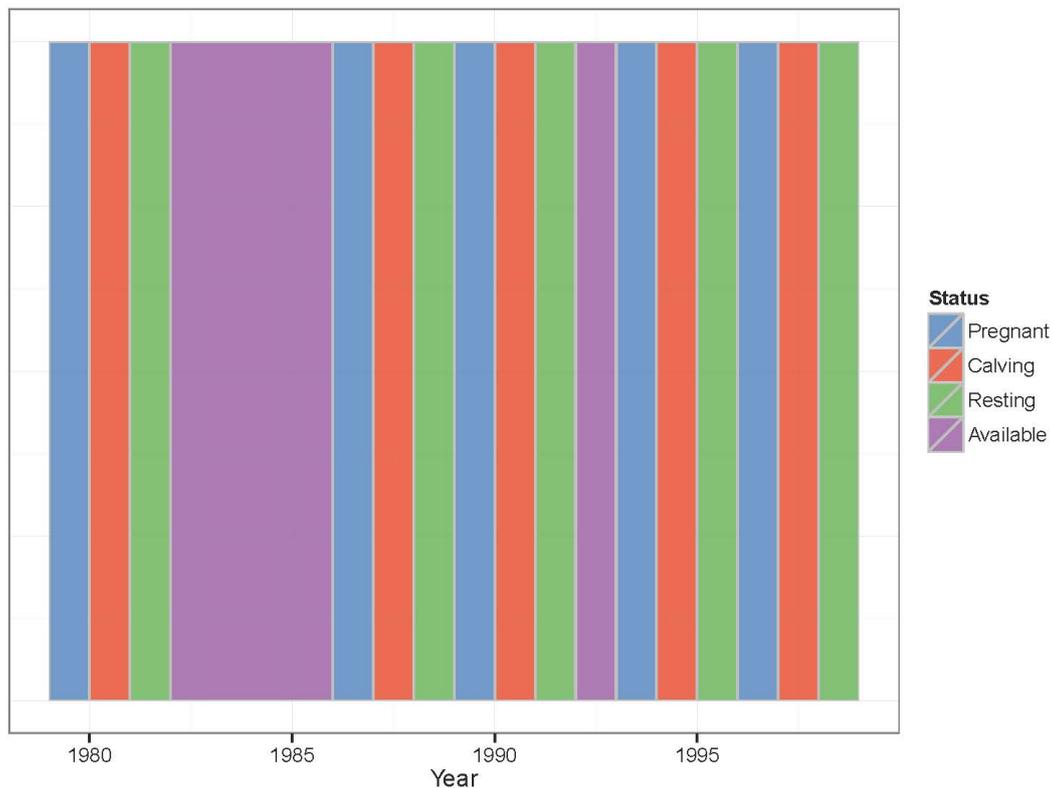


Figure S1. The reproductive history of a female North Atlantic right whale (EG# 1004) illustrating the 3 + year calving cycle (1979-1999). This whale had five calves born in 1980, 1987, 1990, 1994, and 1997. The pregnancy, lactation and resting years for each calving event are shown in different colors, along with years in which this whale was available to become pregnant following the resting year.

LITERATURE CITED

- Best PB (1994) Seasonality of reproduction and the length of gestation in southern right whales *Eubalaena australis*. *J Zool (Lond)* 232: 175–189
- Bradford AL, Weller DW, Punt AE, Ivashchenko YV, Burdin AM, VanBlaricom GR, Brownell Jr RL (2012) Leaner leviathans: body condition variation in a critically endangered whale population. *J Mammal* 93: 251–266
- Browning CL, Rolland RM, Kraus SD (2010) Estimated calf and perinatal mortality in western North Atlantic right whales (*Eubalaena glacialis*). *Mar Mamm Sci* 26: 648–662
- Knowlton AR, Kraus SD, Kenney RD (1994) Reproduction in North Atlantic right whales (*Eubalaena glacialis*). *Can J Zool* 72:1297–1305
- Kraus SD, Pace III RM, Frasier TR (2007) High investment, low return: the strange case of reproduction in *Eubalaena glacialis*. In: Kraus SD, Rolland RM (eds) *The urban whale: North Atlantic right whales at the crossroads*. Harvard University Press, Cambridge, MA, p 172–199

- Lockyer C (1986) Body fat condition in Northeast Atlantic fin whales, *Balaenoptera physalus*, and its relationship with reproduction and food resource. *Can J Fish Aquat Sci* 43:142–147
- Miller CA, Reeb D, Best PB, Knowlton AR, Brown MW, Moore MJ (2011) Blubber thickness in right whales *Eubalaena glacialis* and *Eubalaena australis* related with reproduction, life history status, and prey abundance. *Mar Ecol Prog Ser* 438: 267–283
- Miller CA, Best PB, Perryman WL, Baumgartner MF, Moore MJ (2012) Body shape changes associated with reproductive status, nutritive condition and growth in right whales *Eubalaena glacialis* and *E. australis*. *Mar Ecol Prog Ser* 459: 135–156
- Pettis HM, Rolland RM, Hamilton PK, Brault S, Knowlton AR, Kraus SD (2004) Visual health assessment of North Atlantic right whales (*Eubalaena glacialis*) using photographs. *Can J Zool* 82: 8–19
- Williams R, Vikingsson GA, Gislason A, Lockyer C, New L, Thomas L, Hammond PS (2013) Evidence for density dependent changes in body condition and pregnancy rate of North Atlantic fin whales over four decades of varying environmental conditions. *ICES J Mar Sci* 70:1273–1280

Supplement 2.

Linear mixed effects model testing the difference in adult female health as a function of calving success.

Linear mixed effects model results

The difference in adult female health as a function of calving success was tested using a linear mixed effects model (Bates et al. 2014, 2015). The fixed effects portion of the model was health value in the available year as a function of pregnancy status (pregnant/not pregnant) in the following year. The random effects portion was year. Following is the tabular summary of this model, along with the caterpillar plot for the coefficients of the random effects (Fig. S2).

Table S1. Summary output from the fixed effects component of the linear mixed effects model. Successful females were on average 1.18 health units higher.

	Estimate	Standard Error	t-value
(Intercept)	73.2262	0.854	85.75
Pregnant	1.1783	0.8737	1.35

Table S2. Summary output from the random effects component of the linear mixed effects model with year as a random effect.

Groups	Name	Variance	Standard Dev
Year	(Intercept)	10.42	3.227
Residual		99.18	9.959

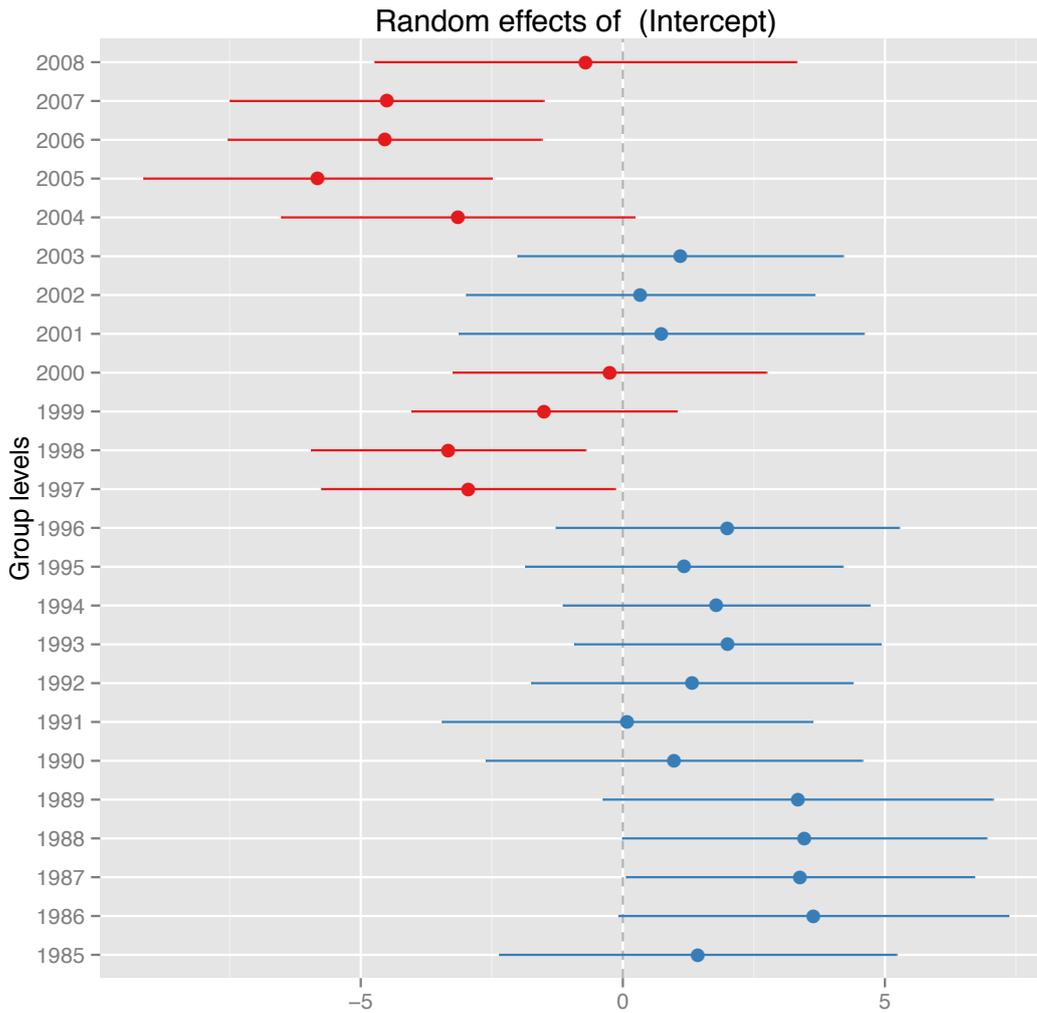


Figure S2. Coefficient plot of the random effects (year) in the linear mixed effects model testing the differences in available female health as a function of subsequent calving success (pregnant/not pregnant). This caterpillar plot shows the intercept values and standard deviation around health estimates for each year. The inclusion of the random effect for year shows that whales were in poorer overall health in the late 1990's and the mid-2000's.

LITERATURE CITED

- Bates D, Maechler M, Bolker B, Walker S (2014) lme4: Linear mixed-effects models using 'Eigen' and S4. R package version 1.1-7. <http://cran.r-project.org/package=lme4>
- Bates D, Maechler M, Bolker B, Walker S (2015) Fitting linear mixed-effects models using lme4. *J Stat Softw* 67:1–48. doi 10.18637/jss.v067.i01