

Expert elicitation of seasonal abundance of North Atlantic right whales *Eubalaena glacialis* in the mid-Atlantic

Cornelia Oedekoven*, Erica Fleishman, Philip Hamilton, James S. Clark, Robert S. Schick

*Corresponding author: cso2@st-andrews.ac.uk

Endangered Species Research 29: 51–58 (2015)

Supplement. Questionnaire on the distribution and movements of right whales

The following represents the revised questionnaire of the elicitation that was distributed to the 10 experts (see Materials and Methods, main manuscript).

Introduction

Thank you for agreeing to participate in this expert elicitation. As you know, we aim to estimate four aspects of the distribution and movements of North Atlantic right whales (*Eubalaena glacialis*) in the mid-Atlantic: 1) the number of adult female right whales that are present in the mid-Atlantic during four different months of the year; 2) the number of adult male right whales that are present in the mid-Atlantic during four different months of the year; 3) the number of adult female right whales that move into the mid-Atlantic during January; and 4) the number of adult male right whales that move into the mid-Atlantic during January.

We defined the mid-Atlantic as all waters north of Georgia (32°N) and south of Cape Cod (42°N) and west of Great South Channel (70°W), which is consistent with the definition in the Right Whale Catalog (Figure 1).

We anticipate using the elicited information to inform Bayesian priors in models of movement (see below) and to highlight gaps in knowledge of current use of the mid- Atlantic by right whales.

Knowledge of right whales' movements within and through the mid-Atlantic largely is uninformed. It is known that a relatively high proportion of the population occupies the southeastern United States and the northern regions, but the timing of migration and number of right whales that migrate between these regions through the mid-Atlantic is highly uncertain. Use of the mid-Atlantic during months outside the assumed migration period is even more uncertain.

Schick et al. (2013) used a Bayesian analysis to model movements of different groups of right whales at different times of the year (e.g., females moving from the southeastern United States through the mid-Atlantic to Cape Cod Bay). This analysis incorporated information on both the prior distribution of values of a parameter and the likelihood that a given value of a parameter is accurate. Information on priors in a Bayesian analysis may be derived from empirical data or expert knowledge. The priors reflect belief about the magnitude of uncertainty in a parameter value. If a prior is well-informed, the value is assumed to have low uncertainty. In contrast, a flat prior reflects high uncertainty in the value of a parameter.

Schick et al.'s (2013) analysis used informed priors. These priors were based on one person's professional judgment, and as a result the effects of uncertainty in these priors on estimates of movement were unknown. Prior-sensitivity analyses suggested that estimates of movement, especially into and out of the mid-Atlantic, depended strongly on the priors (Figures 2 and 3). The uninformed priors (Figure 3) resulted in estimates that very few whales moved into and out of the mid- Atlantic.

The attached questionnaire has four sections, each corresponding to one of the four aspects of distribution and movements listed above. All questions request best estimates of quantities and associated uncertainties. You are not required to answer a given question if you do not feel your knowledge is sufficient.

The structure of each four-part question follows that in Speirs-Bridge et al. (2010). We ask you for a low estimate, a high estimate, an estimate of the mode (i.e., the most common value in a set of data), and an estimate of your confidence in the answers (expressed as a percentage from 0-100).

Please answer the questions on the basis of your knowledge of right whale biology without consulting anyone else. When we convene as a group, we will discuss the set of confidential answers. You then will have the opportunity to revise your confidential answers on the basis of what you have discussed with other participants.

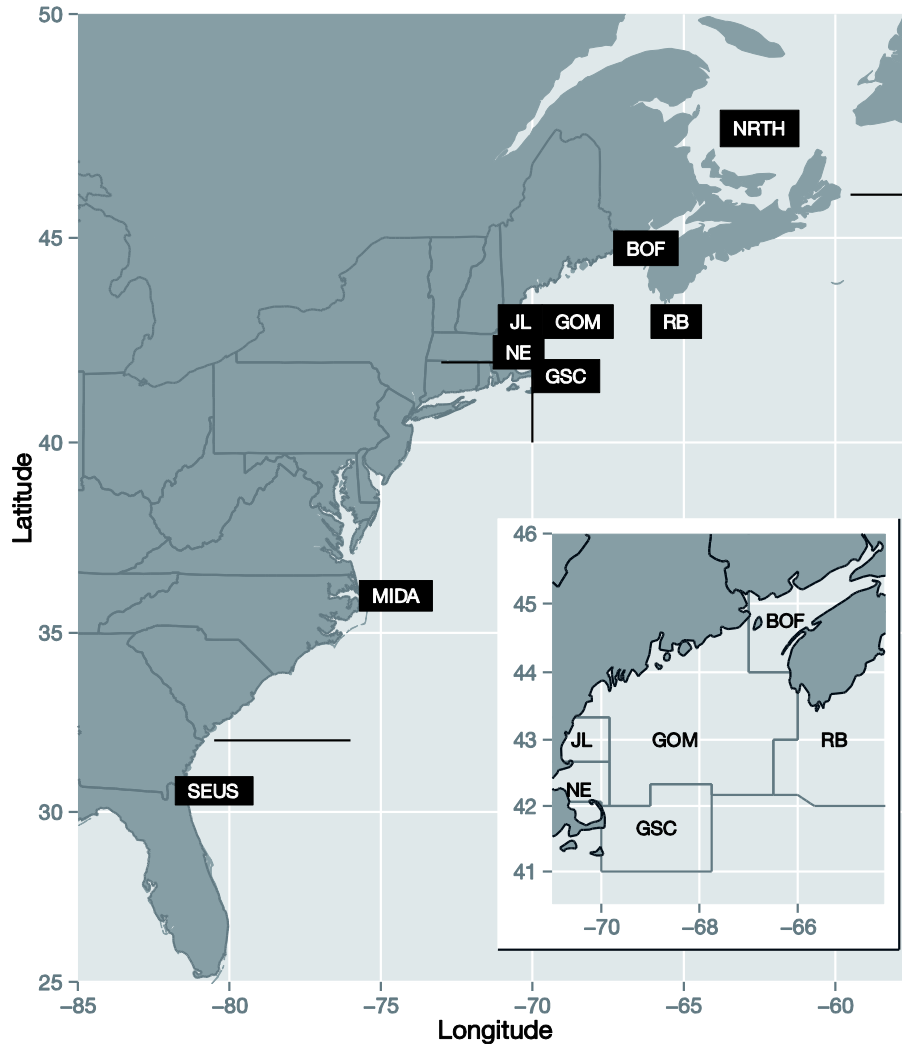


Figure S1. Regions included in the Right Whale Catalog. NRTH, North; BOF, Bay of Fundy; GOM, Gulf of Maine; RB, Roseway Basin; JL, Jeffreys Ledge; NE, New England (Cape Cod and Massachusetts Bays)¹; GSC, Great South Channel; MIDA, mid-Atlantic; SEUS, southeastern United States.

¹ The larger figure and inset inadvertently cut off Cape Cod Bay; the lines associated with New England are incorrect. We will correct this figure in future iterations.

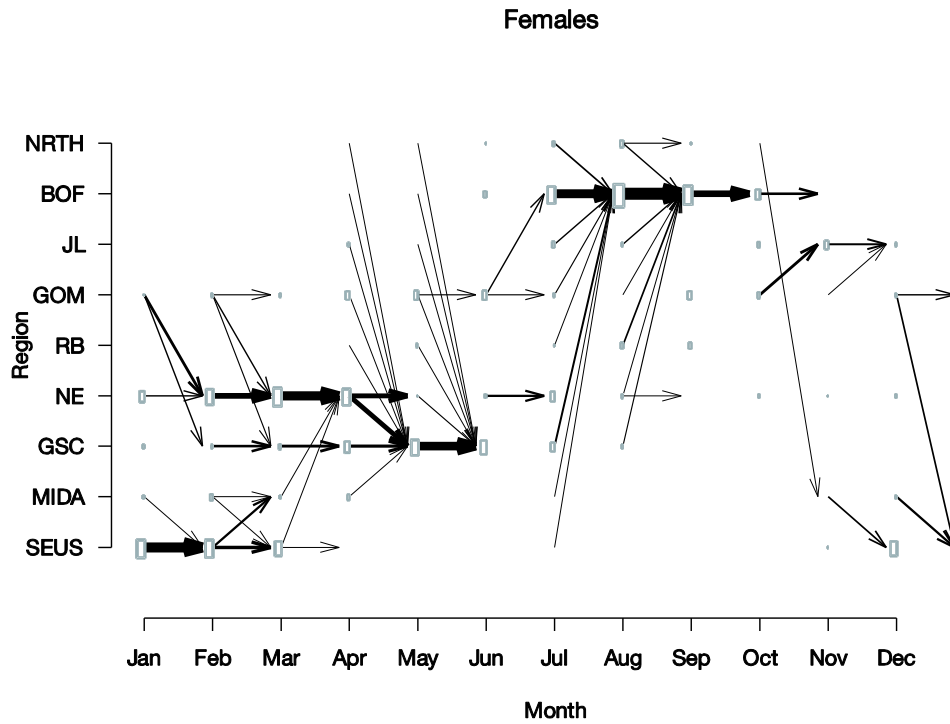


Figure S2. Estimated posterior probabilities (> 0.25) of movements of adult female right whales among regions during successive months on the basis of informed priors from Schick et al. (2013) and the likelihood of observed transitions. Thickness of arrow is correlated with probability. NRTH, North; BOF, Bay of Fundy; GOM, Gulf of Maine; RB, Roseway Basin; JL, Jeffreys Ledge; NE, New England; GSC, Great South Channel; MIDA, mid-Atlantic; SEUS, southeastern United States

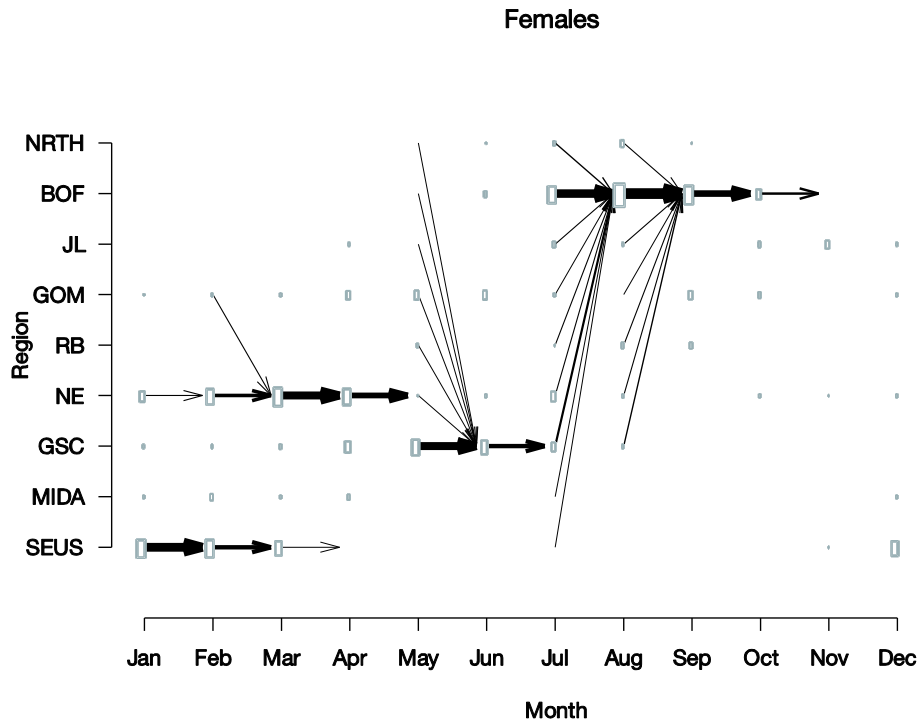


Figure S3. Estimated probabilities (> 0.25) of movements of adult female right whales among regions during successive months on the basis of flat (uninformed) priors. Thickness of arrow is correlated with probability. Note the absence of estimates to and through the mid-Atlantic region. NRTH, North; BOF, Bay of Fundy; GOM, Gulf of Maine; RB, Roseway Basin; JL, Jeffreys Ledge; NE, New England; GSC, Great South Channel; MIDA, mid-Atlantic; SEUS, southeastern United States

The first two sections focus on estimating the number of adult right whales that are present in the mid-Atlantic during four different months: January, April, July, and October. We treat females and males separately.

Section 1 – Distribution of adult female right whales in the mid-Atlantic

- 1) Consider a population of 100 adult **female** right whales. The following questions address the number of those whales *present in the mid-Atlantic*, for any duration, during **January**.
 - a) Think of all the reasons why the number may be low. What is the smallest plausible value?
 - b) Think of all the reasons why the number may be high. What is the highest plausible value?
 - c) What is your best estimate of the modal number of adult female right whales that are present in the mid-Atlantic during January? Please base your estimate of the mode on the period from 1995 to present.
 - d) Expressed as a percentage, how confident are you that the true number of adult female right whales that are present in the mid- Atlantic during January lies within the lower and upper bounds you specified?

- 2) Consider a population of 100 adult **female** right whales. The following questions address the number of those whales *present in the mid-Atlantic*, for any duration, during **April**.
 - a) Think of all the reasons why the number may be low. What is the smallest plausible value?
 - b) Think of all the reasons why the number may be high. What is the highest plausible value?
 - c) What is your best estimate of the modal number of adult female right whales that are present in the mid-Atlantic during April? Please base your estimate of the mode on the period from 1995 to present.
 - d) Expressed as a percentage, how confident are you that the true number of adult female right whales that are present in the mid- Atlantic during April lies within the lower and upper bounds you specified?

- 3) Consider a population of 100 adult **female** right whales. The following questions address the number of those whales *present in the mid-Atlantic*, for any duration, during **July**.
 - a) Think of all the reasons why the number may be low. What is the smallest plausible value?
 - b) Think of all the reasons why the number may be high. What is the highest plausible value?
 - c) What is your best estimate of the modal number of adult female right whales that are present in the mid-Atlantic during July? Please base your estimate of the mode on the period from 1995 to present.
 - d) Expressed as a percentage, how confident are you that the true number of adult female right whales that are present in the mid- Atlantic during July lies within the lower and upper bounds you specified?

- 4) Consider a population of 100 adult **female** right whales. The following questions address the number of those whales *present in the mid-Atlantic*, for any duration, during **October**.
 - a) Think of all the reasons why the number may be low. What is the smallest plausible value?
 - b) Think of all the reasons why the number may be high. What is the highest plausible value?

- c) What is your best estimate of the modal number of adult female right whales that are present in the mid-Atlantic during October? Please base your estimate of the mode on the period from 1995 to present.
- d) Expressed as a percentage, how confident are you that the true number of adult female right whales that are present in the mid- Atlantic during October lies within the lower and upper bounds you specified?

End of section 1.

Section 2 – Distribution of adult male right whales in the mid-Atlantic

- 5) Consider a population of 100 adult **male** right whales. The following questions address the number of those whales *present in the mid-Atlantic*, for any duration, during **January**.
 - a) Think of all the reasons why the number may be low. What is the smallest plausible value?
 - b) Think of all the reasons why the number may be high. What is the highest plausible value?
 - c) What is your best estimate of the modal number of adult male right whales that are present in the mid-Atlantic during January? Please base your estimate of the mode on the period from 1995 to present.
 - d) Expressed as a percentage, how confident are you that the true number of adult male right whales that are present in the mid-Atlantic during January lies within the lower and upper bounds you specified?
- 6) Consider a population of 100 adult **male** right whales. The following questions address the number of those whales *present in the mid-Atlantic*, for any duration, during **April**.
 - a) Think of all the reasons why the number may be low. What is the smallest plausible value?
 - b) Think of all the reasons why the number may be high. What is the highest plausible value?
 - c) What is your best estimate of the modal number of adult male right whales that are present in the mid-Atlantic during April? Please base your estimate of the mode on the period from 1995 to present.
 - d) Expressed as a percentage, how confident are you that the true number of adult male right whales that are present in the mid-Atlantic during April lies within the lower and upper bounds you specified?
- 7) Consider a population of 100 adult **male** right whales. The following questions address the number of those whales *present in the mid-Atlantic*, for any duration, during **July**.
 - a) Think of all the reasons why the number may be low. What is the smallest plausible value?
 - b) Think of all the reasons why the number may be high. What is the highest plausible value?
 - c) What is your best estimate of the modal number of adult male right whales that are present in the mid-Atlantic during July? Please base your estimate of the mode on the period from 1995 to present.
 - d) Expressed as a percentage, how confident are you that the true number of adult male right whales that are present in the mid-Atlantic during July lies within the lower and upper bounds you specified?
- 8) Consider a population of 100 adult **male** right whales. The following questions address the number of those whales *present in the mid-Atlantic*, for any duration, during **October**.

- a) Think of all the reasons why the number may be low. What is the smallest plausible value?
- b) Think of all the reasons why the number may be high. What is the highest plausible value?
- c) What is your best estimate of the modal number of adult male right whales that are present in the mid-Atlantic during October? Please base your estimate of the mode on the period from 1995 to present.
- d) Expressed as a percentage, how confident are you that the true number of adult male right whales that are present in the mid-Atlantic during October lies within the lower and upper bounds you specified?

End of section 2.

In our original analysis (Schick et al. 2013), we established priors for many of the transitions (i.e., movements) within and between the nine geographic regions during each month. Estimating all of the latter priors within this elicitation is not feasible, so we instead focus on one month (January) and three regions (southeastern United States, mid-Atlantic, and all northern regions).

The goal of sections 3 and 4 is to elicit your best estimates of the total number of whales that either (1) move into the mid-Atlantic at any point in time during January or (2) were present in the mid-Atlantic during December and remain in the mid-Atlantic for any period of time during January. An individual whale that moves into the mid-Atlantic during January may either travel through the mid-Atlantic or remain in the mid-Atlantic for some period of time; all are present in the mid-Atlantic for some amount of time during January and should be included in your estimate.

To limit the number of questions, we group all northern regions. That is, instead of asking you to differentiate between movements from the Gulf of Maine to the mid-Atlantic and from Jeffrey's Ledge to the mid-Atlantic, we ask you to address movements from all northern regions to the mid-Atlantic.

Please base your answers on the period from 1995 to present. Please consider all whales regardless of health, condition, or injury.

Section 3 – Transitions of adult female right whales into the mid-Atlantic during January

- 9) Consider a population of 100 adult **female** right whales that are present in the northern regions during December and move *south to the mid-Atlantic* during **January**.
 - a) Think of all the reasons why the number may be low. What is the smallest plausible value?
 - b) Think of all the reasons why the number may be high. What is the highest plausible value?
 - c) What is your best estimate of the modal number of adult female right whales that move from the northern regions to the mid-Atlantic during January?
 - d) Expressed as a percentage, how confident are you that the true number of adult female right whales that move from the northern regions to the mid-Atlantic during January lies within the lower and upper bounds you specified?

- 10) Consider a population of 100 adult **female** right whales that are present in the mid-Atlantic during December and **remain in the mid-Atlantic** for any duration during **January**.
- Think of all the reasons why the number may be low. What is the smallest plausible value?
 - Think of all the reasons why the number may be high. What is the highest plausible value?
 - What is your best estimate of the modal number of adult female right whales that remain in the mid-Atlantic during January?
 - Expressed as a percentage, how confident are you that the true number of adult female right whales that remain in the mid-Atlantic during January lies within the lower and upper bounds you specified?
- 11) Consider a population of 100 adult **female** right whales that are present in the southeastern United States during December and move **north to the mid- Atlantic** during **January**.
- Think of all the reasons why the number may be low. What is the smallest plausible value?
 - Think of all the reasons why the number may be high. What is the highest plausible value?
 - What is your best estimate of the modal number of adult female right whales that move from the southeastern United States to the mid- Atlantic during January?
 - Expressed as a percentage, how confident are you that the true number of adult female right whales that move from the southeastern United States to the mid-Atlantic during January lies within the lower and upper bounds you specified?

End of section 3.

Section 4 – Transitions of adult male right whales into the mid-Atlantic during January

- 12) Consider a population of 100 adult **male** right whales that are present in the northern regions during December and move **south to the mid-Atlantic** during **January**.
- Think of all the reasons why the number may be low. What is the smallest plausible value?
 - Think of all the reasons why the number may be high. What is the highest plausible value?
 - What is your best estimate of the modal number of adult male right whales that move from the northern regions to the mid-Atlantic during January?
 - Expressed as a percentage, how confident are you that the true number of adult male right whales that move from the northern regions to the mid-Atlantic during January lies within the lower and upper bounds you specified?
- 13) Consider a population of 100 adult male right whales that are present in the mid-Atlantic during December and **remain in the mid-Atlantic** for any duration during **January**.
- Think of all the reasons why the number may be low. What is the smallest plausible value?
 - Think of all the reasons why the number may be high. What is the highest plausible value?
 - What is your best estimate of the modal number of adult male right whales that remain in the mid-Atlantic during January?

- d) Expressed as a percentage, how confident are you that the true number of adult male right whales that remain in the mid-Atlantic during January lies within the lower and upper bounds you specified?
- 1) Consider a population of 100 adult **male** right whales that are present in the southeastern United States during December and move *north to the mid- Atlantic* during **January**.
- a) Think of all the reasons why the number may be low. What is the smallest plausible value?
 - b) Think of all the reasons why the number may be high. What is the highest plausible value?
 - c) What is your best estimate of the modal number of adult male right whales that move from the southeastern United States to the mid- Atlantic during January?
 - d) Expressed as a percentage, how confident are you that the true number of adult male right whales that move from the southeastern United States to the mid-Atlantic during January lies within the lower and upper bounds you specified?

End of section 4.

LITERATURE CITED

- Schick RS, Kraus SD, Rolland RM, Knowlton AR, Hamilton PK, Pettis HM, Kenney RD, Clark JS (2013) Using hierarchical Bayes to understand movement, health, and survival in the endangered North Atlantic right whale. PLoS ONE, 8:e64166
- Speirs-Bridge A, Fidler F, McBride M, Flander L, Cumming G, Burgman M (2010) Reducing overconfidence in the interval judgments of experts. Risk Analysis 30:512-523