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Article

ANALYSIS OF THE ERROR OF A NEW OBSERVER IN AERIAL SURVEYS CENSUSES WITHOUT REPETITION

Nicolas Sueyro[1,2], Enrique Alberto Crespo[1,2] & Mariano Alberto Coscarella[1,2]

[1]Laboratorio de Mamíferos Marinos (LAMAMA), Centro para el Estudio de Sistemas Marinos (CESIMAR—CCT CENPAT-CONICET), Bv. Almte Brown 2915, Puerto Madryn, Chubut, Argentina. [Correspondence: Nicolas Sueyro <nicosueyro@cenpat-conicet.gob.ar>].
[2]Facultad de Ciencias Naturales y Ciencias de la Salud, Universidad Nacional de la Patagonia San Juan Bosco, Bv. Almte Brown 3050, Puerto Madryn, Chubut, Argentina.

ABSTRACT. Abundance estimation by means of aerial surveys is prone to errors related to the observer's performance. We developed a monitoring method based on aerial surveys off the coastline for the Southern Right Whale (*Eubalaena australis*) in the breeding grounds of the Southwestern Atlantic. These surveys have been taking place since 1999, and whales have been counted by many different observers meanwhile. This paper examines the influence of observer's experience over whale counts within the GAM framework, and also determines how many flights are needed for a new observer to be trained. We modeled the number of whales counted using the number of flights performed as a proxy for the experience of the observers. Our results indicate that when inexperienced observers reach the fifth training flight, they are able to provide counts similar to observers with high experience in this type of sampling. Finally, we evaluate the logistic and economic implications for the training.

RESUMEN. ANÁLISIS DEL ERROR DE UN NUEVO OBSERVADOR EN CENSOS AÉREOS SIN REPETICIÓN. La estimación de la abundancia realizada mediante censos aéreos es propensa a errores relacionados con el desempeño del observador. Desarrollamos un método de seguimiento basado en censos aéreos costeros para la ballena franca austral (*Eubalaena australis*) en las zonas de reproducción del Atlántico sud-occidental. Estos relevamientos se realizaron desde 1999 y distintos observadores contaron ballenas durante dicho período. Este trabajo examina la forma en que la experiencia de los observadores influye en los conteos de ballenas usando GAM y también determina cuántos vuelos son necesarios para que un observador se considere entrenado. Modelamos el número de ballenas contadas por cada observador usando el número de vuelos realizados como un proxy de la experiencia del observador. Nuestros resultados indican que cuando un observador sin experiencia alcanza cinco vuelos de entrenamiento, realiza conteos similares a observadores experimentados en este tipo de muestreo. Finalmente se evalúan las implicaciones logísticas y económicas para el entrenamiento.

Key words: Cetaceans, marine ecology, modelling, protected areas.

Palabras clave: Áreas protegidas, cetáceos, ecología marina, modelado.

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INTRODUCTION

Abundance estimates are essential for studying population dynamics (Williams et al. 2002). The validity of the estimates will be influenced by numerous factors that greatly affect the reliability of the information. This is, in a broad sense, the accuracy of the recorded information, which in turn depends on the quality of the instruments used and the ability of operators to record data with a minimum error.

Observers error is reduced by training (Dirschl et al. 1981; Pollock & Kendall 1987; Buckland et al. 1993). However, on some occasions, it is impossible to repeat the exact same sampling conditions. This is the case of aerial surveys in which the operating cost is high and there is no chance to repeat exactly the same flight due to natural, logistic or financial restrictions (Caughley 1977; Beard 1999).

The observation error is relevant to the most used methods to estimate abundance. Although, depending on the life history of the studied species (e.g.: long-lived species), it may be difficult to obtain in a short period (Lehner 1998). This is the case of most marine mammals, and it is particularly true for large whales like the southern right whale (*Eubalaena australis*).

Southern right whales (SRW) are the base of a large whale-watching operation in Peninsula Valdés (Crespo et al. 2011; Chalcobsky et al. 2017; Crespo et al. 2019) and both managers and the owners of the whale watching companies need near-real-time information on the number and distribution of whales in the area. In view of this, the Marine Mammals Laboratory (LAMAMA-CENPAT) developed a monitoring method through aerial surveys to provide a clear picture of the number and distribution of whales. More importantly, from the conservation point of view, this information allows estimating the rate of population increase, the number of animals circulating the area around Peninsula Valdés every year and in the long term, any changes in distribution (Sueyro et al. 2018; Crespo et al. 2019).

The monitoring method developed is based on the fact that individuals congregate for breeding between May and December in the gulfs surrounding Peninsula Valdés and adjacent areas (Payne 1986). Each year, the number of whales present in the area gradually increases until it reaches a maximum between August and September, declining afterwards (Payne 1986).

The aerial surveys started in 1999, and during this period, different observers have performed the counts. Consequently, the crew was very often composed by observers with different degree of training. Also, the information gathered by a single observer can change over time, another factor that must be considered in long-term projects such as aerial surveys for SRW. These are two sources of variability known as inter-observer and intra-observer error (Williams et al. 2007). The objective of our study was to assess the influence of observer variability by modelling the way observer's experience (acquired by training) influences the counts of SRW in Peninsula Valdés.

MATERIALS AND METHODS

The censuses were carried out from a single-engine high-wing Cessna B-182 aircraft, flying at a constant height of 500 feet (152 m) and at 80/90 knots (165 km/h) every 45 days from April to December each year. In each survey a distance of 620 km was covered in 4 hours of flight, flying from south to north along the coast (Crespo et al. 2011). The surveyed area (**Fig. 1**) is located between the mouth of the Chubut River and Puerto Lobos, on the border with the province of Rio Negro (Argentina).

The team comprised a pilot, a recorder sitting next to the pilot and two observers in the rear seats, one on each side of the aircraft (Crespo et al. 2019). The observations were made by the naked eye, and the information was recorded in spreadsheets or tablet applications developed ad-hoc with Cyber Tracker™. Information on the group composition was recorded, including mother-calf pairs, solitary individuals and mating groups comprising several males and one female (Crespo et al. 2019). Along with the group type, we recorded the position with a handheld GPS, the number of individuals and the sea state according to the Beaufort scale. Flights were completed and included in the analysis when the visibility was good, and the sea state up to 3 on the Beaufort scale.

Sixty-four aerial surveys were analyzed over a period spanning from 1999 to 2018. On average 4 surveys were carried out per year, except between 2001 and 2003 when no flights were made. Data were analyzed using generalized additive models (GAM) framework (Mccullagh & Nelder 1989; Zuur et al. 2009).

The models were selected using the Akaike Information Criterion corrected variant (AICc) (Akaike 1998). All models were implemented using the MASS software package R (R Core Team 2014).

The total number of whales counted by each observer on each flight was used as the response variable. Explanatory variables used for the model were the month, year and number of flights, this latter was used as an indicator of the observer's experience.

RESULTS

We built a specific model in order to test whether the predictive variables have an influence on the counts of SRW. The proposed GAM model has a Poisson distribution that conforms to the species sampling data.

$$g\ (\text{Total count}) = \alpha + f1\ (\text{Month},4) + f2\ (\text{Year},4) + f3\ (\text{Number of Flights},4)$$

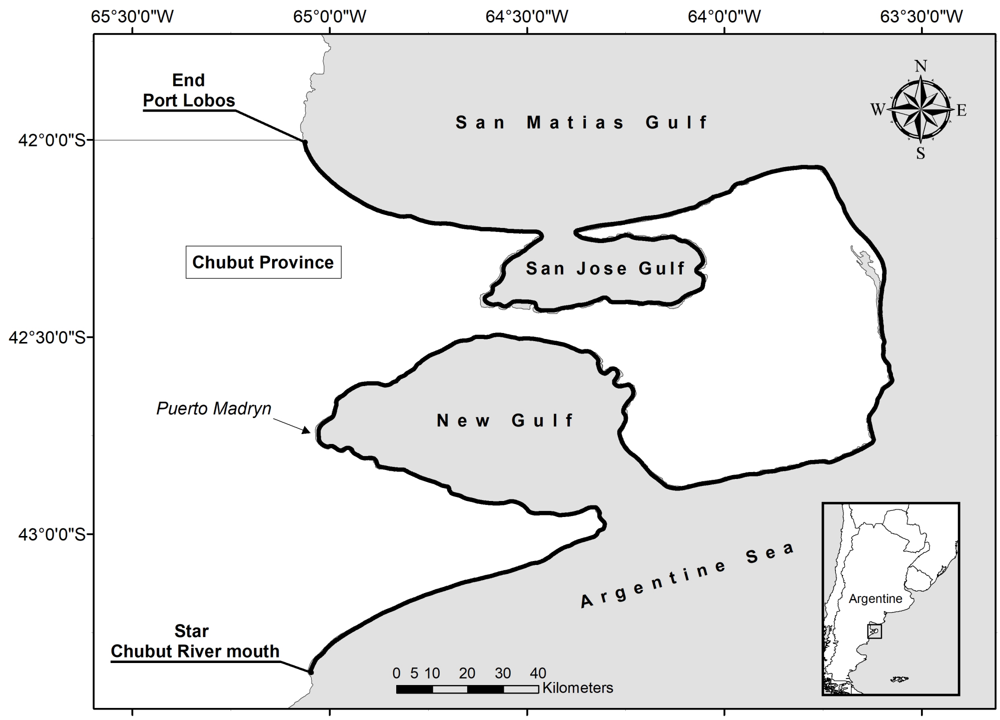

Fig. 1. Diagram of aerial surveys study area.

The total count is the number of whales counted by an observer on a particular flight. The explanatory variables used were month, year, and the Number of Flights performed by observer (e.g. count1 of observer 1, count 2 of observer 1, etc.). The latter is the number of times that a particular observer has flown. The number 4 represents the number of knots the model uses when estimating the smoothers. Month and year are the variables that allow the model to cope with the intra and inter annual variation in the number of SRW.

Table 1 shows the influence of the explanatory variables in the considered nested models. All the variables are significant, with a smoother term > 1, accounting for a nonlinear relationship with the response variable. In the case of no variation, a straight line at 0.0 would be observed on the axis of S (compared variable, significance) (Wood 2006). The selected model includes the three variables and explains 75% of variability.

Figure 2 shows the monthly variation of the SRW count in Península Valdés. In the months between May and June the count is small, these months are when the whales arrive. In the months of July and September it is the peak of the maximum count; the count decreases again when the whales leave the study area.

Figure 3 shows the variation of the SRW count along the years. The number of animals counted per observer grew in the first 5-6 years and later the relationship remained stable. **Figure** 4 shows the variation of the SRW counts of the observers with respect to the number of flights they made, showing a strong increase until the fifth flight and then reaching an asymptote.

Once the fifth flight has been reached, the experience in all the observers remains fairly constant with some random variation. The variation observed in the last part of the curve is related to the lack of information, since not many observers have more than 15 flights. This can be inferred also from the broader confidence interval beyond the tenth flight.

DISCUSSION

Despite the size of the whales, the reliability of the counts during aerial reconnaissance in Peninsula Valdés depends on the number of flights an observer performs. We were able to determine the minimum

Table 1
Models used with the three proposed variables, the percentage of Deviance explained, the value of data used (N) and the value of akaike for each model.

Models	Specific Models	Deviance explained (%)	N	AIC
GAM 1	Total count ∼ s(Month,4) + s(Year,4) + s (Number of Flights,4)	74.9	121	6486.769
GAM 2	Total count ∼ s(Month,4) + s (Number of Flights,4)	73.9	121	6700.35
GAM 3	Total count ∼ s(Year,4) + s (Number of Flights,4)	8.2	121	21569.09
GAM 4	Total count ∼ s (Number of Flights,4)	4.05	121	22530.88

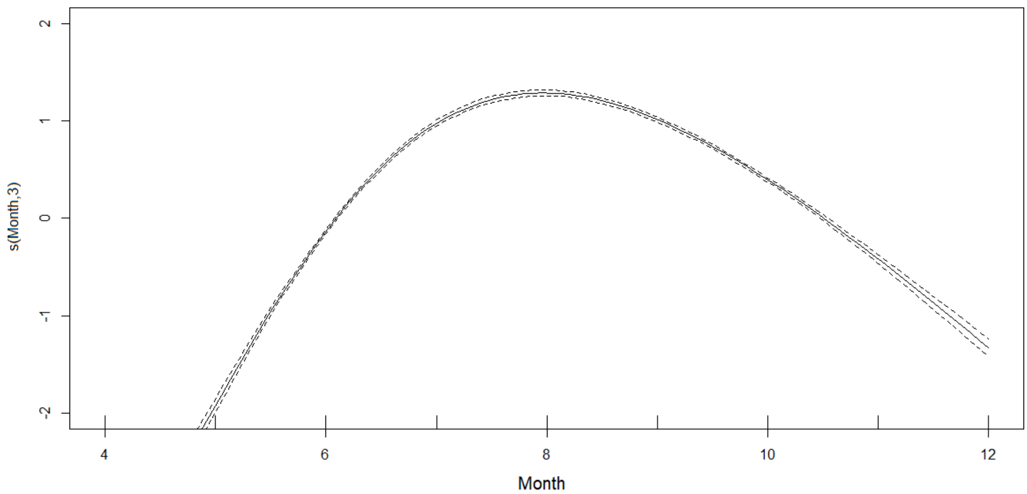

Fig. 2. Relationship of the smoother term (variation of total whale count) with the variable Month.

number of flights required to train a new observer. The differences among observers should always be considered when analyzing data from aerial surveys. This problem is not new, but it is rarely addressed (Mccullagh & Nelder 1989; Frederick et al. 2003).

Regardless of the number of observers used for this work, it allowed us to establish a minimum value required to consider a trained observer. Five flights don‘t seem like a lot, but to train a full crew (2 observers and a recorder with the ability to replace an observer) 15 training flights must be performed. This is because training usually takes place during the surveys, and it is not possible to train the 3 new observers at the same time. The effort required to maintain constant monitoring is high since it must maintain a minimum number of permanently trained observers. Due to both, logistical and weather problems, usually between 3 and 6 flights per year are conducted (Crespo et al. 2019), and hence the number of training opportunities is reduced.

The figure of five flights is not a breaking point at which an observer is fully trained, but instead gives an insight on how costly it is to train a crew. The results of the model that includes the number of flights as a proxy of observers’ experience indicate that the influence of experience over the counts goes beyond the fifth flight.

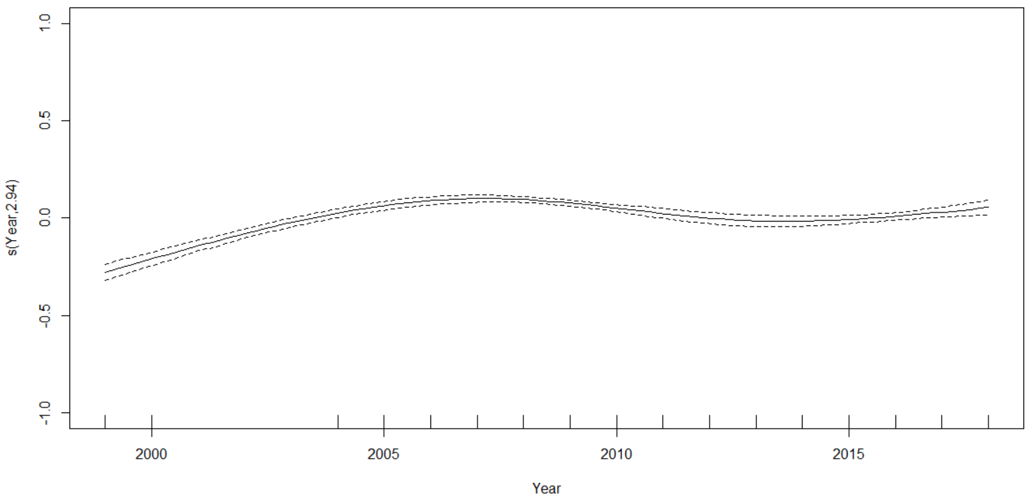

Fig. 3. Relationship of the smoother term (variation of total whale count) with the variable Year.

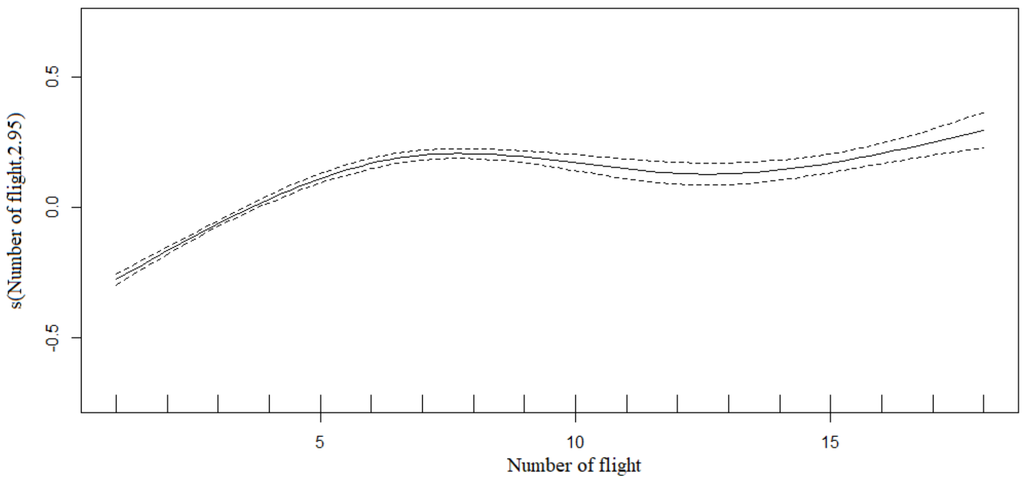

Fig. 4. Relationship of the smoother term (variation of total whale count) with the variable Number of flights, learning curve of an observer.

Considering that SRW arrive in the Peninsula Valdes area by mid-May and stay until December, with a maximum SRW peak between late July and September (Sueyro et al. 2018; Crespo et al. 2019), it would be desirable to perform the training of the new observers during the periods of lower SRW abundance. Hence, April-May and November-December are the two periods when trainees should flight to acquire experience. Although it may be difficult to maintain the same crew for long periods, it is recommended to fly with the same observers to minimize variations due to differences in their counts (Caughley 1977).

This work allowed us to understand the influence of observer's experience on aerial surveys of SRW and analyze the number of flights that an observer needs to be trained. To carry out whale abundance estimations from aerial surveys, it is advisable to consider using only experienced observers in the months of greater whale abundance and train observers with less than 5 flights in the months of lower abundance. Because of this and that it can be difficult to maintain the same crew for long periods, it is recommended to fly with the same observers to minimize variations due to differences in their counts (Caughley 1977).

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