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Assessment of Population Consequences of Harvest Strategies for the Northwest Atlantic grey seal population.

Évaluation des conséquences des stratégies de récolte sur la population du phoque gris de l'Atlantique Nord-Ouest

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ABSTRACT

We used the outputs of a Bayesian analysis of the population dynamics of the Northwest Atlantic grey seal population between 1977 and 2007 as the basis for an investigation of the consequences of a range of potential future harvest strategies. We simulated populations using the posterior distribution of model states and parameters from the fitted model, and then projected these populations forward stochastically for 20 years under different harvest regimes. The management objective was to find harvest levels that have an 80% probability of maintaining the population at above 70% of its largest population estimate to date, i.e., above 210,000. We found that this objective could be achieved with harvests as high as 45,000 animals per year when looking over a 5-year window, or 25,000 animals when looking over a 20-year window for a harvest that was 50% young of the year and 50% older animals. Quotas specifying a higher proportion of young of the year could sustain higher total harvest levels.

These results are preliminary, and more discussion of potential harvest strategies and management goals are needed. Note also that are results are dependent on the adequacy of the population dynamics model used. For example, we make no allowance for any behavioural response of seals to increased hunting levels. Also the nature and extent of density dependence in vital rates is poorly understood and may change over time. How density dependence acts on vital rates will have an impact on sustainable harvest scenarios.

RÉSUMÉ

Nous avons utilisé les résultats d'une analyse bayesienne de la dynamique de la population du phoque gris de l'Atlantique Nord-Ouest de 1977 à 2007 comme fondement d'une enquête sur les conséquences d'une gamme de stratégies de récolte éventuelles. Nous avons simulé des populations au moyen de la répartition a posteriori d'états modèles et de paramètres du modèle adapté, et ensuite effectué une projection stochastique de 20 ans de ces populations sous différents régimes de récolte. L'objectif de gestion était de trouver des niveaux de récolte ayant une probabilité de 80 p. 100 de maintenir la population au-dessus de 70 p. 100 de sa plus importante estimation de population à ce jour, c.-à-d. au-dessus de 210 000. Nous avons jugé que cet objectif pouvait être atteint avec des niveaux de récolte aussi élevés que 45 000 animaux par année sur un horizon de cinq ans, ou 25 000 animaux par année sur un horizon de 20 ans pour une prise composée à 50 p. 100 de jeunes de l'année et à 50 p. 100 d'animaux plus vieux. Les quotas indiquant une proportion plus élevée de jeunes de l'année pourraient maintenir des niveaux totaux de récolte plus élevés.

Ces résultats sont préliminaires, et une discussion plus approfondie des stratégies et des objectifs de gestion de récolte éventuels est nécessaire. Il est également à noter que les résultats dépendent de l'exactitude du modèle de dynamique de population utilisé. Par exemple, nous ne prévoyons aucune marge pour une quelconque réaction comportementale des phoques face à des niveaux de chasse plus élevés. De plus, la nature et l'étendue de la dépendance de la densité dans les indices vitaux sont mal comprises et peuvent varier. La façon dont la dépendance de la densité influe sur les indices vitaux aura une incidence sur les scénarios de capture durable.

INTRODUCTION

To estimate total population size from pup production data, it is necessary to make assumptions about the relationship between pup production and numbers of seals in other age classes, and between observed and actual pup production. Thomas et al. (2007) presented a stochastic discrete-time modelling framework called a state-space model to model the trajectory of the NW Atlantic grey seal population. They fit this to pup production data from 1977-2007.

Average annual rates of population increase were estimated to be 4% in the 1980s (lower due to greater harvests in the Gulf), 9% in the 1990s and 8% in the 2000s.

The results of the most recent assessment resulted in grey seals being considered as 'Data Rich' under the Atlantic Seal Management Framework. This framework allows a more aggressive approach to setting Total Allowable Catches (Hammill and Stenson 2007).

Fisheries and Aquaculture Management has requested advice on total allowable catches (TACs) for NW Atlantic grey seals that would maintain an 80% probability that the population would remain above N70 or 70% of the largest population observed. The most recent assessment, which is the largest observed for grey seals, estimated the population to number approximately 300,000 seals, resulting in an N70 of 210,000. The objective of this paper is to present potential TAC levels that are compliant with this management framework.

MATERIALS AND METHODS

State-space modelling framework

The methods and data used to derive the population estimates have been described in detail by Thomas et al. (2007), and will not be repeated here. In summary, Thomas et al. constructed a mechanistic model for the dynamics of seal populations breeding in three regions: Sable Island, Gulf of St Laurence and Eastern Shore. The model explicitly incorporated age-specific and density dependent survival, age at breeding, movement of recruiting females among breeding colonies and pupping. The modelling framework was Bayesian, and informative prior distributions were specified on model parameters and initial states (numbers of seals by age and region). These were based on an analysis of pregnancy rates in the case of age-specific fecundity, and reported rates from the literature as well as expert opinion in the case of the other model variables. The model was fit to pup production data using a computer-intensive fitting procedure called a particle filter (also known as sequential importance sampling). This yielded samples from the joint posterior distribution of the model parameters and states. Thomas et al. (2007) discussed the advantages and limitations of the model and the fitting method. One limitation is that the model only included females and pups (of both sexes). Male numbers were assumed to be equal to female numbers, and we take the same course approach here.

Predictions from the model

The samples from the model-fitting exercise can be projected forwards in time using the same stochastic population dynamics model, yielding posterior predictions of future states. Known harvest levels were used in fitting the model to past data, but clearly future harvest levels are not yet known and so cannot be used in making predictions. However, we can investigate the future population trajectory under various assumptions about future harvesting strategies.

Broadly, three classes of strategy are available. The first is to do no harvesting. The second is to set a fixed harvest quota, which is constant over time. This quota may be age, sex and region specific. The third is to set a quota that is some proportion of the (estimated) population size, again possibly by age, sex and region. We report results for the first two options here, although the third is also easy to investigate within this modelling framework.

Harvest strategies used

Here we report on strategies where a fixed quota of seals are harvested each year. A fixed proportion of these are specified to be young of the year (YOY). The remainder are harvested in proportion to the size of that age in the population in each year (i.e., no age selectivity with age 1 and older animals). The harvest is divided among regions in proportion to the total population size in each region for each year (no region selectivity). The population dynamics model does not follow age 1 or older males – in Thomas et al. (2007) it was assumed that numbers of males were equal to number of females. We assume that harvest is applied equally to males and females (no sex selectivity), and therefore in simulating the population, half of the harvest quota for age 1+ animals was applied to the adult females.

We investigated two potential strategies for harvest at age: (1) 50% YOY and 50% age 1+ animals, and (2) 90% YOY and 10% age 1+ animals. Harvest quotas ranging from 0 to 60,000 seals per year were investigated. We projected all populations forwards 20 years, and report the proportion of simulations where populations falling below the management target after 5 and 20 years.

For this report, results were based on 20,000 simulations for each harvest scenario.

RESULTS

As an illustration of the simulation output, Figure 1 shows the projected total population size of grey seals over the next 20 years under a no harvest scenario. The population increases as a near-exponential rate, which is unsurprising given how far the population is from its estimated carrying capacity (Thomas et al. 2007). Figure 2 shows the projected total for a harvest of 30,000 seals per year, with 50% being YOY and 50% age 1+ animals. The population is estimated to decline in all regions except the Eastern Shore, and the overall projection across all regions is for a decline. The first year in which the management target (80% of populations having a population size of 210,000 or greater) is missed is 2019.

Summary results over the range of harvest scenarios are given in Figure 3, and Tables 1 and 2. Other things being equal, population sizes are lower in the scenarios where the 50% YOY and 50% age 1+ animals are harvested vs 90% YOY and 10% age 1+. In the former case (50:50 split), the level of harvest that cases 80% of simulations to remain above the management target after 5 years is 45,000 animals, while in the latter case (90:10 split) almost all simulations remain above the target even at the most extreme harvest quota tried (60,000). If a 20-year time window is used instead, the maximum level of harvest is 25,000 pups in the former scenario and 50,000 in the latter.

DISCUSSION

Reliability of results

There are four reasons to treat our results with caution. Firstly, they rely on the models and fitting methods used in the analysis by Thomas et al. (2007); that paper gives several caveats regarding their results and should be referred to for more information. Secondly, by projecting forward based on parameter estimates from past data, we implicitly assume that external drivers such as environmental conditions will remain the same as in the recent past. Thirdly, we assume no selectivity in harvest beyond specifying the proportion of YOY caught – i.e., no selectivity with respect to region, sex, or age for age 1+ seals. Fourthly, our model takes no account of any possible behavioural response of the seals to different harvest regimes.

Inferences about harvest levels

For the scenarios reported here, it appears that the population can sustain substantially larger harvest quotas than the present takes with little chance of dropping below 70% of current population levels in 5 years. However, we note that a true decline of 30% over 5 years would not be a desirable outcome of a management strategy. We feel that looking at the population consequences of potential harvest regimes over the longer term (e.g., 20 years) is helpful, even if we do not expect the same harvest regime to endure for that length of time, nor the environmental or biological conditions to remain constant. Nevertheless, a population that is estimated to be unlikely to drop below 70% of current levels over 25 years is certainly better buffered than one where the same criterion is applied over 5 years. This inevitably results in smaller quotas – for example, in the 50:50 YOY:age 1+ scenario, this reduces the maximum allowable quota from 45,000 to 25,000 animals per year.

The finding that a substantial YOY harvest produces smaller declines than a balanced YOY:1+ harvest is unsurprising. It is also unsurprising that it is effectively impossible to reduce the population to 70% of current levels over 5 years with the YOY-biased harvest strategy. In the extreme, even if all YOY were culled each year, this would only begin to have a substantial effect on recruitment 5 years later, and with adult survival of seals estimated to be very high, it would take a substantial time before the adult population to decline to below the target level. Nevertheless, removal of a substantial proportion of the young seal population would have undesirable long-term consequences and is clearly not a good strategy.

Future work

We have only considered a very limited range of potential harvest scenarios here, as a method of focussing discussion on feasible and desirable strategies and outcomes. Repeating the simulations with alternative strategies is extremely simple, and the software we have written to do this is relatively easy to run, without requiring a strong knowledge of the underlying statistical and mathematical foundation of the models. We hope this work contributes to a rational debate on harvest strategies for Atlantic grey seal populations.

LITERATURE CITED

Hammill, M.O. and G.B. Stenson. 2007. Application of the precautionary approach and conservation reference points to management of Atlantic Seals. ICES Journal of Marine Science.

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Table 1. Results from population projection under harvest scenario 50% young-of-the-year, 50% age 1+ animals. p(pop>210000) is proportion of simulations where total population size was greater than 21000. Mean (pop) is mean population size over simulations. 80% LCL (pop) is the lower 80th percentile of population sizes over simulations.

Annual harvest quota	*After 5 years*			*After 20 years*		
	p(pop> 210000)	*Mean (pop) 000s*	*80% LCL (pop) 000s*	*P (pop> 210000)*	*Mean (pop) 000s*	*80% LCL (pop)000s*
0	1	402	354	1	795	591
5000	1	387	340	1	725	532
10000	1	371	326	1	652	469
15000	1	356	311	1	575	403
20000	1	340	296	0.91	492	331
25000	0.99	324	281	0.86	400	249
30000	0.97	308	266	0.72	295	151
35000	0.89	291	250	0.27	181	21
40000	0.88	275	235	0.15	73	0
45000	0.85	258	219	0.05	28	0
50000	0.74	241	201	0	1	0
55000	0.67	223	187	0	0	0
60000	0.37	205	170	0	0	0

Table 2. Results from population projection under harvest scenario 90% young-of-the-year, 0% juveniles, 10% adults. P (pop>210000) is proportion of simulations where total population size was greater than 21000. Mean (pop) is mean population size over simulations. 80% LCL (pop) is the lower 80^{th} percentile of population sizes over simulations.

Annual harvest quota	*After 5 years*			*After 20 years*		
	p(pop> 210000)	*Mean (pop) 000s*	*80% LCL (pop) 000s*	*P (pop> 210000)*	*Mean (pop) 000s*	*80% LCL (pop) 000s*
0	1	402	354	1	795	591
5000	1	395	349	1	768	572
10000	1	389	344	1	740	551
15000	1	382	340	1	710	529
20000	1	375	334	1	678	504
25000	1	367	328	1	643	479
30000	1	359	322	1	605	453
35000	1	351	315	1	562	424
40000	1	343	308	1	515	399
45000	1	333	300	1	460	369
50000	1	324	291	0.97	394	294
55000	1	313	282	0.79	312	207
60000	0.99	302	272	0.44	218	110

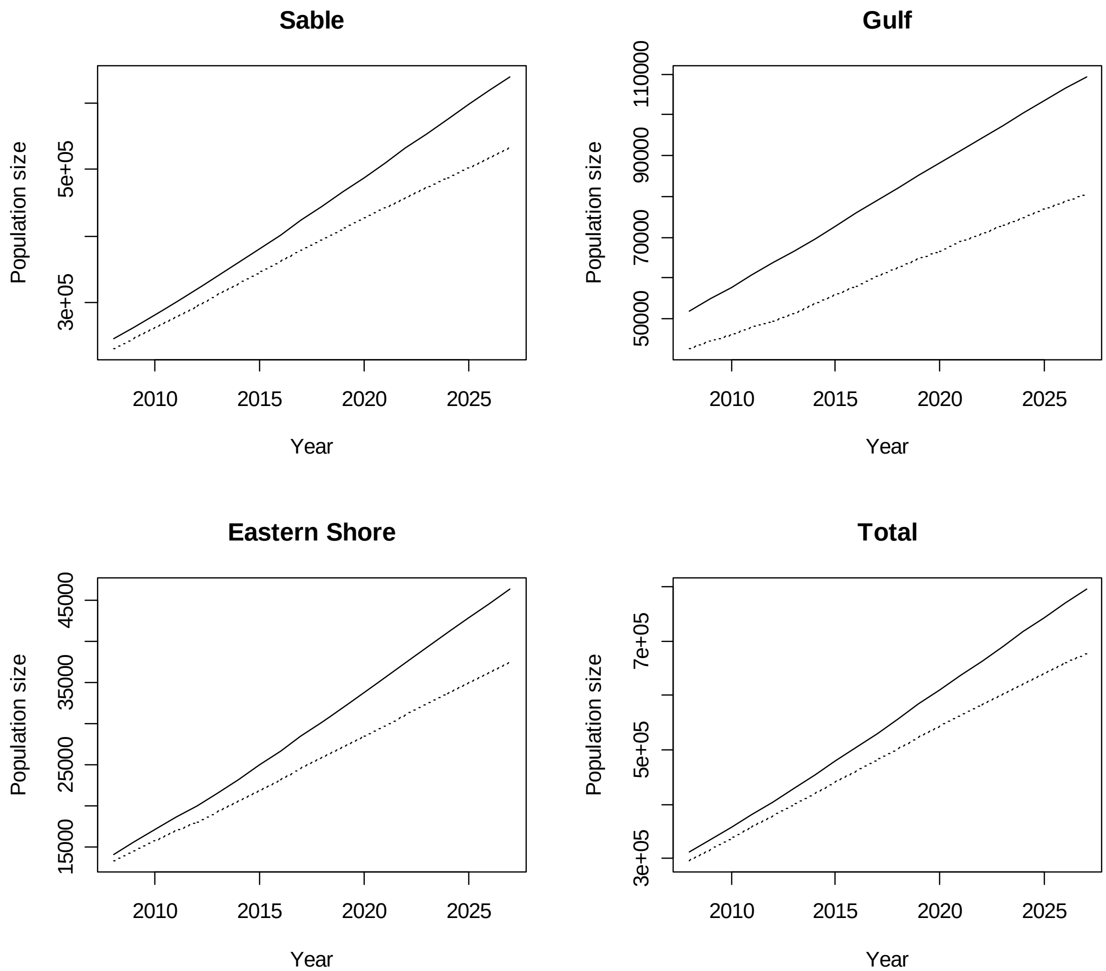

Figure 1. Predicted total population size under a no harvest scenario. Solid line shows mean of simulation, dotted line lower 20th quantile.

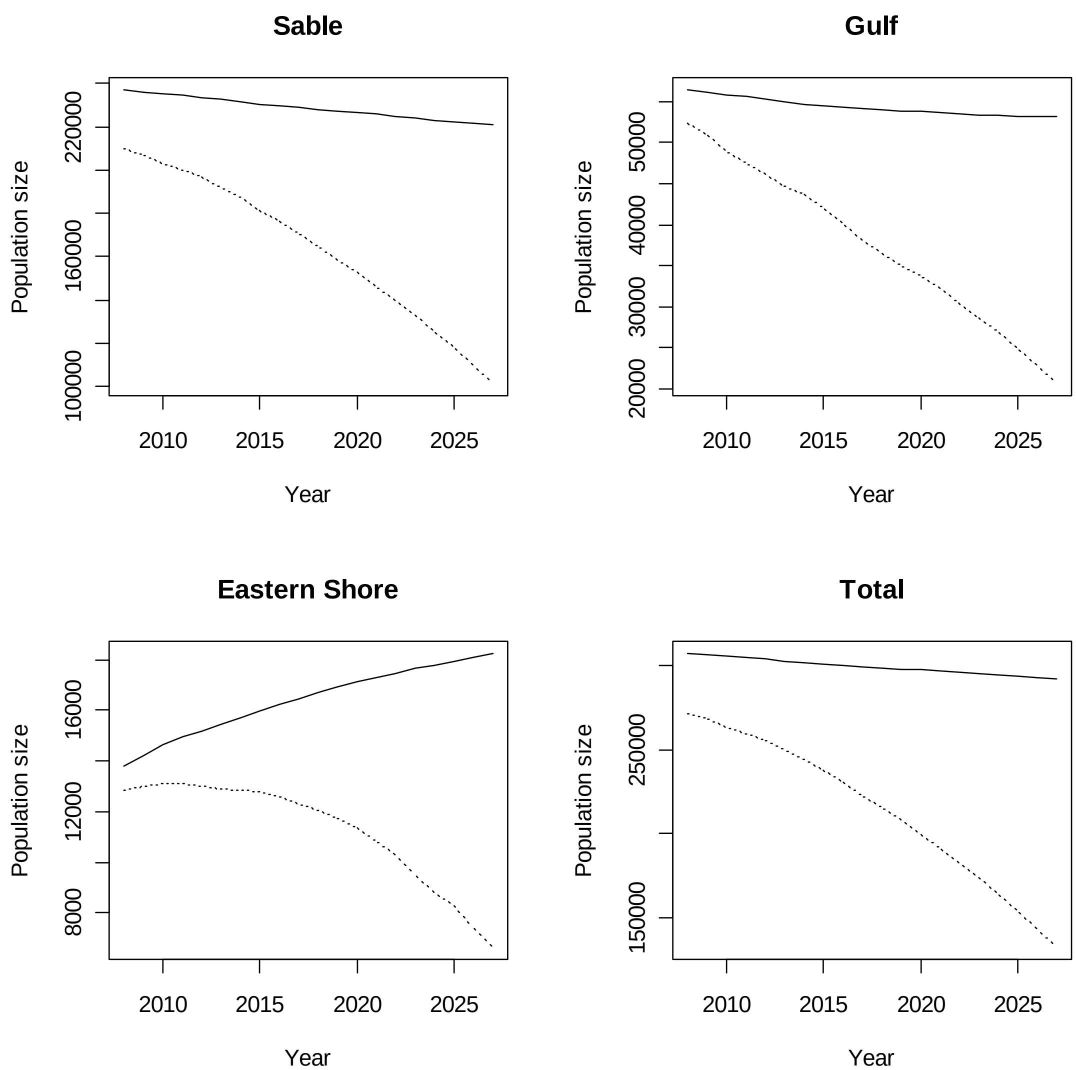

Figure 2. Predicted total population size under a scenario where 30,000 seals are harvested each year, with 50% being young of the year, and 50% being age 1+ animals. Solid line shows mean of simulation, dotted line lower 20th quantile.

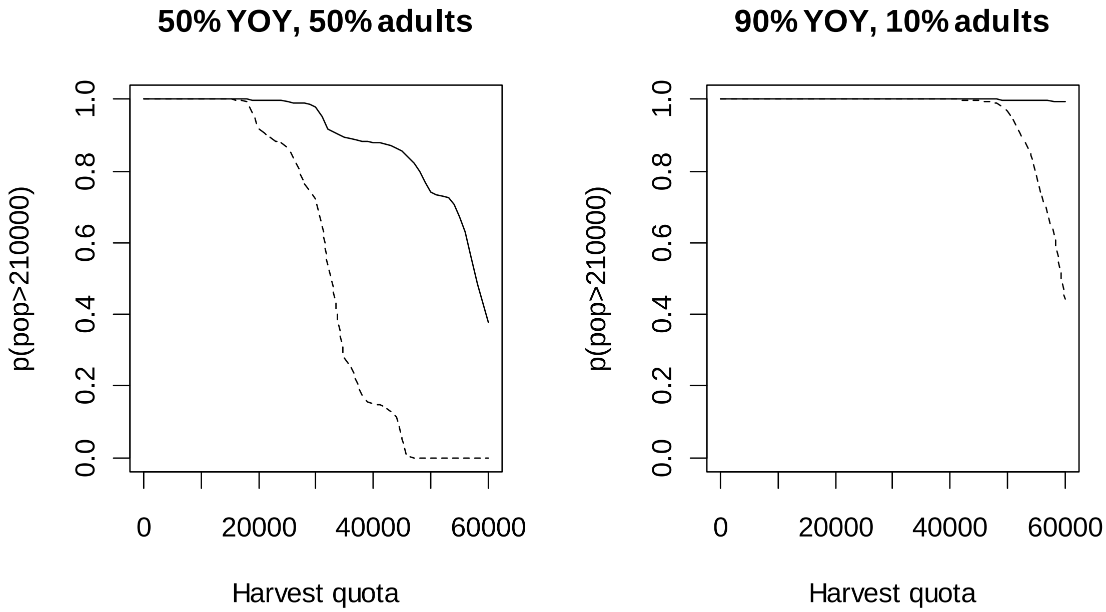

Figure 3. Proportion of simulations where the population remained above the target of 210,000 animals after 5 (solid line) and 20 (dashed line) years, over a range of harvest quota levels. Harvest comprises 50% young-of-the-year, and 50% age 1+ animals (left panel); 90% young-of-the-year, 10% age 1+ animals (right panel).