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

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

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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 2010 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 244,230. We found that this objective could be achieved with harvests as high as 30,000 animals per year when looking over a 20-year window, given a harvest that was 50% young-of-the-year and 50% older animals, assuming that mortality was distributed among ages, sexes and regions in proportion to relative abundance. Quotas specifying 95% young-of-the-year and 5% older animals could sustain higher total harvest levels, up to 70,000 animals per year, and still meet the management objective. Higher quotas could be sustained over shorter time periods, but for a long-lived species such as grey seal, it is debatable whether even 20-years is a long enough time window to judge long-term sustainability.

These results are preliminary, and more discussion of potential harvest strategies and management goals are needed. Note also that 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 bayésienne de la dynamique de la population de phoques gris de l'Atlantique Nord-Ouest de 1977 à 2010 comme fondement pour une enquête sur les conséquences d'une gamme de stratégies de récolte éventuelles. Nous avons simulé des populations à l'aide de la répartition *a posteriori* d'états modèles et de paramètres du modèle adapté, puis nous avons 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 % de maintenir la population au-dessus de 70 % de sa plus importante estimation de population à ce jour, c'est-à-dire au-dessus de 244 230. Nous avons conclu que cet objectif pouvait être atteint avec des niveaux de récolte aussi élevés que 30 000 animaux par année sur un horizon de 20 ans pour une prise composée à 50 % de jeunes de l'année et à 50 % d'animaux adultes, en supposant que la mortalité est répartie parmi les groupes d'âge, les sexes et les régions proportionnellement à l'abondance relative. Des quotas indiquant 95 % de jeunes de l'année et 5 % d'animaux adultes pourraient maintenir des niveaux totaux de récolte plus élevés, soit jusqu'à 70 000 animaux par année, et tout de même atteindre l'objectif de gestion. Des quotas plus élevés pourraient être maintenus pendant des périodes plus courtes, mais pour des espèces comme les phoques gris dont l'espérance de vie est élevée, on peut se demander si un horizon de 20 ans est suffisamment long pour nous permettre de juger de la durabilité à long terme.

Il s'agit de résultats préliminaires, et une discussion plus approfondie sur les stratégies et les objectifs de gestion de récolte éventuels est nécessaire. Il est également à noter que les résultats dépendent de l'exactitude du modèle de dynamique des populations utilisé. Par exemple, nous ne prévoyons aucune marge pour une quelconque réaction comportementale des phoques par rapport 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 au fil du temps. La façon dont la dépendance de la densité influe sur les indices vitaux aura une incidence sur les scénarios de récolte 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. (2010) 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 1977-2010. Average annual rates of population increase were estimated to be 6% in the 1980s, 9% in the 1990s and 6% in the 2000s.

Grey seals area considered as 'Data Rich' under the Atlantic Seal Management Framework. This framework (Hammill and Stenson 2007) allows a more aggressive approach to setting Total Allowable Catches (TACs). Fisheries and Aquaculture Management has requested advice on 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 348,900 seals, resulting in an N70 of 244,230. 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. (2010), 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 Coastal Nova Scotia. 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 earlier 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. (2010) 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. (2010) 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) 95% YOY and 5% age 1+ animals. Harvest quotas ranging from 0 to 80,000 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 3, 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. 2010). 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. The first year in which the management target (80% of populations having a population size of 244,230 or greater) is missed is 2030.

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 95% YOY and 5% 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 20 years is 30,000 animals, while in the latter case (95:5 split) this level is 70,000 animals.

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. (2010); 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 3 or 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 or more) 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 20 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 30,000 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 (0.961 in Thomas et al. 2010), 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. One option would be to use an even longer time window, so that lack of recruitment has an opportunity to depress the population levels, when considering the long-term sustainability of management scenarios.

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

Thomas, L., Hammill, M.O. and Bowen, W. D. 2010. Estimated size of the Northwest Atlantic grey seal population 1977-2010. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/017

Table 1. Results from population projection under harvest scenario 50% young-of-the-year, 50% age 1+ animals. p(pop>244230) is proportion of simulations where total population size was greater than 244230. 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 3 years**			**After 5 years**			**After 20 years**		
	p(pop> 244230)	***Mean (pop) 000s***	***80% ICL (pop) 000s***	***p(pop> 244230)***	***Mean (pop) 000s***	***80% LCL (pop) 000s***	***p(pop> 244230)***	***Mean (pop) 000s***	***80% LCL (pop) 000s***
0	1	382	354	1	424	393	1	733	676
5000	1	375	347	1	410	379	1	671	613
10000	1	368	340	1	395	364	1	607	546
15000	1	360	333	1	381	350	1	541	480
20000	1	353	326	1	366	335	1	470	412
25000	1	346	318	1	351	320	1	394	337
30000	1	339	311	1	336	305	0.81	311	250
35000	1	331	304	1	321	290	0.3	213	147
40000	1	324	296	0.99	305	275	0.05	98	9
45000	1	316	289	0.94	290	259	0	18	0
50000	1	309	281	0.78	274	243	0	2	0
55000	0.99	301	274	0.66	258	227	0	0	0
60000	0.98	293	266	0.49	241	211	0	0	0
65000	0.95	286	258	0.27	225	194	0	0	0
70000	0.9	278	251	0.09	207	177	0	0	0
75000	0.76	270	243	0.06	189	159	0	0	0
80000	0.7	262	235	0.04	171	140	0	0	0

Table 2. Results from population projection under harvest scenario 95% young-of-the-year, 5% age 1+ animals. p(pop>244230) is proportion of simulations where total population size was greater than 244230. 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 3 years**			**After 5 years**			**After 20 years**		
	p(pop> 244230)	***Mean (pop) 000s***	***80% LCL (pop) 000s***	***p(pop> 244230)***	***Mean (pop) 000s***	***80% LCL (pop) 000s***	***p(pop> 244230)***	***Mean (pop) 000s***	***80% LCL (pop) 000s***
0	1	382	354	1	424	393	1	733	676
5000	1	380	353	1	420	390	1	720	663
10000	1	378	351	1	417	387	1	705	648
15000	1	376	349	1	412	383	1	690	634
20000	1	374	347	1	408	379	1	673	620
25000	1	371	345	1	404	375	1	655	604
30000	1	369	343	1	399	371	1	636	587
35000	1	366	340	1	394	367	1	615	568
40000	1	363	338	1	388	362	1	592	547
45000	1	360	335	1	382	357	1	566	520
50000	1	356	332	1	376	351	1	536	494
55000	1	353	329	1	369	344	1	502	463
60000	1	349	325	1	361	337	1	460	422
65000	1	344	321	1	353	329	0.99	408	368
70000	1	339	316	1	344	320	0.85	338	290
75000	1	333	310	1	333	310	0.47	249	177
80000	1	327	305	1	322	299	0.11	171	127

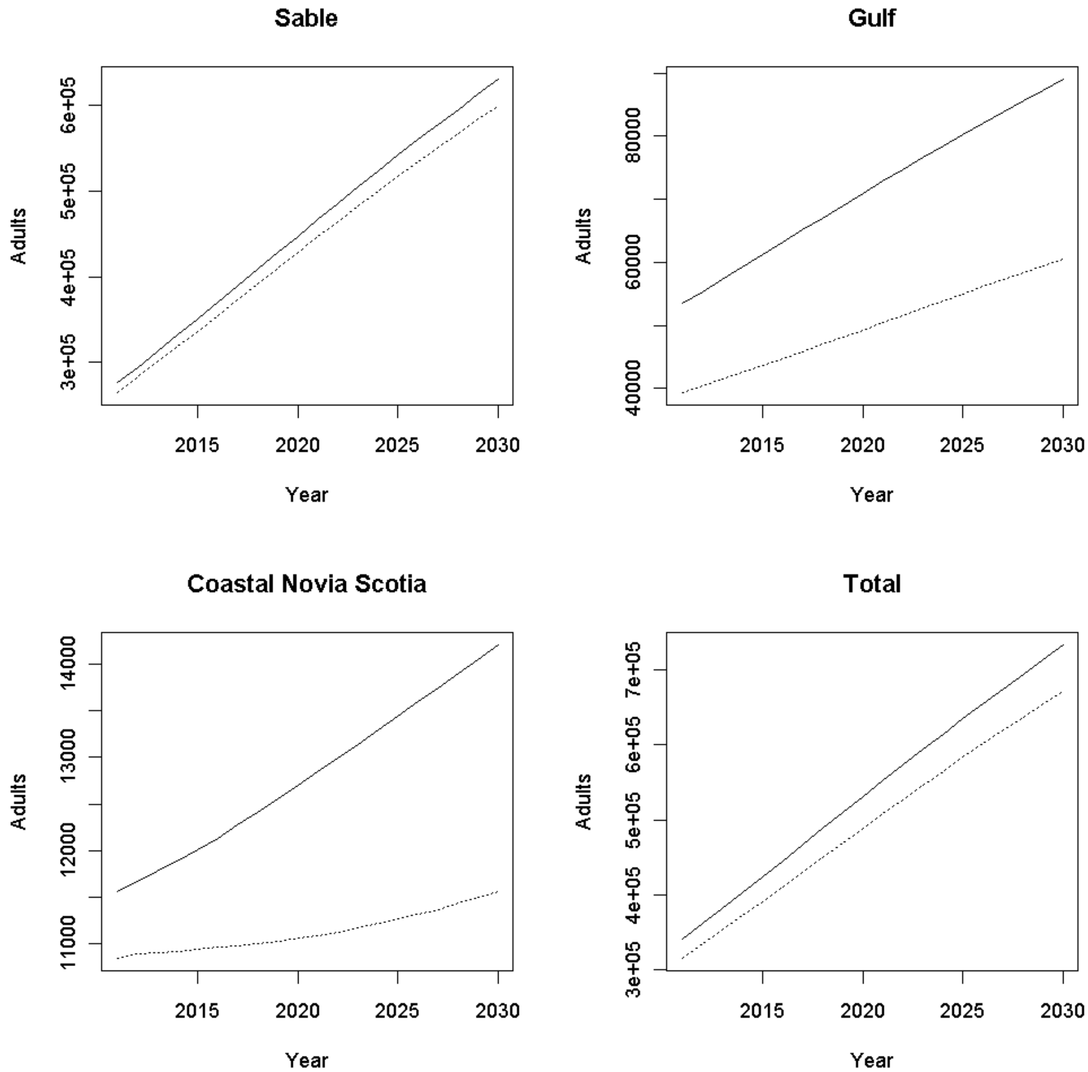

Figure 1. Predicted total population size under a no harvest scenario. Solid line shows mean of simulation, dotted line lower 20th quantile.

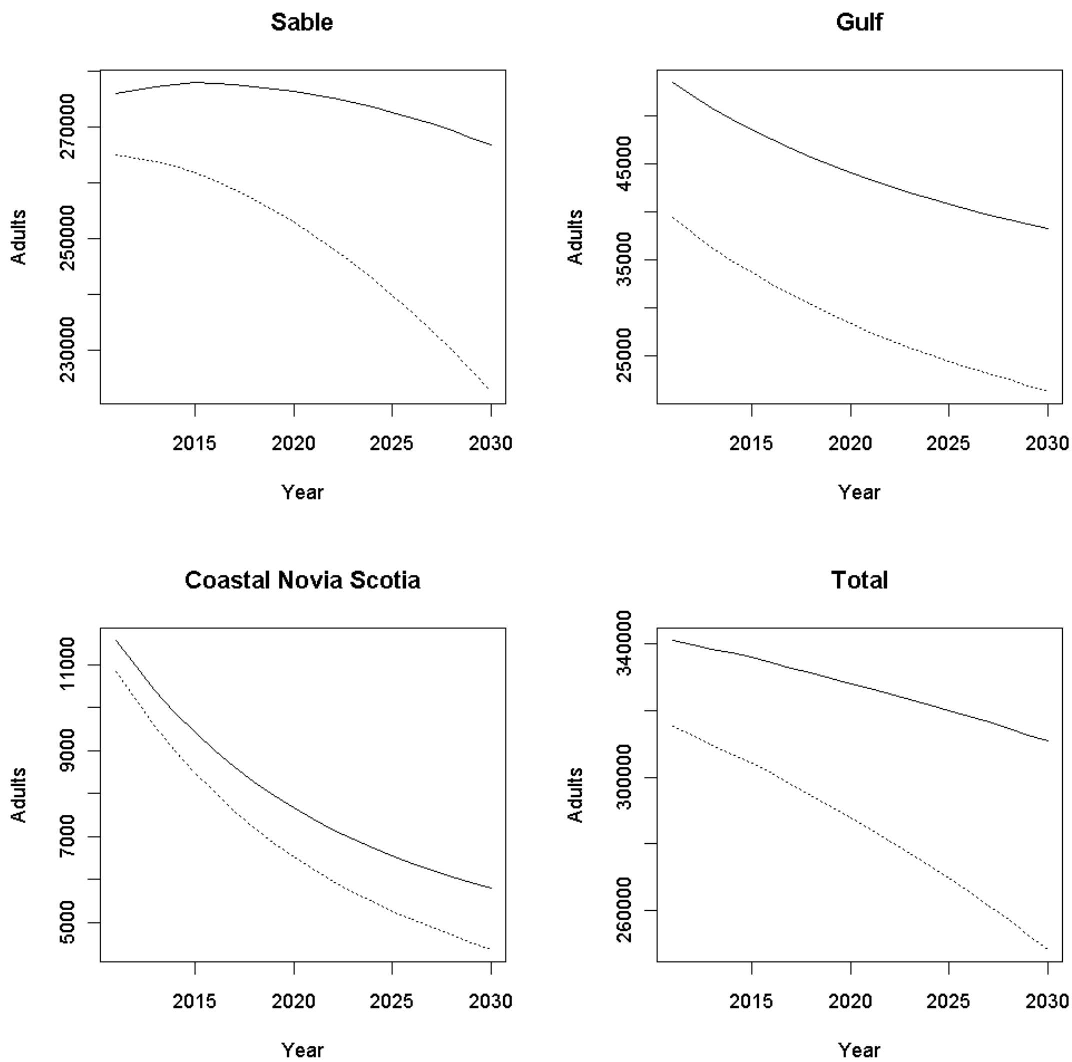

Figure 2. Predicted total population size under a scenario where 30,000 seals are harvested each year, with 50% being young of the year, and 50% being age 1+ animals. Solid line shows mean of simulation, dotted line lower 20th quantile.