PBR - is it really the only tool we want in the toolbox?

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Introduction

The *Potential Biological Removal (PBR)* was developed to estimate acceptable levels of bycatch, that would allow a depleted population to have a 95% probability of recovering above Maximum Net Productivity Level (MNPL, NMFS 2016) within 100 years.

$$PBR = N_{min} \cdot 0.5 \cdot R_{max} \cdot F_R$$

N_{min}: minimum estimated population size
R_{max}: maximum rate of population increase;
F_R: recovery factor (between 0.1 and 1).

- PBR is very easy to estimate and requires only 1 single population abundance estimate
- Simulation trials have shown that with a recovery factor F_R = 0.5, removals at PBR levels would respect the management objective 95% of the time (Wade 1998)
- PBR is increasingly being applied or proposed to estimate allowable removal levels across a range of species and conditions outside of its original application (Hammill and Stenson 2007, Curtis et al. 2015., Dillingham and Fletcher 2011)

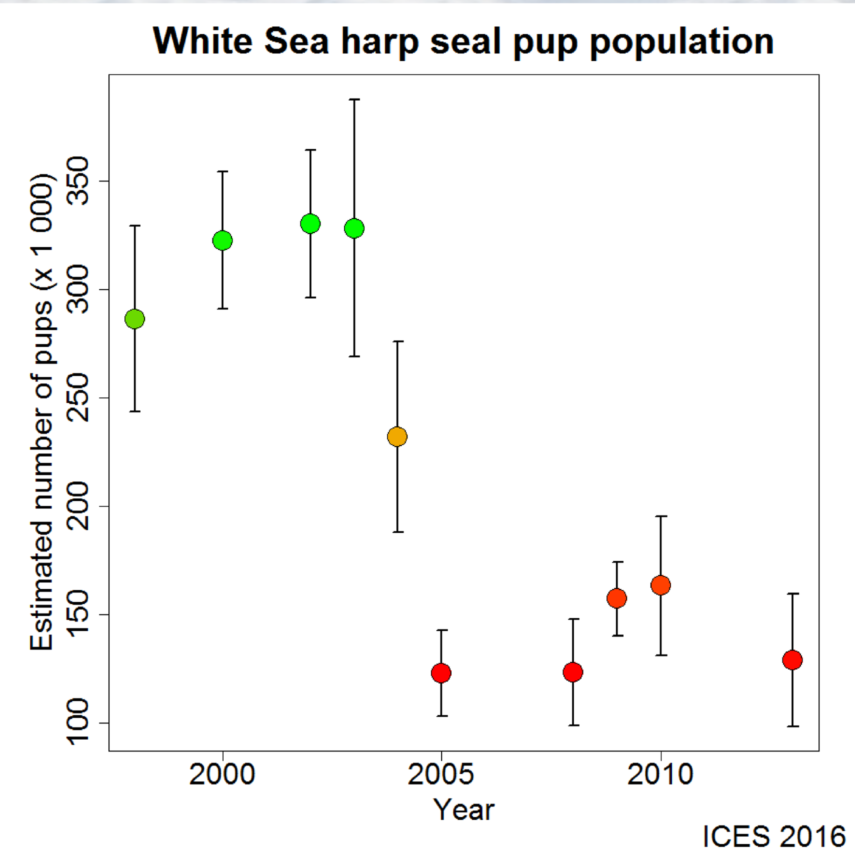
But is it reliable in all circumstances?

The White Sea harp seal case

While assessing the White Sea harp seal (*Pagophilus groenlandicus*), we applied PBR to estimate removals.

The use of PBR estimates into the model led to a projected population decline of 16% over 10 years !

Impact of an ecological shift ?
White Sea harp seal pup production levels of around 340,000 prior to 2003, declined to roughly 140,000 after 2004, suggesting that some ecological shift had occurred.



- ➢ **We explore the effects of changes in ecosystem carrying capacity (K), on the ability of PBR to respect management objectives identified under MMPA.**

Methodology

Simulations
We simulated population trajectories from specific starting sizes, to test the appropriateness of the PBR framework under different scenarios. Every 5th year, an 'aerial survey estimate' was drawn randomly and a new PBR estimated.

Population dynamics equation:

$$N_{t+1} = \omega * N_t + N_t \cdot (\lambda_{max} - 1) \cdot \left[1 - (N_t / A * K)^{\theta}\right] - C_t$$

ω = process error
N_t = total abundance in time *t*
N_0 = initial population size (7000 or 2000)
λ_{max} = maximum finite rate of increase = 0.12
K = environmental carrying capacity (10,000)
A = reduction parameter (1, 0.8, 0.6, 0.5, 0.4, 0.2)
theta (θ) = shape of the density-dependent function (θ = 1 so MNPL=0.5K)
C_t = total removals where **C_t = PBR**

Discussion

- **PBR is very simple and easy to estimate.**
- **However, when K declines by 40% or more -> removals at PBR levels have a high probability of not respecting the management objectives.**

A decline in carrying capacity of 40% is significant, but is it realistic?

Significant changes in productivity such as the 50% decline in White Sea harp seal pup production, the failure of St Lawrence beluga, North Atlantic Right whale and Cook Inlet beluga populations to recover, are well known examples where current populations are much lower than historical estimates, and yet in spite of considerable efforts these stocks have shown little to no sign of recovery.

➢ *These examples point to significant ecosystem changes.*

These may be due to changes in productivity (less food) or to anthropogenic causes which limit access to resources, effectively reducing carrying capacity e.g. increased noise, excessive vessel traffic.

Results

- With a decline in K ≤20%, the simulated population trajectory, was above MNPL, 95% of the time after 100 years.
- When the reduction in K exceeded 20% , the management objectives were not respected.
- For F_R = 0.5 and a ≥40% decline in K, the probability that the population was above MNPL was ≤60%
- Model simulations with CV=0.2, had a lower probability of respecting the management objectives than did scenarios with CV=0.5, probably because of the lower N_{min} estimated by the PBR formula.

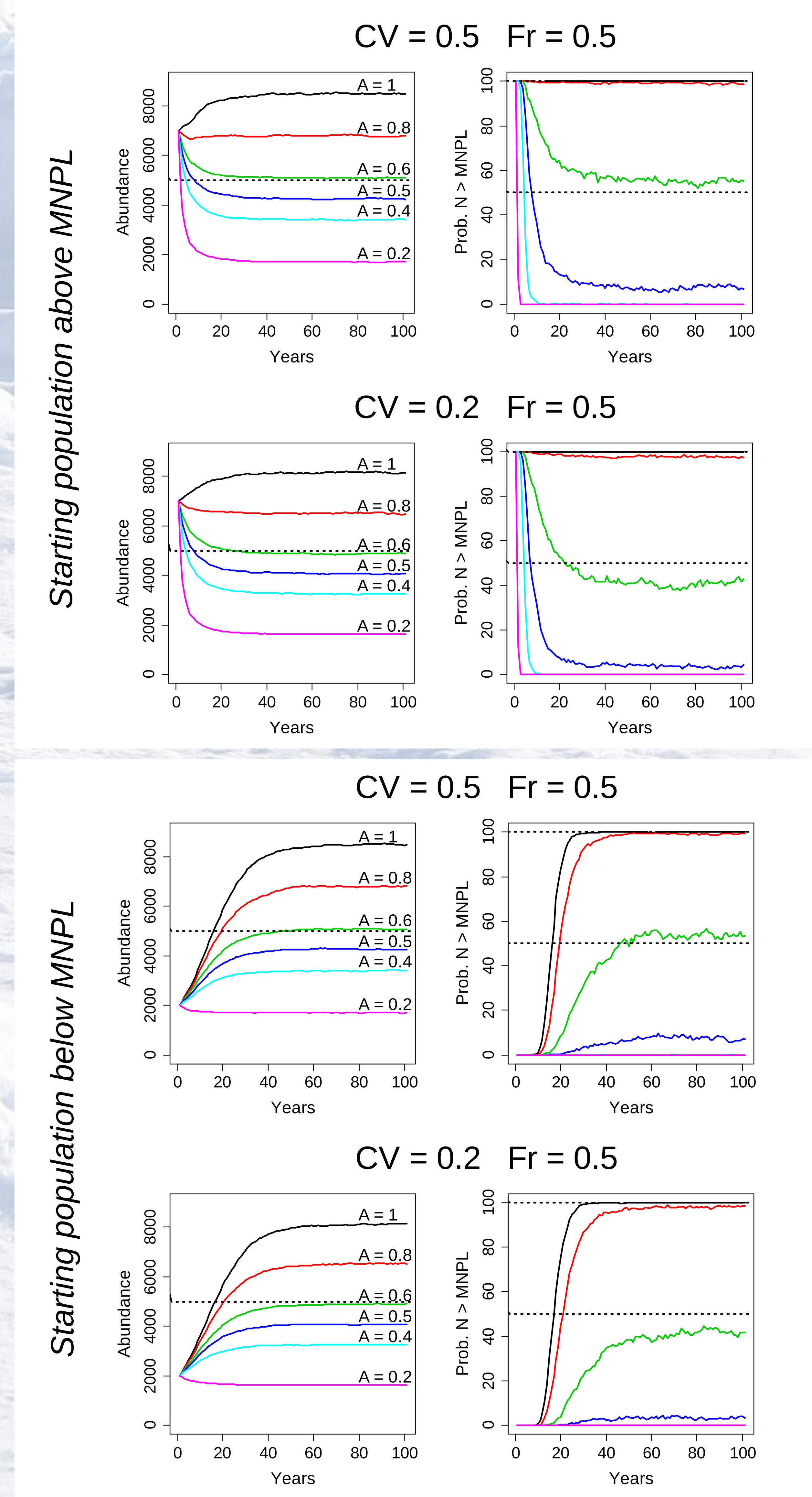


Figure 2. Impacts of changes in ecosystem carrying capacity (A*K) on changes in abundance and the probability of the population being above the Maximum Net Productivity Level (MNPL) after 100 years. K is carrying capacity , A is a proportion between 0 and 1, for different starting population sizes (N), and coefficient of variation (CV) . The recovery factor (F_R) =0.5).

PBR is an effective tool, but using it alone, without taking into consideration additional survey, demographic or ecological information, is not recommended

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