Appendix 1

Manager and user budget choice

The observed resource population size is passed on to the manager sub-model, whose role is to enact a harvesting quota that best minimizes deviations from the manager-specific target abundance. Choice of harvest quota by the manager is implemented using a genetic algorithm that finds an adaptive – but not necessarily optimal – policy, thereby mimicking a goal-oriented process prone to human error (see Duthie et al. 2018 for more details). The resulting quota is then transferred to the harvest sub-model, which also calls a genetic algorithm to determine a harvest that minimizes deviation from an user-specific target abundance whilst taking into account varying levels of user budget/

In the GMSE framework, both manager and user actions are constrained by their respective budgets (Duthie et al. 2018). A high budget for the manager increases the range of quotas they can set, and therefore enables them to exert more control on population management. In contrast, the user budget defines the maximum harvest that can be obtained by the user in the absence of management. When the user budget is high but the manager budget is low, the user is able to remove more animals from the population as the manager is unable to set a high enough quota.

Although interesting in their own right, scenarios in which the manager is unable to control the user, or in which the user is unable to fulfil the quotas set by the manager, would consistently lead to over- or under-exploitation of the wildlife population,

respectively. Our focus in this study is to instead consider scenarios in which both manager and user possess the means to effectively manage the wildlife population. This enables us to focus on quantifying how, and to what extent, conflicting objectives prevent the attainment of management targets that would otherwise be met. This requires selecting values for manager and user budgets that enable a given target to be met in the absence of perturbations caused by potential disagreements.

To evaluate the influence of manager and user budgets on management outcomes, we carried out simulations in which both budgets were varied between 0 and 10,000. For each budget combination we ran 10 management time steps and recorded wildlife population size at the final time step. Simulations were carried out with μ set to 0.2, K to 2000, and population target to 1000 individuals.

When user budget is low, the wildlife population grows beyond the population target to carrying capacity regardless of manager budget (Fig A1.1). This reflects a situation in which even the maximum possible harvesting capacity is insufficient to prevent a managed population from growing. In contrast, when manager budget is low and the ability of the user to affect the wildlife population increases, extinction becomes more likely. This illustrates a situation in which a manager cannot control a highly effective harvesting strategy. This could occur, for example, if the manager repeatedly under-estimated harvesting power.

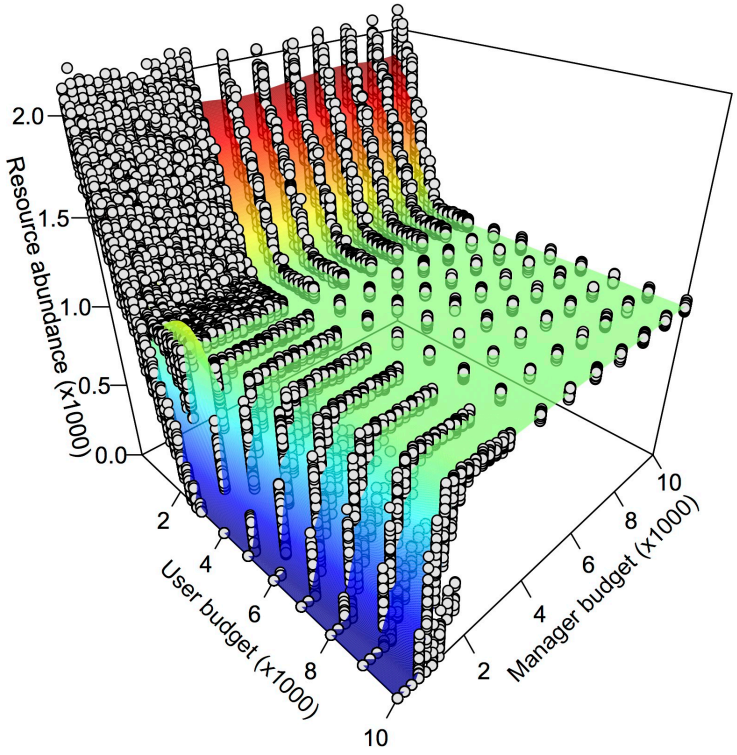

Fig. A1.1. Natural resource abundance observed as a function of user and manager budgets in the absence of conflict over management objectives. Dots denote resource abundance during the final management time step for each iteration of a user and manager budget combination. The fitted surface was obtained from a Poisson generalized additive model with a smooth tensor product representing the interaction between user and manager budgets. The surface colours are indicative of natural resource abundance (red = under-exploitation; green = target; blue = over-exploitation). The management target remained constant at 1000 individuals across the different combinations of user and manager budget. The natural resource population followed a logistic growth with an intrinsic growth rate of 0.2 and a carrying capacity of 2000 individuals.

Most importantly, we find that the management target can be achieved only for a subset of all manager and user budget combinations. In theory, any combination belonging to this subset will result in effective management in the absence of external perturbations. Based on these results, we chose to vary user budget each management

year between 5,000 and 10,000, while maintaining the manager budget at 10,000. This accounts for stochastic fluctuations in user budget that may affect harvesting capacity.

Literature cited

Duthie A. B., J. J. Cusack, I. J. Jones, J. Minderman, E. B. Nilsen, R. A. Pozo, R. A., S. Rakotonarivo, B. Van Moorter, and N. Bunnefeld. 2018. GMSE: an R package for generalised management strategy evaluation. *Methods in Ecology and Evolution* 9: 2396-2401.