



Preference heterogeneity among landowners and spatial conservation prioritization: response to Eyvindson et al. 2017

Anne Sofie Elberg Nielsen,¹ Niels Strange ,^{2*} Hans Henrik Bruun ,³ and Jette Bredahl Jacobsen²

¹COWI A/S, Parrallelvej 2, DK-2800 Lyngby, Denmark

²Department of Food and Resource Economics, Center for Macroecology, Evolution and Climate, University of Copenhagen, Rolighedsvej 23, DK-1958 Frederiksberg C, Denmark

³Department of Biology, Center for Macroecology, Evolution and Climate, University of Copenhagen, Universitetsparken 15, DK-2100 Copenhagen O, Denmark

Eyvindson et al. (2017) comment on our recent paper, Nielsen et al. (2017), in which we examined the revealed participation choice of Danish forest owners in a voluntary conservation program. We used the results to predict spatially the likelihood of all Danish forest owners participating in such programs and assessed the value of such information.

Eyvindson et al. acknowledge that the issues we address are important. Further, they agree with us that our data and tools could be further developed into a spatial optimization model that could be used to prioritize for conservation each forest holding. However, they believe that our results are too optimistic, caused by the species' persistence probability model and how we compared the uninformed and informed cases with the integer programming model.

Eyvindson et al. say the applied species-survival probability model is based on an implicit assumption that if no area is conserved in a particular cell, there will be a 0% probability of any species surviving. They argue that this assumption ignores the remaining ecological value of intensively used forests. Their argument is at least partly incorrect because the model by design always selects grid cells with some forest area. Grid cells of the lowest priority for conservation actually had no forest area at all. Most of the species included in our study depend on habitats rarely found in intensively used forests or at least found much less frequently in intensively used forests than in natural forest stands. These habitats

include microhabitats and habitats associated with old-growth trees: hollows, sap flows, rotted holes, and coarse sun-exposed bark associated with large deadwood and natural glades with abundant floral resources associated with undisturbed soil profile or forest wetlands. Intensively managed forest in Denmark has been efficiently deprived of these features through drainage, planting, thinning, removal of unwanted trees and shrubs, soil tillage, and timber harvest. For these reasons, almost half the species in our data set are on Denmark's National Red List (near threatened and threatened).

Some of the included species may find habitat in more or less managed forest, but we find our assumption a justified simplification; that is, species' survival probability changes at least an order of magnitude between intensively used forests and natural forest stands. Further, the survival-probability model relied on a 2-component estimate of probability. The first part was the current probability of a given species being present in a grid cell and depended on current forest area, the amount of broadleaved forest cover, forest productivity (mean annual increment) of regions, and current area of unmanaged forest for each species. Empirical data were applied to parameterize the probability model for each species. In contrast to what Eyvindson et al. claim, when an area was not prioritized for conservation, the probability of a species being present was still likely if the grid cell contained some broadleaved forest cover, some

*email nst@ifro.ku.dk

Paper submitted June 29, 2017; revised manuscript accepted July 26, 2017.

forest productivity, or if some forest area was unmanaged forest. Under these conditions, in the short run, we expect species' survival even if no area is conserved. The second part was the probability of long-term survival. Because no empirical data were available, we assumed 2 hypothetical relations, sigmoidal and linear, between area conserved and survival probability. This long-term survival probability could be close to zero if only a small area of unmanaged forest was set aside. Based on the expected supply of conserved forest, the probability of the medians across all 633 grid cells applying the sigmoidal and linear long-term survival-probability models was 0.5% and 9%, respectively. These estimates are hypothetical, and as Eyvindson et al. discuss, they may be too low. We do not know the correct model or parameterization because the empirical foundation is not available for the species involved in our study. In any case, this should not affect the general message that there is value in information about forest-owner preferences for conservation that should be addressed in future research.

Eyvindson et al. argue that our comparison of the uninformed and informed models is not appropriate because the areal extent (and cost) of the uninformed model is expected to be higher than the informed. We disagree and argue that they are comparable in the sense that we consistently used the uninformed scenario to select the grid cells to target. We assumed the authority responsible for a conservation program (e.g., the Danish Nature Agency) would target those areas. However, the expected area supplied voluntarily by forest owners was lower than anticipated. We estimated the conservation cost of the expected area in this uninformed scenario and used it as the budgeted amount in the spatial optimization of the informed scenario. Therefore, the total cost of the 2 scenarios is similar. In that sense, they were indeed comparable, but species' survival probability differs between them.

The expected species' survival was higher in the informed scenario than in the uninformed scenario. The reason was that when we applied the informed model, we were able to target the areas with highest combined occurrence probability and long-term survival probability. One important factor in identifying grid cells with high species' survival probability is the size of the expected conserved area in the grid cells.

Eyvindson et al. criticize our application of an integer programming model (Arthur et al. 2004) to select priority areas from among the 633 grid cells covering the entire area of Denmark. They argue that if one can adjust the proportion of land available for conservation in each cell, what is the justification for conserving all land in a particular cell and the requirement of integer programming? They claim the efficiency gained in the informed scenario stems from higher spatial resolution of data combined with the integer programming model rather than directly from the use of landowner information. It has been demonstrated that increasing spatial resolution increases

efficiency (Arponen et al. 2012). Because we applied the uninformed and informed scenarios at similar spatial resolutions, we disagree that the efficiency gain stems from increased spatial resolution. The efficiency gain is associated with the value of information (information about social preferences for conservation) and how it affects the expected supply of available areas. We do agree that when appropriate data exist at high resolution (e.g., biodiversity data at the level of forest owner or forest polygon), it would be possible and desirable to allow for more flexibility in the selection of specific forests to conserve. However, such modeling should factor in that biologically relevant areas for species are not always compatible with the forest-estate configuration. This is particularly true for Denmark, where most privately owned forests are relatively small. Approximately 90% of Danish forest estates are from 0.5 to 20 ha (on average each owner has 25 ha of forest) (Johannsen et al. 2013). Therefore, in some cases, species' home ranges will overlap with several small estates. For large forest estates, biodiversity value is very heterogeneous (e.g., occurrence of red-listed species restricted to reserves or small areas with low or no forestry interventions). Therefore, and bearing in mind that data at the biotope scale are incomplete, a direct match between forest-estate polygons and biodiversity data is often impossible, even for high-resolution, quality-checked data, such as we used. This limitation prevented us from running the analysis at forest-polygon level. Because data were lacking, the selection was kept to a rather coarse spatial resolution (10 × 10 km). This also means the difference in expected species coverage between the informed and the uninformed scenarios was caused only by more precise social targeting of grid cells under similar budget assumptions and not by the use of higher spatial resolution in the informed scenario, as claimed by Eyvindson et al. They built a hypothetical data set with the aim of evaluating the efficiency gains of an informed and uninformed model. Their analysis confirms our finding that, with intermediate budgets, the difference between the informed and uninformed scenarios is rather high and this difference decreases as the budget for conservation increases. They found, with the same budget, that a greater number of cells were protected when the available area for conservation was low. For this reason, they claim, the informed scenario was more cost-efficient than the uninformed scenario due to the lower costs of protecting each cell and the potential bias in the prediction of species occurrence. We found for the same budget, almost a similar total area was conserved, but the number of selected grid cells was significantly lower in the informed scenario. The reason is simple: the long-term probability of survival increased significantly as the size of the area potentially available for conservation increased. This implies that fewer grid cells were selected and the ones selected included larger areas available for conservation.

Although we acknowledge that the value of information (comparing efficiency with and without information about social preferences) is sensitive to context, we argue that the choice of data and modeling approach was driven by data quality and the need for a coarse spatial resolution (10×10 km). Therefore, we suggested application of coarse-resolution data for a national priority analysis based on forest-owner participation models as a first step toward selecting priority areas. Subsequently, we have been suggesting setting aside all required state-owned forest areas that have sufficiently high biodiversity value followed by targeting privately owned forests with sufficiently high biodiversity values and a maximum likelihood of participation based on our participation model.

Finally, Eyvindson et al. correctly note that the cost of implementing conservation is not as simple as using cost of setting aside forest land. This has been discussed extensively (Naidoo et al. 2006; Armsworth 2014) in terms of applying comprehensive data to cost categories (e.g., acquisition, compensating foregone income, management cost, and transaction cost) and in terms of spatial precision and dynamics (e.g., negotiation and demand and supply affecting land prices). A recent choice-experiment study on Danish forest owners' willingness to set aside forest areas shows that owners not only have heterogeneous preferences, but also may be willing to conserve biodiversity almost without compensation (Vedel et al. 2015). Thus, despite forest owners facing opportunity costs from lost timber production, private utility gains and altruistic benefits from protecting biodiversity may be considerable for some forest owner

types. Landowners may hold individual values and beliefs about conditions and threats that may affect what they value and that may spark voluntary preservation of areas of conservation value on their land (Stern 1999).

Literature Cited

- Armsworth PR. 2014. Inclusion of costs in conservation planning depends on limited datasets and hopeful assumptions. *Annals of the New York Academy of Sciences* **1322**:61–76.
- Arponen A, Lehtomäki J, Leppänen J, Tomppo E, Moilanen A. 2012. Effects of connectivity and spatial resolution of analyses on conservation prioritization across large extents. *Conservation Biology* **26**:294–304.
- Arthur JL, Camm JD, Haight RG, Montgomery CA, Polasky S. 2004. Weighing conservation objectives: maximum expected coverage versus endangered species protection. *Ecological Applications* **14**:1936–1945.
- Eyvindson K, Repo A, Burgas D, Monkkonen M. 2017. Landowner preferences and conservation prioritization: response to Nielsen et al. *Conservation Biology* **xxx**:xxx–xxx.
- Johannsen VK, Nord-Larsen T, Riis-Nielsen T, Suadicani K, Jørgensen BB. 2013. Skove og Plantager 2012. Skov & Landskab, Frederiksberg, Denmark (in Danish).
- Naidoo R, Balmford A, Ferraro PJ, Polasky S, Ricketts TH, Rouget M. 2006. Integrating economic costs into conservation planning. *Trends in Ecology & Evolution* **21**:681–687.
- Nielsen ASE, Strange N, Bruun HH, Jacobsen JB. 2017. Effects of preference heterogeneity among landowners on spatial conservation prioritization. *Conservation Biology* **31**:675–685.
- Stern PC. 1999. Information, incentives, and proenvironmental consumer behavior. *Journal of Consumer Policy* **22**:461–478.
- Vedel SE, Jacobsen JB, Thorsen BJ. 2015. Forest owners' willingness to accept contracts for ecosystem service provision is sensitive to additionality. *Ecological Economics* **113**:15–24.

