Supplementary material

Using integrated multispecies occupancy models to map co-occurrence between bottlenose dolphins and fisheries in the Gulf of Lion, French Mediterranean Sea

Comparison of precision between multi-species vs. single-species occupancy models

Valentin Lauret[1], Hélène Labach[2], Léa David[3], Matthieu Authier[4,5], Olivier Gimenez[1]

(1) CEFE, Univ Montpellier, CNRS, EPHE, IRD, Montpellier, France
(2) MIRACETI, Connaissance et conservation des cétacés, Place des traceurs de pierres, 13500 La Couronne, France
(3) EcoOcéan Institut, 18 rue des Hospices, 34090 Montpellier
(4) Observatoire Pelagis, UAR 3462, CNRS-La Rochelle Université, 17000 La Rochelle, France
(5) Adera, 162 Avenue Albert Schweitzer. CS 60040 – 33608 Pessac CEDEX, France

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Data and codes are available on Github.

Introduction

In this supplementary document, we want to assess the benefit of the multispecies occupancy framework by comparing the precision of ecological estimation. Then, we ran several competing integrated occupancy models using both SAMM aerial line-transects data and GDEGeM boat search-encounter data:

- dolphins integrated occupancy model
- trawlers integrated occupancy model
- multispecies integrated occupancy model

Methods

Model formulation

We ran an integrated multispecies occupancy model following the formulation described in our manuscript. We compared mutlispecies occupancy model estimation that with dolphins and trawlers space-use probabilities estimated with single-species occupancy models fitted à la Lauret et al. (2021).

Occupancy process

Because we compared models that have a limited amount of data, we modeled the occupancy probability with only a linear effect of bathymetry (*i.e.* without the GAM on geographical coordinates). For single-species occupancy models:

$$\text{logit}(\psi) = \alpha_0 + \alpha_1 \text{depth}$$

For the multispecies occupancy model:

$$\delta^k = \alpha_0^k + \alpha_1^k \text{depth}$$

where α_0 and α_1 are to be estimated.

Detection process

Each monitoring program B (for boat surveys) and A (for aerial surveys) has a different detection probability, p_A and p_B, modeled as a logit-function of sampling effort

$$\text{logit}(p_A) = \beta_{0A} + \beta_{1A} \text{sampling effort}$$

where β_0 and β_1 are to be estimated.

In integrated single-species occupancy models, we now consider one species at a time, hence 4 observation events can occur :

- 0 for none species detected
- 1 for targeted species detected by boat surveys
- 2 for targeted species detected by aerial surveys
- 3 for targeted species detected by both monitoring programs

From the 2 ecological states and the 4 observation events, we have the observation process with the following 4x2 matrix.

$$t(\theta'') = \begin{bmatrix} 1 & 1 - p_A - p_B + p_A p_B \\ 0 & p_A(1 - p_B) \\ 0 & p_B(1 - p_A) \\ 0 & p_A p_B \end{bmatrix}$$

Run with NIMBLE

We ran each model on NIMBLE with 3 chains and 150 000 iterations. See R codes for model comparison

Model comparison

From parameters α_1, α_0, we calculated the predicted space-use probability of the targeted species ψ for single-species occupancy models. For multispecies occupancy model, we derived marginal occupancy of bottlenose dolphins and trawlers calculating:

- $\Pr(\text{dolphins use the grid-cell}) = \psi_2 + \psi_4$
- $\Pr(\text{trawlers use the grid-cell}) = \psi_3 + \psi_4$

We reported maps of median and standard deviation of the posterior distribution of ψ.

Results

Concerning space-use probability, multispecies integrated occupancy model exhibits a higher precision (i.e. lower standard deviation) that single-species occupancy models that estimate species occupancy in isolation (Figure 1). Trawlers dataset being longer than bottlenose dolphins dataset, standard deviation of space-use are likely to be lower for trawlers than for dolphins (Figure 2).

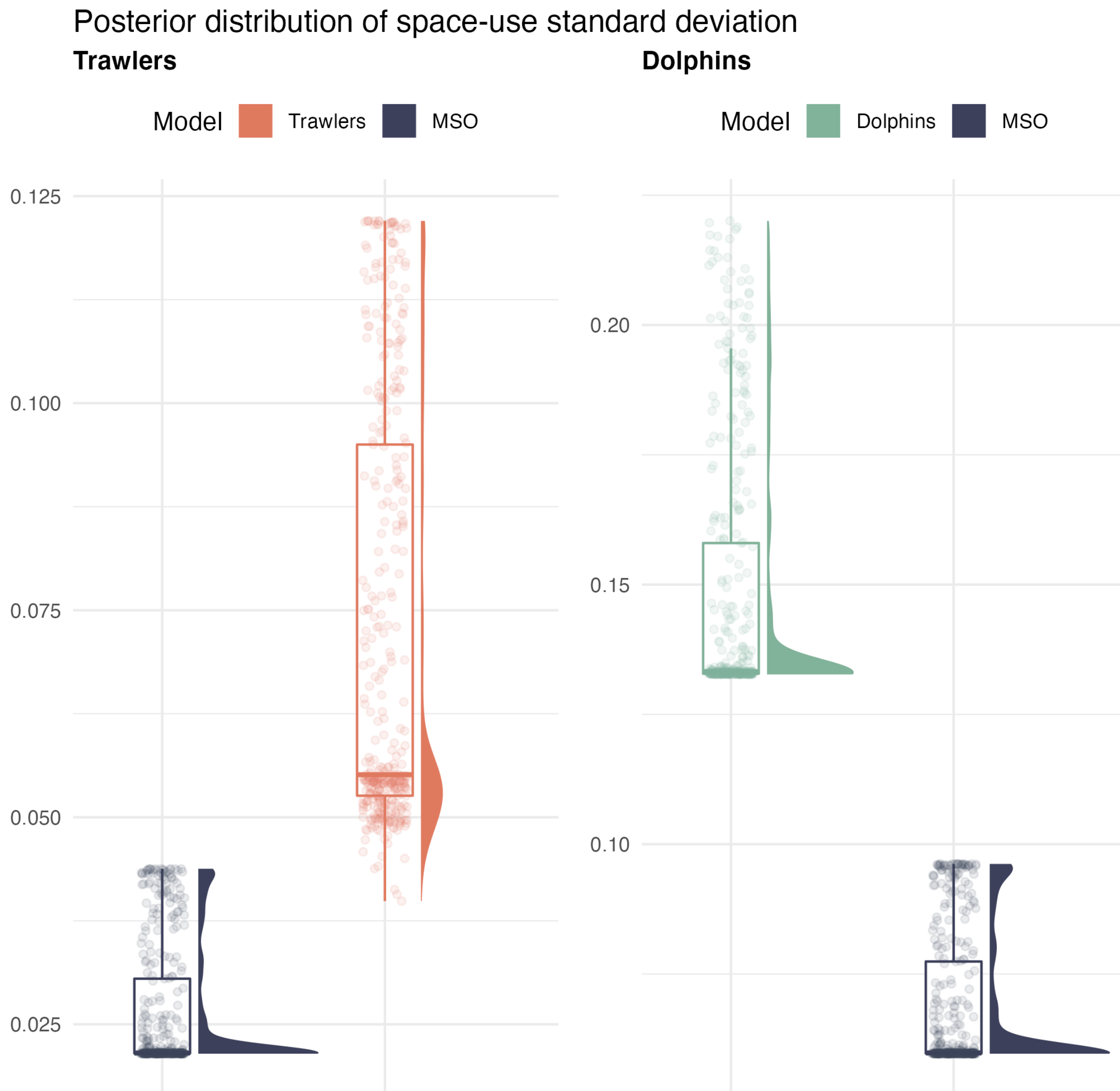

Figure 1: Standard deviation associated with space-use probability for single-species vs mutlispecies integrated occupancy models.

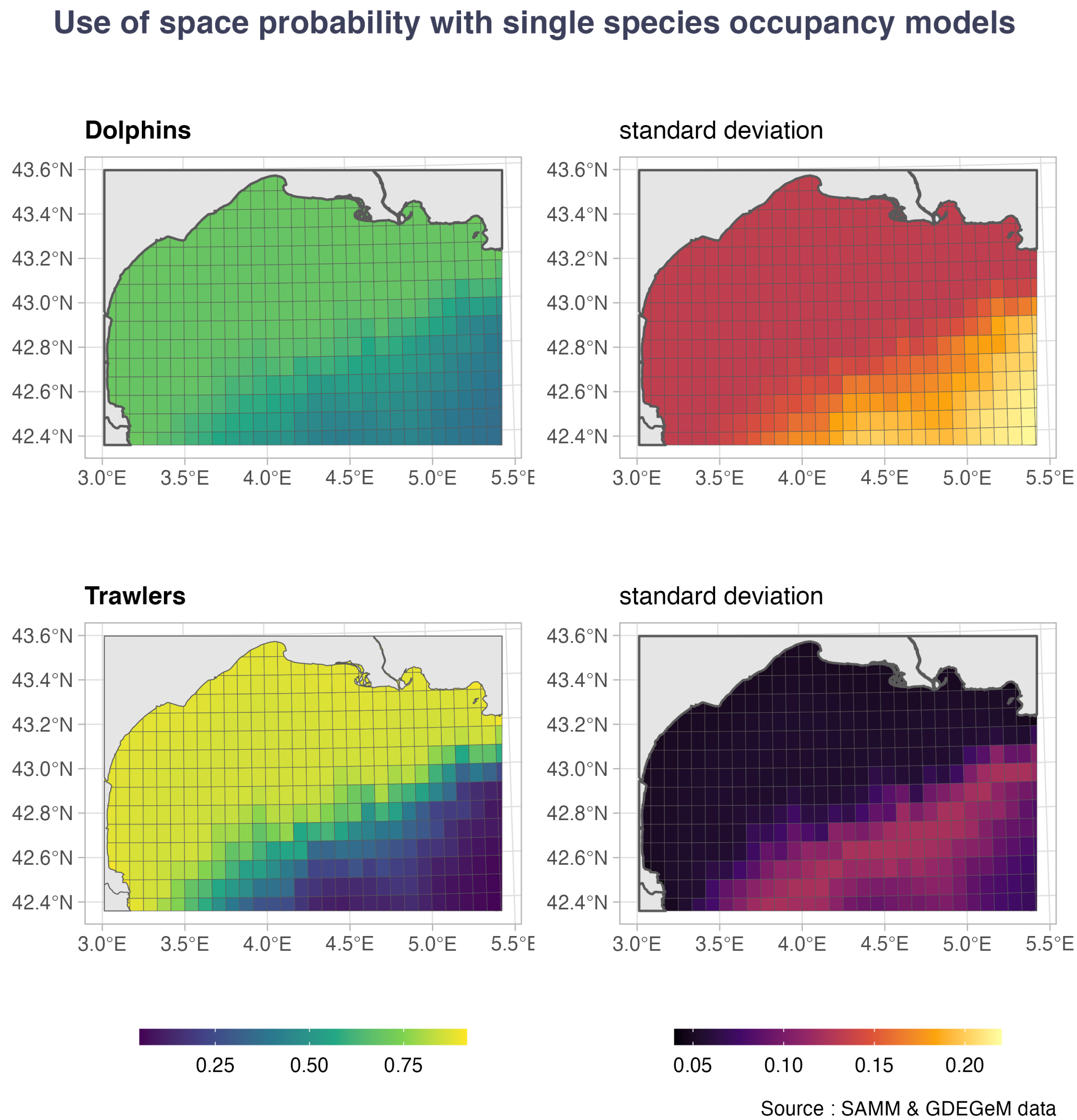

Figure 2: Maps of space-use probability and associated standard deviation for the dolphins and trawlers single-species integrated occupancy models.

Discussion

Comparing multispecies with single-species integrated occupancy models put emphasis on the benefit of the multispecies framework to improve precision associated with ecological estimation. We support that inferring multiple species space-use simultaneously help to overcome data scarcity that occur when estimating only one species at a time. Despite our case lack ecological exploration of multiple covariates due to a limited amount of data, we suggest that simulations studies in various situations would help to better understand the performance of multi-species compared to single-species occupancy models.

Nevertheless, we presented a potential illustration of multispecies models benefit. Multi-species models constitute an asset for to investigate ecological interaction deeper that superposition of species distribution, *e.g.* multi-species models allow to estimate co-occurrence probability as a function of environmental covariates. Through our case study on bottlenose dolphins and fisheries, we provided an promising illustration to extend multispecies occupancy models to integrated multiple datsets.

References

Lauret V, Labach H, Authier M, Gimenez O (2021) Using Single Visits into Integrated Occupancy Models to Make the Most of Existing Monitoring Programs. Ecology:848663.