Agreement on the Conservation of Albatrosses and Petrels

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# A probabilistic time geographic approach to quantifying bycatch risk of seabirds

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**SUMMARY**

1. Accounting for uncertainty is essential for precautionary approaches to managing seabird bycatch in fisheries. However, there is no existing mechanism to explicitly quantify the uncertainty of individual birds encountering (co-occurring within 30 km) and attending (within 5 km) individual fishing vessels.

2. Here we draw from the field of time geography to develop a method to measure seabird-vessel interactions (encounters and attendances) probabilistically. The approach involves creating voxel-based probabilistic space-time prisms (PSTPs) to model the movements of individual birds and vessels, with trajectory data derived from bird-borne GPS devices and vessel Automatic Identification Systems (AIS). We intersected these PSTPs to quantify the probability of interaction between bird-vessel pairs over time and space.

3. We demonstrate the approach with a case study of interactions of Endangered Toroa (Antipodean Albatross; *Diomedea antipodensis antipodensis*) with pelagic longline vessels in part of the western south Pacific high seas in July 2019. We found 15 vessels within 150 km and three hours of two individual birds, yet interaction occurred with only two of those vessels. We visualised the probability of encounter and attendance over time and space and determined that these interactions lasted several hours each (up to 6.2-14.1 hours attendance, 20.8-26.1 hours encounter for one bird-vessel pair).

4. *Synthesis and applications*. The time geographic approach adds to existing tools to quantify seabird bycatch risk by providing an explicit measure of uncertainty of seabird-vessel interactions. When scaled up, the method could strengthen the evidence base for enforcement of existing bycatch mitigation requirements and advocacy for improved strategies. We provide a flexible methodological pathway and R scripts, the application of which would allow managers to estimate bycatch risk for multiple marine species, even those with lower-resolution positional datasets.