frontiers

Supplementary Material

Grey Reef Sharks

Nonlinear mixed-effects model fit by maximum likelihood
Model: value ~ SSlogis(ordmonth, Asym, xmid, scal)
Data: data1

AIC	BIC	logLik
3126.346	3149.177	-1557.173

Random effects:
Formula: Asym ~ 1 | factor(TagID)

	Asym.(Intercept)	Residual
StdDev:	105.4017	21.42753

Fixed effects: list(Asym ~ mcpMax, xmid + scal ~ 1)

	Value	Std.Error	DF	t-value	p-value
Asym.(Intercept)	43.22887	35.22005	303	1.227394	0.2206
Asym.mcpMax	0.00031	0.00196	303	0.157460	0.8750
xmid	2.96390	0.11853	303	25.005249	0.0000
scal	0.89745	0.10211	303	8.789328	0.0000

Correlation:

	As.(I)	Asym.M	xmid
Asym.mcpMax	-0.806		
xmid	0.014	-0.007	
scal	0.013	-0.006	0.121

Standardized Within-Group Residuals:

Min	Q1	Med	Q3	Max
-8.72470999	-0.03239218	-0.01820643	0.07346520	11.77496839

Number of Observations: 332
Number of Groups: 26

Table S1. Effect of array size on estimates of space use of Grey Reef Sharks. Summary statistics of a non-linear mixed effect models of the monthly dBBMM KUD estimates of the grey reef shark as a function of month and the minimum convex polygon (MCP) of the array receiver locations. For each individual (TagID) we tested the effect of the largest MCP where the shark was detected. The model summary shows that the effect of the MCP on the asymptote (Asym) is not statistically significant at the 95% confidence level.

Silvertip Sharks

Nonlinear mixed-effects model fit by maximum likelihood
Model: value ~ SSlogis(ordmonth, Asym, xmid, scal)
Data: data1

AIC	BIC	logLik
5093.807	5118.02	-2540.904

Random effects:
Formula: Asym ~ 1 | factor(TagID)

	Asym.(Intercept)	Residual
StdDev:	260.4833	90.286

Fixed effects: list(Asym ~ mcpMax, xmid + scal ~ 1)

	Value	Std.Error	DF	t-value	p-value
Asym.(Intercept)	278.6502	64.17037	382	4.342350	0.000
Asym.mcpMax	-0.00495	0.00595	382	-0.831909	0.406
xmid	3.69469	0.17956	382	20.576783	0.000
scal	1.62194	0.16811	382	9.648115	0.000

Correlation:

	As.(I)	Asym.M	xmid
Asym.mcpMax	-0.692		
xmid	0.071	-0.015	
scal	0.058	-0.014	0.252

Standardized Within-Group Residuals:

Min	Q1	Med	Q3	Max
-4.24126378	-0.20676467	-0.03402898	0.09917892	6.52271866

Number of Observations: 418
Number of Groups: 33

Table S2. Effect of array size on estimates of space use of Silvertip Sharks. Summary statistics of a non-linear mixed effect models of the monthly dBBMM KUD estimates of the silvertip shark as a funtion of month and the minimum convex polygon (MCP) of the array receiver locations. For each individual (TagID) we tested the effect of the largest MCP where the shark was detected. The model summary shows that the effect of the MCP on the asymptote (Asym) is not statistically significant at the 95% confidence level.

Term	Estimate	SD	Z statistic	P value
(Intercept)	0.81	0.336	2.412	0.016
Distance	-0.126	0.019	-6.512	<0.001
Species.Silvertip	0.276	0.405	0.682	0.495
Distance:Species.Silvertip	0.042	0.021	1.968	0.049

Table S3: Model parameters for binomial GLM regression of tag detection probability against receiver distance from tagging location (Distance) and species (factor, Silvertip = 1).

Species	Mean speed (m/s)	N	Days monitored	Median detection gap (min)	Tags exiting	Total exits	Exits per tag	Days between exits
Grey reef	0.63	61	16,601	2.1	32	148	2.6	112.2
Silvertip	0.73	60	22,188	3.5	47	206	3.3	107.7

Table S4: Potential exits from the BIOT MPA based on gaps in acoustic detection, by species. 'Exits' assume animals travelled in straight lines from their last detection point to the MPA boundary between consecutive detections. Cruising speeds taken from Ryan et al. Mar Biol. 2015; 162(6):1307–18.

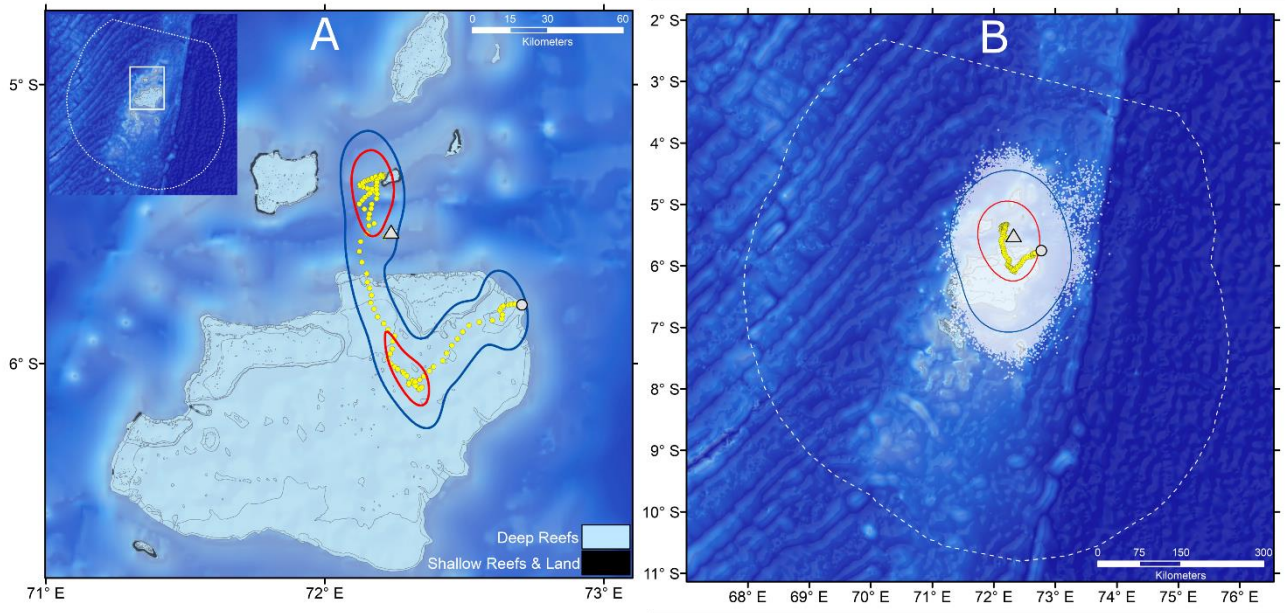

Figure S1: Example of different estimates of kernel utilization distributions (KUD) for Silvertip Shark 3914018. A) The SSM track (most probable track, yellow circles) and its 95% (blue contour) and 50% (red contour) KUD. The SSM takes into account geolocation uncertainty in reconstructing this track, however this KUD is for the modelled track and does not take into account uncertainty for each position. B) SSM track (yellow circles, most probable track), the full posterior distribution (white points, all estimated possible positions for each daily geolocation) from the SSM model used to estimate the most probable track, and the KUDs of the full posterior distribution. This KUD takes into account the uncertainty used in modelling the most probably track. Tagging location shown with white triangle, pop-off location is white circle. MPA boundary is shown with the dashed white line.

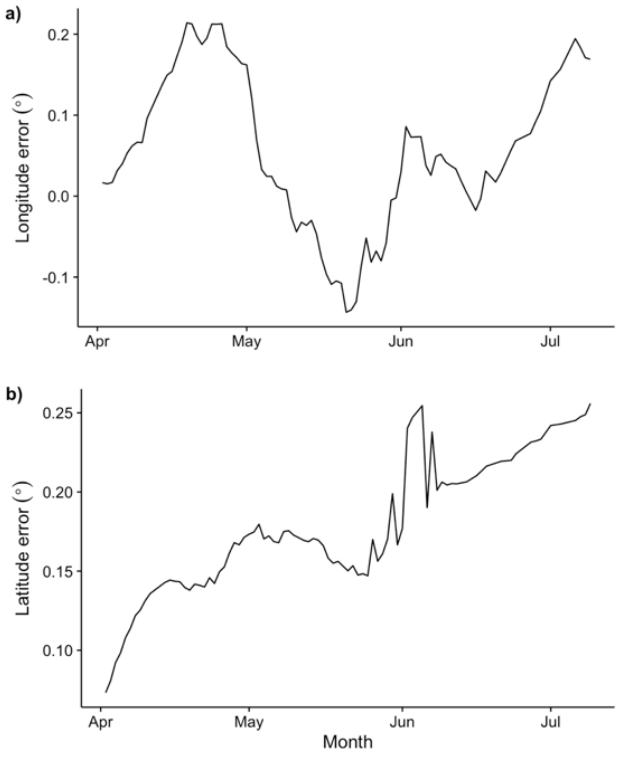

Figure S2: Error in degrees of latitude and longitude between daily SSM estimates of shark position and mean daily location as determined by concurrent acoustic receiver detections.

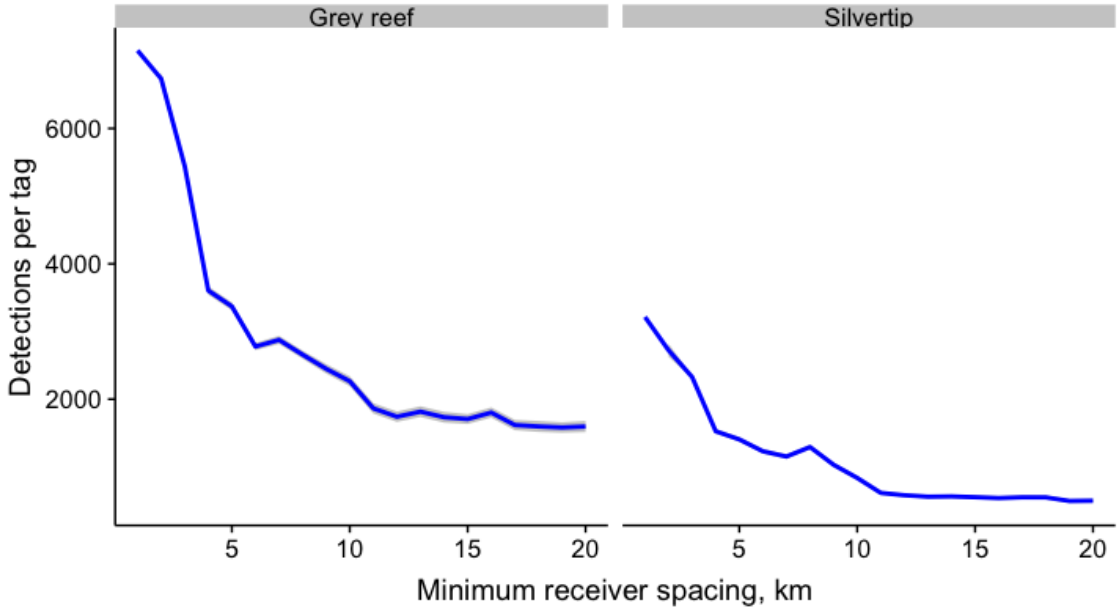

Figure S3: Mean detections per tag for Grey Reef and Silvertip Sharks vs acoustic receiver spacing.