Demonstrating stewardship of the environment and ecologically sustainable forestry

Testing the effectiveness of actions to mitigate impacts of forest practices on Tasmanian masked owls

Final report
Project No: VNC457-1718

Date
March 2026

Forest & Wood Products Australia

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Testing the effectiveness of actions to mitigate the impact of forest practices on the Tasmanian masked owl - Subproject 2

The report is prepared for

Forest & Wood Products Australia

By

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Publication: Demonstrating stewardship of the environment and ecologically sustainable forestry

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IMPORTANT NOTICE

This work is supported by funding provided to FWPA by the Department of Agriculture, Fisheries and Forestry (DAFF).

ISBN: 978-1-922718-81-5

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Executive summary

The Tasmanian forest practices system has a wide range of management strategies in place to mitigate negative impacts of forest practices on important values, including threatened species. The objective of this sub-project was to investigate the habitats selected by Tasmanian masked owls, with the intent to inform current management of the species. The specific aim of this study was to determine the attributes of locations used by masked owls during (a) active hours, (b) roosting and (c) nesting.

To assess the areas used during active hours and when roosting, GPS transmitters were attached to six owls. However, data from only four birds were used in the analyses as two of the birds were incubating eggs. The transmitters were programmed to obtain five locality fixes during the night (active hours) and one fix just after dawn and just prior to dusk (roosting). Available habitat was assessed by generating 'available' points at a 10:1 ratio within the home range (100% minimum convex polygon) of each owl. A resource selection function (RSF) was fitted to the data from each bird using generalized linear modelling techniques, assessing which habitat variables were related to patterns of use for active hours or roosting. The coefficient of the effect size for each bird was then fitted to an intercept-only linear model to determine if there was a consistent pattern of selection among the four birds. While some evidence of selection was identified for individual birds, no generalised patterns of selection were identified.

To assess the areas used by masked owls for nesting, nest records obtained from the current study (n = 2) and other historic sources (n = 16) were collated. The area of 'available habitat' was assessed in a 20.2 km^2 area around each record and ten points of 'available' habitat were evenly distributed within this area. The relationship between nest sites and 'available' points were analysed using another RSF generalized linear model. A model selection process identified the best candidate model predicting where nests were likely to be located. A negative relationship with solar radiation was the only predictor in the final candidate model.

Current management of masked owls in production forest areas of Tasmania takes a landscape approach to the maintenance of mature trees likely to contain tree hollows. The small sample size of the current study prevents strong conclusions from being drawn about the effectiveness of this management, but results are consistent with focusing management on tree hollows. The lack of a relationship between areas used by masked owls when they are active during the night and the habitat variables considered suggest that masked owls may be willing to hunt in a range of environments. The roost sites identified in the current study were located in both tree hollows and dense mid-storey shrubs. Masked owls are only known to breed in tree hollows, a result supported by the two nest sites located during this study, which supports focusing masked owl management on the hollows these owls use.

The current study suggested that owls may select nest sites in areas with lower solar radiation. There is not a strong ecological basis for this finding given the thermal properties of tree hollows, so more research using larger sample sizes is needed. The lack of a strong predictive relationship may be due to the scale considered by the current study. Many hollow-using species are extremely selective of the dimensions of the hollows they use. More research is needed to determine if owls select nest sites primarily on hollow attributes rather than landscape attributes.

This research was done by Jack Service as his Honours research (Service 2023).

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Introduction

Forestry activities conducted in Australia need to meet state and federal environmental requirements, including the management of threatened species. Under the Tasmanian forest practices system threatened species management is triggered by species records and/or the occurrence of potential habitat. Management recommendations are developed between the regulator of forestry activities (FPA) and the government department that administer the *Threatened Species Protection Act* 1995 (NRE Tas), based on available information about the ecology of the species. The level of information on the habitat requirements and impact of forestry varies greatly between species.

Habitat loss plays a major role in the decline of many threatened taxa so understanding the habitat requirements of threatened species is a critical component of many conservation strategies (e.g., Angelstam et al., 2004). The habitat selected by species can change depending on their behavioural state (Roever et al. 2014, Suraci et al. 2019). For example, feeding behaviour will require habitat resources that support prey, whereas sleeping behaviour may require habitat that provide protection. Understanding species behaviour-specific habitat requirements allows habitat management strategies to target areas likely to have the greatest conservation outcomes.

The Tasmanian masked owl (TMO), a subspecies of the Australian masked owl (Hogan et al. 2013), is listed as endangered under Tasmanian legislation (The Department of Premier and Cabinet 1995) and Vulnerable under federal legislation (Department of Agriculture 2022). The primary threat to TMOs is thought to be habitat loss from agriculture, forestry, and urbanization (Bell et al. 1997), although rodenticide poisoning, vehicle collisions, and electrocution have caused many deaths (Mooney 1993, Young et al. 2020). The most recent estimate of population size based on predictive habitat modelling suggests 500 breeding pairs likely inhabit the Tasmanian landscape (Todd, 2012). Little is known about TMOs because their nocturnal, cryptic, and rare nature makes them difficult to study.

Previous research on the Tasmanian masked owl has largely utilized call playback surveys to investigate occupancy patterns. The first study to systematically examine the distribution of TMOs using this technique found the subspecies preferentially occupies areas with low elevation (<600 m), high mean annual temperature and low mean annual rainfall (Bell et al. 1997). A later study modelled site occupancy as a function of environmental variables and found that TMOs generally occupied areas of lower elevation, and that they prefer mature, dry eucalypt forests (Todd et al. 2018). More recently Cisterne et al. (2020) used call playback to determine that prey availability in Tasmania's southern forests was positively correlated with site occupancy by TMOs, suggesting that distributions of TMOs may be somewhat determined by prey abundance and diversity.

Although call playback can be used to assess large-scale occupancy patterns, this method has considerable limitations. The detection probability of TMOs varies with weather and is greatest under warm still conditions (Todd et al. 2018). The technique only works if owls are aggressively motivated to defend their territory around the time of breeding, but there is uncertainty about whether TMOs have a consistent breeding period. TMOs have large home-ranges so audio broadcasts may not always reach individuals. Furthermore, call playback only establishes the presence of TMOs within a large area, it does not describe how owls select and use habitat inside their territories.

Only one previous study has investigated how TMOs select habitat, using radio telemetry to track the movements of two individuals (Young et al. 2020). The data from these two birds

indicated they like to roost in riparian forest and forage at forest edge ecotones, with riparian areas potentially being particularly important (Young et al. 2021). Tree hollows were demonstrated to provide important roost sites (Young et al. 2021). While the study by Young et al. (2021) makes an important contribution to masked owl research, the extremely limited sample size of this study means that strong conclusions cannot be drawn. More research is urgently needed to investigate habitat use by TMOs in order to inform and review current management of this species.

Aims

The current project is part of a broader project assessing the effectiveness of current management of several iconic threatened species in Tasmania. The objective of this sub-project was to investigate the habitats selected by TMOs, with the intent to inform current management of the species.

The specific aim of this study was to determine the attributes of locations used during (a) active hours, (b) roosting and (c) nesting.

This research was done as part of the Honours research conducted by Jack Service:

> *Service, JH 2023, Behaviour-specific habitat selection of the Tasmanian masked owl* (Tyto novaehollandiae castanops), *Honours thesis, University of Tasmania*.

A summary of the research is provided below.

Methodology

Study area

This study was done in eastern Tasmania which is characterized by a relatively dry climate with mean annual rainfall ranging 400–1000 mm (Bureau of Meteorology Commonwealth of Australia 2010). Trapping locations were identified opportunistically from call playback surveys done at sites (Figure 1) known to have historically or recently been used by owls (Cisterne et al. 2020, Todd et al. 2018, NRE Tas 2022 and the Tasmanian public via a Facebook page).The area is a mosaic of agriculture, urban areas and native vegetation (Land Tasmania 2019), with the latter consisting largely of dry sclerophyll eucalypt forest and native grasslands (NRET 2020).

Data collection

Active hours and roosting: GPS telemetry

Call playback involved projecting owl vocalisation for six minutes, followed by a five-minute listening period. Locations where owls responded to the call playback were identified as potential trapping sites.

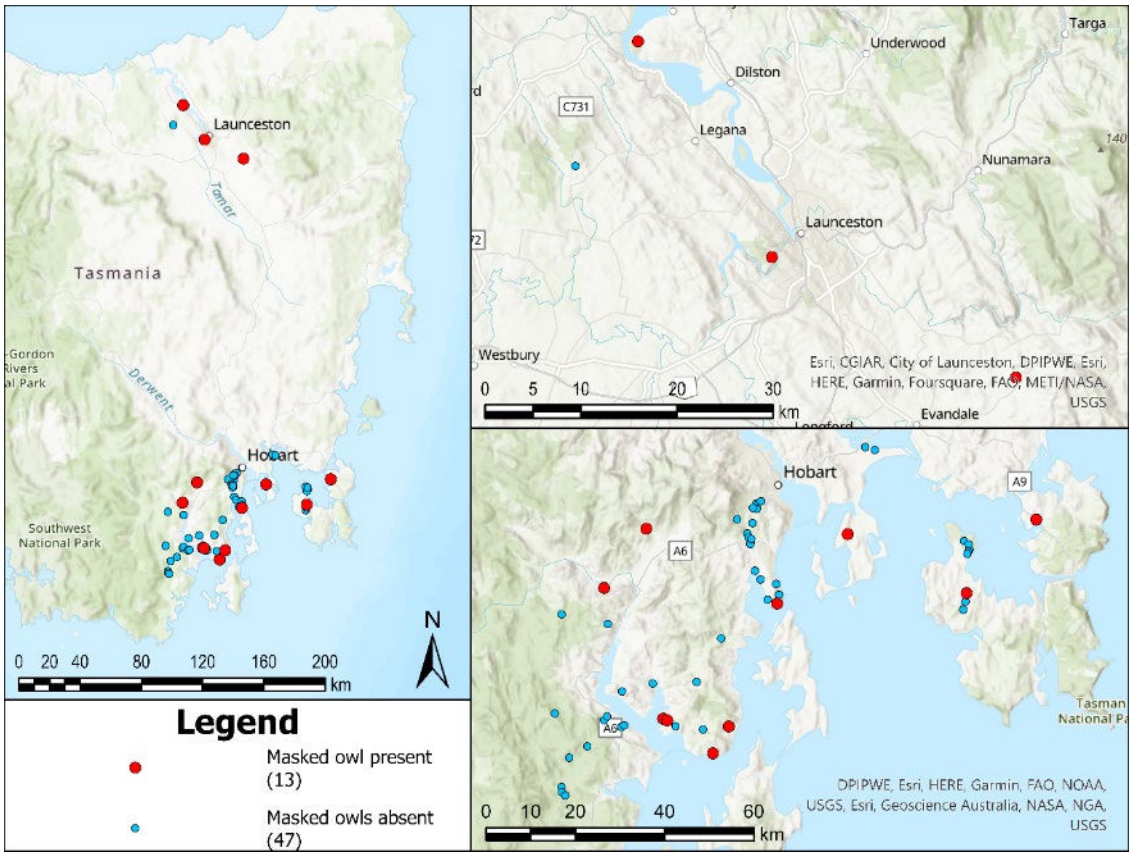

Figure 1. Locations of call playback surveys. Red indicates an owl responded to the call playback and blue indicates no owls responded.

Two techniques were used to trap owls (Figure 2). Four owls were caught using a modified Dho-gazza technique where a 10 × 15 m net is suspended between trees and owls are lured into the net by projecting owl vocalisations from speakers either side of the net. Two owls were captured using a bow net technique where a circular net (~1.5 m^2) is triggered to trap an owl when it comes to investigate a taxidermy owl next to a small speaker projecting owl calls.

Each trapped owl was fitted with a GPS-ULR transmitter (CTT-ES200 Series; Cellular Tracking Technologies, Rio Grande, NJ, USA (CTT 2022a)). GPS transmitters were attached to six adult masked owls. Transmitters were attached with four 5 mm-wide Teflon ribbons arranged in a 'backpack' style, connected via a single stitch of cotton fibre (a modification of Ruiz et al. 2021). Each telemetry unit was programmed to record seven GPS fixes each 24-hour period, with five spaced evenly during night-time hours and two programmed for the daylight side of dawn and dusk. Units relayed GPS data to a remotely positioned receiver using UHF radio transmissions. A tower module (SensorStation; Cellular Tracking Technologies, Rio Grande, NJ, USA (CTT 2022b)) decoded the radio transmissions and uploaded the data to the internet via the GSM cellular network.

Fixes acquired between 6 minutes before sunrise and sunset were classified as 'roosting', with all other fixes classified as 'active hours'. The exception was data from two birds (ID#s: 52523419♀ & 4B61522D♀) that produced only 30 combined night-time fixes and were field-verified to be incubating eggs (i.e. nesting). Data from these two birds were not used for active hours or roosting analyses due to the small number of fixes which were largely centred on the nest site. All roost sites that were in the same proximity at dawn and dusk were field verified to determine if they were likely to be in tree hollows or other vegetation.

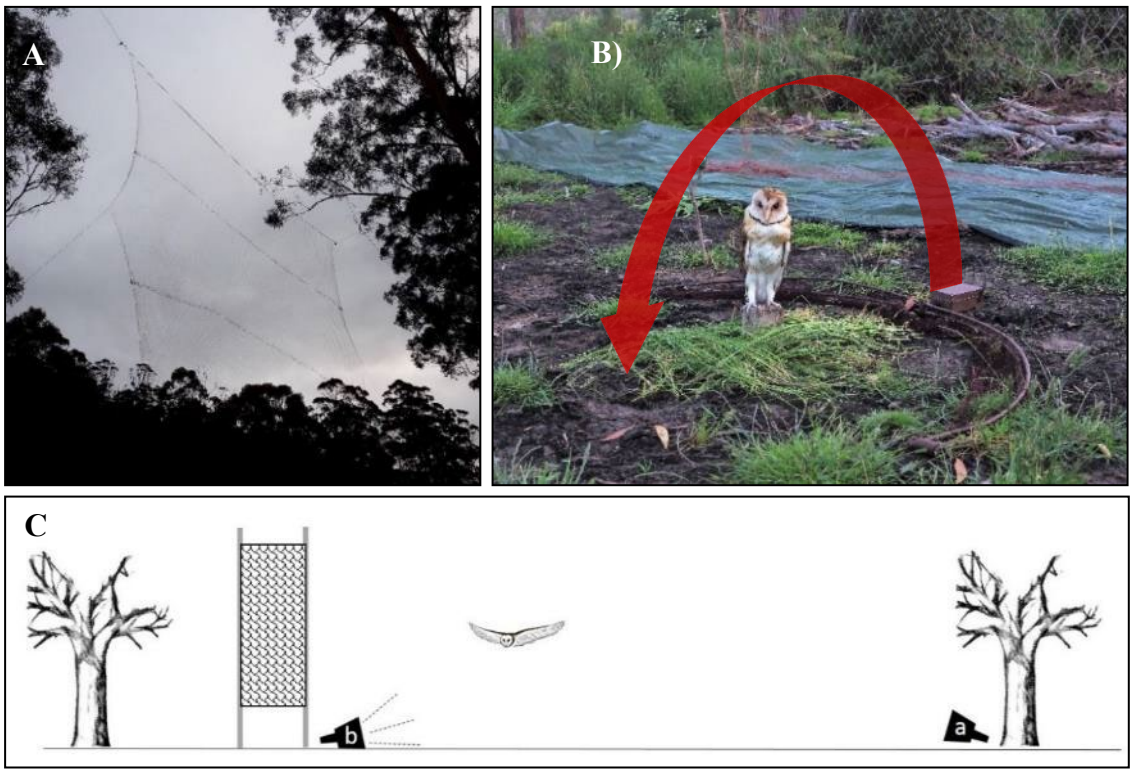

Figure 2. Trapping methods
A) Modified Dho-gazza net. B) Bow net with taxidermy lure owl. The red arrow indicates the path of the semicircular, spring-loaded net frame. C) Modified Dho-gazza illustration where owls are captured as they approach vocalizations being played from Speaker b.

Nest records

Locations of masked owl nest sites were determined from (a) telemetry data collected during the current study and verified by tree climbing (n = 2), (b) historic nest records from other studies (Bell et al. 1997, Koch et al. 2008b), filtered to include only accurate records (accuracy ± 100 m) verified by a qualified biologist that were spatially independent (n = 16). These nest records varied in age with the oldest being recorded 35 years prior to the analysis.

Habitat variables

The predictor variables used in the modelling of 'active hours', 'roosting' and 'nesting' are outlined in Table 1. The number of variables used were limited due to small sample sizes and the predictor variables were selected to be ecologically meaningful, particularly given consideration of the age of the nest records.

Table 1. Habitat variables derived from spatial data used in modelling of 'Active hours', 'Roosting' or 'Nesting'.

Habitat variable	Model(s)	Description
Land cover	Active hours Roosting	Binary classification of habitat as 'open' or 'forested' based on TASVEG 4.0 data (NRET 2020). Forested areas included 'dry eucalypt forest and woodland, wet eucalypt forest and rainforest and non-eucalypt forest. Open areas were classified as all unforested polygons.
Distance to forest edge	Active hours	Distance (m) from forest edge, where forest is defined in 'land cover' above.
Distance to watercourse	Active hours	Distance (m) from watercourses and waterlines identified in theLIST's Hydrographic Lines dataset, which includes rivers, streams, and creeks (Land Tasmania 2014).
Wind exposure	Active hours Roosting Nesting	The level of wind exposure in an area based on topographic features (elevation data and wind direction). Larger values indicate greater wind exposure (Ringeler 2008, Koch et al. 2013).
Morphological Protection Index (MPI)	Roosting Nesting	A measure of wind exposure based on how convex/concave the landscape is (Yokoyama et al. 2002, Koch et al. 2013). Larger cell values indicate a higher degree of enclosure/protection due to concave topographic features, while lower values are associated with convex landforms (i.e., hills and flats; Koch et al. 2013).
Solar radiation	Roosting Nesting	The amount of solar radiation an area receives (WH/m^2), created using 25 m DEM data in the Area Solar Radiation geoprocessing tool (ESRI 2022).
Terrain slope	Nesting	The percent rise of terrain, as derived from a 25 m DEM: *% rise=((Elevation change)/(Horizontal change))×100*

Data analysis

Resource selection functions (RSFs) featuring logsitic regression techniques were used to compare the attributes of locations used by animals compared to the locations available (i.e. accessible but not necessarily utilized). All analyses were done using R version 4.2.2 (R Core Team 2022) unless otherwise stated.

Active hours

The habitat available to each tracked owl (i.e. home range) was estimated using 100% minimum convex polygons (MCPs) calculated using all GPS fixes received for that bird. 100% MCPs establish the smallest possible polygon without inward-pointing vertices (i.e. internal angles ≤ 180°) around an individual's locational fixes (Burgman and Fox 2003), and were calculated using the '*mcp()*' function in the *adehabitatHR* package (Calenge 2006).

To reflect the characteristics of habitat available to each animal, 'available' points were generated in a 10:1 ratio with 'active hours' fixes using the '*st_sample()*' function in the *sf* R package (Pebesma 2018). The locations of 'available' points were evenly distributed in the 100% MCPs for each of the four owls used in the analysis (Figure 3). The attributes of each 'available' point were attributed as per Table 1. None of the habitat attribute pairs were strongly correlated (Pearson correlation coefficient less than 0.6).

Due to the small sample size a two-stage sampling approach was adopted (as per Murtaugh 2007, Fieberg et al. 2010, 2021). This involved (1) fitting a separate multivariate model to each of the four birds and (2) analysing the variation in the parameter estimates for the four birds. Logistic regressions were completed in R using generalized linear models with a binomial distribution. Covariates were z-score transformed to help model convergence. Locations for GPS fixes and 'available' points were weighted 1 and 1000 respectively (as recommended by Fithian and Hastie 2013).

Because RSFs examine differences between used and available locations, the proportions of available habitat can strongly influence effect sizes. Increases in the amount of a particular habitat type are commonly associated with decreases in its associated effect size (Aarts et al. 2013). To investigate the potential influence of habitat availability on effect sizes, changes in effect sizes between owls for a single predictor were compared to variation in availability of the same resource. If selection of a resource consistently decreased as its availability increased, then the apparent selection might only be driven by the resource's scarcity.

Sample-level habitat selection (i.e., generalisations across the four owls assessed) was analysed using intercept-only linear modelling. For each habitat variable the parameter estimates for each bird ($\widehat{\beta}_i$s) were treated as individual observations (n = 4) and weighted by their reciprocal squared standard errors ($1/SE^2$). The y-intercept and 95% confidence interval of this model were considered the weighted mean effect size ($\hat{\hat{\beta}}$) of the habitat variable (Murtaugh 2007).

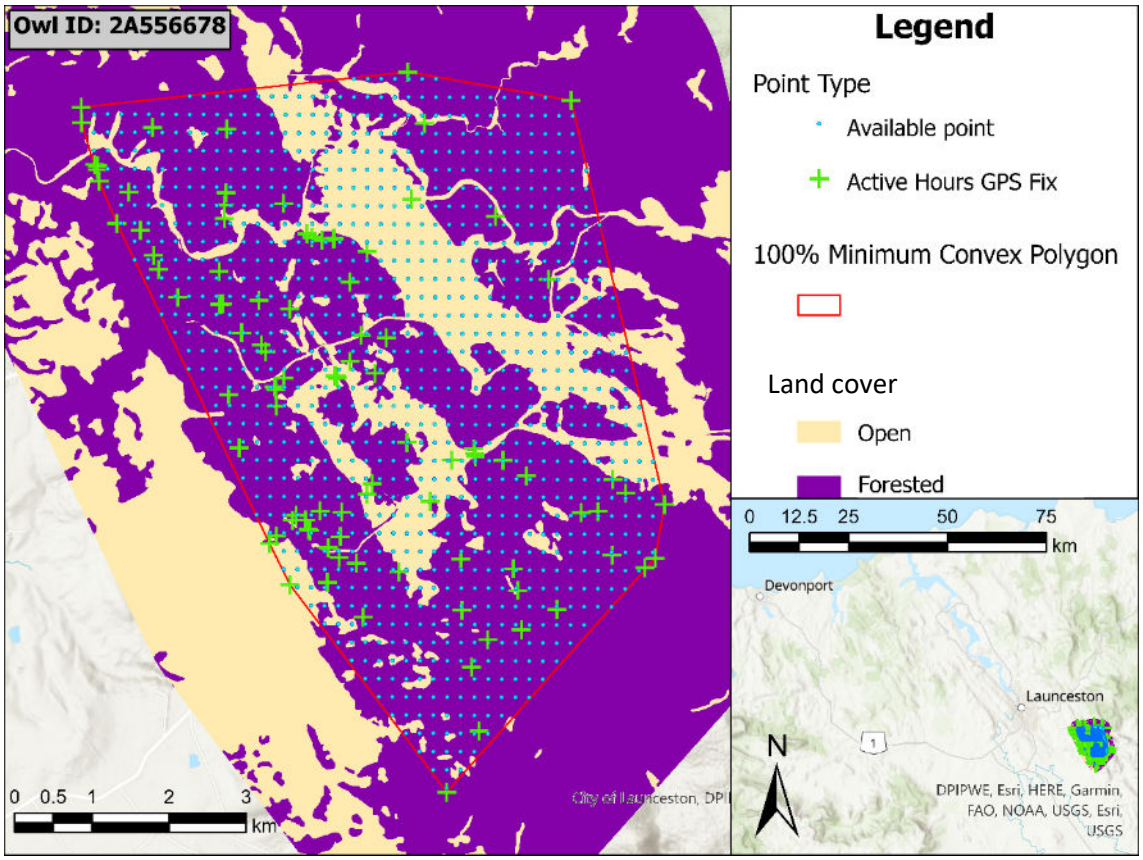

Figure 3. An example of habitat used (green crosses) and habitat available (blue dots) for one owl (ID#: 2A556678♀) in the active hours RSF, using land cover broadly characterized as 'open' and 'forested'.

Roosting

To identify areas that were 'available' for owls to roost, buffers were established around known roost sites. While two roosting fixes were acquired for each bird per day (one before sunrise and another on sunset), only the morning fix was selected from each day. Each morning fix location was buffered by 25 m, and touching buffers were merged. Roost fidelity could be measured by the number of overlapping buffered fix locations at a given location (e.g., 5 overlapping buffers = 5 days of use). Within the 100% MCP outlined above, 'available' points were generated at a 10:1 ratio with roost locations (Figure 4). These 'available' points were also buffered by 25 m.

Habitat attributes assigned to each roost and 'available' habitat polygon are outlined in Table 1, with the value for each attribute averaged across the polygon and then z-score transformed to aid model convergence. None of the predictor variable pairs were strongly correlated (Pearson correlation coefficient < 0.6).

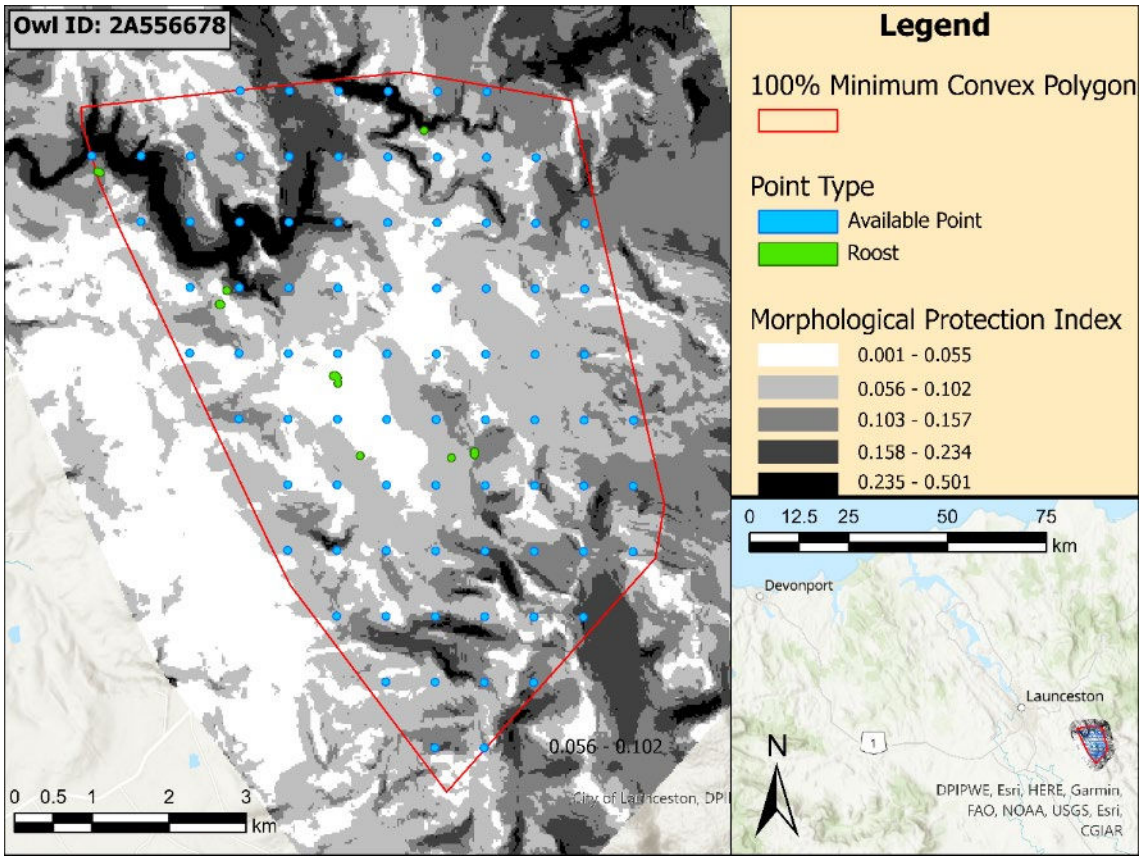

Figure 4. An example of predictor value assignment (MPI) in the roost RSF using data from one owl (ID#: 2A556678♀). This process was repeated for the other covariates of the analysis.

As per the active hours analysis, a two-stage sampling resource selection function was used to assess habitat selection during roosting. For each of the four birds generalized linear models with a binomial distribution were used to assess the characteristics of areas selected for roosting. Roost observations were weighted by the number of days they were used, and locations of 'available' habitat were given a weight of 1000 (Fithian and Hastie 2013). To produce sample-level effect sizes ($\hat{\beta}s$) intercept-only linear models of the estimates for each habitat variable were weighted by their reciprocal squared standard errors.

Active vs. roosting

To examine if TMOs exhibit different selection of habitats for active and roosting behaviours, the parameter estimates for each habitat variable were compared between the two analyses. Only wind exposure and land cover could be considered as these were the only habitat variables used for both models. This was done for each bird by determining whether the confidence intervals around the parameter estimates overlapped (Roever et al. 2014, Séchaud et al. 2021).

Nesting

Each nest record was given an estimated territory equal to the average 100% MCP area of the four birds used in the analyses above: 20.207 km^2. A 10:1 ratio was again used to create locations of 'available' habitat using the Create Fishnet geoprocessing tool (ESRI 2022, Figure 5), and for each habitat variable (Table 1) the mean value was obtained within a 100 m radius. A 100 m radius was used to account for spatial inaccuracies of nest records and summarize the habitat characteristics spread around nesting locations. Mean values of habitat variables were z-score transformed to aid model convergence.

The ‘selection’ for a particular habitat during nesting was examined using a generalized linear model with a binomial distribution. Nests and points of ‘available’ habitat received weightings of 1 and 1000 respectively (Fithian and Hastie 2013). To examine which combination of habitat variables best predicts the location of nests, every nested model of the full model containing five covariates was considered and ranked by its ΔAIC values with the “dredge()” function in the R package MuMIn (Bartoń 2022). Only models that produced a ΔAIC value <6 and for which a simpler nested version with a smaller ΔAIC did not exist were selected (Richards et al. 2011). Habitat variables that were strongly correlated (Pearson correlation coefficient > 0.6) were not included in the same model. To examine the impact of influential points on coefficients, dfbeta values were produced using the ‘dfbetaPlots()’ function in the ‘car’ package (Fox and Weisberg 2019). Points with a dfbeta value exceeding ±1 standard error (SE) were removed sequentially from the dataset. If multiple points exceeded ±1 SE, only the datum with the largest absolute value SE was removed before refitting the model. This continued until a model fit containing no points in excess of ±1 SE was achieved. The inverse logit link function “exp()” in base R was used to convert model parameter outputs into values interpretable from an odds ratio perspective.

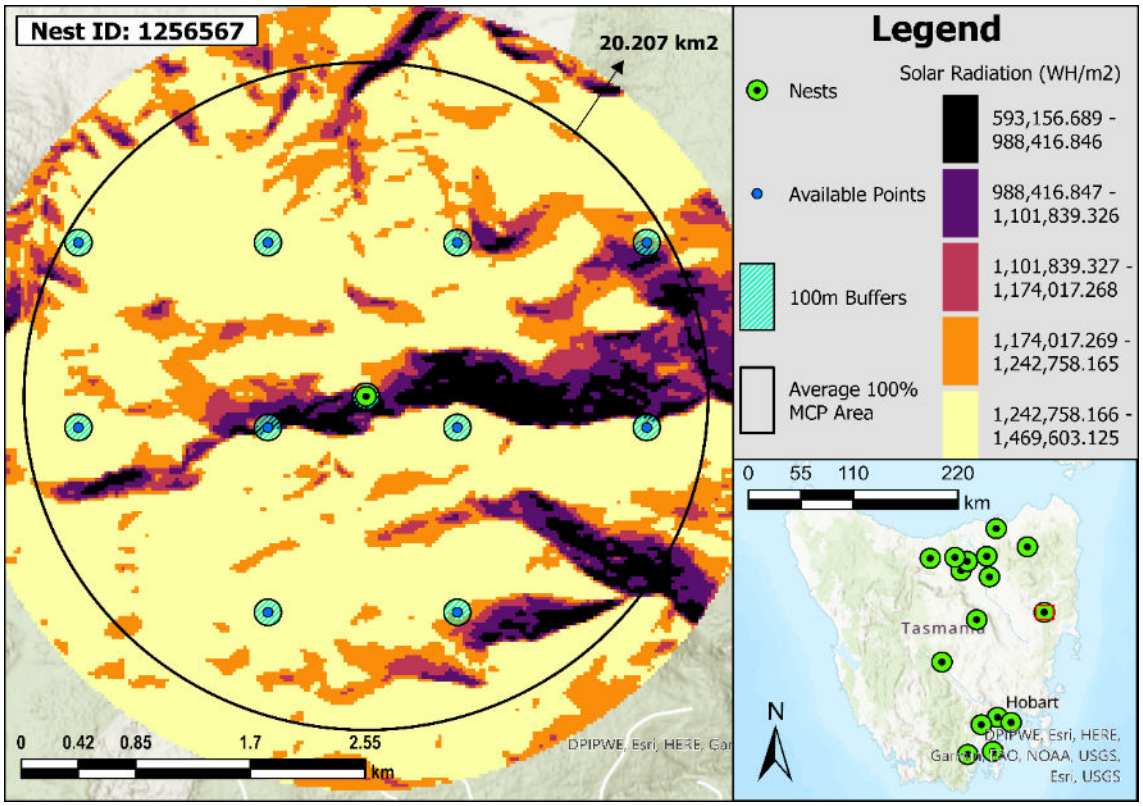

Figure 5. An example of variable value assignment in the nesting RSF using solar radiation in watt-hours/metre^2 for one nest (ID: 1256567). This process was repeated for the other habitat variables and nests.

Results

A total of 680 fixes were obtained from the six owls tracked, with a mean of 113.3 ± 82.9 (±SD) total fixes per bird, 71.5 ± 47.9 active hours fixes per bird, and 41.8 ± 35.7 roosting fixes per bird (Table 2, Figure 6). Data collection occurred over 177 days between the 8th of September 2022 and 22nd of January 2023, with a mean collection period of 29.5 ± 10.9 days per owl. The mean area of 100% MCPs for individuals with >100 GPS fixes was 20.207 ± 18.189 km^2 (Table 2, Figure 6).

Table 2. Summary of the data obtained for each bird from the GPS trackers.
Birds excluded from active hours and nesting analyses due to small sample sizes of GPS fixes are labelled in purple.

	Period of Collection			# of GPS Fixes			100% MCP
OWL ID	**START**	**END**	**# DAYS**	**ROOSTING**	**ACTIVE**	**TOTAL**	**AREA**
52523419♀	08/09/2022	26/09/2022	18	0	24	**24**	0.014 km^2
2A523361♂	05/11/2022	20/12/2022	45	93	129	**222**	26.120 km^2
4B61522D♀	14/09/2022	03/10/2022	19	1	6	**7**	0.038 km^2
33524C4B♀	21/09/2022	24/10/2022	33	54	95	**149**	5.148 km^2
4C2A1E66♂	30/11/2022	24/12/2022	24	50	71	**121**	6.221 km^2
2A556678♀	15/12/2022	22/01/2023	38	53	104	**157**	43.340 km^2
TOTAL	**-**	**-**	**177**	**251**	**429**	**680**	-
MEAN ($\bar{X}$)	-	-	**29.5**	**41.83**	**71.5**	**113.3**	20.207 km^2
SD	-	-	10.9	35.71	47.88	82.87	18.189 km^2

Active hours

The four owls considered exhibited different selection for habitat variables during active hours (Figure 7). The lack of a consistent pattern in habitat selection was confirmed by the weighted mean effect sizes ($\widehat{\beta}_{\iota}s$), which had 95% CIs overlapping zero (Figure 7b). There was no evidence that the importance of habitat variables for individual birds was related to habitat availability, as individual owl effect sizes did not consistently decrease as availability of associated habitat variables increased (Figure 8).

Only one owl (ID: 4C2A1E66♂) selected areas used when active based on distance to forest edge ($\widehat{\beta}_{\iota}$ = -0.61, 95% CI [-1.16, -0.14], Figure 7A). This owl selected areas closer to forest edges and had the smallest mean distance to forest edge ($\bar{X}_i$ = 80 m ± 3 (SE)) compared to other birds. Smaller mean distances to forest edge indicate a higher degree of forest fragmentation, meaning that the owl occupying the most fragmented forest habitat was the only individual to select for forest edges.

Two owls appeared to select by land cover during active hours (Figure 7B), but one preferred open areas (ID: 4C2A1E66♂; $\widehat{\beta}_{\iota}$ = -0.56, 95% CI [-1.09, -0.06]) while the other selected forest areas (ID: 2A556678♀; $\widehat{\beta}_{\iota}$ = 0.71, 95% CI [0.20, 1.27]). Neither bird had extremely high or low availability of forest within the area of available habitat assessed (Figure 8B).

Only one owl (ID: 2A523361♂) selected habitat based on distance to water during active hours (Figure 7A), preferring areas further from bodies of water ($\widehat{\beta}_{\iota}$ = 0.25, 95% CI [0.03, 0.46]). This bird had an intermediate mean distance to water of its available points ($\bar{X}_i$ = 96 ± 2 metres) (Figure 8C). The same owl appeared to select during active hours for areas protected from the wind (Figure 7) ($\widehat{\beta}_{\iota}$ = -1.47, 95% CI [-2.06, -0.95]). This bird had the least amount of wind exposure in its territory ($\bar{X}_i$ = 0.905 ± 0.003) (Figure 8D).

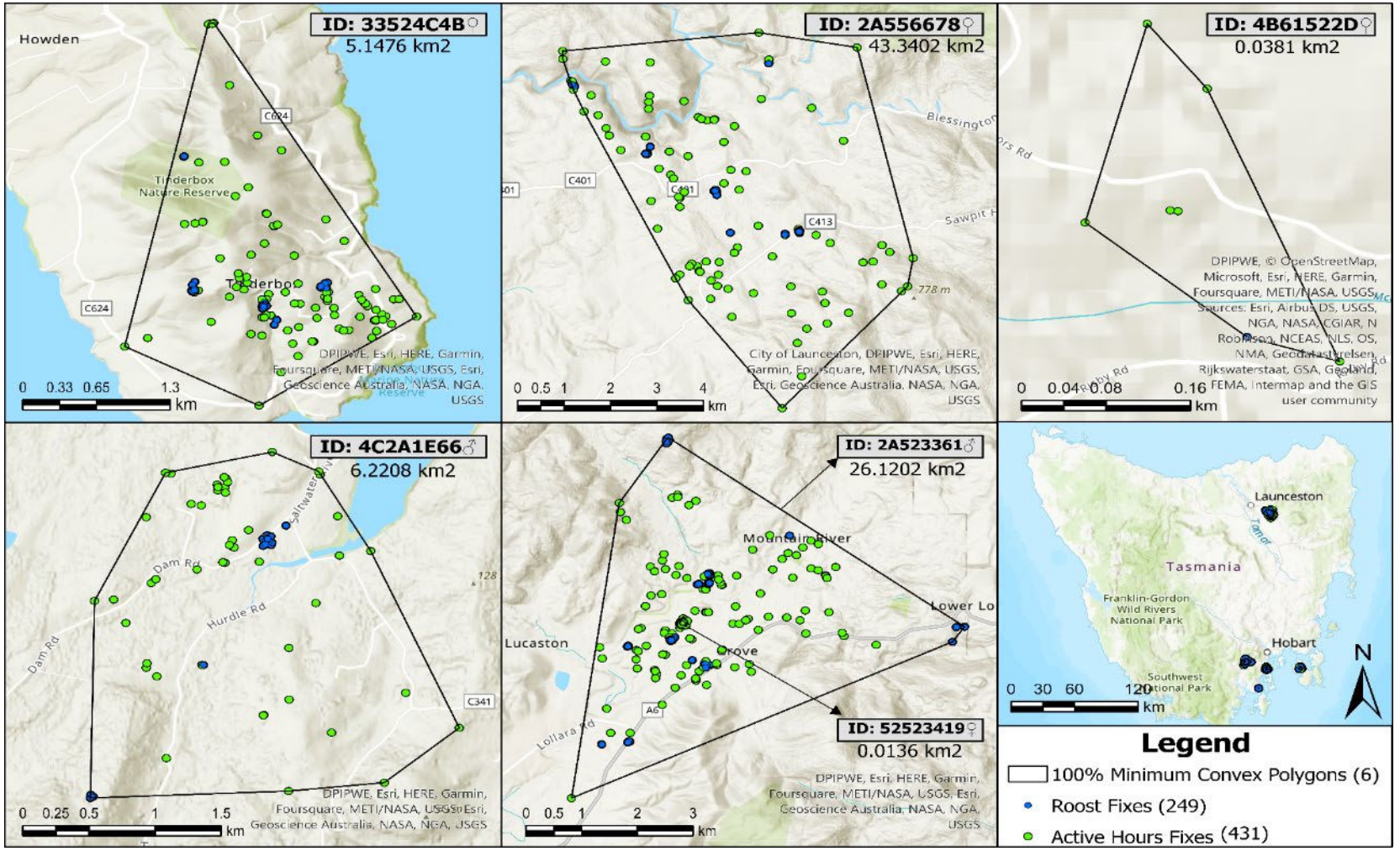

Figure 6. GPS Fixes and 100% MCPs for all owls. Fixes for active hours are in green and for roosting are in blue. 100% Minimum convex polygons are delimited in black. Note that two owls (ID#s: 52523419♀ & 2A523361♂) comprised a breeding pair within a single territory.

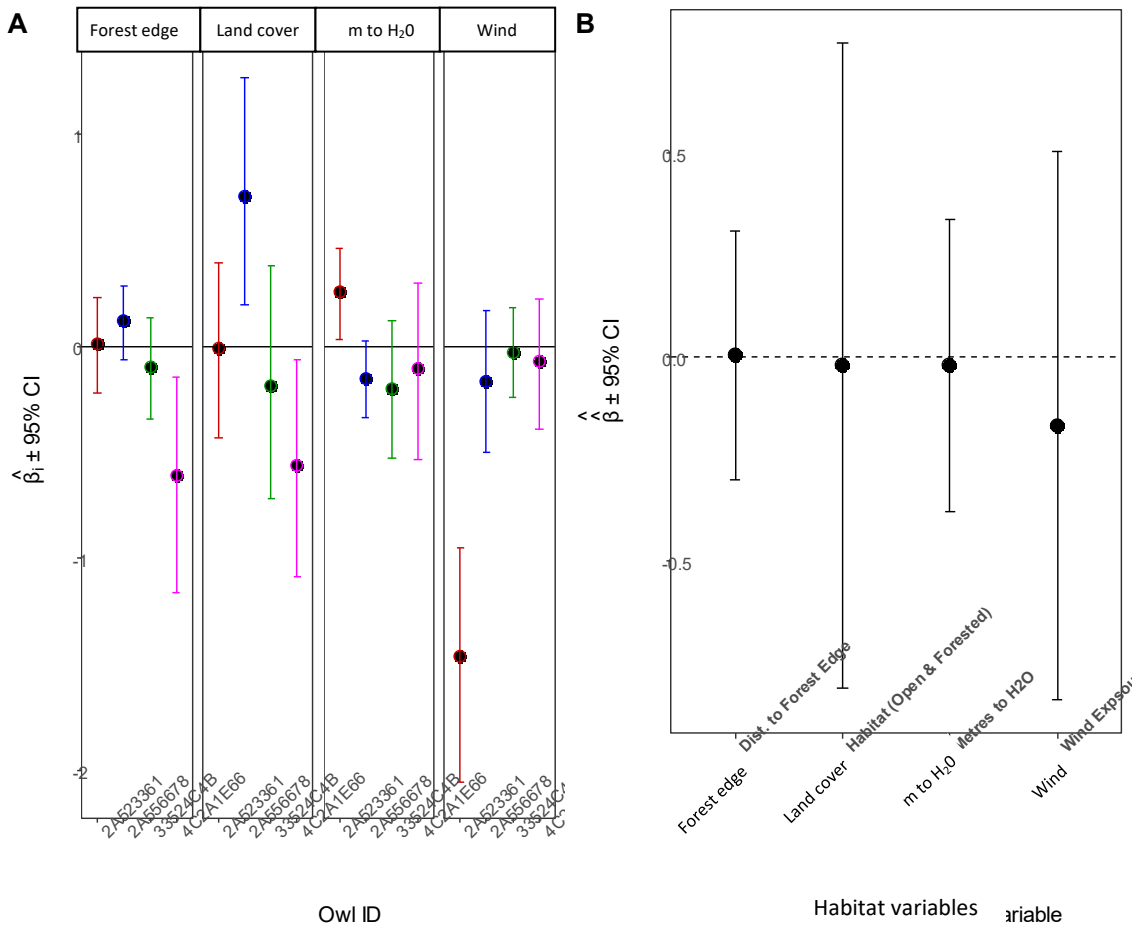

Figure 7. Results of (A) the individual owl GLM model and (B) the combined linear models of effect size examining habitat selection during active hours. Circles are the mean effect size and bars indicate the 95% confidence intervals. The horizontal lines specify a selection coefficient of zero, indicating a habitat was used proportional to its availability. Positive coefficients indicate a habitat was selected for and negative coefficients indicate a habitat that was selected against.

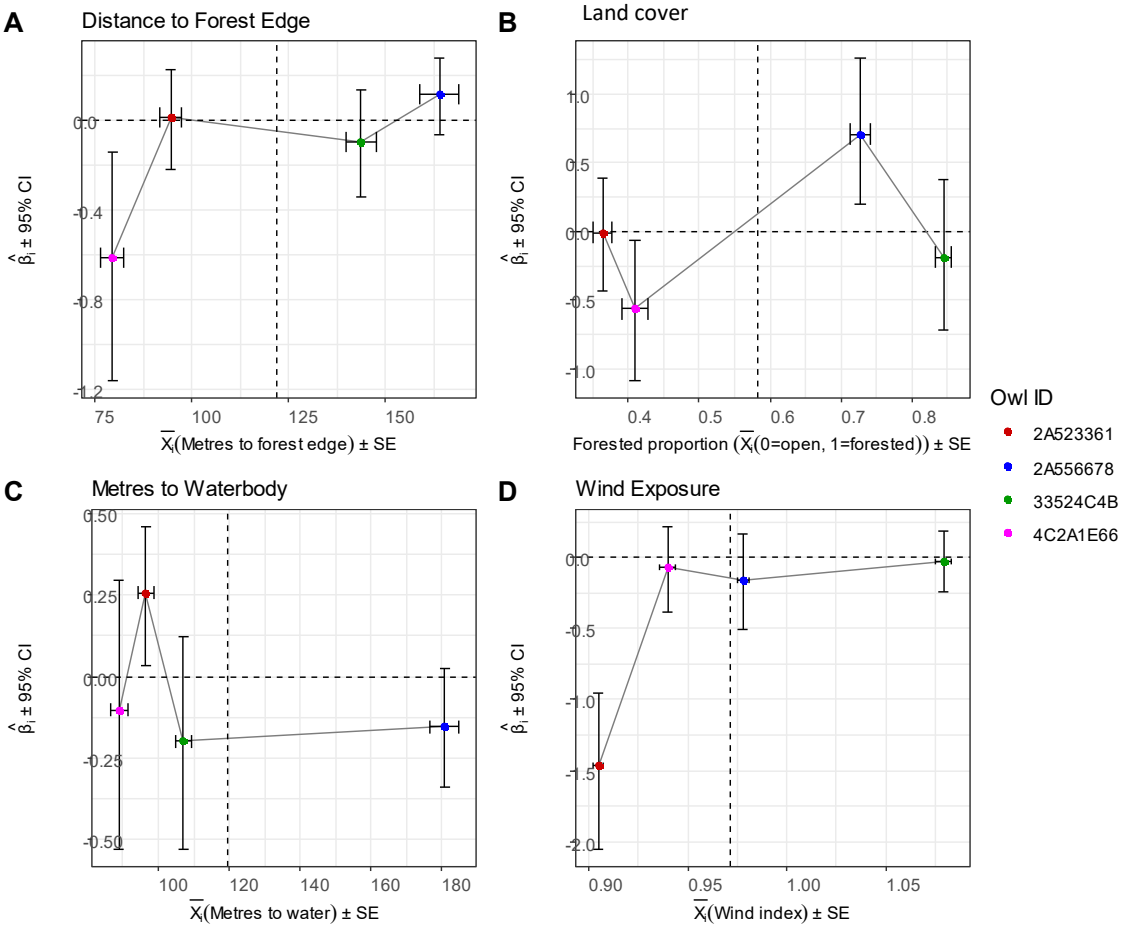

Figure 8. Relationship between modelled habitat selection effect sizes during active hours ($\widehat{\beta_i}$s ± 95% CIs) and the mean available habitat values for A) Distance to forest edge (m), B) Land cover ('open' = 0, 'forested' = 1), C) Distance to waterbody (m), and D) Wind exposure. $\widehat{\beta_i} = 0$ and combined sample means ($\overline{X}_i$s) are represented with dashed lines. Changes in habitat availability (x axes) did not result in consistent changes in effect sizes (y axes), indicating the statistically significant habitat selection was likely not a product of the type and quantity of resources available to individuals.

Roosting

The roost sites used during this study were located in a range of overstorey and mid-storey species. Of the 18 roost sites that were field-verified, five appeared to be in tree hollows (two of these were used for nesting) (Figure 9, Table 3). Two of regularly used roost sites in mid-storey species could be easily identified due to the large number of owl feathers in the tree.

Table 3. A summary of the roost site locations that were assessed on the ground, with best estimates to the location used for roosting. Evidence means signs of use by owls and can include excrement/whitewash (WW), feathers or regurgitated pellets. * indicates a measurement has not yet been recorded at the time of writing this report.

Owl	Roost type	Tree species	Tree dbh (cm)	Evidence
2A523361	Hollow	*E. obliqua*	180	WW
4C2A1E66	Hollow	*Eucalyptus*	91	WW and one feather
2A556678	Hollow	*Eucalyptus* (dead)	50	None
33524C4B	Hollow	*E. obliqua*	157	WW around the tree
2A523361	Vegetation	Tea tree? *Solanum*?	6	None
2A523361	Vegetation	Willow	44	None
2A523361	Vegetation	*E. globulus*	140	None
2A523361	Vegetation	*Eucalyptus*	*	None
33524C4B	Vegetation	*A. verticillata*	16	Feathers, pellets
33524C4B	Vegetation	*Allocasuarina?*	>20	None
33524C4B	Vegetation	*Exocarpus*	>20	None
4C2A1E66	Vegetation	*E. viminalis?*	86	None
2A556678	Vegetation	*Melaleuca* sp.	16	None
2A556678	Vegetation	*Melaleuca* sp.	15	None
2A556678	Vegetation	*Melaleuca* sp.	11	None
2A556678	Vegetation	*Eucalyptus*	49	None
2A556678	Vegetation	*A. verticillata*	14	None

The four owls differed in their selection of habitat variables when roosting (Figure 10A). The lack of a consistent pattern in habitat selection was confirmed by the weighted mean effect sizes ($\widehat{\beta}_l s$), which had 95% CIs overlapping zero (Figure 10B). There was no evidence that the importance of habitat variables for individual birds was related to habitat availability, as no consistent decrease in effect size was observed and relative quantities of habitat types increased (Figure 11).

Three owls appeared to select roost sites according to MPI, but in different ways (Figure 10A). Owl 2A523361♂ selected more exposed roosts, had more exposed (lower-than-average morphological protection) within its home range compared to other owls ($\bar{X}_i$ = 0.090 ± 0.004 (±SE)), and produced the smallest effect size for MPI ($\widehat{\beta}_l$ = -1.67, 95% CI [-2.57, -0.88]). Owl 2A556678♀ lived in a more sheltered area ($\bar{X}_i$ = 0.11 ± 0.01), but also roosted in more exposed sites with lower MPI ($\widehat{\beta}_l$ = -0.85, 95% CI [-1.53, -0.30]). The individual with the most sheltered habitat (i.e., higher MPI) (ID: 33524C4B♀, $\bar{X}_i$ = 0.13 ± 0.01) was the only individual to select for sheltered areas ($\widehat{\beta}_l$ = 0.99, 95% CI [0.43, 1.58]). The only individual that did not appear to select habitat in relation to MPI (ID: 4C2A1E66♂) had the least morphologically protected habitat ($\bar{X}_i$ = 0.07 ± 0.01).

Only one individual (ID: 2A556678♀) appeared to select roost sites based on wind exposure (Figure 10A). This bird had a territory with moderate exposure to wind ($\bar{X}_i$ = 0.98 ± 0.01), and selected roosts in more sheltered areas with less wind exposure ($\widehat{\beta}_l$ = -1.70, 95% CI [-2.75, -0.83]) (Figure 11B).

Owls 2A523361♂ and 4C2A1E66♂ appeared to select roost sites in areas with lower levels of solar radiation (Figure 15C) ($\widehat{\beta}_i$ = -1.80, 95% CI [-2.50, -1.15]; $\widehat{\beta}_i$ = -1.10, 95% CI [-2.00, -0.24]), and had almost the same amount of solar radiation in their available habitats ($\bar{X}_i$ = 615,988 ± 3,459 WH/m^2 and $\bar{X}_i$ = 615,880 ± 4,618 WH/m^2, respectively). The individuals with the least ($\bar{X}_i$ = 596,427 ± 7,252 WH/m^2) and most ($\bar{X}_i$ = 636,204 ± 5,887 WH/m^2) exposure to solar radiation did not exhibit selection involving this variable.

Only one individual (ID: 2A523361♂) appeared to select according to land cover when roosting (Figure 15D). This individual occupied a relatively unforested area compared to other owls ($\bar{X}_i$ = 0.40 ± 0.04 forested proportion) and selected for open areas ($\widehat{\beta}_i$ = -0.63, 95% CI [-1.10, -0.24]).

Figure 9. Roost tree at saltwater river: entrance (left) and inside (right). (Photo: D James).

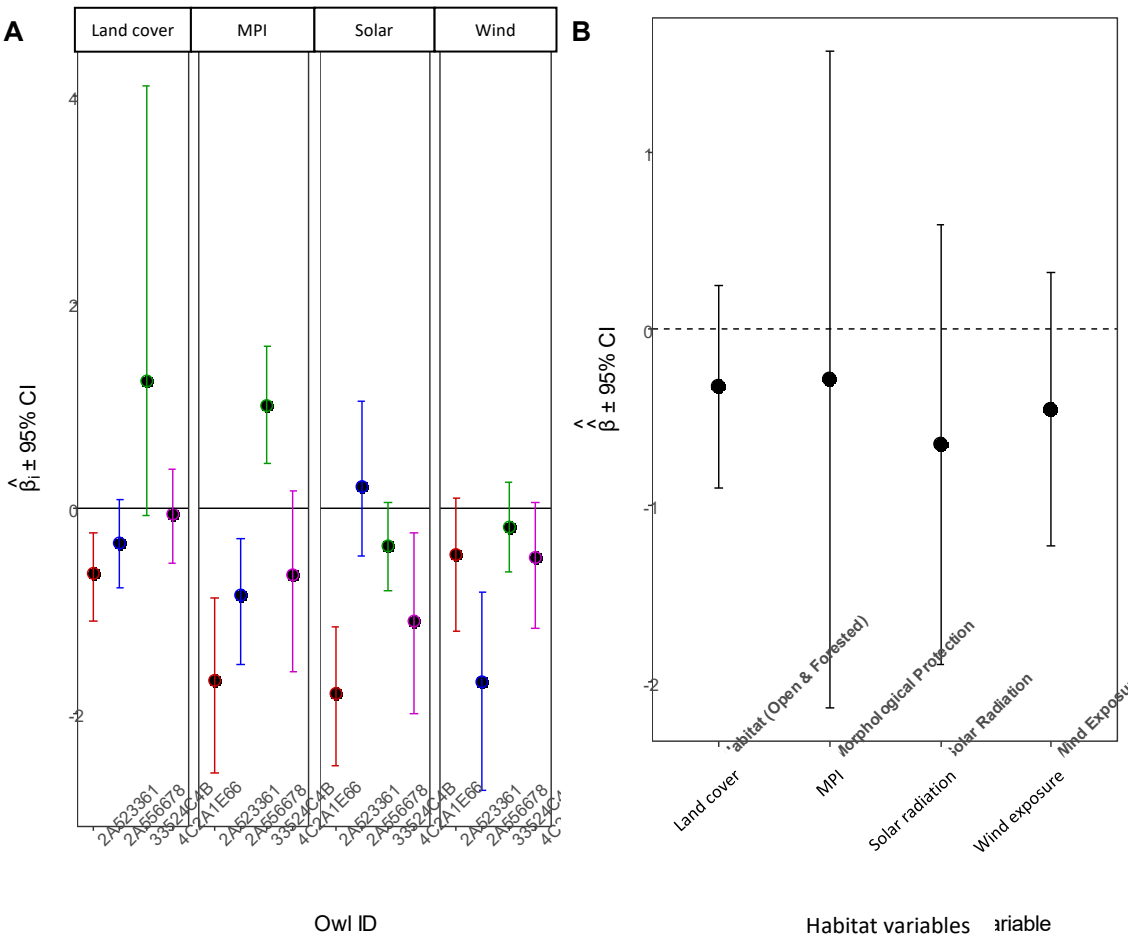

Figure 10. Results of (A) the individual owl GLM model and (B) the combined linear models of effect size examining habitat selection when roosting. Circles are the mean effect size and bars indicate the 95% confidence intervals. The horizontal lines specify a selection coefficient of zero, indicating a habitat was used proportional to its availability. Positive coefficients indicate a habitat was selected for and negative coefficients indicate a habitat that was selected against.

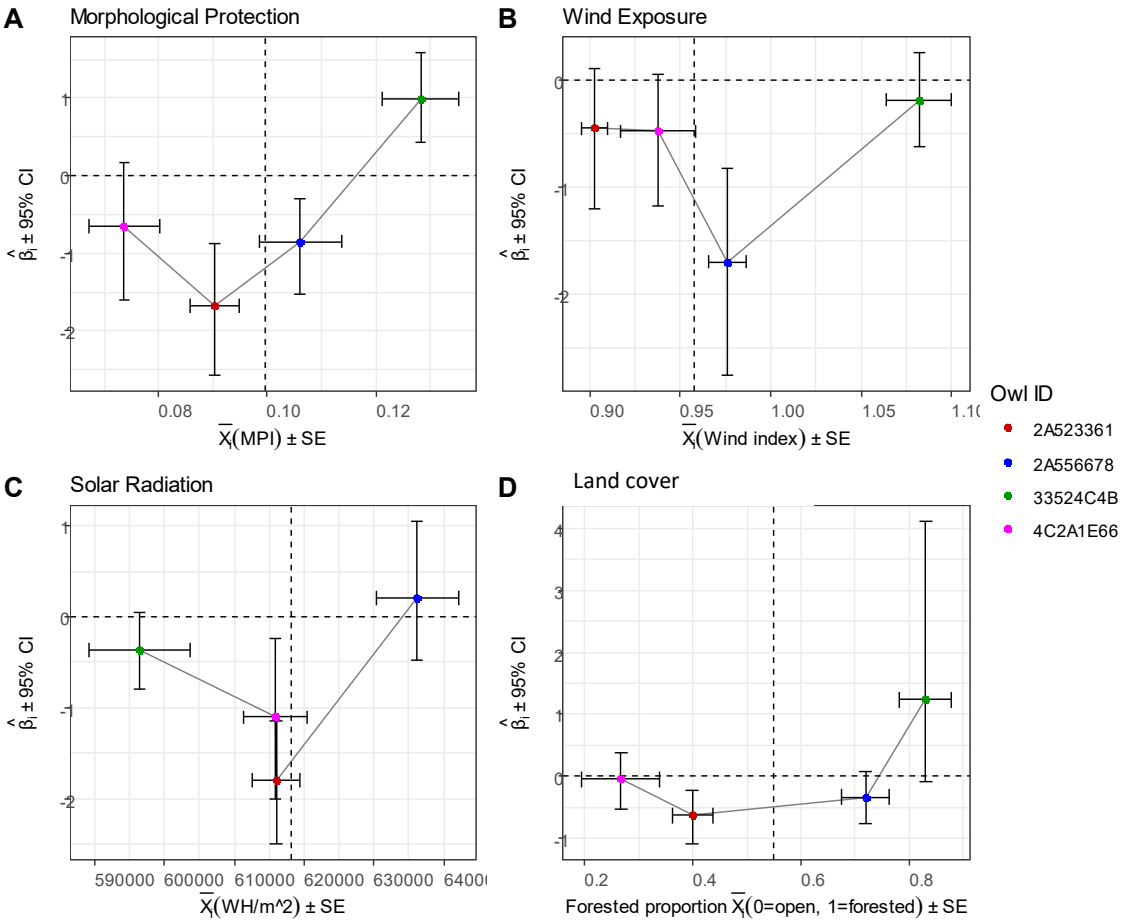

Figure 11. Relationship between modelled habitat selection effect sizes when roosting ($\widehat{\beta_i}$s ± 95% CIs) and the mean available habitat values for A) Distance to forest edge (m), B) Land cover ('open' = 0, 'forested' = 1), C) Distance to waterbody (m), and D) Wind exposure. $\widehat{\beta_i}$ = 0 and combined sample means ($\overline{X}_i$s) are represented with dashed lines. Changes in habitat availability (x axes) did not result in consistent changes in effect sizes (y axes), indicating the statistically significant habitat selection was likely not a product of the type and quantity of resources available to individuals.

Active vs. roosting

Only one owl (ID#: 2A556678♀) appeared to select markedly different habitat depending on the behaviour it was exhibiting (Figure 12). This individual selected more forested habitat during active hours ($\widehat{\beta_i}$ = 0.71, 95% CI [0.20, 1.27]), but showed no preference for forest or open habitat when roosting. The same individual selected against windy areas when roosting habitat ($\widehat{\beta_i}$ = -1.70, 95% CI [-2.75, -0.83]), but not during active hours.

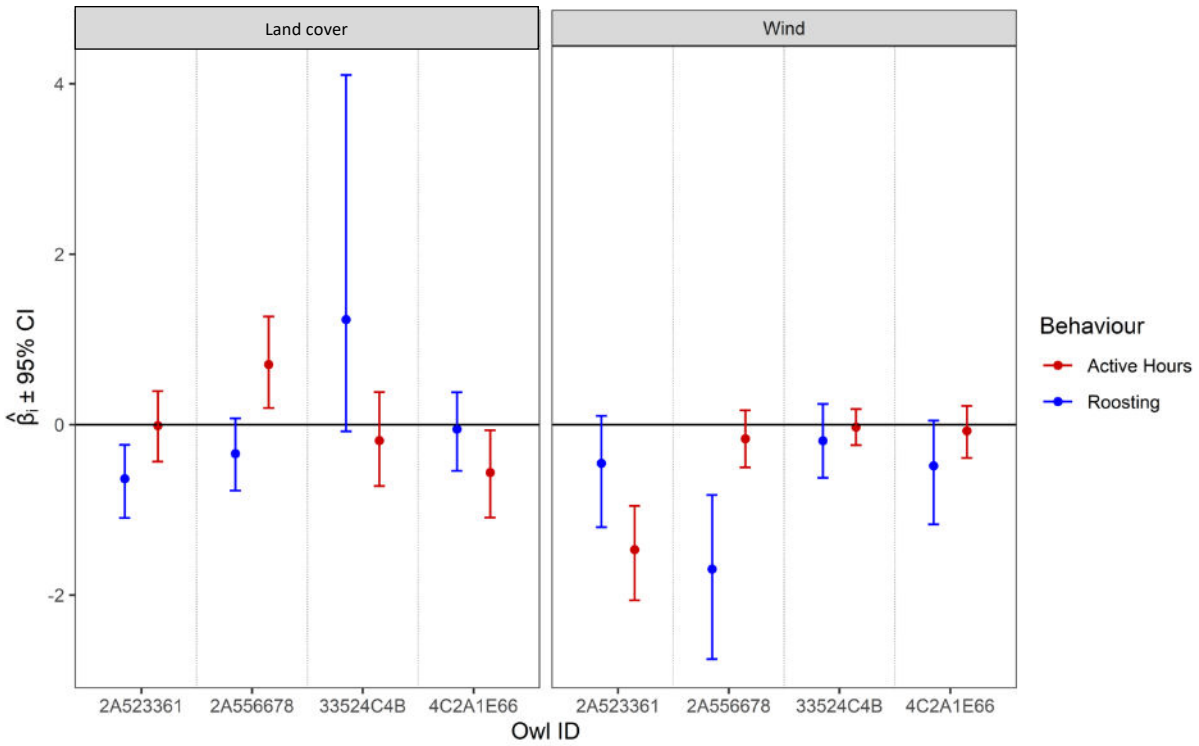

Figure 12. Effect sizes ($\widehat{\beta_i}$s) for models of roosting (blue) and active hours (red) plotted per bird. The horizontal lines specify a selection coefficient of zero, indicating a habitat was used proportional to its availability. Positive coefficients indicate a habitat was selected for and negative coefficients indicate a habitat that was selected against. Error bars for each mean selection coefficient are extended to the 95% confidence interval.

Nesting

The two nesting hollows found as part of the telemetry component of this project were both climbed (Figure 13, Figure 14, Table 3). The attributes of one nest hollow (Crabtree) were measured after breeding was completed (Table 4), but the other had not yet been measured at the time of writing this report. One of the tree hollows confirmed as a roost site (Saltwater River) was also measured (Table 4, Figure 9).

The nesting habitat model selection process yielded only a single candidate model, with a negative relationship with solar radiation (Table 5a). This relationship ($\beta_{z(Solar\ Radiation)}$ = -0.72, 95% CI [-1.12, -0.27]) indicates that the TMO nest records considered were in areas with lower values of solar radiation than expected (Table 7b). For each increase in the value of solar radiation by 1 SD (79,148 WH/metre^2), the odds of nest site usage decrease by approximately one half (exp($\beta_{z(Solar\ Radiation)}$) = 0.49, 95% CI [0.33, 0.77]).

Table 4. Attributes of the tree hollows used by masked owls that were climbed and measured.

Hollow attributes	Crabtree nest	Saltwater river roost
Hollow height above ground (m)	17	12
Hollow dimensions at exterior of tree (mm)	300 wide × 300 high	140 wide × 940 high
Minimum hollow dimensions (mm)	150 wide × 250 high	140 wide × 940 high
Internal height (bottom edge of entrance to floor of chamber) (mm)	1900	2500
Dimensions of floor of chamber (mm)	700 × 450	450 × 450
Angle of chamber (°)	~45	90

Figure 13. The hollow-bearing tree at Crabtree used for nesting by owl 52523419♀. The nest hollow is the upwards facing hollow just below and to the right of the tree climber (D. James) (Photo: J Service). Inset shows the view inside the entrance of the hollow (Photo: D James).

Figure 14. Middleton hollow which was used for nesting by owl 4B61522D♀ (Photo: J Service).

Figure 15. Photograph of inside the Middleton nesting hollow (left) on 03/10/22 and the Crabtree nesting hollow (right) on 14/09/22 (Photos: D James).

Table 5. Results for (A) nesting habitat model selection and (B) estimates of model parameters. Only models with ΔAIC < 6 for which a more simple, nested model with smaller ΔAIC value did not exist are listed. The null model is provided as a point of comparison. The inverse link function (exp()) was used to interpret the effect size of solar radiation ($\beta_{z(Solar\ Radiation)}$).

A) Model Selection: *Full model: Nest Presence ~ z(Slope) + z(Solar Radiation) + z(Distance to water) + z(Wind) + z(MPI)*					
Nested Models	*Deg. Freedom*	*Log-likelihood*	*AICc*	*ΔAIC*	*Weight*
Logit(p_{nest}) ~ -9.373 + -0.716(z-Solar Radiation)	2	-158.72	321.5	0	0.19
Logit(p_{nest}) ~ -9.204 (NULL)	1	-163.23	328.6	7.04	0.01

B) Selected Model Estimates: *Nest Presence ~ Solar Radiation*			
Coefficient	*Calculation*	*Estimate*	*95% Confidence Interval*
Intercept (β_0)	*value*	-9.37	(-9.99, -8.86)
	exp(value)	$8.50e^{-5}$	($4.58e^{-5}$, $1.42e^{-4}$)
$\beta_{z(Solar\ Radiation)}$	*value*	-0.72	(-1.12, -0.27)
	exp(value)	0.49	(0.33, 0.77)

Discussion

The results of this study provide no strong guidance on the areas used by masked owls for roosting, nesting, or during active hours, although some individual birds showed evidence of habitat selection. This could be due to the small sample size in the current study. However, it could indicate that TMOs are not highly selective of habitat during some behaviours, or they select by features not considered in the current study.

Active hours is a broad classification of behavioural state, which encompasses hunting, territorial defence, parental care, and all other night-time behaviours. Only five fixes per night were obtained per bird, so it was not possible to classify behaviours more finely during active hours. The lack of a consistent relationship with any of the habitat variables considered may indicate that owls can undertake these behaviours in a range of areas. Alternatively, areas used by owls during the night may be selected by attributes not considered in the current study. For example, prey availability is known to determine many aspects of owl ecology (Newton 2002) and has been related to site occupancy by Tasmanian masked owls (Cisterne et al. 2020). It is possible that factors influencing prey availability were not adequately captured by the habitat variables in this study.

For the four owls that were not incubating eggs, successful fixes for roosting were obtained on most, but not all nights (Table 2). The 18 roost sites that were field verified indicated that the owls studied regularly roost in tree hollows and dense mid-storey vegetation. Some owls showed high fidelity to roost sites, while others changed roost sites regularly. TMOs may not be selective in the areas they roost, but if they are it is expected they would select roost sites free from disturbance and sheltered from extremes in temperature and wind. The level of protection from extremes in temperature and wind provided by a tree hollow would be higher than that provided by dense vegetation, so if owls are selective in where they roost the habitat variables considered may depend on whether the roost site is a hollow or not. It was not possible to determine the type of roost for each roost included in this RSF analysis. Although roost fixes were collected on the daylight side of dawn and dusk, morning fixes occasionally occurred in different locations than the pre-dusk fix from the same day. This suggests that on

some occasions individuals either had not yet settled to roost at the time of the morning fix, changed roosting locations during the day, or left roosts to hunt before the dusk fix was collected. Given the ambiguity surrounding roost locations on these days, only locations with post-dawn and pre-dusk fixes in the same location were field verified to determine if a hollow was present (Table 3). Future analyses might benefit from including only these verified roosts as opposed to the entirety of the roosting data.

This study was limited in the way nesting habitat selection was considered. Some of the nest records used were more than 30 years old so it was not possible to obtain information on all the habitat variables of interest. Results from this study did suggest that masked owl nest sites may occur more frequently in areas with low solar radiation than expected. A similar result was found for Mexican spotted owls (*Strix occidentalis lucida*), but in that study the relationship was attributed to owls limiting evaporative water loss in a dry climate (Ganey 2004). This is unlikely to be a contributing factor in Tasmania. Tree hollows generally provide relatively stable thermal environments (Mayer et al. 1982, Cooper 1999, Paclík and Weidinger 2007, Isaac et al. 2008) so a relationship between solar radiation and nest occurrence seems tenuous. Solar radiation is correlated with many other environmental variables including topographic aspect (Kumar et al. 1997) and forest community (Kumar and Skidmore 2000), so the apparent relationship found in this study may be a surrogate for a different causative relationship. More research with a larger sample of nests is required to verify the importance of solar radiation for locating nest sites.

Management conclusions

The objective of this sub-project was to investigate the habitats selected by TMOs, with the intent to inform current management of the species.

Current management of masked owls focuses on the retention of nesting and roosting habitat, primarily by the retention of mature forest throughout the landscape. The level of retention required is greater in dry forest than wet forest, due to the higher occupancy in dry forest as determined using call playback (Todd, 2012). Management is typically implemented at a landscape-scale, using the Mature Habitat Availability Map as a tool for assessing the availability of suitable hollow-bearing forest (Koch et al. 2018).

The limited sample size of the current research prohibits strong conclusions being drawn when reviewing masked owl management, and further research is required. However, the lack of a relationship between where birds were active during the night and any of the habitat variables considered suggests that Tasmanian masked owls may be able to use a variety of landscapes when active. Similarly, the lack of evidence that owls are highly selective in the location of roost sites suggest owls may be flexible in the areas they choose to roost, as long as hollows or dense vegetation with the required qualities are available. Given that dense vegetation is common throughout many vegetation communities and large hollows only occur in large old trees (Koch et al. 2008a), the current management focus on mature forest seems appropriate.

While the current management strategy focuses on retention of mature forest (as a surrogate for hollow-bearing trees), it is a landscape approach and no emphasis is provided on identifying or retaining suitable trees within the harvest operation. Very little data are available on the trees and hollow used by masked owls, information needed to help identify masked owl hollow-bearing habitat trees, so the data collected in the current study are extremely important. However more data are required on the attributes of the trees and

hollows used by masked owls. Tree hollows form in older trees (Koch et al 2008a) and masked owls are the largest hollow-using species in Tasmania (Koch et al 2008b). This means that hollows likely to be used by masked owls are expected to be in trees greater than 200 years old, and rare in some landscapes. Therefore, greater information on the attributes of the trees and hollows used by masked owls is urgently needed.

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Acknowledgements

This work was supported by a matched funding scheme through Forest and Wood Products Australia Limited, with funding provided by Forico Pty Ltd, SFM, Forest Practices Authority, Sustainable Timber Tasmania, Timberlands, Norske Skog, and Private Forests Tasmania. We are grateful to the many volunteers who helped to collect data and samples, and the landowners who were so accommodating in providing access to their land.

A more detailed account of this research is published in the thesis below.

Service, J. (2023) *Behaviour-specific habitat selection of the Tasmanian masked owl* (Tyto novaehollandiae castanops), Honours thesis, University of Tasmania.

Researcher's Disclaimer

This research was done in fulfilment of the requirements for the degree of Bachelor of Science with Honours at the University of Tasmania. The research abides by the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes, 7th edition, 2004 and the University of Tasmanian Animal Ethics Guidelines. The research was carried out under University of Tasmania Animal Ethics Approval A0018609 and the Tasmanian Department of Primary Industries, Parks, Water, and the Environment Permits TFA22340.