Population estimates for Stubble Quail in Victoria

Results from the 2025 survey

M.P. Scroggie and D.S.L. Ramsey

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Population estimates for Stubble Quail in Victoria

Results from the 2025 survey

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Summary

Context:

Regular (annual) estimates of the abundance of Stubble Quail (*Coturnix pectoralis*) in Victoria assist with determining the arrangements for the annual hunting season. A survey methodology using line-transect distance sampling was developed and tested in previous years (Scroggie and Ramsey 2023) and has again been applied to analyse the 2025 survey data to obtain updated populations estimates.

Aims:

This report aimed to:

i. obtain updated estimates of total and regional abundance of Stubble Quail in Victoria, using the established survey methodology

ii. compare the resulting estimates of abundance with those obtained from the previous comparable (2023 and 2024) surveys

iii. provide recommendations for any necessary improvements to the data collection and analysis procedures so that future surveys can continue to deliver precise and accurate estimates of Stubble Quail abundance.

Methods:

The line-transect distance sampling methodology used to obtain the 2024 population estimates was repeated during January 2025, with transects being surveyed at a total of 78 sites across Victoria. A model-based approach was used to obtain abundance estimates at both statewide and regional (Catchment Management Authority area) scales.

Results:

The model-based analysis yielded a statewide abundance estimate of 2.3 million Stubble Quail (95% CI: 1.5 – 3.6 million). This was lower than the previous (2024) estimate of 5.3 million (95% CI: 4.1 – 6.9 million) and is indicative of a large decline in abundance of over 50% during the last 12 months.

The model indicated that spatial variation in abundance of Stubble Quail in Victoria during 2025 was largely driven by rainfall during the preceding 12 months (with highest abundances at intermediate rainfall) and woody vegetation (with highest abundances where cover of woody vegetation was lowest).

Conclusions and implications:

The survey methodology that was originally adopted in the 2023 report once again yielded estimates of abundance with sufficient precision to support decision-making regarding the arrangements for hunting of Stubble Quail in Victoria. The statewide estimate of abundance was over 50% lower than that obtained during 2024. Much of Victoria experienced a large deficit in rainfall during the 2024 calendar year, which may at least partially explain the population trend. Due to the limited number of surveys of Stubble Quail conducted to date, it is not yet possible to undertake a meaningful analysis of the relative contributions of the effects of hunting, climatic conditions and other drivers of the population dynamics of Stubble Quail to the observed decline at this time.

Recommendations:

We recommend that the survey is repeated annually using the current methodology. This will allow ongoing monitoring of trends in abundance and regular re-assessment of the ecological sustainability of the hunting arrangements. To gain a better understanding of the effects of seasonal harvest arrangements on Stubble Quail populations, it is recommended that relationships between seasonal harvest arrangements (bag limits and season length) and the size of harvest be investigated.

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1 Introduction

In Victoria, hunting of Stubble Quail (*Coturnix pectoralis*) by licenced hunters is permitted during an annual hunting season. Seasonal hunting arrangements, including daily bag limits, season length and hunting methods, are prescribed in the Wildlife (Game) Regulations 2024.

The total numbers of Stubble Quail taken by hunters during each hunting season are estimated each year from telephone surveys of licensed hunters. The likely total number harvested is inferred from the telephone survey data by statistical extrapolation of the self-reported hunting bags of randomly surveyed hunters to the (known) total number of licensed hunters (see Moloney and Flesch 2023; Moloney and Flesch 2024). While these telephone surveys provide estimates of the total harvest take, without knowledge of the pre-harvest population size the harvest take estimates are of limited utility for assessing the sustainability of the hunting arrangements. To this end, the Game Management Authority (GMA) has funded work to develop a survey method for estimating the total size of the Victorian Stubble Quail population.

Annual surveys for Stubble Quail are undertaken at a representative sample of sites across the state using line-transect distance sampling (Buckland et al. 1993). This method was initially developed prior to the 2022 hunting season (Scroggie and Ramsey 2022), with further refinements and improvements to the methods being implemented during 2023 (Scroggie and Ramsey 2023). Subsequent surveys during 2024 (Scroggie and Ramsey 2024) and 2025 (this report) have used the same field methodology and analytical methods to obtain estimates of abundance of Stubble Quail at regional and statewide scales. Use of a consistent methodological approach now allows trends in abundance over time to be assessed, which provides a further useful input for management of hunting of the Victorian Stubble Quail population.

During January of 2025, a survey was conducted across Victoria to provide an updated assessment of abundance at regional and statewide scales. This report describes the results of this survey as well as an assessment of changes in abundance since the last survey.

1.1 Objectives

The aims of this study were to:

(i) undertake an additional survey of the state's Stubble Quail population using the methodology developed by Scroggie and Ramsey (2023)

(ii) derive updated estimates of the abundance of Stubble Quail at statewide and regional scales and compare these to estimates from previous surveys to assess population trends

(iii) provide recommendations for further improvements to the design, implementation and interpretation of future Stubble Quail surveys in the state.

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2 Methods

2.1 Monitoring sites

A total of 78 sites were sampled during January 2025, a slight increase on the 77 sites that were surveyed during 2024. The predominant land uses at the sites were pasture, dryland cropping and native grassland. Sites were stratified across Victorian Catchment Management Authority (CMA) areas as well as across the three land use types to obtain a sample that was broadly representative of Stubble Quail habitats across the state. The former Port Phillip and Westernport CMA was merged with Melbourne Water during 2021. For consistency with legacy spatial data that were used in our analyses, we have retained the previous name for this CMA throughout the report. Land use data were obtained from White et al. (2020) and were identical to those used in previous Stubble Quail abundance reports.

While a proportion of the Victorian Stubble Quail population may occupy other habitat types, the three land uses that were targeted in our surveys represent the majority of likely habitat, and are the habitats in which hunting is most likely to occur. Consequently, we consider that the approach to survey site selection was appropriate for the intended management use of the resulting population estimates, but stress that it likely represents an underestimation of total abundance. The locations of survey sites and of mapped habitat types are displayed in Figure 1. The numbers of sites that were in each CMA and land use category (based on the mapped land use at the site centroid) are given in Table 1.

Each site consisted of several distinct transects which were typically 1 km in length. Transects at the same site were usually arranged in parallel, with a spacing of at least 200 m between adjacent transects to avoid issues with birds being flushed from one transect to another and double counted. It was intended that a total of approximately 4 km (i.e. 4 x 1 km transects) would be surveyed at each site. However, logistic, safety or access constrains resulted in less than 4 km of total effort at some sites. The actual transect lengths were recorded with the aid of a portable GPS device and this information was incorporated into the statistical modelling process to account for the actual survey effort that applied at each site. Across all 78 sites, the average transect length per site was 3.58 km, with a total of approximately 280 km of total transect effort across the entire study.

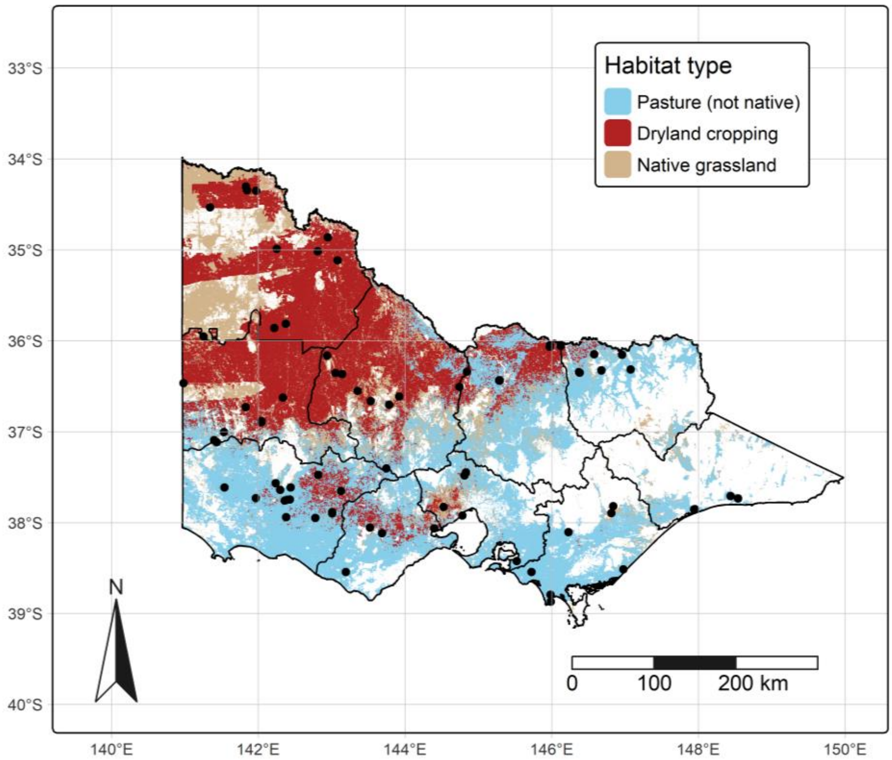

Figure 1. Map showing broad land use categories and locations of survey sites within Victoria.
Map shading illustrates broad land use categories within the state, as well as the boundaries of Catchment Management Authority regions (black internal boundaries) and the locations of the survey sites for the 2024 Stubble Quail survey (black points).

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Table 1. Number of sites within each a) Catchment Management Authority (CMA) area, and b) broad land use category. Tabulation of habitat types is based on mapped land use at the site centroid.

a) CMA	Number of sites
Corangamite	4
East Gippsland	5
Glenelg Hopkins	14
Goulburn Broken	7
Mallee	10
North Central	10
North East	7
Port Phillip and Westernport	5
West Gippsland	7
Wimmera	9
TOTAL	**78**

b) Predominant land use category	Number of sites
Dryland crops	29
Native grassland	7
Non-native pasture	42
TOTAL	**78**

2.2 Survey methods

As was the case in previous survey years, Stubble Quail density was estimated from the survey data using line-transect distance sampling methods (Buckland et al. 1993). The field methodology and approach to interpretation and analysis of the data used for the 2024 surveys was identical to that used during 2023 and 2024. A full description of the methods can be found in the previous report (Scroggie and Ramsey 2023; Scroggie and Ramsey 2024). In brief, a team of three observers slowly walked each transect in a line-abreast formation along the line itself, with a secondary observer on each side, 10 m from the line. A 20 m rope was held by all three observers to maintain constant spacing and to assist with flushing of birds. All flushed Stubble Quail groups were counted and their perpendicular distances from the transect line when first detected were measured using a laser range-finder and compass. Sightings of other ground-dwelling bird species (mainly Little Button-quail, *Turnix velox* and Brown Quail, *Coturnix ypsilophora*) were also recorded, but are not considered further here.

2.3 Estimating Stubble Quail abundance

2.3.1 Distance sampling

A two-stage modelling process was adopted for analysing the data. First, a detection function was fitted to the distance data to estimate the effective detection distance of groups of birds located in the vicinity of the transect line (the transect half-width). The fitted distance function provided a basis for statistical estimation of the proportion of Stubble Quail groups that were detected and counted by the observers out to the maximum truncation distance (20 m) either side of the transect lines. We considered several alternative distance models for the data including hazard rate, half normal and uniform functions with and without cosine, polynomial and Hermite adjustment terms (Buckland et al. 1993). Adjustment terms were progressively added to the basic (key function only) models until there was no improvement in Akaike's Information Criterion (AIC, Burnham and Anderson 2002). We also considered models with and without a group size effect, because it was considered likely that larger groups of Stubble Quail might have been easier to detect.

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While selection of a final, preferred distance model was mainly guided by AIC values, we also evaluated the goodness of fit using Chi-squared tests and compared models with different approaches to binning of the distance data into discrete distance bands. This latter approach is helpful where distinct “spikes” occur in the histogram of detection distances as a result of either unintentional rounding of distances by the observers or repulsive movement of animals away from the observers (Buckland *et al.* 1993).

2.3.2 Model-based estimates of abundance

Model-based estimation of abundance followed the same process as was used in previous reports. We used density-surface models (DSMs, Miller et al. 2013; Buckland et al. 2016) to relate the densities of Stubble Quail observed on the transects to spatially-referenced covariates. This allowed us to establish a statistical relationship between habitat variables and Stubble Quail density, which could then be extrapolated to the entire study area. The resulting model allows prediction of density at any location in the study area as well as estimation of the total population, or the population in any subset of the study area (in this case the CMA regions) by summing the predicted abundances within grid cells of the area of interest to obtain an abundance estimate.

The DSMs allowed for non-linear relationships between abundance and habitat variables using generalised additive models (GAMs, Wood 2017). Selection of variables for inclusion in the model was done by eliminating uninfluential variables until there was no further improvement in AIC. We fitted the DSMs using the R package *dsm* (Miller et al. 2020), which provides a wrapper for incorporating distance sampling data into the facilities for fitting of GAMs provided by the R package *mgcv* (Wood 2017).

2.3.3 Spatial modelling

The habitat covariates included in the spatial model were the same as those used in the 2024 report, with the addition of estimated annual rainfall for the calendar year 2024 (reflecting rainfall in the period preceding the surveys), and an updated map of the Normalized Difference Vegetation Index for January 2025 (reflecting vegetation greenness at the time of the surveys). Maps showing spatial variation in the habitat variables used in the models are given in the Appendix to this report. All variables were mapped at a 1 km grid cell resolution. The variables considered for inclusion in the model are described in Table 2.

Table 2. Gridded habitat and environmental variables used as predictors of Stubble Quail density.

Variable	Details	Source
Landcover	Percentage cover of crop, pasture, grassland and woody vegetation within each 1 km grid cell.	Calculated by aggregating the original 25 m resolution dataset of White et al. (2020)
Woody ecotone	Amount of ecotonal habitat between woody and open habitat types (crop, pasture, grassland).	Derived from White et al. (2020)
NDVI	Normalised difference vegetation index (Pettorelli et al. 2005) during January 2025. NDVI is a remote-sensed index of vegetation greenness	From the MODIS satellite platform (Didan 2015). Data were downloaded from Google Earth Engine (Gorelick et al. 2017).
Rainfall	Mean annual rainfall during the calendar year 2024. Grids were interpolated from meteorological data following the methods described in Jeffrey et al. (2001).	longpaddock.qld.gov.au

The latitude and longitude of each survey location was also treated as a predictor of abundance to detect any large-scale spatial trends in abundance that were not well explained by the habitat covariates.

Initially, six models for the density of Stubble Quail were considered:

1. A null model with no covariates (i.e. constant Stubble Quail density across all habitats).
2. A spatial trend model that included only latitude and longitude covariates, specified as a bivariate thin-plate spline (Wood 2003).
3. A model that included only vegetation greenness (NDVI). The relationship between Stubble Quail density and NDVI was modelled using a thin plate spline term.

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4. A model that included only mean annual rainfall. The relationship between Stubble Quail density and rainfall was modelled using a thin plate spline term.
5. A model with both habitat (proportional land use), NDVI and rainfall covariates, all specified as separate thin plate splines. Initial fits included all land use categories and NDVI, with uninfluential and/or redundant variables being progressively eliminated until no further reduction in AIC was noted.
6. A model identical to 5., but with a bivariate thin-plate spline on latitude and longitude also included in the model to account for spatial variation in quail density that was not explained by the habitat covariates.

We compared the performance of alternative versions of the candidate models with Poisson, Negative Binomial and Tweedie error distributions. Alternative models were compared using AIC with the intention of maximising model parsimony and therefore, predictive performance (Burnham and Anderson 2002).

The preferred model was used to predict variation in the density of Stubble Quail across suitable habitat for the entire state, and to infer the total abundance for the state and for each CMA region. Assessment of the uncertainty in the abundance estimates accounted for uncertainty in both the detection model (determined using distance sampling) and the habitat-abundance model (fitted using generalised additive models as per the methods described by Miller et al. (2022)).

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3 Results

3.1 Survey results

A total of 90 detections of Stubble Quail groups were included in the analysis after removing some very long-distance detections and thereby truncating the maximum detection distance at 20 m. These sightings were made over a total of 280 km of transect surveys. The 90 groups comprised a total of 122 individual birds, with the mean group size being 1.36 birds.

3.1.1 Analysis of distance-detection

The various distance functions were fitted to the distance sampling data, and the parsimony of the resulting models was compared on the basis of AIC (Burnham and Anderson 2002). Binning of the detection data was used to deal with an excess of detections close to the transect line. Comparison of fitted models (Table 3) led to selection of a hazard-rate model with a group-size covariate included, supporting the hypothesis that larger groups of Stubble Quail were easier to detect. Model selection uncertainty was relatively high, with multiple models having ΔAIC within two units of the best-supported model. However, despite the considerable model selection uncertainty, the effective half-widths and detection probabilities of all well-supported models were broadly comparable. The detection probability ($\hat{p}$) under the best supported model was 0.505, which was comparable to estimates from previous surveys (2024: $\hat{p}$ = 0.53; 2023 $\hat{p}$ = 0.562, see Scroggie and Ramsey 2023; Scroggie and Ramsey 2024).

Table 3. Summary statistics for the distance-detection models.

A smaller AIC indicates a more parsimonious model with better expected predictive performance. $\hat{p}$ is the area under the fitted distance function out to the right-truncation distance of 20 m and gives the probability of detecting each quail group present within the 10 m strip either side of the central observer. The effective transect half-width is the equivalent transect half-width (m) for a hypothetical transect survey that detects all groups actually present.
Adjustment = adjustment series, df = degrees of freedom, ΔAIC = the difference between the AIC of the model and the AIC of the model with minimum AIC. The preferred model is given in boldface.

Key function	Adjustment	Covariate	df	ΔAIC	$\hat{p}$	Effective half-width
Hazard rate	**-**	**Group Size**	**3**	**0.00**	**0.505**	**10.10**
Hazard rate	-	-	2	0.18	0.527	10.53
Half-normal	-	-	1	0.91	0.449	8.98
Uniform	Polynomial	-	3	1.06	0.439	8.79
Hazard rate	Hermite	-	3	2.22	0.519	10.38
Hazard rate	Polynomial	-	3	2.22	0.519	10.38
Hazard rate	Cosine	-	3	2.25	0.525	10.50
Half-normal	Polynomial	-	2	2.60	0.445	8.90
Half-normal	-	Group Size	2	2.62	0.448	8.96
Uniform	Cosine		1	3.64	0.531	10.61
Half-normal	Hermite		2	3.79	0.472	9.45
Half-normal	Cosine		3	3.86	0.493	9.87
Uniform	Hermite		2	4.87	0.532	10.63

Checking of the predictions of the preferred model against the observed data using a Chi-squared test showed no significant goodness-of-fit issues (χ^2= 6.006, P = 0.113). The fitted detection model is illustrated in Figure 2, along with the binned distance-detection data. The fitted curve shows a broad, flat ‘shoulder’ out to approximately 5 m from the transect line, with detection probabilities dropping off gradually beyond that distance out to the right-truncation distance of 20 m.

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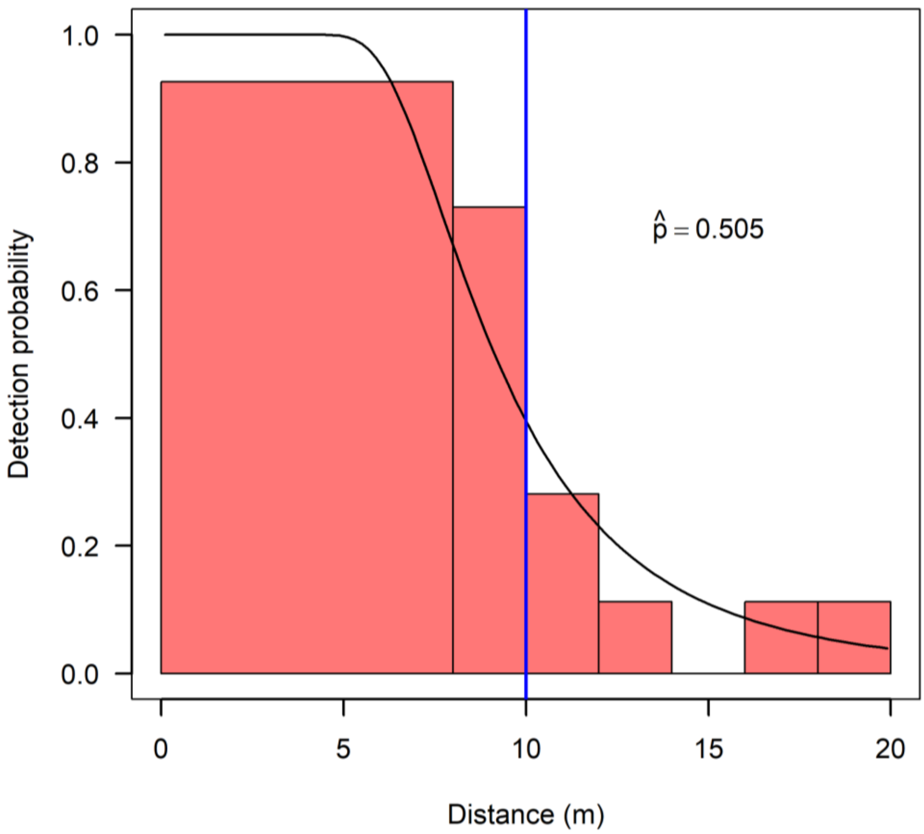

Figure 2. Fitted distance function (hazard rate).

The vertical blue line indicates the distance from the transect line at which the outer observers were positioned while surveying the transect. The black line is the fitted hazard rate function. $\hat{p}$ is the estimated proportion of Stubble Quail groups detected out to the right-truncation distance of 20 m.

3.2 Abundance estimates

3.2.1 Model-based estimates of abundance

As was the case in previous years, density surface models with Tweedie error distributions were strongly preferred based on AIC. Summary statistics for each of the models that were considered in the analysis are given below in Table 4, with better support (lower AIC) models at the top of the table. A model with smooth terms for annual rainfall and the proportion of woody vegetation was found to be marginally superior based on AIC; however, a similar model which also included a bivariate smoothing term for latitude and longitude effects explained a slightly higher proportion of total deviance (20.8% versus 17.1%). Support for the remaining four models in the candidate set was negligible and all four explained a very low proportion of total deviance.

Further examination and comparison of the two well-supported models showed that their predictions regarding Stubble Quail abundance were very similar. However, it was found that the model which included a bivariate latitude/longitude term had a high degree of concurvity (Siems et al. 2023) between the latitude/longitude smooth and the rainfall smooth, suggesting an (unsurprisingly) high degree of redundancy between these two covariates in the model. Accordingly, for the purposes of prediction of Stubble Quail abundance across the state, we have favoured the model that did not include the latitude/longitude smooth.

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Table 4. Summary statistics for the set of candidate density surface models (DSMs) for the density of Stubble Quail across Victoria.

All models used the Tweedie error distribution for their responses. The notation s(x) indicates a smooth relationship (in this case described by a thin-plate spline, see methods). Models are ordered in decreasing order of parsimony, based on their AIC values. edf – effective degrees of freedom, AIC – Akaike's information criterion, ∆AIC = AIC – min(AIC). The preferred model that was used for prediction of Stubble Quail density across the state is given in boldface.

Model	edf	∆AIC	% Deviance explained
s(rain) + s(woody)	**6.94**	**0.00**	**17.1**
s(latitude, longitude) + s(rain) + s(woody)	8.66	0.36	20.8
Null model (intercept only)	3.00	5.40	0.0
~s(ndvi)	3.00	5.40	0.0
~s(rain)	3.00	5.41	0.0
~s(latitude, longitude)	5.25	7.16	3.7

The fitted curves for the habitat-abundance relationships in the preferred DSM (Figure 3) showed that Stubble Quail abundances were highest at intermediate rainfall (around 500 mm), and that they declined with increasing cover of woody vegetation.

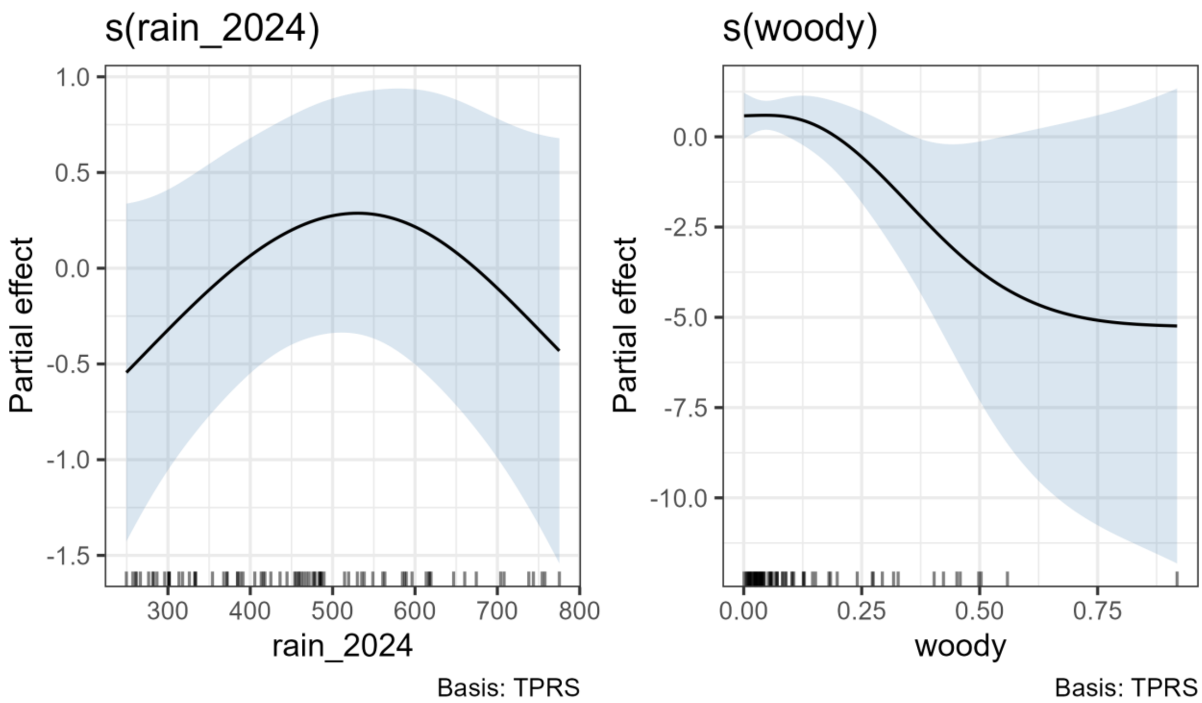

Figure 3. Effects of covariates on log-density of Stubble Quail in the study area.

These are thin-plate regression spline (TPRS) terms representing the partial effect of annual rainfall for 2024 and the proportion of woody vegetation on the log-abundance of Stubble Quail on the survey transects.

Prediction of Stubble Quail density at each 1 km grid cell allowed estimation of the total Stubble Quail abundance for each CMA, and for the entire study area (Table 5). The largest population was found in the North Central CMA, which was estimated to contain 471,000 Stubble Quail. In contrast, the population of Stubble Quail in the East Gippsland CMA was estimated at only 32,000 (Table 5). The estimate of Stubble Quail abundance for the entire study area was 2.3 million.

Relative precision of the population estimates for the CMAs (expressed as the coefficient of variation, CV) were generally less than 0.3, except for the West Gippsland, North East and Mallee CMAs. The CV of the

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overall, statewide estimate of abundance was 0.23, which indicates that there was an adequate level of precision in the overall population estimate.

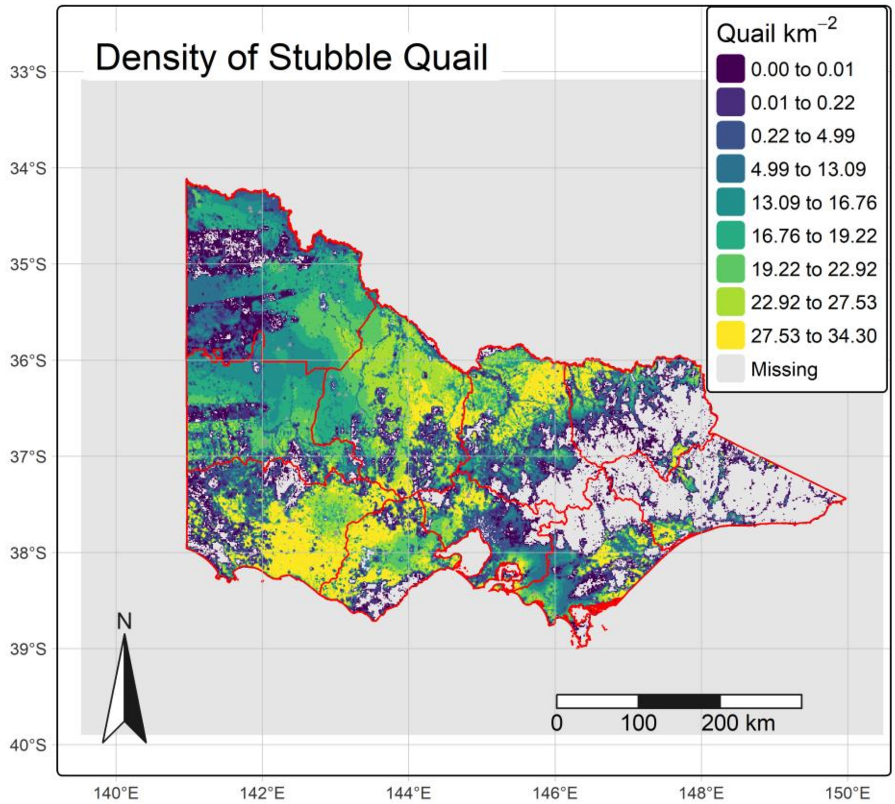
Table 5. Model-based estimates of abundance.

Abundance, ($\widehat{N}$, rounded to the nearest thousand) for Stubble Quail based on stratification of the survey sites into three major habitat types. CV = coefficient of variation. Area of habitat totals included only the areas within each CMA, which were mapped as dryland crops, native grasslands and pastures.

CMA	Area of habitat (km^2)	Abundance ($\widehat{N}$)	Lower 95% bound	Upper 95% bound	CV
Corangamite	8,375	205,000	130,000	324,000	0.24
East Gippsland	1,980	33,000	19,000	58,000	0.29
Glenelg Hopkins	16,825	100,000	247,000	648,000	0.25
Goulburn Broken	12,895	267,000	167,000	427,000	0.24
Mallee	25,976	369,000	194,000	700,000	0.34
North Central	22,476	471,000	293,000	756,000	0.24
North East	5,468	80,000	42,000	152,000	0.34
Port Philip and Westernport	5,781	107,000	64,000	179,000	0.26
West Gippsland	6,142	111,000	60,000	203,000	0.32
Wimmera	17,740	282,000	159,000	501,000	0.30
TOTAL	123,658	2,325,000	1,503,000	3,595,000	0.23

3.2.2 Spatial variation in Stubble Quail density

The density surface model allowed for the prediction of Stubble Quail density within suitable habitat across the entirety of the study area, along with associated measures of uncertainty (i.e. the coefficient of variation, CV). The spatial predictions also allowed for identification of areas of especially high and low expected density (Figure 4). High densities of Stubble Quail (>20 quail per km^2) were predicted for much of south-western Victoria, while lower densities were predicted for much of the dryland cropping zone in central and northern Victoria (Figure 4). Uncertainties in the predictions (as measured using the CV) were highest in locations with very low predicted densities, while for the parts of the state with high predicted densities (such as pastoral country of south-west Victoria and much of the state's dryland cropping zone), coefficients of variation for the predicted abundances within each CMA were mostly less than 0.3, indicating a good level of predictive certainty for the spatial model (Figure 4).



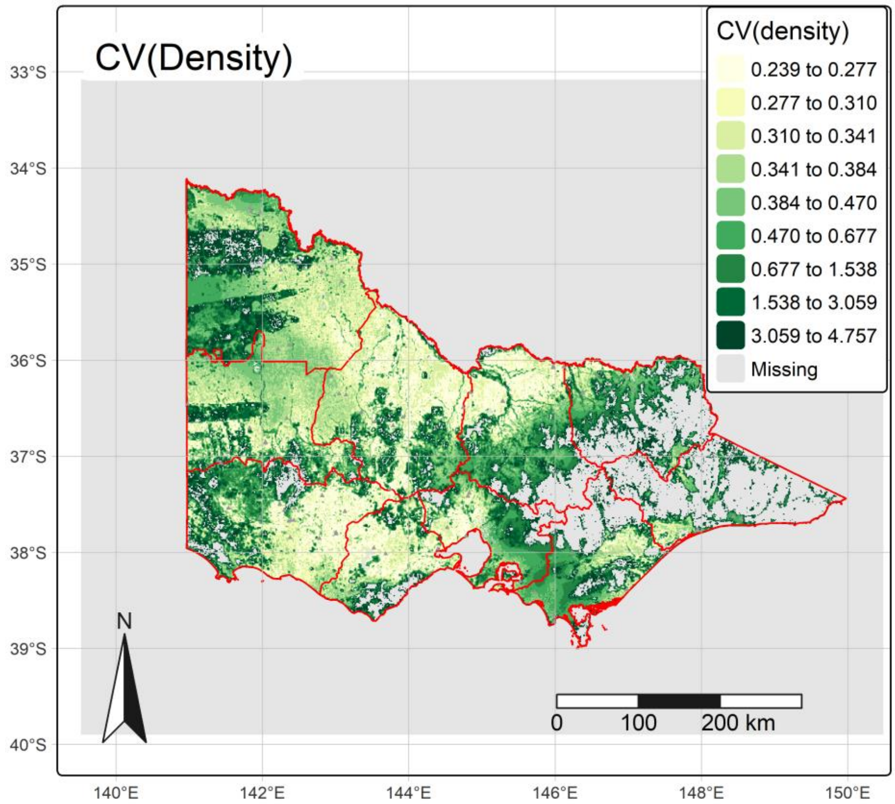


Figure 4. Spatial variation in Stubble Quail density during January 2025.

The upper panel represents the predicted density of Stubble Quail within suitable habitat (crops, grasslands, pastures) across the study area. It is important to note that not every grid cell (1 km x 1 km) within the prediction domain of the model consists entirely of suitable habitat (crop, grassland, pasture), so the inferences are of density within the portion of each grid cell that consists of these habitat types, however small that may be. Overlaid red internal boundaries are the CMA areas. The lower panel represents relative uncertainty in the density estimates, expressed as the coefficient of variation (CV).

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3.2.3 Temporal trends in Stubble Quail abundance

The total estimate of abundance for Stubble Quail in the study area for the year 2025 was lower than comparable estimates made from survey data collected during the preceding two years. This year's estimate was 50% lower than the 2024 estimate, and the confidence intervals for the two estimates are clearly non-overlapping (Figure 5), which suggests that that the population has undergone a large decline during the 12 months preceding the current survey.

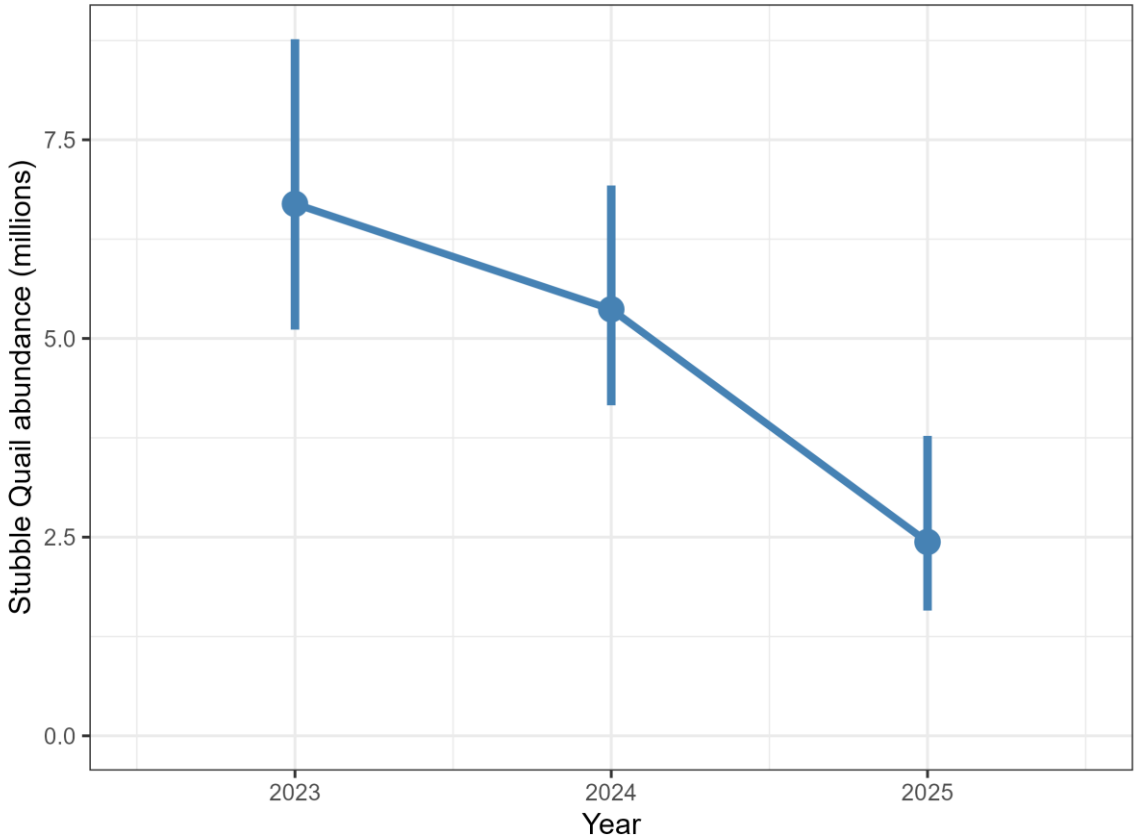

Figure 5. Model-based estimates of total Stubble Quail abundance for the entire study area, for the years 2023–2025.

Error bars are the 95% confidence limits of the estimates.

Considering the abundance estimates at a regional (CMA) level, the temporal trends in abundance vary considerably across the state (Figure 6). For some CMAs (Mallee, Wimmera, North Central), there has been a clear and consistent decline in abundance over the last two years. For the Goulburn Broken CMA, the point estimates are suggestive of a decline, but uncertainty in the successive population estimates does not allow an unequivocal conclusion regarding the temporal trend. The remaining CMAs had more complex results, with either an increase followed by a decline (e.g. Corangamite), or large uncertainties which precluded us from making a definitive conclusion regarding the temporal trend (e.g. West Gippsland, Port Philip and Westernport) (Figure 6).

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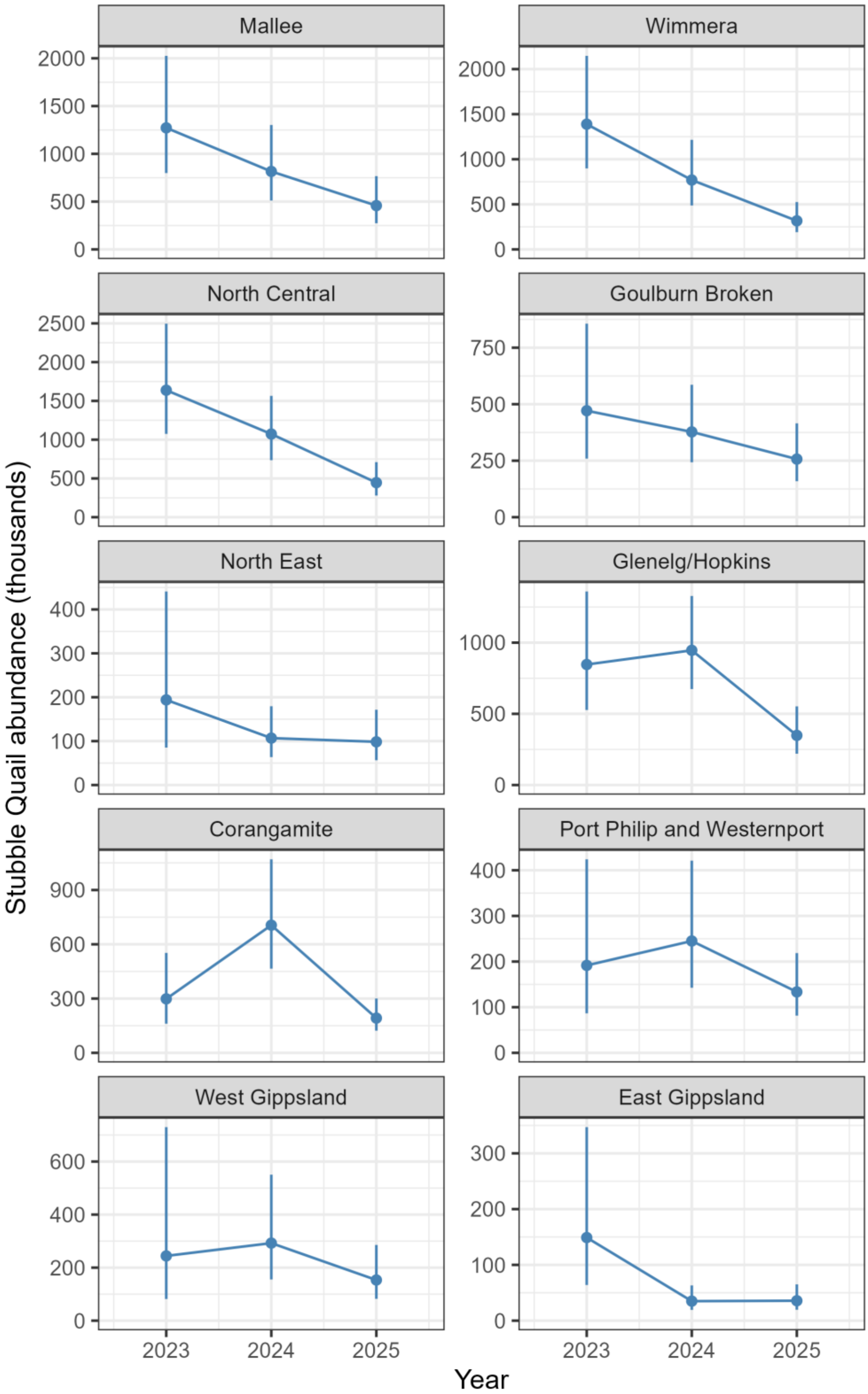

Figure 6. Model-based estimates of total Stubble Quail abundance (in thousands) for each Victorian Catchment Management Authority (CMA) area, for the years 2023–2025.

Error bars are the 95% confidence limits of the estimates. Note, the y-axis scales differ between CMAs to accommodate widely varying abundances. Panels are presented in approximately geographic order from north to south and west to east.

4 Discussion

This year's statewide population estimate of 2.3 million Stubble Quail was over 50% less than the estimate from the previous (2024) survey, indicating that the population has undergone a large decline during the preceding year. This year's estimate is also relatively precise (CV=0.23), meaning that there is little uncertainty regarding the extent of this apparent decline in abundance.

The available data and survey methods do not provide a straightforward means of assessing the likely causes of the decline. It is notable that the decline has occurred during a prolonged period of low rainfall across much of the state. For the calendar year 2024, nearly the entire state experienced below-average rainfall. It is plausible that this below-average rainfall may have led to emigration from the state, and/or lower than usual survival and reproductive rates in Victorian Stubble Quail populations (perhaps due to food limitation), and thereby caused a reduction in abundance. However, suitable data to test this hypothesis are lacking.

During the 2024 hunting season, it has been estimated that Victorian hunters took approximately 457,000 (95% CI: 362,000–577,000) Stubble Quail (Moloney and Flesch 2024). Based on last year's total population estimate of 5.36 million Stubble Quail (Scroggie and Ramsey 2024), the 2024 total harvest represents approximately 8.5 % of the Victorian Stubble Quail population. The extent to which hunting has contributed to the decline of the population during the last year is also unknown.

While unfavourable climatic conditions, dispersal and harvesting could plausibly have contributed to the observed decline in the population, it is not currently possible to determine the relative contribution of these processes to the dynamics of the Victorian Stubble Quail population. As longer time-series of population estimates and harvest statistics accrue, it will become possible to construct population models that allow the effects of hunting, climate and other drivers of survival, reproduction and dispersal to be explored in a rigorous manner. Such an approach will, however, require several more years of population surveys before it would become viable.

In the meantime, during years when climatic conditions are likely to be unfavourable to the survival and reproduction of Stubble Quail it may be desirable to consider reducing the impacts of harvesting by altering the harvest arrangements (i.e. season length and bag limits). Since the commencement of these surveys, seasonal harvest arrangements have resulted in harvests that have not exceeded 10% of the estimated population. However, to further fine tune the setting of harvest arrangements, it would be beneficial to gain a better understanding of the relationships between seasonal harvest arrangements (bag limits and season length) and the size of harvest. Such relationships are currently being actively investigated for game duck harvests, under an adaptive management approach (Ramsey et al. 2025).

4.1 Recommendations

Given that the existing survey methodology is continuing to work well, we recommend that surveys continue to be repeated annually using the same field methodology. The current amount of survey effort (75+ sites, each with approximately 4 km of transect) is consistently yielding estimates of statewide and CMA-level abundance with coefficients of variation mostly < 0.3, so no changes to the survey design are recommended. Wherever possible, conducting surveys at the same sites each year will maximise the comparability of results from surveys in different years. We therefore recommend that, unless access or other circumstance dictate otherwise, the same sites be surveyed each year as far as is practicable.

To gain a better understanding of the effects of seasonal harvest arrangements on Stubble Quail populations, it is recommended that relationships between seasonal harvest arrangements (bag limits and season length) and the size of harvest be investigated. Once five years of successive population estimates and harvest data are available, it should become possible to build more complex population models that incorporate population dynamic processes, hunting pressure and seasonal conditions. Over time (and as additional data accumulates), such models could provide a more rigorous and transparent basis for making recommendations regarding the harvest arrangements for Stubble Quail.

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Appendix

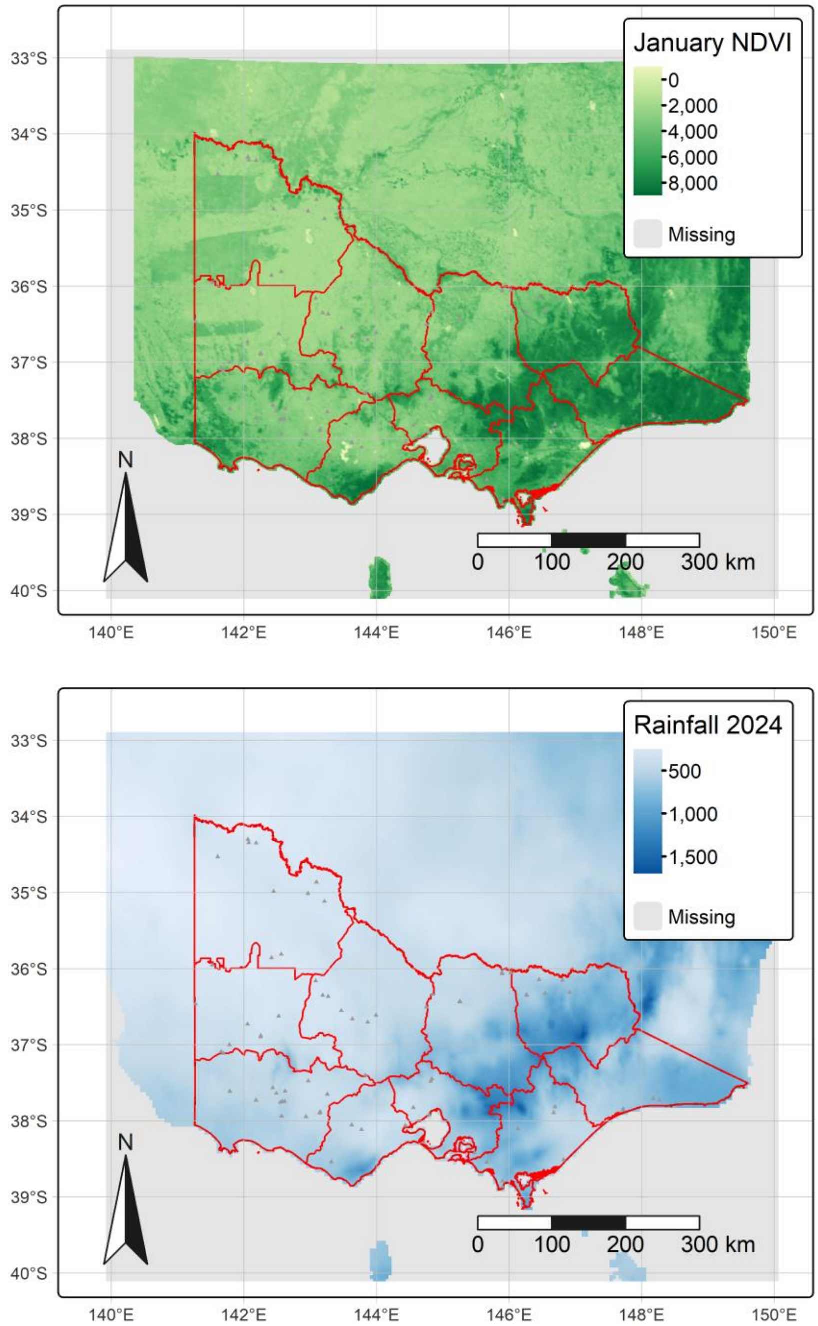

Figure A1. Maps of Normalized Difference Vegetation Index (NDVI) for January 2025, and annual rainfall for the calendar year for 2024 – which were used as predictors in the density surface models for Stubble Quail in Victoria. All other covariates were identical to those use in the 2024 report.

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