

Spatial Modelling of Commercially Harvested Macropods in Queensland

Density surface modelling

Density surface modelling (DSM) is a modern approach for estimating wildlife abundance across large landscapes and is currently used to estimate the abundance of commercially harvestable macropods in Queensland. DSMs are a spatially explicit extension of traditional line-transect sampling that combines aerial survey observations with environmental variables such as rainfall, vegetation productivity, land cover and temperature to model how macropod density varies across the landscape. Unlike traditional line-transect approaches, which assume surveyed areas are representative of much larger regions, DSMs identify relationships between macropod occurrence and environmental conditions and leverage those relationships to estimate density in unsurveyed areas. This provides a more spatially explicit representation of how macropod populations are distributed across Queensland, reduces uncertainty and improves stability of abundance estimations.

Macropod count data derived from annual aerial surveys are adjusted for detectability using established distance sampling methods (Buckland *et al.* 1993) before being integrated with environmental variables in a density surface modelling framework. This approach estimates density right across the species' known distribution, thereby generating estimates for both surveyed and unsurveyed areas. These predictions are then summed across harvestable areas within each harvest zone to derive population estimates and associated measures of uncertainty.

For the Macropod Management Program, DSMs represent the next evolution in population monitoring. The modelling framework makes better use of historical aerial survey data, improves the scientific robustness of abundance estimates whilst lowering variability and brings us in line with other States (Scroggie *et al.* 2025). This provides an explicit understanding of macropod population distribution and their relationship with environmental conditions. Importantly, these improvements can be achieved within the existing monitoring and quota-setting framework, enabling a seamless transition to a more robust approach for population assessment.

Why is Queensland adopting DSMs?

The transition to the DSM methodology offers a range of significant benefits. The most notable advantage over line-transect sampling is the improved precision in density estimations and a more spatially explicit representation of variation in density across the landscape. Traditional line-transect approaches estimate density within surveyed areas and extrapolate those estimates across larger regions. This approach performs well where surveyed areas are representative of broader landscapes but can be less effective where environmental conditions and macropod densities vary substantially across space. The DSM improves upon this by identifying and leveraging correlations in macropod observations and environmental variables to model the change in species density and distribution. This results in more reliable and scientifically robust abundance estimates.

The transition to a DSM approach reflects the continued evolution and improvement of macropod population monitoring in Queensland. Aerial surveys were first undertaken by the CSIRO in 1980, with annual surveys conducted between 1984 and 1992. Responsibility for the survey program was subsequently assumed by the Queensland Government, which has continued to refine survey design and analytical methods in response to advances in science and technology. Early surveys employed strip-transect methodology, which was later

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replaced by distance sampling techniques that explicitly account for detection probability and provide more robust estimates of population abundance. More recently, the introduction of a rotating survey design for selected paired survey blocks has reduced survey effort while maintaining the effectiveness and integrity of the monitoring program. By integrating advances in spatial modelling, statistical analysis, and environmental data, DSMs provide a more sophisticated framework for estimating macropod abundance and distribution across Queensland whilst building on the extensive long-term survey dataset collected.

DSM's also provide greater flexibility in survey design, enabling the swapping or relocation of survey sites to further improve estimate reliability. By explicitly incorporating spatial and environmental information, DSMs can reduce uncertainty and improve the stability of population estimates relative to traditional line-transect approaches. DSM methodology provides a more efficient and scientifically robust framework for population monitoring and represents a significant advancement in Queensland's macropod monitoring program.

How does the modelling process work?

Annual aerial surveys are conducted over 17 monitoring blocks, between May – August, with between two to eight east-west orientated transect lines 40–80km in length, and systematically 10km apart. Transects lines are flown close to dawn and dusk to coincide with generally higher macropod activity. Observation data of the three commercially harvestable macropod species are collected through aerial observations, using Panasonic Toughpads and the SPOTTER application developed by NSW Department of Primary Industries and Regional Development. Two observers sit in the rear of a Robinson R44 Raven 1, with horizontal booms extended from either side of the aircraft to assist observers in identifying perpendicular distances of detected animals.

Survey observations are first analysed using multi-covariate distance sampling, which accounts for factors that may influence detectability, such as survey conditions, observer effects and group size. The resulting detection-adjusted observations are then incorporated into a DSM framework. Following the approach described by Scroggie et al. (2025), a suite of candidate spatial and spatio-temporal models are assessed to identify the structure that best represents patterns in macropod abundance. Candidate models are evaluated using established model selection criteria and diagnostic procedures to ensure assumptions are met and predictions are biologically plausible.

Environmental variables known to influence macropod abundance and distribution, including measures of vegetation productivity, rainfall, temperature and land cover, are then incorporated into the model. These variables influence habitat suitability, forage availability and water resources, which are important drivers of macropod populations across Queensland. A large, pooled (i.e. State-wide) DSM combines data from all monitoring blocks to increase sample size and strengthen relationships between observed abundance and environmental conditions. This enables the model to distinguish broad ecological patterns from localised noise whilst retaining regional variation in population distribution. The modelling framework also provides flexibility to incorporate historical survey data where those data are considered suitable for analysis.

The final model is used to predict macropod density across the landscape, including areas not directly surveyed. Estimations are combined within each harvest zone and are accompanied by measures of uncertainty. Areas associated with unacceptably high uncertainty can be excluded from abundance estimation where appropriate.

How are quotas derived?

Sustainable harvest quotas are calculated using a fixed proportion of the estimated macropod populations within Queensland's harvest zones. The maximum proportions used for each species are 15% of populations for eastern grey kangaroos and common wallaroos and 20% of the population for red kangaroos. Due to the significantly lower macropod harvest in Zones 1 and 5, they are not surveyed with the same intensity as Zones 2 – 4. The maximum proportions are only applied to populations within Zones 2 – 4 where survey effort is greatest and hence

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confidence limits for population estimates are within acceptable limits. In Zones 1 and 5 more conservative harvest proportions of 10% for all three species are applied. These sustainable-use harvest proportions are based on research and modelling undertaken by Caughley et al. (1987) and Hacker et al. (2002) and are currently accepted by the scientific community, the macropod industry, the Queensland Government and the National Environmental Protection Agency.

Aerial surveys are known to underestimate common wallaroo (*Osphranter robustus*) density relative to ground counts. Estimates derived from ground surveys for common wallaroo density are approximately 1.9-2.0 times that recorded for helicopter surveys (Clancy et al. 1997). To account for this detection bias, Queensland, in line with other States, applies a conservative correction factor of 1.85 to wallaroo density estimates derived from aerial surveys. No correction factors are applied to eastern grey (*Macropus giganteus*) and red kangaroo (*Osphranter rufus*) density estimates as recommended by Clancy et al. (1997).

To ensure populations of macropods are harvested sustainably, where a macropod population drops below 1.5 standard deviations over the long-term average for the harvest zone the harvest quota is halved. If this falls below 2 standard deviations, the harvest of this species is closed for that harvest period. Due to the change in methodology, these trigger points have been reviewed and re-determined using density surface modelling on historical data.

Overall, the adoption of a DSM strengthens Queensland's macropod monitoring program by providing a more robust, spatially explicit foundation whilst maintaining its commitment to supporting a sustainable commercial industry.

What does it mean for harvest and quota setting?

The primary benefit of the transition is greater confidence that population estimates accurately reflect changes in macropod abundance and distribution over time. While DSM-derived population estimates may differ from those generated using traditional line-transect methods, these differences reflect improvements in how population distribution is modelled across the landscape rather than changes to harvest management arrangements. As the actual harvest remains substantially below the prescribed quota, any changes in quota estimates resulting from the adoption of DSMs are unlikely to influence harvest outcomes. Analysis of species- and zone-specific harvest data over the past decade indicates that realised harvest levels have consistently remained well below both historical quotas and quotas derived under the DSM framework, demonstrating that the revised abundance estimates are unlikely to constrain harvest activity. Additionally, model projections indicate that future harvest levels are expected to remain well below the quota derived from the DSM framework. As such the transition from line-transect methodology to DSM is expected to have a negligible impact on the harvest macropod industry.

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References

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