Systematic definition of threatened fauna communities is critical to their conservation

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Abstract

Aim: Most terrestrial ecological communities are defined primarily on their constituent flora. We aimed to develop a repeatable approach to defining a community, both intact and degraded, based on its fauna. We demonstrate how the approach can be used to guide conservation—for example, determining whether a multispecies community of animals is threatened.

Location: Temperate and subtropical woodlands of Australia.

Methods: We used expert opinion to develop a definition of the Australian Temperate and Subtropical Woodland Bird Community and metrics of its condition. Using continental-scale vegetation change mapping, and national bird atlas data, we assessed this community against criteria for listing as a threatened ecological community under national biodiversity conservation law.

Results: We defined and described a recognizable and consistent Australian Temperate and Subtropical Woodland Bird Community. Although taxonomically and functionally very similar, we identified six community variants that show species- or genus-level substitutions. The community was evaluated to be Endangered or Critically Endangered across its extent based on criteria from Australia's Environment Protection and Biodiversity Conservation Act 1999. We used a novel metric of condition using historical changes in woodland extent and bird species, to demonstrate the community has declined substantially in geographical extent and integrity and is subject to severe and ongoing threats.

Conclusions: The consequences of global change affect entire communities, not just single species; however, defining ecological communities based predominantly on plant species composition can fail to illuminate the complex associations of animals that are both sustained by, and sustain, the vegetation. In this study, we present a process for defining and evaluating the status of a fauna community against threat criteria. The explicit recognition and protection of fauna communities can be an important complement to the protection of plant-based ecological communities.

KEYWORDS
birds, ecological community, ecosystem, endangered, Environment Protection and Biodiversity Conservation Act, EPBC, fauna community, threat
INTRODUCTION

The management of biodiversity is often focussed on protection of threatened species, exemplified by widely used tools such as the IUCN Red List of Threatened Species. There is good reason for such a focus, with species decline and extinction approaching catastrophic levels (Ceballos, Ehrlich, & Dirzo, 2017). However, given that multiple species within different taxonomic groups, geographical locations and communities are under threat (Pimm et al., 2014), it is well accepted that a species-focussed approach is insufficient (Mace, 2014), and increasingly, ecosystems and ecological communities are being recognized as principal entities needing protection. For example, in 2015, the IUCN endorsed a new set of criteria for listing ecosystems as threatened entities (Keith et al., 2015), in recognition that the concept of ecosystem collapse is analogous to that of species extinction (Keith et al., 2013).

Focussing conservation action on ecological communities presents pragmatic benefits. A community-wide approach recognizes explicitly that numerous species contribute to ecosystem function via a complex array of biotic and abiotic interactions (Hooper et al., 2005; Ings et al., 2009). It follows that changes in elements of these communities—even if those elements do not individually qualify as “threatened”—can cause unforeseen or cascading effects (Newsome & Ripple, 2015). From a management perspective, a focus on communities allows for a more holistic approach to addressing anthropogenic threats because it accounts for the array of ecological processes, interactions and species-specific responses that characterize multispecies assemblages (Keith et al., 2015). Furthermore, perverse or unintended consequences of management actions may be avoided, as management actions are designed in consideration of community-level responses and the cascading interactions in ecological and socioeconomic systems, a central tenet of network theory (Dee et al., 2017). Lastly, from a perspective of cost-effectiveness, simultaneously managing multiple species that share ecological traits, threats and habitat characters can help to better prioritize and target limited funding for conservation (Gonthier et al., 2014).

Ecological communities can be defined as biotic assemblages delineated by a characteristic composition of species, associated abiotic environmental variables, and their ecological functions and interactions, occurring within a bounded space (adapted from Keith et al., 2013). In practice, however, most ecological communities documented and formally protected under policy are vegetation communities. Only two include non-plant biota (microbes and invertebrates) in their description (Australian Government, 1999).

Importantly, animal communities can be degraded even in ecosystems that appear, superficially at least, to have relatively intact vegetation. While habitat loss is a major driver of biodiversity declines, a multitude of other threats acts on animal species, including many insidious threats operating within apparently intact systems (Maxwell, Fuller, Brooks, & Watson, 2016). For example, the depletion of wild animals through overexploitation is recognized from tropical forests across the world (“empty forest syndrome”) (Wilkie, Bennett, Peres, & Cunningham, 2011). Several other examples occur from different Australian ecosystems, including (a) the ongoing depletion of small mammals in northern Australia due to feral predators and altered fire management regimes, in a biome generally considered to be largely uncleared and minimally modified (Fisher et al., 2014; Lawes et al., 2015); (b) the sustained high levels of predation of birds by introduced cats in natural environments (>250 million per year), particularly in Australia’s least-modified regions (the dry, arid interior) (Woinarski et al., 2017); and (c) the degradation of bird communities even in continuous, intact woodland due to the dominance of a hyper-aggressive native competitor (Howes & Maron, 2009).

Declines in animal species can therefore precede—and indeed, precipitate—ecosystem collapse. This is because a depauperate or degraded animal community can itself be a threat to the persistence and health of vegetation communities, given the key role performed by intact animal assemblages in maintaining vegetation through services such as pollination, predation, seed dispersal and preventing invertebrate outbreaks (Sekercioglu, 2006; Wilkie et al., 2011). For example, small insectivorous birds play an important role in ecosystem health and provide vital ecosystem functions such as pollination, seed dispersal, insect control and decomposition (Şekercioglu, Daily, & Ehrlich, 2004; Wenny et al., 2011). These functions are economically important in both natural and agricultural landscapes (Wenny et al., 2011; Whelan, Şekercioglu, & Wenny, 2015). Similarly, the local extinction of co-evolved pollinators and effective pollination processes threatens the long-term persistence of entire forest and woodland ecosystems (Woinarski, Connors, & Franklin, 2000). As such, failing to protect animal communities may undermine conservation actions that focus on individual threatened species and/or vegetation communities.

Here, we emphasize that defining and, where necessary, protecting whole animal communities are crucial complements to efforts focussed on conserving individual threatened species, plant communities and ecosystems. Yet, it is rarely done in terrestrial settings. In this paper, we present an approach to first defining, and then estimating trends in the extent and condition of, the woodland bird community of Australia’s highly modified temperate and subtropical zone. This large group of birds has been the focus of substantial research for many decades (e.g., Recher, Holmes, Schulz, Shields, & Kavanagh, 1985, Barrett, Ford, Recher, & Barrett, 1994, Ford, 2011b), not least because of prevailing long-term concerns regarding the declining...
status of the community, its exposure to ongoing threats and evidence that many species that comprise this community are on the brink of calamitous decline (Ford, 2011a; McGinness, Arthur, & Reid, 2010; Szabo, Vesk, Baxter, & Possingham, 2011; Vesk & MacNally, 2006). Degradation of the vegetation communities in which the community is found does not appear reliably to indicate a degraded woodland bird community is present, nor does high-condition vegetation necessarily obviate bird community degradation (Howes & Maron, 2009; Kath, Maron, & Dunn, 2009; Maron, 2005; Maron & Lill, 2005). Yet consensus on what comprises this “woodland bird” community and where it occurs is lacking. Further, differences in how this community is defined may affect the extent to which it meets criteria for being threatened (Fraser, Garrard, Rumpff, Hauser, & White, 2015). Therefore, despite widespread concern about the community, its threat status has never been formally assessed.

Here, we detail a method to define and evaluate a widespread, continental-scale fauna community, in this case the Australian Temperate and Subtropical Woodland Bird Community. Using structured expert elicitation, we describe which species comprise the community then we examine how community characteristics relate to variation in expert‐judged community condition and distinguish it from other bird communities. We apply a method developed for plant communities to create a metric of the condition of the community, where it occurs (Sinclair, Griffioen, Duncan, Millett‐Riley, & White, 2015). Last, we evaluate the community against the Australian Government’s criteria for listing as a threatened ecological community under national biodiversity conservation law.

2 | METHODS

There were two main components to this work (see Figure 1): (a) defining and describing a recognizable, consistent community of woodland birds, and (b) evaluating the community against the criteria for listing as a threatened ecological community (TEC) under Australia’s Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). This is the pathway for officially identifying a threatened ecological community in Australia; we made no a priori supposition that the community will meet the criteria, though as a starting point, there is recognition that the community as an entity is diminishing (Barrett et al., 1994; Ford, 2011a, 2011b; Recher et al., 1985). Our approach is outlined below and described in further detail in Supporting Information Appendix S1.

2.1 | Defining and describing the community

2.1.1 | Expert workshops

We invited woodland bird experts from across Australia to attend two workshops, one in 2015 (Adelaide, focussed on south‐eastern Australia) and a second in 2016 (Fremantle, focussed on Western Australia). The aim of these workshops was to (a) determine the potential distribution of the temperate and subtropical woodland bird community in Australia; (b) capture and compare the conceptualizations of the woodland bird community already held by researchers; (c) determine how to distinguish at which sites the woodland bird community is present; and (d) measure the condition of the community where it is present, based on species composition data. A total of 37 experts who, collectively, had familiarity with all parts of the temperate and subtropical woodland zones contributed. Through open discussion and systematic examination of candidate species, the experts reached consensus on the species characteristic of the woodland bird community within each of six climatic community variants of the community (Figure 2).

During the workshops, we established the extent of the woodland bird community based on climatic ecoregions and vegetation types that experts agreed supported a Temperate and Subtropical Woodland Bird Community (hereafter, TSWBC). Experts determined that, based on climate zones and the predominance of woodland vegetation, the community could occur in the regions shown in Figure 2. Within these regions, experts considered the potential habitat for the TSWBC to be restricted to areas of woody vegetation with a canopy cover less than 70% (i.e., excluding wetter, forest ecosystems: Specht, 1970), excluding mallee (low woody vegetation of a particular, multi‐stemmed growth form of various species of Eucalyptus) as it was associated with more arid climates and distinct bird species. Beyond these broad parameters delineating the relevant vegetation formation and climatic zones, descriptions of the community and its condition were based on bird species composition alone.
For eastern Australian states, experts were then presented with a list of all Australian land birds and asked to individually respond to a series of questions for each bird species: 1. "Is this species a part of most woodland bird communities (degraded or intact)?"; and then if yes, two further questions: 2. "Would you expect to see this species more often in intact than degraded communities?"; and 3. "Would you expect to see this species more often in degraded than intact communities?". This process was designed to identify the full suite of species comprising the woodland bird community, including generalist as well as specialist species. Crucially, participants were instructed to focus on their concept of intact versus degraded bird communities in their answers, not intact versus degraded vegetation. This distinction is important, because there is often limited direct relationship between vegetation community condition (typically measured in relation to floral and structural composition) and the species richness or composition of woodland bird communities (Fraser, Rumpff, Yen, Robinson, & Wintle, 2017).

We compiled information from all experts and identified the species included by 70% or more of experts under each question. For Question 1, this threshold was identified by the experts as distinguishing between a clear member of the TSWBC and one only tenuously associated with woodlands. We excluded introduced species from lists generated by Question 1 and Question 2 but retained them for Question 3 because an increased richness or abundance of introduced species might be an indication that the bird community is degraded. We circulated, for further comment, the compiled information to all the contributing experts as well as a range of experts who were unable to attend on the day. This process is broadly consistent with the process of deciding on objectives and measures of performance used in structured decision making (Gregory et al., 2012) and allowed us to reach a consensus on which species should be included in a TSWBC.

Because of the narrower geographical coverage and lower number of experts in the Western Australian workshop, experts went through the list of potential woodland bird species as a group for each of the two Western Australian subcommunities (Banksia Woodland or Eucalyptus Woodland) to establish a consensus response to each of the three questions for each species. This list was then circulated via email among experts for final approval. Providing the opportunity for independent responses helped minimize the possibility of social-dominance effects (Burgman, Fidler, Mcbride, Walshe, & Wintle, 2006).

2.1.2 | Community definition

In workshop discussions, experts agreed that beyond a list of species, there was a characteristic taxonomic and functional profile of...
the bird community that varied across the temperate and subtropical ecoregions of Australia primarily through species- or genus-level substitutions. We therefore considered the TSWBC to cover the entire extent depicted in Figure 2, but in conjunction with expert opinion provided in the workshops, we developed descriptions of six subcommunities, split by their ecoregional affinity. Each subcommunity had its own species list (described in Supporting Information Appendix S1) and threat was assessed separately for each group.

2.1.3 Community composition

Following the workshops, participating experts provided published and unpublished bird survey data from 20 projects collected using a 20-min, 2-ha survey method in woodland, forest, heathland and grassland habitats. For each survey, we recorded bird species richness and the proportion of species that were TSWBC species (determined through the expert workshop process described above); species more typically associated with intact woodland bird communities (determined through the expert workshop process described above); species more typically associated with degraded woodlands (determined through the expert workshop process described above); water birds; hollow nesters; small birds (<50 g); ground insectivores; bark insectivores; foliage insectivores; granivores; carnivores; frugivores; and nectarivores (trait data from G. Luck unpublished data). Species could belong to multiple categories. We compared the proportion of species in each of these groups among the four habitat types by looking at the 95% confidence intervals around the proportions, to identify the extent to which the TSWBC was distinct from assemblages in other habitats.

2.1.4 Community condition

For each site for which bird data were submitted, the submitting expert noted whether they considered the bird community to be intact or degraded for a subset of bird surveys from woodland sites. We compared the same variables (i.e., proportions of TSWBC species, small species) between sites considered by the submitter to support intact versus degraded bird communities. The variables that differed substantially (i.e., had little or no overlap in confidence intervals) between intact and degraded examples of the TSWBC were then used as the basis of an online survey to gain a more nuanced understanding of expert perceptions of TSWBC condition. The format of the online survey was adapted from Sinclair et al. (2015) to allow online distribution but preserve the integrity of the swing-weighting system (Von Winterfeldt & Edwards, 1986, Supporting Information Appendix S1).

We sent the online survey to 99 experts and received 49 responses. Seven experts had knowledge of the subtropical Queensland ecoregion, 18 of temperate south-east mainland Australia, 4 of temperate South Australia, 4 of Tasmania, 10 of Western Australian Eucalyptus Woodland communities and 5 of Western Australian Banksia Woodland communities. Experts from Tasmania and Western Australian ecoregions saw slightly different versions of this survey than those from other ecoregions, tailored to the species assemblages more commonly seen in those areas. The version for the survey used for experts in the subtropical Queensland, temperate south-east mainland Australia and temperate South Australia ecoregions included 23 sites (individual 2-ha 20-min bird surveys). The version for experts in Western Australian Banksia communities included 13 sites, Western Australian Eucalyptus communities 14 sites and Tasmanian communities 20 sites. The different number of sites in each of these surveys was due to having access to different numbers of bird surveys from each region.

We selected bird data for the online survey from the submitted data provided by our experts. Examples of survey data were selected to represent different levels of each of the variables that had differed between the communities that the submitting experts had nominated as intact and degraded (i.e., low or high species richness, and the proportion of species that are small, associated with intact communities or associated with degraded communities). In the survey, experts were asked to assign absolute condition values on a scale of 0–100 to each of five woodland bird community calibration sites, based on species lists (from 2-ha 20-min bird surveys), where 0 represents the worst possible condition and 100 represents the best possible condition of the TSWBC. These five calibration sites were chosen to include sites that we expected to be in very good (intact: high species richness, a high proportion of species that are small or associated with intact communities, and a low proportion of species associated with degraded communities) or very bad (degraded: low species richness, a low proportion of species that are small or associated with intact communities, and a high proportion of species associated with degraded communities) condition based on our initial analysis of expert-specified intact and degraded communities.

Next, participants were asked to answer a series of questions, rating the relative value of a number of other sites based on species lists using swing weighting (Von Winterfeldt & Edwards, 1986). In each question, we included one of our calibration sites so that the relative weights given by each expert could be calibrated to a common condition scale of 0 and 100.

We took these values for expert-judged community condition and investigated how they related to the key variables identified as being likely to align with condition: (a) species richness, (b) the proportions of species that were small (<50 g), (c) the proportion of species primarily associated with intact communities and (d) the proportion of species primarily associated with degraded communities. We divided the expert-judged condition score by its maximum to rescale the data between 0 and 1. Using the package glm2 (Marschner, 2014) in R Version 3.3.3 (R Core Development Team, 2017), we constructed binomially distributed generalized linear models for the whole Australia-wide dataset and separately for each of the community variants. We conducted backwards model selection based on AIC values to select the most parsimonious model for explaining judgements of TSWBC condition (Supporting Information Appendices 1 and 2). We compared the model coefficients and significance of relationships between the models for each of the
community variants to determine whether there are ecoregional differences in the way that experts perceive bird community condition.

2.2 | Evaluating the community against listing criteria

2.2.1 | EPBC listing criteria

The EPBC Act has six criteria governing the threat status of ecological communities (Table 1; Threatened Species Scientific Committee, TSSC, 2017). If a community meets any of these criteria, it may be eligible for listing as Critically Endangered, Endangered or Vulnerable. Under current practice, explicit protection is only provided to communities classified as Endangered or Critically Endangered (TSSC, 2017). Although we assessed the community against five of the six criteria, in this manuscript we detail only the analysis against Criteria 1 and 4: decline in extent and condition of the community because the methods we used to explore these two criteria are most broadly applicable to other animal communities. However, we include discussion of additional criteria in Supporting Information Appendices 3 and 4.

2.2.2 | Quantifying declines in extent

Data on bird occurrence and distributions across suitable habitat types within the relevant ecoregions are not available from prior to 1977. This is unfortunate because the most profound declines in the TSWBC are thought to have occurred before then, when large swathes of their habitat was cleared for agriculture (Bradshaw, 2012; Evans, 2016). Therefore, we developed an estimate of the potential historical extent of the TSWBC based on the woody vegetation data from the Australian Government’s National Vegetation Information System (NVIS) v4.2 (DoTEE, 2016a). These data approximate the distribution of different vegetation types across Australia at two time periods—pre-1750 (pre-European settlement) and current (i.e., circa 2016). We identified 16 NVIS major vegetation groups (MVGs) that matched our definition of woodland as potential habitat for the woodland bird community. Using these MVGs (mapping
obtained BirdLife Australia data from 1-km

vesting and management of such areas were considered to distort

for the woodland bird community, the frequent har

occurs on both public and private land. While such areas may pro

extraction of sawlogs or pulpwood. It includes production from

land bird habitat (the major vegetation groups described above).

Finally, we removed any areas of production forestry based

land bird habitat (the major vegetation groups described above).

To quantify more precisely the extent of potential habitat

for the TSWBC within its geographical distribution, and changes

thereto in recent decades, we first determined the extent of

woody vegetation based on Landsat raster (~30 m pixel resolu

tion) imagery mapped via the Forest Extent and Change proto

col for the National Carbon Accounting System (NCAS, Australian

Department of the Environment & Energy, 2015) within each

ecoregion at three time points: 1980, 1998 and 2015. Second,

we intersected the pre-1750 distribution of woodland MVGs (as

mapped in the NVIS 4.2) with the 30-m woody vegetation layer for

each period, thereby allowing us to identify mapped woody vegeta

tion pixels corresponding with the historic distribution of wood

land bird habitat (the major vegetation groups described above).

Finally, we removed any areas of production forestry based on

2015 land use mapping (Australian Bureau of Agricultural &

Resource Economics & Sciences, 2015). Production forestry re

lates to areas as at 2015 managed for various purposes such as

extraction of sawlogs or pulpwood. It includes production from

both native forests and plantations in modified environments. It

occurs on both public and private land. While such areas may pro

vide habitat for the woodland bird community, the frequent har

vesting and management of such areas were considered to distort

analyses of changes in woodland extent.

2.2.3 Evaluating declines in condition

We obtained BirdLife Australia data from 1-km², 20-min bird surveys

conducted for the first Atlas of Australian Birds (Birdlife Australia,

2012) and 2-ha, 20-min bird surveys from the second and ongo

ing Atlas (BirdLife International & NatureServe, 2016), allowing us

to use models developed above to estimate the mean condition of

the TSWBC in each of three time periods: 1977-1981 (referred to

as 1981), 1998-2002 (referred to as 2002) and 2011-2016 (referred
to as 2016). Some issues arise when comparing these two datasets
directly (Barrett et al., 2004), especially because the first atlas al

lowed for a wider range of survey methodologies to be used than

are accepted by the second atlas, and none of the methodologies

from the first atlas correspond directly to those used in the second

atlas. We standardized sampling effort and constrained the variation

in survey methodologies by only including data from 20-min surveys

in both atlases.

For this analysis, we eliminated all the surveys that occurred out

side the specified ecoregions and those in which less than 70% of

species were included on the appropriate ecoregional TSWBC list,

indicating they were likely to have been done in a vegetation type

not characterized as woodland. Then, we calculated the condition

of bird communities identified from each of the remaining surveys

using the equations relevant to the ecoregion where the survey was
done, derived from the online survey data (Tables 3 and 4). For each

ecoregion, we calculated the proportion of the surveys categorized

as having low (condition score <25), moderate (25–50), high (50–75)

and pristine (75–100) condition classes. Using discrete categories is

a requirement of the legislative assessment process and allows the

comparison of least degraded (pristine) and most degraded (low)
sites. BirdLife Australia’s survey data from the ecoregions we fo

cussed on are conducted disproportionately in treed habitats, rather

than areas completely cleared of native vegetation. Therefore, es

ablishing an average condition score without accounting for the

fact that much woodland has been entirely lost does not accurately

capture the average condition across the original distribution of the

community. Consequently, we adjusted the condition estimates to

reflect the amount of treeless habitat in each ecoregion at each point

in time. We assumed that the woodland bird community in treeless

areas would be in low condition and weighted the raw community

condition estimates accordingly.

To estimate the pre-1750 baseline condition of the TSWBC (for

which no survey data are available), we calculated the estimate sep

arately based on two alternative assumptions:

1. a very conservative assumption—the proportion of communities

falling into the different condition classes would be the same

as calculated for 1981. In this case, the only difference between

the two estimates is related to the extent of woodland ve

etation and

2. a more plausible assumption—division of sites between moderate,

high and pristine would be the same as in 1981 but no bird com

munities would be in low condition. This is consistent with the

premise that natural processes and indigenous interventions

would be unlikely to generate low community condition in wood

land areas but may still underestimate original community condition.

3 RESULTS

3.1 Community composition

Species richness, the proportion of species within foraging trait
groups and the proportion of species associated with either intact

or degraded bird communities did not differ substantially between

bird communities in grassland, forest, heathland and (Eucalyptus and

Bankia) woodland vegetation types. In contrast, the proportion of
the community that was included on at least one of the community variant lists of the TSWBC was quite different between habitat types. At 0.77 (±0.01 95% CI), the highest proportion of birds in the ecological community were found in surveys in forest habitat (Figure 3). These birds also comprised 0.67 (±0.01) of birds in surveys of woodland habitats, while the proportion in grassy (0.27 ± 0.03) or heathland (0.62 ± 0.02) habitat types was significantly lower. Therefore, we determined that a bird community would qualify as the woodland bird community if 70% or more of species were included in the appropriate regional list of woodland bird species (Supporting Information Appendix S3).

### 3.2 Community condition

For all six community variants of the woodland bird community, the condition of the community as judged by experts was best characterized by species richness combined with either the proportion of small species or proportion of intact species (Supporting Information Appendix S2). Because the three eastern mainland ecoregions (subtropical Queensland, temperate south-east mainland Australia and temperate South Australia) are contiguous and the coefficients were similar among ecoregions, we used averaged coefficients to calculate community condition for all three associated community variants (Table 2).

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**TABLE 2** Parameter estimates from woodland bird community condition model

| Ecoregions                      | Coefficients | \( \text{Explained deviance (\%)} \) |
|--------------------------------|--------------|--------------------------------------|
|                                | Intercept    | Species richness | Proportion intact | Proportion small | |
|                                | Estimate     | Error             | Estimate     | Error             | Estimate     | Error             | Estimate     | Error             |
| Subtropical Queensland         | −2.01        | 0.46              | 0.12         | 0.03              | na           | na                | 1.60         | 0.59              | 57.66         |
| Temperate South-eastern Mainland | −2.03        | 0.28              | 0.10         | 0.01              | na           | na                | 1.63         | 0.37              | 46.32         |
| South Australia                | −2.54        | 1.02              | 0.13         | 0.05              | na           | na                | 1.65         | 1.19              | 61.02         |
| Average South-eastern Mainland | −2.19        | 0.12              | na           | na                | 1.63         | 0.61              | 43.92         |
| Tasmania                       | −1.67        | 0.57              | 0.10         | 0.04              | 1.78         | 0.95              | na           | na                | 52.74         |
| South-west Western Australia Banksia woodlands | −1.00        | 0.64              | 0.14         | 0.08              | 0.16         | 3.05              | na           | na                | 26.02         |
| South-west Western Australia Eucalyptus woodlands | −0.48        | 0.40              | 0.05         | 0.04              | 1.06         | 0.89              | na           | na                |
| Average South-west Western Australia | −0.74        | 0.09              | 0.61         | na                | na           | na                |

The model rescales condition from a scale on 0–100 to a scale of 0–1 and uses a binomial generalized linear model with a logit link to describe the relationship. na means that the variable is not included in the best model. Errors are standard errors.
For Western Australian Eucalyptus Woodland, Western Australian Banksia Woodland and Tasmanian variants of the TSWBC, condition was best characterized by species richness and the proportion of intact species in the community (Supporting Information Appendix S2). Even though the same variables were included in the most parsimonious models describing community condition in Tasmania, Western Australian Eucalyptus Woodland and Western Australian Banksia Woodland, the regions are not contiguous, and the coefficients were different enough between community variants to justify calculating the condition of the community differently between Western Australian and Tasmanian community variants. We used averaged coefficients to calculate the condition of the two Western Australian woodland bird communities (Table 2).

3.3 | Evaluating declines in extent

We estimated substantial declines in the amount of suitable habitat for the TSWBC since 1750. In 1750, there was approximately 168 million hectares of potential woodland habitat available, and in 2016, only 92 million hectares remained (Figure 4). This decline has not been evenly distributed across Australia (Table 3). The percentage reduction in habitat area ranges from 41% in Subtropical Queensland to 70% in temperate South Australia.

Between 1980 and 2015, woodland bird habitat extent had declined substantially in some ecoregions (particularly Subtropical Queensland and Western Australian Eucalyptus Woodland). The loss of habitat for the TSWBC was focussed in some parts of ecoregions, creating hotspots of threat to the community. For example, within the subtropical Queensland ecoregion, smaller bioregions had undergone very dramatic continued woodland losses; the Brigalow Belt North declined by 31%, Brigalow Belt South by 16% and Mulga Lands by 38% between 1980 and 2015. In contrast, habitat extent had increased slightly in some parts of temperate south-east mainland Australia, as clearing has slowed, and land abandonment and revegetation initiatives have increased.

3.4 | Evaluating declines in bird community condition

Based on our estimates, the average condition of the TSWBC declined severely since 1750. For all community variants except Tasmania, most of this decline happened between 1750 and 1981 (Figure 5). In Tasmania, there was also a dramatic decline between 2002 and 2016. Similarly, the TSWBC in the two Western Australian community variants declined in condition between 1981 and 2016 (Figure 5).

3.5 | EPBC Act listing criteria

Our evaluation suggested that the newly described TSWBC meets the criteria for Endangered or Critically Endangered across its entire extent. This is based on the evidence presented here regarding reduction in both the extent and condition of community, supported by information in Supporting Information Appendices S3 and S4 with regard to the loss of functionally important species and continued threats. Our analyses showed that the TSWBC had reduced in extent substantially enough since 1750 to qualify as Vulnerable (>50% decline) in temperate south-east mainland Australia and Western Australian Banksia Woodland community variants and Endangered (>70% decline) in temperate South Australia (Tables 1 and 4). Our
calculations regarding the reduction in community integrity indicate an even more substantial decline with the two Western Australian community variants qualifying as Endangered (>50% decline) and the other 4 community variants qualifying as Critically Endangered (>80% decline).

Evidence in Supporting Information Appendix S3 shows Severe and Very Severe declines in several functionally important bird species and discussion in Supporting Information Appendix S4 evaluates the rate of continuing detrimental change in the community—both of which provide evidence that the community meets the criteria for Endangered or Critically Endangered under the EPBC Act.

**DISCUSSION**

We developed a repeatable process for defining and evaluating the threat status of an animal community on a continental scale, using the protocols of the Australian’s national biodiversity conservation legislation (TSSC, 2017). These protocols are similar to those for the IUCN Red List of Ecosystems (IUCN, 2016). We developed a description of an ecological community—the Temperate and Subtropical Woodland Bird Community (TSWBC)—based on bird species composition, and a method for evaluating its condition based on existing data sources and expert opinion. This allowed us to describe quantitatively the oft-cited declining “woodland bird community” (Rayner, Lindenmayer, Gibbons, & Manning, 2014), and formally nominate the TSWBC for protection as a threatened ecological community under Australian environmental law. The state of terrestrial animal communities is less tractable, due to the challenges of defining the condition and composition of communities that are mobile and span multiple vegetation types (Ferenc, Sedláček, & Fuchs, 2014). However, the process we developed led to a widely accepted, quantitative description of a faunal community.

**TABLE 3** Change in extent of potential habitat for the Temperate and Subtropical Woodland Bird Community from pre-European settlement (pre-1750) to 2016 and for the periods 1980–1998, 1998–2015 and 1980–2015 or each ecoregion in which the woodland bird community occurs

| Ecoregion                        | NVIS data |                  |                       | Landsat data |                  |                       |
|----------------------------------|-----------|------------------|-----------------------|--------------|------------------|-----------------------|
|                                  |           | Pre-1750 | 2016 | Change (%) | Area woodland (ha) | 1750–2016 | 1980–1998 | 1998–2015 | 1980–2015 | 1980–1998 | 1998–2015 | 1980–2015 |
| Subtropical Queensland           |           | 72,773,917 | 42,854,810 | -41 | 25,400,737 | 22,247,211 | 21,481,848 | -3 | -5 | -15 |
| Temperate South-eastern Mainland |           | 62,752,896 | 30,682,848 | -51 | 14,299,709 | 14,819,136 | 15,308,276 | 4 | 3 | 7 |
| Temperate South Australia        |           | 4,912,108 | 1,493,620 | -70 | 415,266 | 439,595 | 433,298 | 6 | -1 | 4 |
| Tasmania                         |           | 4,297,019 | 2,902,766 | -32 | 2,187,395 | 2,121,905 | 2,074,200 | -3 | -2 | -5 |
| South-west Western Australia     |           | 21,432,343 | 13,308,682 | -38 | 10,239,133 | 9,680,556 | 9,705,904 | -5 | 0 | -5 |
| Eucalyptus woodlands             |           | 1,415,477 | 523,841 | -63 | 510,632 | 530,812 | 449,530 | 4 | -15 | -12 |

The NVIS dataset and Landsat datasets provide different estimates of habitat extent due to differing resolutions and inclusion criteria. See detailed methods for more information.
Defining an animal community

We distinguished potential woodland bird habitat from the definition of the TSWBC itself. Based on the input of contributing experts, we determined a set of criteria that were mostly independent of characteristics of vegetation. This is a key distinction of our process—recognizing that the occurrence of an animal community is not necessarily tied to a discrete set of abiotic and/or vegetation associations (Ives...
et al., 2016; McAlpine et al., 2016). Indeed, in Australian woodlands, vegetation condition is often not strongly associated with bird species richness or composition (Fraser, Rumpff, et al., 2017). In such cases, animal communities are most appropriately characterized directly, rather than bundled with a type or condition of vegetation.

### 4.2 Broader applications

The approach described in this article engages experts in the process of describing a community. This capitalizes on available knowledge, creates support for the definition of the community and mutes inconsistencies that appear in the broader literature (Fraser et al., 2015; Fraser, Pichancourt, et al., 2017).

Our method is particularly appropriate for communities that are well recognized, but not yet formally described, because it relies on the collaboration of multiple experts. In cases where there is a dearth of experts or experts have difficulty agreeing, it may be possible to begin the process by developing a species list based entirely on occurrence data (see Fraser, Hauser, Rumpff, Garrard, & McCarthy, 2017). However, subjectivity is inherent to delimiting and ascribing condition scores to examples of ecological communities. With some availability of data and experts, describing an animal community in enough detail to evaluate trends in its extent and condition through time is achievable, and can allow for threatened animal communities to be protected—a necessity for a holistic approach to biodiversity conservation.

### 4.3 Evaluating threat status of the community

Our evaluation clearly identified that the TSWBC met criteria for Endangered or Critically Endangered status across four of the Australian threatened ecological community criteria, two of which we report here, across all six community variants. Declines in community integrity provided the strongest evidence that the TSWBC is threatened. The EPBC Act states that a community qualifies as Endangered if the change in integrity is severe and unable to be reversed soon (20 years or five generations). We found that the integrity of the woodland bird community has undergone severe or very severe declines that are unlikely to be restored in 20 years (due to the absence of nesting hollows etc). These declines were based on average values calculated across large numbers of 20-min surveys. In assessing the condition of a particular example of a bird community at a site, the condition value calculated from a single 20-min survey is unreliable on its own (Maron, Lill, Watson, & Nally, 2005). Therefore, site-level assessments of the presence and integrity of the TSWBC will require multiple surveys, ideally across different seasons, to derive an understanding of the community’s condition at that site.

Bird species richness and the proportion of species that were small (<50 g) and those which experts judged were typically more common intact bird communities were the most influential factors determining the condition of the TSWBC. This makes intuitive sense, as the proportion of small or intact woodland

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**Table 4**

| Criteria | Subtropical Queensland | Temperate south-east mainland Australia | Temperate South Australia | Western Australian Banksia Woodland | Western Australian Eucalyptus Woodland | Tasmania |
|----------|------------------------|----------------------------------------|---------------------------|-------------------------------------|---------------------------------------|---------|
| 1. Decline in geographical distribution | Does not meet criteria | Does not meet criteria | Does not meet criteria | Does not meet criteria | Does not meet criteria | Does not meet criteria |
| 2. Small geographical distribution coupled with demonstrable threat | E | E | E | E | E | E |
| 3. Loss or decline of functionally important species | CE | CE | CE | CE | CE | CE |
| 4. Reduction in community integrity | CE | CE | CE | CE | CE | CE |
| 5. Rate of continuing detrimental change | CE | CE | CE | CE | CE | CE |
| 6. Quantitative analysis showing probability of extinction | None available | None available | None available | None available | None available | None available |

CE, Critically Endangered; E, Endangered; V, Vulnerable.
species are strongly influenced by the two most severe threats to the woodland bird community in Australia: land clearance, and incursion by hyper-aggressive native birds of the genus *Manorina*, which are favoured by landscape modification (Kutt, Vanderduys, Perry, Mathieson, & Eyre, 2016; MacDonald & Kirkpatrick, 2003; Robertson, McAlpine, House, & Maron, 2013; Thomson et al., 2015). Both processes are listed as Key Threatening Processes under the EPBC Act. The small-bodied species that form the majority of the TSWBC play vital roles in ecosystem health through complementary pollination, seed dispersal, insect control and decomposition services (Şekercioğlu et al., 2004; Wenny et al., 2011), and their loss can result in declines in vegetation condition (Grey, Clarke, & Lown, 1998; Maron et al., 2013).

Our evaluation of the long-term declines in the condition of the woodland bird community was limited by the difficulties of comparing data between the two BirdLife Australia Atlases. Surveys in each were conducted using somewhat different methodologies, which may have affected our estimates of declines in community integrity between 1981 and 2002, despite our efforts to minimize the differences by restricting our analyses to 20-min surveys. About one-quarter of species were likely to be found less commonly in the second atlas based purely on differences in survey methodology (Barrett et al., 2004), potentially resulting in lower species richness estimates in 2002. However, most of the species that Barrett et al. (2004) identified as less likely to be detected due to survey methodology are large-bodied birds. So, while species richness may be higher as an artefact of survey methodology, the proportion of small birds may also be artificially higher, having the opposite effect on condition scores.

The TSWBC did not meet the criteria for threatened status based on decline in geographical distribution alone in all ecoregions, and this reflects the history of land clearing in eastern Australia, where there is a gradient of vegetation loss from temperate to tropical woodlands. Nevertheless, extensive clearing of woody vegetation is continuing, and even increasing, in Australia (Reside et al., 2017) and globally (Richards & Friess, 2015). Based on our analyses of changes in extent of potentially suitable habitat, we estimate that the loss of woodland bird habitat since pre-1750 is 76,000,000 ha across Australia, approximately 45%. In temperate South Australian and temperate-south-eastern mainland regions, little woodland remains and clearing has all but ceased (Bradshaw, 2012; Evans, 2016). Other areas (especially subtropical Queensland) are now the focus of agricultural expansion. The extent of clearing has recently been increasing with a significant surge in Queensland (395,000 ha/year) (Reside et al., 2017; Queensland Department of Science Information Technology & Innovation, 2015 affecting the subtropical Queensland community variant). There are also projected increases in New South Wales (Eco Logical Australia 2016, affecting the temperate south-east mainland community variant) and Western Australia (Government of Western Australia, 2015, affecting the Western Australian *Eucalyptus* and *Banksia* community variants). This incremental and continuing vegetation loss, combined with predicted and intersecting climate change effects on forests, woodlands and agriculture (Lawrence & Vandecar, 2015), suggests that the geographical distribution of the TSWBC will continue to decline.

5 | CONCLUSION

The consequences of global change affect entire communities, not just single species. However, defining ecological communities based solely or predominately on plant species composition risks missing the point of community-focused conservation. While a focus on the protection of vegetation communities shines a light on key proximate threats like deforestation, it often fails to illuminate the complex biotic associations that are both sustained by, and crucially, sustain the vegetation. Focussing conservation on an interacting community of animal species might be more likely to prevent an unnoticed gradual attrition of individual species, perhaps considered more “common,” but vital component for the function of both the vegetation community and the animal community (Birdlife Australia, 2015; Gaston, 2010; Gaston & Fuller, 2008). As such, we advocate that biodiversity conservation must extend beyond protection of vegetation communities to also consider animal communities as an essential complement to the protection of species habitat.

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DATA ACCESSIBILITY

All data to which we have rights are provided in appendices or on the Open Science Framework (https://osf.io/dhq6b/). All other data sources are either cited in text and available from other sources (e.g., BirdLife data) or provided by woodland bird experts for purely exploratory purposes.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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