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Title: Evaluating the effectiveness of overstory cover as a surrogate for bird community diversity and population trends

Article Type: Research Paper

Keywords: Keywords: biodiversity surrogate, species richness, population trends, vegetation, monitoring

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Order of Authors: Jennifer C. Pierson; Alessio Mortelliti; Philip S Barton; Peter W Lane; David B Lindenmayer

Abstract: Landscape features are often used as surrogates for biodiversity. While landscape features may perform well as surrogates for coarse metrics of biodiversity such as species richness, their value for monitoring population trends in individual species is virtually unexplored. We compared the performance of a proposed habitat surrogate for birds, percentage cover of vegetation overstory, for two distinct aspects of bird assemblages: community diversity (i.e. species richness) and population trends. We used four different long-term studies of open woodland habitats to test the consistency of the relationship between overstory percentage cover and bird species richness across a large spatial extent (>1000km) in Australia. We then identified twelve bird species with long-term time-series data to test the relationship between change in overstory cover and populations trends. We found percentage cover performed consistently as a surrogate for species richness in three of the four sites. However, there was no clear pattern in the performance of change in percentage cover as a surrogate for population trends. Four bird species exhibited a significant relationship with change in percentage overstory cover in one study, but this was not found across multiple studies. These results demonstrate a lack of consistency in the relationship between change in overstory cover and population trends among bird species, both within and between geographic regions. Our study demonstrates that biodiversity surrogates representing community-level metrics may be consistent across regions, but provide only limited information about individual species population trends. Understanding the limitations of the information provided by a biodiversity surrogate can inform the appropriate context for its application.

Response to Reviewers: We have indicated the reviewers' comments in italics.

Reviewers' comments:

Reviewer #1:

This is an interesting manuscript where authors test the effectiveness of overstory cover as surrogate of bird species richness and population trends over time. They found that overstory cover can be used

as surrogate for richness but no significant relationship between population trends and overstory cover could be generalized across species.

Comment: Although I think the analyses are sound and adequate for the goal the authors pursue I have a minor concern about how the independent variable for the population trend model was estimated. In P10-L20 authors state "We estimated the change in percentage cover by calculating the difference between the most recent estimate and the initial estimate at each site." If population trends were assessed as change in abundance between two consecutive periods, why was the independent variable for the model (change in cover) calculated relative to the initial cover? I think that the magnitude of cover change will be overestimated in this way.

Author's response: We have clarified our methods to better explain our approach (line 196-199). Briefly, the population trends and change in cover were both estimated over the same time period but with slightly different methods. Avian point counts were conducted more often than the vegetation surveys which allowed population trends to be estimated using linear regression on the time series data. As fewer data points were available for the same time period in the percent cover data, we were unable to estimate a linear trend using regression approaches. Therefore, we calculated the difference in percentage cover between the first and last dates coinciding with the avian time series data.

Comment: Moreover, was there a significant change in overstory cover over time when considering changes between two consecutive periods only (I saw in Figure 4 data ranged from -40 to 40, however this is maximum change over 10 years)? The lack of relationship between population trends and cover might be well explained by no or weak change in cover. If that was true, we could not conclude change in overstory is not a good surrogate, simply did not change enough as to produce a significant effect.

Author's response: We agree that a lack of change in cover could obscure a relationship with population trends. However, our main interest was testing if the change in percentage cover could be a good indicator of trends in avian populations in a real-world monitoring context. Our interpretation is that a practical indicator must be sensitive to, and be able to predict, changes in population trends in a wide range of circumstances, not just at the edges of the distribution (i.e., extreme change in cover). Given this objective, we used empirical data from two different long-term monitoring studies that incorporate sites with a wide range of changes in cover (see new Supplementary Fig. 1). These ranges include both small (0) and relatively large (> +/- 50%) changes in cover over the years monitored and provide a good basis to test percentage cover as an effective indicator of population trends under a range of scenarios.

Comment: I find a bit of inconsistency in the dependent variable used. Why was species richness used in one case and trends in abundance in the other?

Author's response: We set out to test the performance of percentage cover as habitat surrogate for two distinct monitoring objectives (1) diversity of bird communities and 2) trends in bird populations. Species richness is a common metric used to examine bird community diversity among sites, and thus was used as the metric to examine changes in bird community diversity from our study sites over time. By contrast, our analysis of population trends of individual bird species was based on their relative abundance.

Comment: What would happen if we tried to explain trends in species richness over time using the same methodology?

Author's response: While this is an interesting question, we feel it is outside the scope of our original study. The addition of this question would expand the current study to examine the ability of percentage overstory cover to predict trends in community diversity over time. We felt the addition of

this question would obscure our main point in this manuscript which was to compare the usefulness of one surrogate for two the two stated objectives: representativeness of community diversity and population trends.

Comment: I missed some important dependent variables that could also have significant, such as the land cover in the matrix where transects were located. Were there significant changes in land cover in the surrounding areas?

Author's response: An important motivation behind our study was the idea that a useful surrogate is one that is simple to measure and use, as well as being an effective predictor of the target variable of interest. From this perspective, it can be understood that building complex relationships between the surrogate and target variables potentially undermines the usefulness of the surrogate. There is also a fundamentally different objective behind testing the strength and consistency of a direct surrogate-target relationship, and building models that best describe variation in a target variable where the surrogate variable is relegated to one of many explanatory variables. Our objective was to test the surrogacy value of overstory in predicting bird diversity and trends as opposed to determining the range of covariates that may best describe patterns of bird diversity and trends. For these reasons, we deliberately chose to keep all models simple, and to focus on testing the strength and consistency of the direct relationship between percentage overstory cover and birds. While adding other relevant covariates would most likely improve the ability to predict avian species richness and/or population trends, the best covariates to include will likely change in each study. Thus, we are testing the consistency of the surrogate relationship by keeping the models simple and looking for consistency among studies/regions.

We have added a section clarifying our approach in the methods (ln 243-247)

Comment: I think both the title and some of the conclusions (e.g., P14-L41) should be narrowed down to the content of the study, that's it surrogacy value of overstory cover, instead of environmental surrogates in general. There are many other environmental surrogates commonly used and not tested here.

We agree the specific results of our study are limited to inferences regarding the effectiveness of percentage overstory cover for monitoring bird populations when considering selecting a surrogate. We have restructured existing text (ln 306-309), added text to the discussion (ln 309-312) and changed the title (ln 4-5) to address these concerns. The goal of the study was to compare surrogacy effectiveness for multiple objectives, including community diversity and population trends, and we chose to use percentage overstory cover as the surrogate as it has been shown to be a robust surrogate for overall bird species richness (Barton et al. 2014). Therefore, we feel it is important to discuss these implications in the context of evaluating surrogates more broadly.

Minor comment: P15-L30. Delete "(" before Cunningham.

Author's response: We have corrected this error

REVIEW (This part will also be sent to the author):

1. Does the subject of the paper fall within the scope of the journal?

YES

If no, comments:

2. Is it a new and original contribution? (not applicable for review articles) YES/NO If no, comments:

3. Does the paper support the progress in indicator development or does it provide interesting and new indicator applications?

YES

If no, comments:

4. Are the interpretations and conclusions sound, justified by the data and consistent with the objectives?

YES

If no, comments:

If the answers to any of the above points are negative, please give clear arguments for the rejection of the papers.

If the answers are positive, please continue with the following items:

5. Does the title of this paper clearly reflect its content?

NO

If no, comments: Title should reflect more clearly the single environmental surrogate tested here.

Author's response: We have changed the title: Evaluating the effectiveness of overstory cover as a surrogate for bird community diversity and population trends

6. Is the abstract sufficiently informative especially when read in isolation?

YES

If no, comments:

7. Are the keywords informative and appropriate?

YES

If no, comments:

8. Is the statement of objectives of the paper adequate and appropriate in view of the subject matter?

YES

If no, comments:

9. Are the methods exposed correctly and sufficiently informative to allow replications of the research?

YES

If no, comments:

10. Are the statistical methods used correctly and adequate?

YES

If no, comments:

11. Are the results clearly presented?

NO

If no, comments: I'd suggest showing more explicitly potential change in overstory cover over time.

Author's response: We have added supplementary figures depicting the distribution of change in percentage overstory cover over time.

12. Is the article structured in agreement with the guidelines for authors? Is the organization of the article satisfactory?

YES/NO -

If no, comments:

13. Does the content justify the length of the article?

YES

If no, comments:

14. Are the illustrations and tables all necessary, complete, clearly presented, and are the captions adequate and informative?

YES

If no, comments:

15. Are the references adequate and in agreement with the Guide for Authors?

YES

If no, comments:

16. Is the quality of the English satisfactory and understandable for a multidisciplinary and multinational readership?

YES

If no, comments:

Reviewer #2:

This MS evaluates to which extent a structural element in the landscape (cover of vegetation overstory) can consistently predict both species richness and population trends. This is a relevant question because both aspects are important in conservation decision making. The authors found that, while overstory cover appeared to perform moderately well in predicting species richness, it did not perform as a sensible indicator of population trends.

I was a bit surprised to see so few species showing significant correlation between vegetation and population trends. I am a bit concerned that the authors did not account for two potential confounding effects:

Comment: 1. A majority of species are likely to present a non-linear reaction to vegetation cover (i.e. probably not the same increase in abundance when passing from 0-20% than from 80-100% habitat cover). The authors, however, combine those.

Author's response: We appreciate this insightful comment and are grateful to the reviewers for bringing this issue to our attention. We undertook some additional analyses to investigate this potential problem. For each of the two long-term studies that we used to evaluate population trends (Nanangroe and Southwest Slopes), we created two new datasets: 1) sites that initially had percent overstory cover < 25% and 2) sites that had initial overstory cover > 50%. Following re-analysis of these split datasets, we did find different patterns with more birds showing a relationship with change in percentage overstory cover when initial cover was > 50%. However, the patterns were not consistent between the two studies, or among different bird species, thus confirming that cover was not a consistent indicator regardless of the initial cover.

We have added the results from these additional analyses to the supplementary material (Table S2) as well as some new text in the discussion (ln 385-396).

Comment: 2. The authors choose to monitor a set of rather common species as surrogated taxa. Common species tend to be more generalist and therefore might not react so closely to change in habitat characteristics. From a practical perspective, it would also be more interesting to know the correlation of species of higher conservation concern which, in turn, tend to be more constrained by

habitat availability. In my opinion lack of consistency of vegetation cover as surrogate of population trends between the two sites with longer monitoring periods was the most interesting finding. I was however a bit disappointed to see only 12 common species in the analyses.

Author's response: We agree that ideally we would have enough data on more species of conservation concern on which to test the effectiveness of the surrogate relationship. The species chosen were on the basis of having enough data to estimate population trends, unfortunately many of the species of conservation concern did not fall into this category. However, we were fortunate to have enough data on brown treecreepers, a bird included in the original analyses that is classified as threatened in New South Wales, Australia. Further, we believe that our results are robust because the species chosen are all woodland birds with a wide range of life history characteristics (Table S1). This is reflected in the most common species being among the ones that did indeed have a relationship between trend in relative abundance and change in overstory cover (e.g., Australian Magpie, Common Starling, Red Wattlebird).

We have added text better describing the range of characteristics the species included represent (ln 216-230) and table to the supplementary material (Table S1) to better describe the range of characteristics (e.g., Family, diet, foraging behaviour, nest type) of the species chosen.

Comment: Authors suggest in their discussion that the lack of consistency of vegetation cover as surrogate of population trends might be due to the matrix context where the studies are based. I also tend to believe that this might be the main cause of the discordances they found between study sites. Would it be possible to get a graphical overview on landscape/habitat differences between studies?

Author's response: All studies focus on woodland remnants dominated by similar vegetation, box-gum grassy woodland (ln 139--173). We have added brief descriptions of the landscape in which the remnants exist to the study descriptions that did not previously include this information (ln 173)

Comment: I think the MS would benefit from shortening. Still, albeit the English language is correct, there is room for improving order in the text and redundancies.

Author's response: We have made extensive changes to the body of the manuscript. We have shortened the overall length of the manuscript while adding important clarifications to our methods and reasoning in our discussion. We have restructured the manuscript where appropriate by removing sections and moving sections from the introduction to the methods. We have incorporated the changes suggested below. We appreciate the suggestions and believe the manuscript has been improved as a result.

Overall this is an interesting paper that would still need extensive revision.

Author's response: We thank the reviewer for the positive feedback. We have made extensive revisions to the manuscript that we believe has resulted in a stronger contribution. We are grateful for the helpful feedback.

Below some more specific comments that I hope the authors could address:

## INTRODUCTION

Pg3, L13: "feature" should be "features"  
done

Pg5, L54 - Pg6, L17: Paragraph suits more the Methods section. I suggest removing it from the Introduction section

Author's response: We have made this change

Pg6, L20 - L37: paragraph is a summary of the study. I find it highly redundant with the Abstract. Remove.

Author's response: We have removed this paragraph

## METHODS

Please be consistent with order and how you name the different studies across text, figures and tables.

Author's response: We have implemented this suggestion

Section 2.1: Please follow the same order of descriptors across the 4 sites. Also, common attributes could be put outside the study-specific paragraph, like "Each remnant contains a survey site that consists of a permanent 200m transect for sampling a range of biodiversity metrics".

Author's response: We have implemented this suggestion

Pg10, L29-36: Years do not match with Table 1.

Author's response: Vegetation data was not collected all of the years that point counts were conducted. The community diversity data was only tested during the years that vegetation data was collected (Table 1). However, the full point count dataset was used to estimate the population trends

Pg11, L8-20: It is not clear why the authors decide to use relative abundance index instead of the original abundance data

Author's response: We used an index to reduce variability that may be caused by different number of visits and differences in observers. This method has been validated in previous work within these studies. We have added text to better explain our reasoning (ln 231-232)

In my opinion, the first paragraph (describing how change in vegetation cover is measured) from section 2.4 could fit better in section 2.2.

Author's response: We have implemented this suggestion

Pg12, L20-23. Sentence is a repetition from first paragraph in section 2.4. I suggest removing it.

Author's response: We have implemented this suggestion

## RESULTS

Pg12, L40-42. Title of section 3.2 makes one understand that authors here address consistency across time. However, this is not the case. I suggest removing the "time" bit from the title.

Author's response: We have implemented this suggestion

Pg.12, L48-53: I'm not sure what they mean with "sets of repeated samples". Is this a true result or rather an aspect to be presented in the Methods section?

Author's response: We have removed this statement

Pg.12, L56: I would argue that 4-5 years of surveys (Table 1) do not categorize as "long-term study". I would just remove the "long-term" bit.

Author's response: We have implemented this suggestion

Pg.13, L32-37: talking about "several species" is an overstatement. I would remove this sentence altogether as it does not add information to the following sentence at the end of the paragraph.

Author's response: We have implemented this suggestion

## DISCUSSION

Pg.16, L28-30: Taking into account that there are only four studies, saying that Southern Slopes Restoration study is a "strong outlayer" sounds like an overstatement.

Author's response: We have removed this statement

Pg.16, L38-53: It would be good to explain with further detail the possible causes of discordance of of the Southern Slopes Restoration study as compared to the rest of studies.

Author's response: We agree this is a very interesting result and are curious for the reason. We added a brief summary of one of the possible explanations we have tested (In 354-364). However, we were concerned an in-depth examination of this may be distracting from the main message of the manuscript so tried to keep our summary brief.

Pg.17, L12: change "as a result in" by "as a result of"

Author's response: We have implemented this suggestion

Figure 2: Is "range of" necessary on axis title?

Author's response: We have removed this statement

Figure 4: Axis labels nearly unreadable

Author's response: We have implemented this suggestion

Table 3: significant values could be in bold characters.

Author's response: We have implemented this suggestion

Please note that your recommendation and reviewer report are expected to cover the Highlights and Graphical Abstract if submitted with the manuscript.

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## REVIEW

1. Does the subject of the paper fall within the scope of the journal?

YES

2. Is it a new and original contribution? (not applicable for review articles) YES

3. Does the paper support the progress in indicator development or does it provide interesting and new indicator applications?

YES

4. Are the interpretations and conclusions sound, justified by the data and consistent with the objectives?

Most likely YES. However, I would have preferred to see species of higher conservation concern. Also I have some doubts on the methodological aspect (see above)

Author's response: Please see above for the manner we addressed this concern

5. Does the title of this paper clearly reflect its content?

YES

6. Is the abstract sufficiently informative especially when read in isolation?



YES.

7. Are the keywords informative and appropriate?

YES

8. Is the statement of objectives of the paper adequate and appropriate in view of the subject matter?

YES

9. Are the methods exposed correctly and sufficiently informative to allow replications of the research?

YES (NO). See comments above

10. Are the statistical methods used correctly and adequate?

YES

11. Are the results clearly presented?

YES

12. Is the article structured in agreement with the guidelines for authors? Is the organization of the article satisfactory?

YES (NO). General structure is good. However some bits are, in my opinion, belonging to other sections (see above). Also, structure within sections and even paragraphs could be improved

Author's response: We have tightened the text of the manuscript and adjusted the order to address these concerns

13. Does the content justify the length of the article?

NO

14. Are the illustrations and tables all necessary, complete, clearly presented, and are the captions adequate and informative?

YES (NO). All are suitable to stay in the main text. They would need some fine tuning (see comments above)

Author's response: We have made the suggested changes to the tables and figures.

15. Are the references adequate and in agreement with the Guide for Authors?

YES

16. Is the quality of the English satisfactory and understandable for a multidisciplinary and multinational readership?

YES



Australian  
National  
University

3 8 July 2015

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7 Roland Ahtziger  
8 Associate Editor  
9 Ecological Indicators

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17 Re: ECOLIND-4940 manuscript revisions

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21 Dear Dr. Ahtziger,

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23 Please consider our revised manuscript, "Evaluating a biodiversity surrogate's effectiveness for  
24 predicting both community diversity and population trends", manuscript ECOLIND-4940, for  
25 publication in *Ecological Indicators*. We received many helpful comments from both the reviewers  
26 and believe this submission has been greatly improved from the feedback we received. We have  
27 addressed the comments of both reviewers and provide details below.  
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32 I look forward to hearing from you soon.

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A handwritten signature in black ink, appearing to read 'Jennifer Pierson', with a long horizontal flourish extending to the right.

Jennifer Pierson (on behalf of all coauthors)

We have indicated the reviewers' comments in italics.

**Reviewers' comments:**

**Reviewer #1:**

*This is an interesting manuscript where authors test the effectiveness of overstory cover as surrogate of bird species richness and population trends over time. They found that overstory cover can be used as surrogate for richness but no significant relationship between population trends and overstory cover could be generalized across species.*

**Comment:** *Although I think the analyses are sound and adequate for the goal the authors pursue I have a minor concern about how the independent variable for the population trend model was estimated. In P10-L20 authors state "We estimated the change in percentage cover by calculating the difference between the most recent estimate and the initial estimate at each site." If population trends were assessed as change in abundance between two consecutive periods, why was the independent variable for the model (change in cover) calculated relative to the initial cover? I think that the magnitude of cover change will be overestimated in this way.*

**Author's response:** We have clarified our methods to better explain our approach (line 196-199). Briefly, the population trends and change in cover were both estimated over the same time period but with slightly different methods. Avian point counts were conducted more often than the vegetation surveys which allowed population trends to be estimated using linear regression on the time series data. As fewer data points were available for the same time period in the percent cover data, we were unable to estimate a linear trend using regression approaches. Therefore, we calculated the difference in percentage cover between the first and last dates coinciding with the avian time series data.

**Comment:** *Moreover, was there a significant change in overstory cover over time when considering changes between two consecutive periods only (I saw in Figure 4 data ranged from -40 to 40, however this is maximum change over 10 years)? The lack of relationship between population trends and cover might be well explained by no or weak change in cover. If that was true, we could not conclude change in overstory is not a good surrogate, simply did not change enough as to produce a significant effect.*

**Author's response:** We agree that a lack of change in cover could obscure a relationship with population trends. However, our main interest was testing if the change in percentage cover could be a good indicator of trends in avian populations in a real-world monitoring context. Our interpretation is that a practical indicator must be sensitive to, and be able to predict, changes in population trends in a wide range of circumstances, not just at the edges of the distribution (i.e., extreme change in cover). Given this objective, we used empirical data from two different long-term monitoring studies that incorporate sites with a wide range of changes in cover (see new Supplementary Fig. 1). These ranges include both small (0) and relatively large (> +/- 50%) changes in cover over the years monitored and provide a good basis to test percentage cover as an effective indicator of population trends under a range of scenarios.

**Comment:** *I find a bit of inconsistency in the dependent variable used. Why was species richness used in one case and trends in abundance in the other?*

**Author's response:** We set out to test the performance of percentage cover as habitat surrogate for two distinct monitoring objectives (1) diversity of bird communities and 2) trends in bird

1 populations. Species richness is a common metric used to examine bird community diversity among  
2 sites, and thus was used as the metric to examine changes in bird community diversity from our  
3 study sites over time. By contrast, our analysis of population trends of individual bird species was  
4 based on their relative abundance.

5  
6 **Comment:** *What would happen if we tried to explain trends in species richness over time using the*  
7 *same methodology?*

8  
9 **Author's response:** While this is an interesting question, we feel it is outside the scope of our  
10 original study. The addition of this question would expand the current study to examine the ability of  
11 percentage overstory cover to predict trends in community diversity over time. We felt the addition  
12 of this question would obscure our main point in this manuscript which was to compare the  
13 usefulness of one surrogate for two the two stated objectives: representativeness of community  
14 diversity and population trends.

15  
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17 **Comment:** *I missed some important dependent variables that could also have significant, such as the*  
18 *land cover in the matrix where transects were located. Were there significant changes in land cover*  
19 *in the surrounding areas?*

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22 **Author's response:** An important motivation behind our study was the idea that a useful surrogate is  
23 one that is simple to measure and use, as well as being an effective predictor of the target variable  
24 of interest. From this perspective, it can be understood that building complex relationships between  
25 the surrogate and target variables potentially undermines the usefulness of the surrogate. There is  
26 also a fundamentally different objective behind testing the strength and consistency of a direct  
27 surrogate-target relationship, and building models that best describe variation in a target variable  
28 where the surrogate variable is relegated to one of many explanatory variables. Our objective was to  
29 test the surrogacy value of overstory in predicting bird diversity and trends as opposed to  
30 determining the range of covariates that may best describe patterns of bird diversity and trends. For  
31 these reasons, we deliberately chose to keep all models simple, and to focus on testing the strength  
32 and consistency of the direct relationship between percentage overstory cover and birds. While  
33 adding other relevant covariates would most likely improve the ability to predict avian species  
34 richness and/or population trends, the best covariates to include will likely change in each study.  
35 Thus, we are testing the consistency of the surrogate relationship by keeping the models simple and  
36 looking for consistency among studies/regions.

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41 We have added a section clarifying our approach in the methods (ln 243-247)

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43 **Comment:** *I think both the title and some of the conclusions (e.g., P14-L41) should be narrowed down*  
44 *to the content of the study, that's it surrogacy value of overstory cover, instead of environmental*  
45 *surrogates in general. There are many other environmental surrogates commonly used and not*  
46 *tested here.*

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49 We agree the specific results of our study are limited to inferences regarding the effectiveness of  
50 percentage overstory cover for monitoring bird populations when considering selecting a surrogate.  
51 We have restructured existing text (ln 306-309), added text to the discussion (ln 309-312) and  
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55 surrogate for overall bird species richness (Barton et al. 2014). Therefore, we feel it is important to  
56 discuss these implications in the context of evaluating surrogates more broadly.

Minor comment: P15-L30. Delete "(" before Cunningham.

**Author's response:** We have corrected this error

REVIEW (This part will also be sent to the author):

1. Does the subject of the paper fall within the scope of the journal?

YES

If no, comments:

2. Is it a new and original contribution? (not applicable for review articles) YES/NO If no, comments:

3. Does the paper support the progress in indicator development or does it provide interesting and new indicator applications?

YES

If no, comments:

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YES

If no, comments:

If the answers to any of the above points are negative, please give clear arguments for the rejection of the papers.

If the answers are positive, please continue with the following items:

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NO

If no, comments: Title should reflect more clearly the single environmental surrogate tested here.

**Author's response:** We have changed the title: Evaluating the effectiveness of overstory cover as a surrogate for bird community diversity and population trends

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YES

If no, comments:

7. Are the keywords informative and appropriate?

YES

If no, comments:

8. Is the statement of objectives of the paper adequate and appropriate in view of the subject matter?

YES

If no, comments:

9. Are the methods exposed correctly and sufficiently informative to allow replications of the research?

YES

If no, comments:

10. Are the statistical methods used correctly and adequate?

YES

If no, comments:

11. Are the results clearly presented?

NO

If no, comments: I'd suggest showing more explicitly potential change in overstory cover over time.

**Author's response:** We have added supplementary figures depicting the distribution of change in percentage overstory cover over time.

12. Is the article structured in agreement with the guidelines for authors? Is the organization of the article satisfactory?

YES/NO –

If no, comments:

13. Does the content justify the length of the article?

YES

If no, comments:

14. Are the illustrations and tables all necessary, complete, clearly presented, and are the captions adequate and informative?

YES

If no, comments:

15. Are the references adequate and in agreement with the Guide for Authors?

YES

If no, comments:

16. Is the quality of the English satisfactory and understandable for a multidisciplinary and multinational readership?

YES

If no, comments:

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*I was a bit surprised to see so few species showing significant correlation between vegetation and population trends. I am a bit concerned that the authors did not account for two potential confounding effects:*

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3 overstory cover < 25% and 2) sites that had initial overstory cover > 50%. Following re-analysis of  
4 these split datasets, we did find different patterns with more birds showing a relationship with  
5 change in percentage overstory cover when initial cover was > 50%. However, the patterns were not  
6 consistent between the two studies, or among different bird species, thus confirming that cover was  
7 not a consistent indicator regardless of the initial cover.  
8

9 We have added the results from these additional analyses to the supplementary material (Table S2)  
10 as well as some new text in the discussion (ln 385-396).  
11

12 **Comment:** *2. The authors choose to monitor a set of rather common species as surrogated taxa.  
13 Common species tend to be more generalist and therefore might not react so closely to change in  
14 habitat characteristics. From a practical perspective, it would also be more interesting to know the  
15 correlation of species of higher conservation concern which, in turn, tend to be more constrained by  
16 habitat availability. In my opinion lack of consistency of vegetation cover as surrogate of population  
17 trends between the two sites with longer monitoring periods was the most interesting finding. I was  
18 however a bit disappointed to see only 12 common species in the analyses.*  
19  
20  
21

22 **Author's response:** We agree that ideally we would have enough data on more species of  
23 conservation concern on which to test the effectiveness of the surrogate relationship. The species  
24 chosen were on the basis of having enough data to estimate population trends, unfortunately many  
25 of the species of conservation concern did not fall into this category. However, we were fortunate to  
26 have enough data on brown treecreepers, a bird included in the original analyses that is classified as  
27 threatened in New South Wales, Australia. Further, we believe that our results are robust because  
28 the species chosen are all woodland birds with a wide range of life history characteristics (Table S1).  
29 This is reflected in the most common species being among the ones that did indeed have a  
30 relationship between trend in relative abundance and change in overstory cover (e.g., Australian  
31 Magpie, Common Starling, Red Wattlebird).  
32  
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35 We have added text better describing the range of characteristics the species included represent (ln  
36 216-230) and table to the supplementary material (Table S1) to better describe the range of  
37 characteristics (e.g., Family, diet, foraging behaviour, nest type) of the species chosen.  
38  
39

40 **Comment:** *Authors suggest in their discussion that the lack of consistency of vegetation cover as  
41 surrogate of population trends might be due to the matrix context where the studies are based. I also  
42 tend to believe that this might be the main cause of the discordances they found between study sites.  
43 Would it be possible to get a graphical overview on landscape/habitat differences between studies?*  
44  
45

46 **Author's response:** All studies focus on woodland remnants dominated by similar vegetation, box-  
47 gum grassy woodland (ln 139--173). We have added brief descriptions of the landscape in which the  
48 remnants exist to the study descriptions that did not previously include this information (ln 173)  
49  
50

51 **Comment:** *I think the MS would benefit from shortening. Still, albeit the English language is correct,  
52 there is room for improving order in the text and redundancies.*  
53

54 **Author's response:** We have made extensive changes to the body of the manuscript. We have  
55 shortened the overall length of the manuscript while adding important clarifications to our methods  
56 and reasoning in our discussion. We have restructured the manuscript where appropriate by  
57 removing sections and moving sections from the introduction to the methods. We have  
58  
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62

1 incorporated the changes suggested below. We appreciate the suggestions and believe the  
2 manuscript has been improved as a result.

3 *Overall this is an interesting paper that would still need extensive revision.*

4 **Author's response:** We thank the reviewer for the positive feedback. We have made extensive  
5 revisions to the manuscript that we believe has resulted in a stronger contribution. We are grateful  
6 for the helpful feedback.  
7

8  
9 *Below some more specific comments that I hope the authors could address:*

10  
11 **INTRODUCTION**

12 *Pg3, L13: "feature" should be "features"*  
13 done  
14

15  
16 *Pg5, L54 - Pg6, L17: Paragraph suits more the Methods section. I suggest removing it from the*  
17 *Introduction section*

18 **Author's response:** We have made this change  
19

20  
21 *Pg6, L20 - L37: paragraph is a summary of the study. I find it highly redundant with the Abstract.*  
22 *Remove.*

23 **Author's response:** We have removed this paragraph  
24  
25

26  
27 **METHODS**

28 *Please be consistent with order and how you name the different studies across text, figures and*  
29 *tables.*

30 **Author's response:** We have implemented this suggestion  
31

32  
33 *Section 2.1: Please follow the same order of descriptors across the 4 sites. Also, common attributes*  
34 *could be put outside the study-specific paragraph, like "Each remnant contains a survey site that*  
35 *consists of a permanent 200m transect for sampling a range of biodiversity metrics".*

36 **Author's response:** We have implemented this suggestion  
37

38  
39 *Pg10, L29-36: Years do not match with Table 1.*

40 **Author's response:** Vegetation data was not collected all of the years that point counts were  
41 conducted. The community diversity data was only tested during the years that vegetation data was  
42 collected (Table 1). However, the full point count dataset was used to estimate the population  
43 trends  
44

45  
46 *Pg11, L8-20: It is not clear why the authors decide to use relative abundance index instead of the*  
47 *original abundance data*

48 **Author's response:** We used an index to reduce variability that may be caused by different number  
49 of visits and differences in observers. This method has been validated in previous work within these  
50 studies. We have added text to better explain our reasoning (ln 231-232)  
51

52  
53 *In my opinion, the first paragraph (describing how change in vegetation cover is measured) from*  
54 *section 2.4 could fit better in section 2.2.*

55 **Author's response:** We have implemented this suggestion  
56

57  
58 *Pg12, L20-23. Sentence is a repetition from first paragraph in section 2.4. I suggest removing it.*

59 **Author's response:** We have implemented this suggestion  
60  
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2 RESULTS

3 *Pg.12, L40-42. Title of section 3.2 makes one understand that authors here address consistency across*  
4 *time. However, this is not the case. I suggest removing the "time" bit from the title.*

5 **Author's response:** We have implemented this suggestion  
6

7  
8 *Pg.12, L48-53: I'm not sure what they mean with "sets of repeated samples". Is this a true result or*  
9 *rather an aspect to be presented in the Methods section?*

10 **Author's response:** We have removed this statement  
11

12  
13 *Pg.12, L56: I would argue that 4-5 years of surveys (Table 1) do not categorize as "long-term study". I*  
14 *would just remove the "long-term" bit.*

15 **Author's response:** We have implemented this suggestion  
16  
17

18  
19 *Pg.13, L32-37: talking about "several species" is an overstatement. I would remove this sentence*  
20 *altogether as it does not add information to the following sentence at the end of the paragraph.*

21 **Author's response:** We have implemented this suggestion  
22  
23

24 DISCUSSION

25  
26 *Pg.16, L28-30: Taking into account that there are only four studies, saying that Southern Slopes*  
27 *Restoration study is a "strong outlayer" sounds like an overstatement.*

28 **Author's response:** We have removed this statement  
29

30  
31 *Pg.16, L38-53: It would be good to explain with further detail the possible causes of discordance of of*  
32 *the Southern Slopes Restoration study as compared to the rest of studies.*

33 **Author's response:** We agree this is a very interesting result and are curious for the reason. We  
34 added a brief summary of one of the possible explanations we have tested (In 354-364). However,  
35 we were concerned an in-depth examination of this may be distracting from the main message of  
36 the manuscript so tried to keep our summary brief.  
37

38  
39 *Pg.17, L12: change "as a result in" by "as a result of"*

40 **Author's response:** We have implemented this suggestion  
41

42 *Figure 2: Is "range of" necessary on axis title?*

43 **Author's response:** We have removed this statement  
44

45  
46 *Figure 4: Axis labels nearly unreadable*

47 **Author's response:** We have implemented this suggestion  
48

49  
50 *Table 3: significant values could be in bold characters.*

51 **Author's response:** We have implemented this suggestion  
52

53 Please note that your recommendation and reviewer report are expected to cover the Highlights and  
54 Graphical Abstract if submitted with the manuscript.  
55

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58  
59 REVIEW  
60

1 1. Does the subject of the paper fall within the scope of the journal?

2 YES

3  
4 2. Is it a new and original contribution? (not applicable for review articles) YES

5  
6  
7 3. Does the paper support the progress in indicator development or does it provide interesting and  
8 new indicator applications?

9 YES

10  
11 4. Are the interpretations and conclusions sound, justified by the data and consistent with the  
12 objectives?

13 Most likely YES. However, I would have preferred to see species of higher conservation concern. Also I  
14 have some doubts on the methodological aspect (see above)

15 **Author's response:** Please see above for the manner we addressed this concern  
16  
17  
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19

20 5. Does the title of this paper clearly reflect its content?

21 YES

22  
23 6. Is the abstract sufficiently informative especially when read in isolation?

24 YES.

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27  
28 7. Are the keywords informative and appropriate?

29 YES

30  
31 8. Is the statement of objectives of the paper adequate and appropriate in view of the subject  
32 matter?

33 YES

34  
35  
36 9. Are the methods exposed correctly and sufficiently informative to allow replications of the  
37 research?

38 YES (NO). See comments above

39  
40  
41 10. Are the statistical methods used correctly and adequate?

42 YES

43  
44 11. Are the results clearly presented?

45 YES

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47  
48 12. Is the article structured in agreement with the guidelines for authors? Is the organization of the  
49 article satisfactory?

50 YES (NO). General structure is good. However some bits are, in my opinion, belonging to other  
51 sections (see above). Also, structure within sections and even paragraphs could be improved

52 **Author's response:** We have tightened the text of the manuscript and adjusted the order to address  
53 these concerns  
54  
55

56  
57 13. Does the content justify the length of the article?

58 NO

14. *Are the illustrations and tables all necessary, complete, clearly presented, and are the captions adequate and informative?*

YES (NO). All are suitable to stay in the main text. They would need some fine tuning (see comments above)

**Author's response:** We have made the suggested changes to the tables and figures.

15. *Are the references adequate and in agreement with the Guide for Authors?*

YES

16. *Is the quality of the English satisfactory and understandable for a multidisciplinary and multinational readership?*

YES

## Highlights (for review)

Four longitudinal studies spanning > 1000 km used to test surrogacy relationships

Overstory cover had a similar relationship to bird diversity in three of four regions

Changes in overstory did not predict individual species' population trends

Clear objectives inform surrogate evaluation and identification of limitations

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10 4 Evaluating the effectiveness of overstory cover as a surrogate for bird  
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13 5 community diversity and population trends  
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16 6 J.C. Pierson<sup>a\*</sup>, A. Mortelliti<sup>a</sup>, P.S. Barton<sup>a</sup>, P.W. Lane<sup>a</sup>, and D.B. Lindenmayer<sup>a</sup>  
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46 17 Running head: Surrogate effectiveness for diversity and trends  
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21 Abstract (400)

22 Landscape features are often used as surrogates for biodiversity. While landscape  
23 features may perform well as surrogates for coarse metrics of biodiversity such as species  
24 richness, their value for monitoring population trends in individual species is virtually  
25 unexplored. We compared the performance of a proposed habitat surrogate for birds,  
26 percentage cover of vegetation overstory, for two distinct aspects of bird assemblages:  
27 community diversity (i.e. species richness) and population trends. We used four different  
28 long-term studies of open woodland habitats to test the consistency of the relationship  
29 between overstory percentage cover and bird species richness across a large spatial extent  
30 (>1000km) in Australia. We then identified twelve bird species with long-term time-series  
31 data to test the relationship between change in overstory cover and populations trends. We  
32 found percentage cover performed consistently as a surrogate for species richness in three of  
33 the four sites. However, there was no clear pattern in the performance of change in  
34 percentage cover as a surrogate for population trends. Four bird species exhibited a  
35 significant relationship with change in percentage overstory cover in one study, but this was  
36 not found across multiple studies. These results demonstrate a lack of consistency in the  
37 relationship between change in overstory cover and population trends among bird species,  
38 both within and between geographic regions. Our study demonstrates that biodiversity  
39 surrogates representing community-level metrics may be consistent across regions, but  
40 provide only limited information about individual species population trends. Understanding  
41 the limitations of the information provided by a biodiversity surrogate can inform the  
42 appropriate context for its application.

43 Keywords: biodiversity surrogate, species richness, population trends, vegetation, monitoring

44

## 45 **1.0 Introduction**

46 A wide variety of both biotic and abiotic features of landscapes have been used as proxies of  
47 biodiversity in both marine and terrestrial environments. In marine environments, for  
48 example, geomorphic characteristics such as sea floor depth, temperature and sediment  
49 attributes are suggested as abiotic surrogates of benthic biodiversity patterns (McArthur et al.  
50 2010). In terrestrial environments, structural features of a landscape are often suggested for  
51 use as biodiversity surrogates. These include abiotic measures such as geodiversity, climate  
52 and topographical features of the landscape (Hjort et al. 2012), and biotic measures such as  
53 vegetation structure or type (Schwab et al. 2002, Smith et al. 2007, Banks-Leite et al. 2011,  
54 Barton et al. 2014). While important structural features of a species' habitat may be easier to  
55 measure, they are not always effective surrogates of broader biodiversity (i.e. abundance and  
56 distribution of species) (Hermoso et al. 2013). This means that thorough evaluation of a  
57 potential biodiversity surrogate is necessary to determine the specific situations in which they  
58 perform well and which ones they do not.

59 The first step in evaluating the performance of a surrogate is to define the particular  
60 goal against which the surrogate is being evaluated (Wiens et al. 2008). Broadly speaking,  
61 most biodiversity surrogates are used for either systematic conservation planning (e.g. reserve  
62 design) (Rodrigues and Brooks 2007) or for monitoring (Wintle et al. 2010). For example, the  
63 objective of reserve design is often to maximize representation of biodiversity within or  
64 among areas (Margules and Pressey 2000), and a particular surrogate(s) may be used as a  
65 proxy for other components of biodiversity (Rodrigues and Brooks 2007). The objective of a  
66 monitoring project, however, may be to assess community diversity, population status, or  
67 trends for the purpose of baseline data or in response to some type of management action  
68 (Block et al. 2001). Importantly, a surrogate that has been identified for one objective may  
69 not be appropriate for other, even closely related, objectives (Caro 2010).

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70 Biodiversity surrogates are often targeted at measuring broad community-level  
71 aspects of biodiversity such as species richness and composition (Magierowski and Johnson  
72 2006). Community-level metrics can provide important information about the number and  
73 kinds of species present, but do not provide any detailed information about population trends  
74 of individual species. Information on population trends, however, can provide early warnings  
75 of species in decline prior to its complete loss (Lindenmayer and Cunningham 2011). Once a  
76 species is lost, it may be difficult to restore. Furthermore, the decline of a population  
77 represents a threat to biodiversity in and of itself by drastically reducing the abundance of  
78 organisms in an environment which results in changing interactions within ecosystems (Dirzo  
79 et al. 2014). While extinction events, even local ones, tend to be relatively rare, a wide range  
80 of populations are suffering declines (Dirzo et al. 2014). Community metrics and population  
81 trends therefore represent two informative and complementary approaches to biodiversity  
82 monitoring, yet are different objectives for a biodiversity surrogate.

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83 Percentage vegetation cover has been identified as a potential surrogate for bird  
84 diversity (Banks-Leite et al. 2011, Barton et al. 2014). It has long been established that bird  
85 assemblage diversity and composition is associated with vegetation structure (MacArthur and  
86 MacArthur 1961, Davies and Asner 2014). In particular, overstory cover (e.g. forest cover,  
87 canopy cover) has been shown to have a positive relationship with species richness,  
88 occupancy and abundance of bird communities in a range of habitats including pine  
89 plantations (Owens et al. 2014), urban habitats (Ferenc et al. 2013, Chong et al. 2014), and in  
90 northern hemisphere forests (Trzcinski et al. 1999, Müller et al. 2010) and southern  
91 hemisphere forests (Cunningham et al. 2014b). This is due, in part, to the strong mechanistic  
92 links between vegetation cover and species diversity via enhanced resource provision and  
93 niche availability (Recher 1969). However, several studies also have documented that  
94 individual species respond differently to vegetation cover (Reidy et al. 2014) with increased



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95 cover not necessarily resulting in a positive response from all woodland birds (Cunningham  
96 et al. 2014a, Rayner et al. 2014).

97 In this study, we evaluated whether a proposed habitat-based biodiversity surrogate  
98 (i.e. percentage overstory cover) consistently represents two different yet complementary  
99 monitoring objectives: bird species richness and population trends. First, we evaluated the  
100 consistency of percentage overstory cover as a surrogate for bird species richness. We  
101 predicted a consistent surrogacy relationship should hold if the mechanistic relationship  
102 between vegetation structure (e.g. overstory cover) and bird communities (e.g. richness) was  
103 strong enough to be a reliable surrogate in similar habitats. We tested this consistency by  
104 examining associations between percentage overstory cover and bird species richness in a  
105 systematic manner across four longitudinal studies from different geographic regions that  
106 comprise similar vegetation types yet experience different anthropogenic pressures. Second,  
107 we tested whether the temporal change in percentage overstory cover was associated with  
108 trends in individual species' populations. We tested this by focusing on bird species common  
109 to two of the longitudinal studies that span >10 years of data. Specifically, we addressed the  
110 following two questions:

- 111 1. Is the surrogate relationship between percentage vegetation cover and bird species  
112 richness consistent across geographic regions and over time?
- 113 2. Can the change in percentage vegetation cover be used as a robust surrogate for trends  
114 in individual bird species' populations?

## 115 116 **2.0 Methods**

117 We compared the relationship between the species richness and percentage vegetation  
118 cover in four geographically distinct large-scale, longitudinal studies conducted in southeast  
119 Australia (Figure 1) that had repeated sampling for both overstory cover and bird species  
120 richness (Table 1). We used a subset of these studies that had both overstory cover and bird  
121 population data that spanned 10 years or more to determine if the change in percentage cover  
122 predicted the trend in bird populations (Nanangroe and Southwest Slopes Restoration studies;  
123 Table 1). We identified 12 species of birds that commonly occurred in these studies and used  
124 them to compare patterns of change in percentage cover to population trends (Table 2, Table  
125 S1).

126 The longitudinal studies we use in this study provided an excellent opportunity to  
127 evaluate consistency of percentage cover as a surrogate measure of bird species richness and  
128 population trends for several reasons. First, the studies span a wide geographic region (>  
129 1000km) yet are all dominated by similar open woodland habitat type (box-gum grassy  
130 woodland) which allows testing of the spatial boundaries of the surrogacy relationship  
131 (Pierson et al. 2015) within a habitat type. Second, the multi-year length of the studies allows  
132 us to test the ability of temporal changes in percentage cover to predict trends in individual  
133 bird populations. Indeed, moving towards predictive models of surrogate relationships is an  
134 important step forward in surrogate ecology (Collen and Nicholson 2014). Finally, all the  
135 studies were designed and implemented by a largely consistent group of individuals which  
136 reduces heterogeneity in data quality due to differences in observer ability. Details of the  
137 longitudinal studies and statistical analysis are described below.

### 138 *2.1 Study sites and field surveys*

139 **Nanangroe (NAN)** –The Nanangroe study is a longitudinal investigation designed to assess  
140 the effects of a changing matrix on fauna in eucalypt woodland remnants. Woodland

141 remnants vary in size from 0.5 – 9.7 ha and are surrounded by either an agricultural matrix  
142 (mostly livestock grazing) or a matrix of recently planted softwood plantations (*Pinus*  
143 *radiata*; planted in 1998-2000) (for details see Lindenmayer et al. (2001)). Dominant  
144 vegetation is eucalypts (yellow box *Eucalyptus melliodora*, red box *E. polyanthamos*, white  
145 box *E. albens*, red stringybark *E. macrorhyncha*, Blakely’s red gum *E. blakelyi*).

**Southwest Slopes Restoration study (SWS)** – The Southwest Slopes Restoration study is a  
longitudinal investigation established to monitor the effects of revegetation of agricultural  
landscapes on wildlife (for details see Cunningham et al. (2007)). Study sites are temperate  
woodland remnants located in agricultural landscapes in Southeast Australia (Figure 1).  
Remnants range from 0.5 – 70 ha and include three categories of vegetation – old growth,  
seedling regrowth, and coppice regrowth. Dominant trees include white box *E. albens*,  
Blakely’s red gum *E. blakelyi*, River Red gum *E. camaldulensis*, red stringybark *E.*  
*macrorhyncha*, yellow box *E. melliodora*, red box *E. polyanthamos*, and grey box *E.*  
*macrocarpa*

**Environmental Stewardship (ES)** – The Environmental Stewardship study is a longitudinal  
study spanning SE Queensland to SW New South Wales, Australia. The study is designed to  
monitor the effectiveness of the agricultural investment scheme in which the Australian  
government paid farmers to modify activities in high-quality remnant woodland patches > 5  
ha in an agricultural landscape (for details see Lindenmayer et al. 2012). These modifications  
include grazing restrictions and limits on fertilizer use. Sites were paired with similar  
woodland remnants on the same farm to determine the response of biodiversity to modified  
management. Dominant vegetation included white box *E. albens*, Blakely’s red gum *E.*  
*blakelyi*, and yellow box *E. melliodora*).

164 **Western Murray Woodlands (WMW)** The Western Murray Woodlands project is a  
165 longitudinal study designed to collect baseline biodiversity data under a range of agri-  
166 environment schemes which include: (i) woodlands used for livestock production, (ii)  
167 woodlands that have been recently become managed with reduced grazing, understory  
168 plantings, and invasive control (< 5yrs), (iii), woodlands that have been managed long-term  
169 with reduced grazing, understory plantings, and invasive control (>10 yr), and (iv) travelling  
170 stock reserves which are woodlands that have been protected from vegetation clearing for >  
171 150 years (for details see Michael et al. 2014). The woodland communities are dominated by  
172 grey box *E. macrocarpa*, boree *Acacia pendula*, white cypress pine *Callitris glaucophylla* or  
173 yellow box *E. melliodora*. All remnants are in an agricultural landscape, and are > 2 ha.  
174 In each study, each remnant had a permanent 200m transect for sampling a range of  
175 biodiversity metrics.

## 176 2.2 Percentage cover

177 In the Nanangroe and Southwest Slopes Restoration study, overstory cover was measured in  
178 three 20m x 20m plots located at the 0, 100, and 200m point along the permanent transect.  
179 Within each of these plots, an observer visually estimated the percent cover of the dominant  
180 species (Nanangroe) or vegetation > 10m (Southwest Slopes Restoration) within the plot.  
181 The estimate of cover for the sites is an average of the three plot-level observations. In the  
182 Environmental Stewardship and Western Murray Woodlands studies, overstory cover was  
183 estimated in two 20 x 50 plots located between the 0 - 50m and 150 - 200m points. At the  
184 Environmental Stewardship sites, an observer recorded whether native overstory cover was  
185 present (binary outcome) every 5m for a total of 10 observations. For example, if cover was  
186 present at 7 of the 10 points, then the percent cover in the plot was 70%. At Western Murray  
187 Woodlands, an observer visually estimated the percent native overstory cover every 5m for a

188 total of 10 observations which were averaged for a plot level estimate of percent cover. The  
189 percent cover estimate for a site was the average of the two plots.

190 While there were minor differences in the methods used to estimate overstory cover,  
191 we are confident they are quantitatively similar. We tested this assumption in the Southwest  
192 Slopes Restoration study. Fortunately, starting in 2008, native vegetation cover was collected  
193 in the same manner as the Western Murray Woodlands study (in addition to the original  
194 overstory cover metric used in the analysis) which allowed us to confirm the estimates of  
195 overstory cover were highly correlated ( $P < 0.001$ ).

196 To estimate the change in overstory cover, we calculated the difference in overstory  
197 cover between first and last year sampled (Table 1). For example, if the estimate of percent  
198 cover was 40% in 1999 at a Nanangroe site and increased to 60% in 2013, the change in  
199 percentage cover is +20.

### 200 *2.3 Species richness and population trends*

201 Point counts were conducted at the 0, 100, and 200 meter points along the permanent  
202 transect located at each site within the larger studies. Each point count was conducted for five  
203 minutes, during which all birds seen or heard within 50m were recorded. Point counts were  
204 conducted during the spring season and a site was visited twice per season (i.e., six point  
205 counts conducted per transect).

206 Bird species richness was calculated for each site each year. If a species was recorded  
207 at least once along the transect within a season, then it was recorded as present on the site for  
208 that year. Species richness was the sum of all species present at a given site in a given year  
209 (Magurran 2004).

210 The Nanangroe and Southwest Slopes Restoration studies both had long-term data  
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2 211 spanning > 10 years which allowed us to evaluate individual bird species' population trends  
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4 212 in relation to changes in overstory cover. In the Nanangroe study, the data were used from  
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7 213 point counts conducted in the spring of 1998, 1999, 2000, 2001, 2003, 2005, 2007, 2009,  
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10 214 2011, 2012, and 2013. In the Southwest Slopes Restoration study, data were used from point  
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12 215 counts conducted in the spring of 2002, 2004, 2006, 2008, 2009, 2011, and 2013.  
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216 We identified 12 woodland-associated species that were commonly encountered in  
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18 217 both the Nanangroe and Southwest Slopes Restoration studies (Table 2) and calculated  
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20 218 population trends for this suite of species. Individual species evaluated included a wide range  
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22 219 of life histories, behaviours, and sizes that were representative of the entire bird community  
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25 220 (Table S1), including species of conservation concern. For example, we included species that  
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27 221 display a variety of foraging behaviours including a leaf-gleaner (Striated Pardalote  
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29  
30 222 *Pardalotus striatus*), an aerial insectivore (Willie Wagtail *Rhipidura leucophrys*), and  
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32 223 honeyeaters (White-plumed Honeyeater *Lichenostomus penicillatus* and Red Wattlebird  
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35 224 *Anthochaera carunculata*). The largest species we evaluated was the Australian Magpie  
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37 225 (*Cracticus tibicen*), which ranges in weight from 206 – 387 g, while the smallest species we  
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40 226 evaluated, the Superb Fairy-wren (*Malurus cyaneus*), weighs 10g. We included a species  
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42 227 listed as Threatened (Brown Treecreeper *Climacteris picumnus*) in New South Wales,  
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45 228 Australia, as well as the Common Starling (*Sturnus vulgaris*) which is a non-native bird  
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47 229 thought to compete with native birds for hollows and food resources (Pell and Tidemann  
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50 230 1997).  
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53 231 We used a relative index of bird abundance to reduce variability due to number of  
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55 232 visits and observers that has been shown to represent local abundance well in these studies  
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58 233 (Cunningham and Olsen 2008, Mortelliti et al. 2015). This abundance index was calculated  
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60 234 by counting the number of times a bird was present during a point count divided by the  
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235 number of point counts conducted. For example, if a bird species was recorded as present at  
236 four of the six point counts, the relative abundance index would be 0.66. We estimated the  
237 trend in relative abundance using a linear regression of the time series of relative abundance  
238 on each site, with year as a continuous explanatory variable. To avoid a high proportion of  
239 zero trend estimates from sites without any detections, we included only sites where a given  
240 species was recorded at least once during the time series. This meant that the analysis of each  
241 species included a different number of total sites in the analysis (Table 2).

#### 242 *2.4 Statistical analysis*

243 We intentionally tested simple models focused solely on the relationship between percentage  
244 overstory cover and either species richness or population trend. While many other covariates  
245 likely contribute to patterns in bird richness and abundance, our logic is that testing the  
246 predictive ability of overstory cover as a surrogate relies on a strong simple relationship  
247 between the surrogate (e.g. overstory cover) and the target of interest (e.g. species richness) .

248 To test if percentage cover of overstory vegetation was a consistent surrogate for bird  
249 species richness, we used a generalized linear mixed model with bird species richness as the  
250 response variable. As this was count data, we used a Poisson distribution with a log-link  
251 function, and estimated the dispersion parameter to account for any overdispersion in the  
252 data. Percentage overstory cover was log-transformed,  $\log(1+x)$ , and was included as a fixed  
253 effect. Both year and site were fitted as random effects to account for repeated sampling  
254 (Zuur et al. 2009).

255 To determine whether the change in percentage cover can be used as a surrogate for  
256 trends in population abundance of individual species, we used a generalized linear model  
257 with a normal distribution and identity link. Normality of all datasets was confirmed through  
258 visual assessments of residuals. We estimated trends in population abundance from time-

259 series data of relative abundance that was collected annually. We used linear regression to  
260 estimate the slope of the growth trend at the site level, and used the slope as the response  
261 variable with change in percentage cover as a fixed effect. All analyses were completed in  
262 GenStat 16 (VSN International 2013).

263

### 264 **3.0 Results**

265 *3.1 Is the surrogate relationship between percentage vegetation cover and bird species*  
266 *richness consistent across geographic regions?*

267 We identified >100 sites within each long-term study that had temporal data on both percent  
268 cover and bird species richness (Table 1). Within each study, the distribution of values for  
269 percentage cover and distribution of values for bird species richness showed similar patterns  
270 (Figure 2).

271 We found a significant positive relationship between percentage overstory cover and  
272 bird species richness among sites from three of the four studies, with highly consistent effect  
273 sizes (Figure 3). The Western Murray Woodlands study had the smallest, and the Nanangroe  
274 study had the largest median estimate of both cover and richness (Figure 2). The effect size of  
275 the relationship between percentage cover and bird species richness was very similar among  
276 the Nanangroe, Environmental Stewardship, and the Western Murray Woodlands studies  
277 (Figure 3). The Southwest Slopes Restoration study was the only study to have a non-  
278 significant and negative relationship between cover and richness (Figure 3).

279 *3.2 Can the change in percentage cover be used as a surrogate for trends in bird*  
280 *populations?*



281 Overall, the temporal change in percentage cover was not consistently associated with  
282 population trends, either between studies or among species within studies. We found a  
283 positive relationship for the Australian Magpie and the Brown Treecreeper, but a negative  
284 relationship for the Red Wattlebird and the Common Starling (Table 3, Figure 4).

285 The Australian Magpie was the only species in the Nanangroe study to exhibit a  
286 significant positive relationship between the change in percentage overstory cover and trend  
287 in population abundance (Table 3, Figure 4). The remaining 11 species evaluated in the  
288 Nanangroe study showed a mix of positive and negative relationships, none of which were  
289 significant.

290 In the Southwest Slopes Restoration study, only the Brown Treecreeper showed a  
291 positive significant relationship between the change in overstory cover and population trend.  
292 The Common Starling and the Red Wattlebird both exhibited a significant negative  
293 relationship between the change in overstory cover and population trend. The remaining nine  
294 species showed primarily non-significant and negative relationships (except the Black-faced  
295 Cuckoo-shrike *Coracina novaehollandiae* and the Rufous Songlark *Cincloramphus*  
296 *mathewsi*) (Table 3).

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#### 298 **4.0 Discussion**

299 Biodiversity surrogates are commonly employed as indicators of community-level  
300 measures of species richness or composition (Lombard et al. 2003, Magierowski and Johnson  
301 2006, Gollan et al. 2008, Lewandowski et al. 2010, Mellin et al. 2011). A complementary  
302 objective of biodiversity monitoring is tracking the trends of populations of species, with the  
303 purpose of detecting declines prior to their potential loss in a particular area (Marsh and

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304 Trenham 2008). In this study, we evaluated the consistency of community vs. population  
305 biodiversity objectives to assess the value of overstory cover as a biodiversity surrogate,  
306 which we discuss in turn below. Our study provides empirical evidence that biodiversity  
307 surrogates (i.e. overstory cover) representing community-level metrics (i.e. species richness)  
308 may not provide useful information regarding population-level metrics (i.e. individual species  
309 trends). While the specific results of this study relate to the relationship between percentage  
310 overstory cover and bird communities and trends, they support the need to carefully consider  
311 the objectives for which a surrogate is being used and the limits of the information a  
312 surrogate provides.

313 *4.1 Is the surrogate relationship between percentage cover and bird species richness*  
314 *consistent across geographic regions?*

315 For our community-level biodiversity objective, we found that percentage overstory cover  
316 performed consistently as a surrogate for species richness in three of four regions we  
317 examined. While this confirms that percentage overstory cover is indeed a suitable surrogate  
318 for bird diversity, the identification of a region where the surrogacy relationship breaks down  
319 confirms the need to evaluate this surrogate in each particular region prior to its application.

320 The concept that the distribution of birds is related to the amount of vegetation cover  
321 has been widely documented across broad landscapes including North America (Trzcinski et  
322 al. 1999), Europe (Mortelliti et al. 2010), and Australia (Radford et al. 2005). This  
323 relationship suggests that, at least in some circumstances, the amount of vegetation cover at a  
324 site may be a useful surrogate for the numbers or kinds of birds at a site. Upon examination,  
325 however, the details of this relationship often vary depending on the scale, type of vegetation,  
326 type of cover (e.g. understory, midstory, etc), and the suite of birds being evaluated (e.g  
327 (Cunningham et al. 2014a).

328 Previous research has shown that percentage overstory cover is a robust surrogate for  
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2 329 bird species richness over time, in a range of vegetation types, and in relation to fire (Barton  
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5 330 et al 2014). However, such previous research was limited to a single landscape, and it was  
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7 331 unknown if these results were applicable to other regions with different bird assemblages and  
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9 332 vegetation. Our study has therefore extended this earlier work and tested the consistency of  
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11 333 this relationship across several other longitudinal studies in different geographic regions in  
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13 334 southeastern Australia, and that employed similar data collection measures of both percentage  
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15 335 vegetation cover and bird species richness. Notably, we used estimates of percentage cover  
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17 336 collected at the site-level by observers ‘on-the-ground’ as opposed to using estimates  
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19 337 obtained remotely via aerial photography or satellite data. Whether our conclusions also  
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21 338 apply to vegetation data acquired remotely remains unknown and overstory cover data  
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23 339 acquired remotely requires independent evaluation as a potential surrogate.  
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30 340 The four longitudinal studies we compared were similar in that they were monitoring  
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32 341 biodiversity in woodland remnants following some type of land management intervention  
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34 342 (eg. planting native vegetation). The remnants in the various studies vary in the particular  
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36 343 plant species that dominate the vegetation community and the local and landscape  
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38 344 disturbance experienced, but all generally represent a critically endangered landscape in  
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40 345 Australia – box gum grassy woodland (Department of Environment 2015). Therefore, at the  
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42 346 outset of this investigation, we expected percentage cover to perform similarly as a habitat  
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44 347 surrogate for bird biodiversity across all the landscapes. Despite finding very similar  
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46 348 relationships (statistically and biologically) among three studies, we found no relationship  
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48 349 between percentage overstory cover and bird diversity in a fourth study (i.e., Southwest  
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50 350 Slopes Restoration study).  
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57 351 There are several possible reasons for the difference observed between the Southwest  
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59 352 Slopes Restoration study and the other three longitudinal studies, such as small differences in  
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1 353 study design, variability in percent cover, and study specific variation (i.e. study specific  
2 354 restoration treatments) could all contribute to the pattern we observed. For example, we  
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4 355 looked at the range of restoration treatments present in the Southwest Slopes Restoration  
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7 356 study as a source of the observed difference. The study design includes three different  
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9 357 categories of remnant woodlands: natural regrowth, coppice regrowth and old growth. We  
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11 358 tested the relationship between percent OS and cover separately among these categories and  
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13 359 found that the old growth sites did indeed exhibit a significant relationship with bird diversity  
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15 360 ( $B = -0.09$ ,  $P = 0.019$ ), however this relationship was negative and in opposition to the other  
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17 361 three longitudinal studies (Figure 3). Regardless of the biological explanation for the  
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19 362 difference in surrogacy relationships between cover and bird diversity among these studies,  
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21 363 the conclusion is that percentage overstory cover did not always perform well as a surrogate  
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23 364 for bird species richness.

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29 365 Our study demonstrates that the strength and pattern of surrogacy relationships can  
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31 366 vary even in regions that share geographic location, habitat type, and range of patch size.  
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33 367 Other work that has evaluated surrogate effectiveness across a range of studies has found  
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35 368 similar inconsistencies. For example, Grantham et al. (2010) evaluated the effectiveness of  
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37 369 biodiversity surrogates for a range of taxa (e.g. mammals, birds, reptiles) and found  
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39 370 surrogates performed differently depending on the study and the method used for evaluation.  
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41 371 In marine environments, a similar outcome has been found where the effectiveness of a  
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43 372 surrogate could change as a result of a small shift in spatial scale, sampling design, or random  
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45 373 processes (Van Wylsberge et al. 2012).

#### 52 374 *4.2 Can the trend in percentage cover be used as a surrogate for trends in bird populations?*

53 375 For our population-level biodiversity objective, we examined population trends in twelve bird  
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55 376 species commonly encountered in two different longitudinal studies. We found that while the  
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1 377 population trends of several species did significantly respond to changes in percentage  
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3 378 overstory cover over time, there was no consistency within species among studies, or among  
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5 379 species within studies.  
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8 380 The wide range of biological (effect size) and statistical significance values we found  
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10 381 when evaluating the ability of changes in cover to predict trends in bird populations clearly  
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12 382 indicates that increases (or decreases) in percentage overstory cover do not necessarily  
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14 383 predict increases in abundance over time (trends) (Table 3). All the patterns that we observed  
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16 384 were both species specific and region specific.  
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21 385 The wide range of overstory cover observed within each study could obscure a signal  
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23 386 if birds responded differently to cover when it is minimal compared to when cover is high.  
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25 387 We tested this by investigating the relationship between population trends and change in  
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27 388 cover when the initial cover was low (< 25%) and high (> 50%). While we found that  
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29 389 different species had a relationship between population trends and change in cover at  
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31 390 different values of initial cover, consistency of these relationships, both among species within  
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33 391 studies and within species between studies, did not improve (Table S2). The lack of  
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35 392 consistency in the direction of the response to changes in cover (that is, some populations  
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37 393 increase and some decrease in relation to cover changes) means that monitoring percentage  
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39 394 overstory cover will not necessarily provide information about population trends. Thus,  
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41 395 percentage overstory cover does not perform consistently well as a surrogate for population  
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43 396 trends.  
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51 397 Four of the twelve species we analyzed, the Australian Magpie, Brown Treecreeper,  
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53 398 Red Wattlebird, and the Common Starling, exhibited a significant relationship between the  
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55 399 change in percentage overstory cover and population trend. For example, the Australian  
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57 400 Magpie was the only species in the Nanangroe study to exhibit a significant relationship  
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401 between the change in percent cover and population trend (Figure 4). We looked to the  
402 treatment effects specific to Nanangroe as a potential explanation; this study is monitoring  
403 the effects of conversion of an agricultural matrix to pine plantation matrix surrounding  
404 remnants. We found a positive significant relationship in remnants within an agricultural  
405 matrix ( $B = 0.00026$ ,  $P = 0.003$ ) and a non-significant relationship in remnants surrounded by  
406 pine matrix ( $B = 0.00004$ ,  $P = 0.706$ ). This suggests that conversion of the matrix to pine  
407 plantation could be a confounding factor driving the increase in magpies within remnants  
408 surrounded by the agricultural matrix. Similarly, the Brown Treecreeper was the only species  
409 in the Southwest Slopes Restoration study to show a positive significant relationship between  
410 population trend and change in overstory cover. Previous studies (Mortelliti and Lindenmayer  
411 2015) found that this species responded negatively to pine plantation establishment in the  
412 Nanangroe study. Therefore, the species was decreasing in sites surrounded by pines.  
413 Consequently, any potential relationship between overstory cover and population trend would  
414 have been confounded by the effect of the matrix. These examples illustrate that local  
415 confounding effects (eg. matrix conversion) may have masked any relationship between the  
416 change in overstory cover and population trend.

#### 4017 *4.3 Implications for application of biodiversity surrogates as indicators of population trends*

4018 This study has revealed several important limitations for the application of a biodiversity  
4019 surrogate, in this case percentage overstory cover. Despite a well-documented relationship  
4020 between percentage overstory cover and bird assemblages (Radford et al. 2005, Müller et al.  
4021 2010, Barton et al. 2014, Chong et al. 2014, Owens et al. 2014), we found an inconsistent  
4022 surrogate relationship between overstory cover and bird species diversity among four  
4023 longitudinal studies conducted in a similar habitat type. The implication of this finding is that  
4024 overstory cover will need to be thoroughly evaluated as a surrogate for bird diversity within

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425 distinct regions and landscapes prior to each application. This evaluation requires monitoring  
426 data on both overstory cover and bird diversity over time and space.

427         The broader implication is that a habitat feature that has long been documented to  
428 influence biodiversity may not always serve as a useful surrogate for biodiversity. Indeed, it  
429 may not be easy to predict when it will work well and when it will not work well and as such  
430 a potential surrogate will require thorough evaluation for each particular proposed  
431 application.

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572 **Figure Legends**

573 **Figure 1.** The location of the four longitudinal studies in Southeast Australia. NSW – New  
574 South Wales, ACT – Australian Capital Territory

575 **Figure 2.** Boxplots showing the range of percent overstory cover and the range of bird  
576 species richness among sites from the four longitudinal studies. WMW: Western Murray  
577 Woodlands study; NAN: Nanangroe study; SWS: Southwest Slopes Restoration study; ES:  
578 Environmental Stewardship study.

579 **Figure 3.** The effect size of percent overstory cover on bird species richness calculated from  
580 generalized linear mixed models with year and site as random effects (\* =  $P < 0.05$ ; \*\* =  $P <$   
581 0.001). Error bars represent standard errors. WMW: Western Murray Woodlands study;  
582 NAN: Nanangroe study; SWS: Southwest Slopes Restoration study; ES: Environmental  
583 Stewardship study.

584 **Figure 4.** Fitted and observed relationships of the population trends estimated from linear  
585 regression of time series data spanning at least 10 years (y-axis), and the change in percent  
586 overstory cover between the earliest and most recent sampling periods (x-axis). The  
587 individual species are indicated at the top of each plot. 95 % confidence intervals are  
588 indicated by the dashed-line envelopes around the fitted relationship.

589

590 **Table 1.** The number of sites that temporal data on percent overstory cover and bird diversity  
 591 was collected.

<b>Study</b>	<b>Number of sites</b>	<b>Sampling years birds</b>	<b>Sampling years vegetation</b>
Nanangroe	112	1999, 2005, 2011	1999, 2005, 2010
Southwest Slopes	138	2002, 2004, 2008, 2013	2002, 2004, 2008, 2013
Environmental Stewardship	324	2010, 2011, 2012, 2013	2010, 2011, 2012, 2013
Western Murray Woodlands	105	2008, 2010, 2012	2008, 2010, 2012

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593

594 **Table 2.** The number of sites at which each species was encountered at least once over the  
 595 course of the monitoring period (Nanangroe: 1998-2013; Southwest Slopes Restoration:  
 596 2002- 2013).

Species	Number of sites	
	Nanangroe	Southwest slopes
Australian magpie ( <i>Cracticus tibicen</i> )	135	130
Black-facked cuckoo-shrike ( <i>Coracina novaehollandiae</i> )	102	104
Brown treecreeper ( <i>Climacteris picumnus</i> )	66	60
Common starling ( <i>Sturnus vulgaris</i> )	85	111
Grey shrike-thrush ( <i>Colluricincla harmonica</i> )	108	84
Red wattlebird ( <i>Anthochaera carunculata</i> )	110	71
Red-rumped parrot ( <i>Psephotus haematonotus</i> )	78	126
Rufous songlark ( <i>Cincloramphus mathewsi</i> )	92	114
Striated pardalote ( <i>Pardalotus striatus</i> )	111	124
Superb fairy-wren ( <i>Malurus cyaneus</i> )	86	58
White-plumed honeyeater ( <i>Lichenostomus penicillatus</i> )	94	111
Willie wagtail ( <i>Rhipidura leucophrys</i> )	89	113

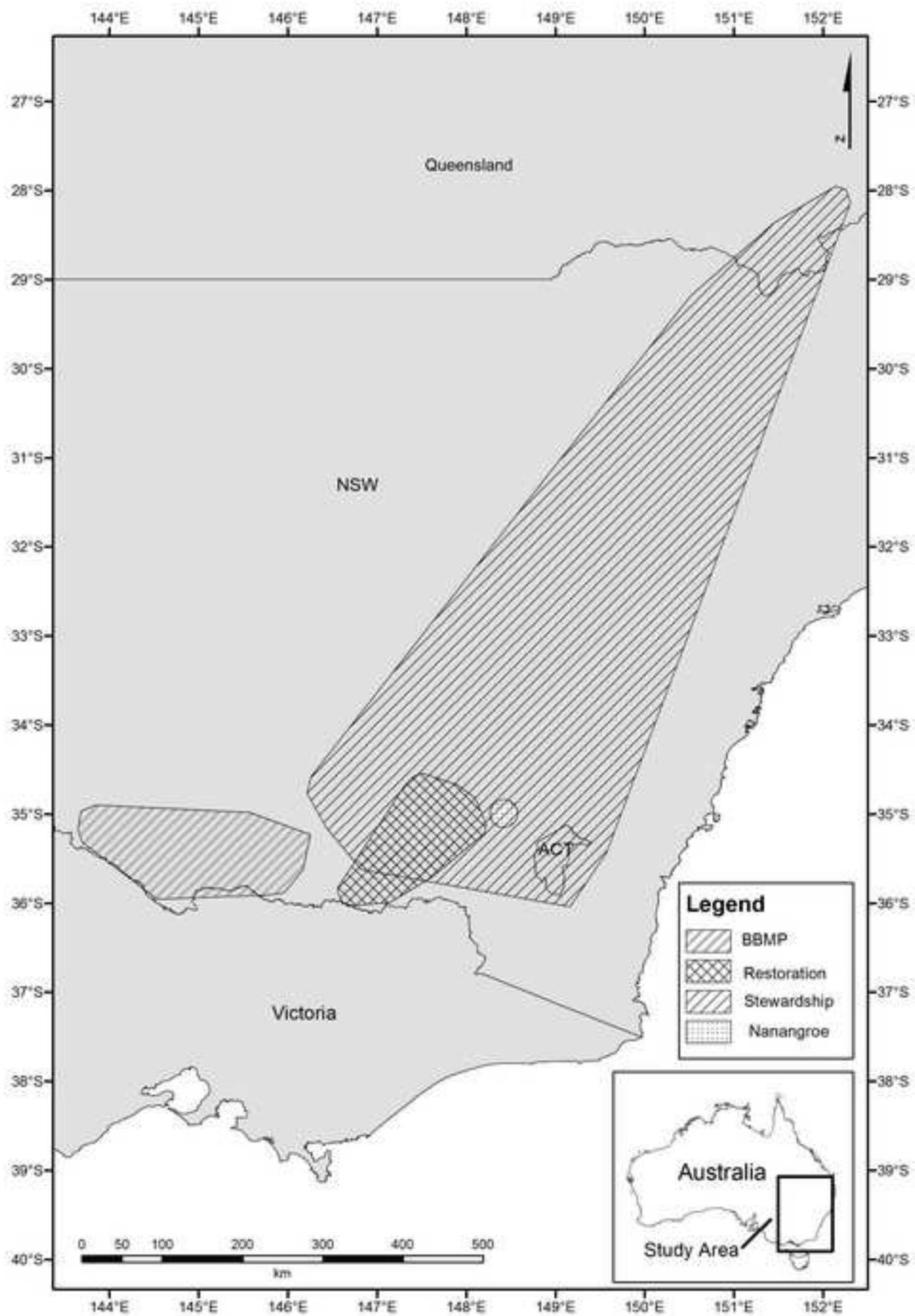
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**Table 3.** Results from linear regression analysis of the effects of change in percentage overstory cover on population trends at the site level.

	Nanangroe				Southwest Slopes Restoration			
	constant	slope	s.e.	<i>P</i> value	constant	slope	s.e.	<i>P</i> value
Australian magpie	0.00052	0.00023	0.00008	<b>0.003</b>	-0.00643	-0.00008	0.00011	0.459
Black-faced cuckoo-shrike	-0.00520	0.00003	0.00004	0.456	0.00291	0.00006	0.00007	0.399
Brown treecreeper	0.00466	0.00016	0.00012	0.191	-0.00178	0.00036	0.00014	<b>0.010</b>
Common starling	-0.00890	0.00009	0.00006	0.129	-0.00200	-0.00033	0.00010	<b>0.002</b>
Grey shrike-thrush	0.00804	-0.00008	0.00008	0.287	-0.00669	-0.00008	0.00011	0.462
Red wattlebird	-0.00719	0.00011	0.00007	0.133	-0.00574	-0.00024	0.00012	<b>0.049</b>
Red-rumped parrot	0.00018	0.00016	0.00010	0.104	-0.00649	-0.00016	0.00009	0.076
Rufous songlark	-0.00041	-0.00006	0.00013	0.61	0.00924	-0.00015	0.00011	0.186
Striated pardalote	-0.00272	0.00012	0.00008	0.154	-0.00327	0.00001	0.00011	0.926
Superb fairy-wren	0.01245	0.00010	0.00011	0.366	-0.00009	-0.00009	0.00011	0.393
White-plumed honeyeater	-0.00931	0.00002	0.00014	0.863	-0.01015	-0.00016	0.00013	0.203
Willie wagtail	-0.00212	0.00013	0.00011	0.243	-0.00009	-0.00009	0.00012	0.443

Figure

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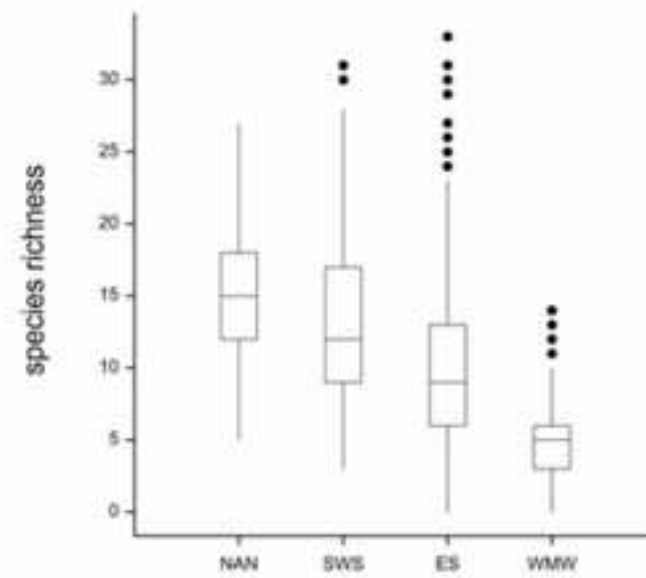
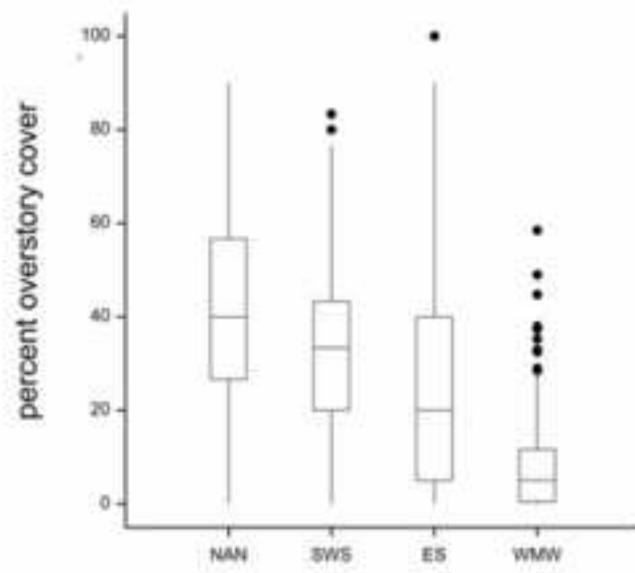
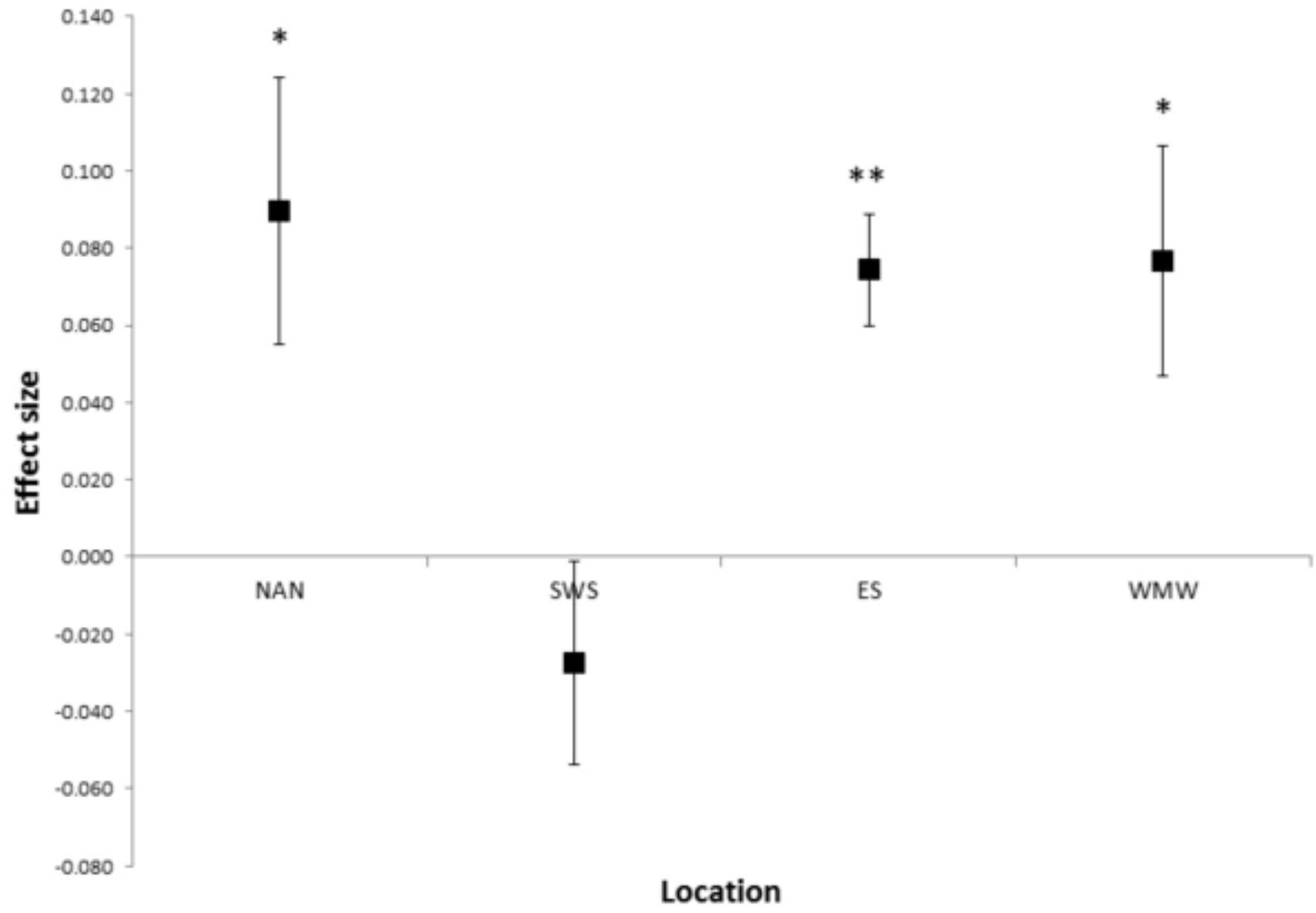


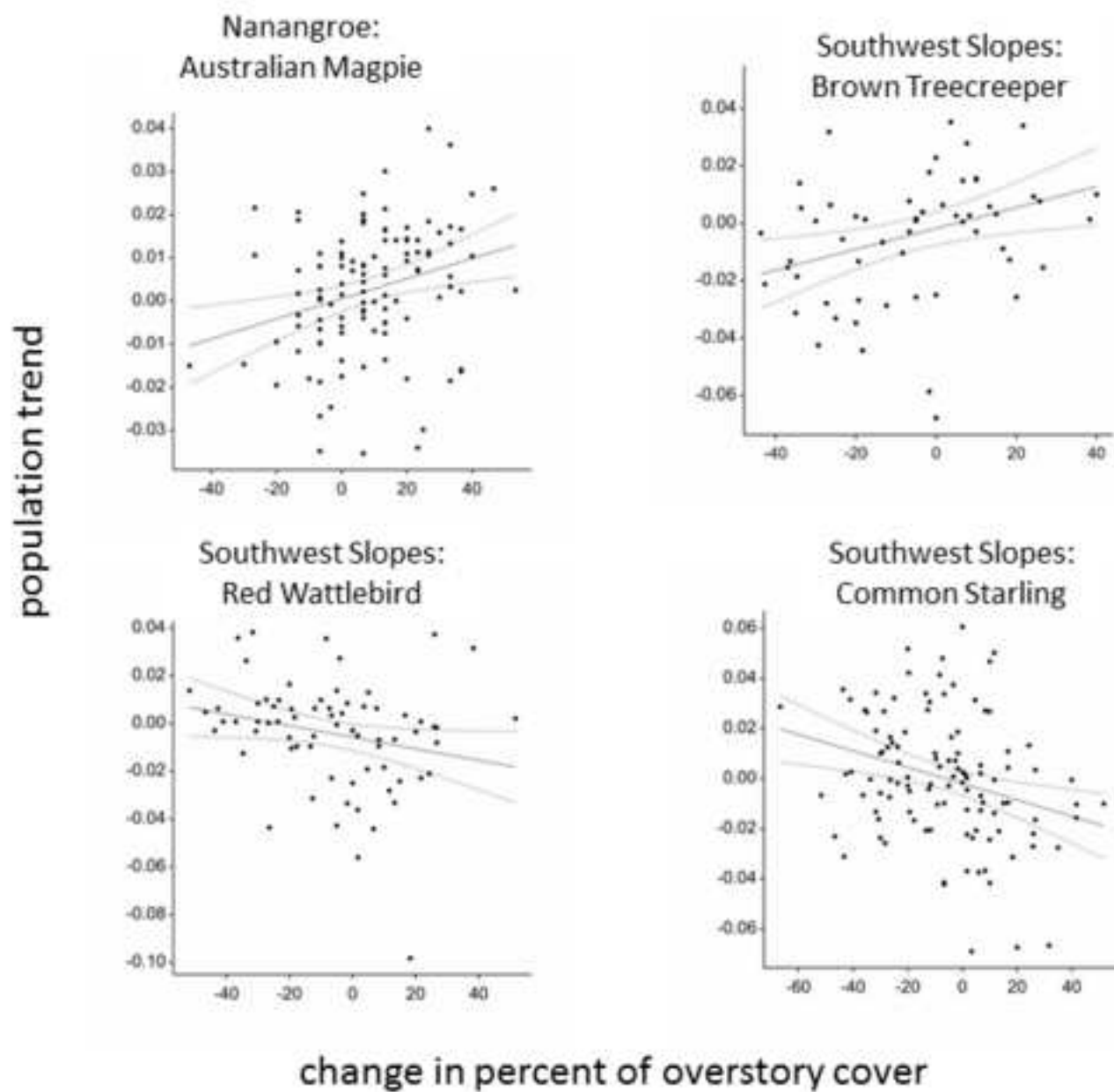


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