Research, Conservation and Outreach Priorities for Conserving Aerial Insectivore Populations in Canada:

Report from March 2020 Aerial Insectivore Workshop in Saskatoon, SK

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Table of Contents

1. Executive Summary

Populations of migratory aerial insectivores have declined by an estimated 59% since the 1970s in Canada and ~32% across North America. This diverse guild of birds including swallows, swifts, nightjars, and flycatchers, all species which forage on flying insects. By 2020, 9 of the 31 species in this guild were listed under Canada's Species at Risk Act. In March 2020, individuals from academia, government, and a non-profit organization convened for a 2-day workshop in Saskatoon, Saskatchewan to critically evaluate mechanisms underlying the declining population trends of aerial insectivores with the following objectives:

1) Synthesize evidence of hypothesized threats to aerial insectivore populations and recommend high-priority research and conservation needs;
2) Recommend management/policy actions;
3) Identify areas for collaboration and coordination among researchers and other stakeholders across the Western Hemisphere.

The synthesis of evidence indicated that recent research and other initiatives have made significant progress to address important information gaps. Many of these gaps were previously highlighted in a 2012 workshop on aerial insectivores, with the following ***new insights and broad conclusions***:

- New modelling results indicate that aerial insectivore declines are complex — with high spatiotemporal variation and limited synchrony in population trends within and among species across North America.
- Understanding of migratory connectivity and non-breeding habitats has improved for several swallow species and nightjars.
- Evidence for long-term declines in aerial insect abundance in North America remains elusive and coordinated research over broad areas is needed.
- Recent studies indicate that aquatic emergent aerial insects may be more nutritious than terrestrial insects, further underscoring the vital importance of wetlands and other aquatic habitats in producing key food resources for many aerial insectivore species.
- Improved estimates of survivorship and dispersal of adult and juvenile birds are now available, especially for the swallows.
- Active research on the threats from agriculture and forestry activities suggest aerial insectivores can be affected in complex ways through pesticides, loss of food and declines in key habitat.
- Integrated (IPM) and other population models have been developed to pinpoint population bottlenecks in Tree Swallows, and IPMs are being extended to Barn Swallows.
- Several recent studies have been able to locate and assess key roosting and congregation sites used during breeding and non-breeding seasons in a range of species.
- Comparative demographic studies of Tree and Barn Swallows have been completed, and others are continuing. Whereas substantial research progress has been made on several

high priority recommendations, especially for swallow species, it will be necessary to redouble such efforts for species of swift, nightjar, and flycatcher.

Knowledge gaps persist for each of the groups of aerial insectivores, producing uncertainty about the most effective ways of addressing population declines; gaps common to all groups include:

1. Lack of reliable baseline estimates or trends in abundances in the north, including boreal regions, where existing bird monitoring programs (e.g., BBS, eBird) do not exist or are limited.
2. Limited or no information about seasonal demographic rates, such as estimates for stages of the annual cycle believed to be most limiting to populations.
3. Uncertainty about non-breeding season ecology and events, including migratory routes, stopover sites, wintering locations, habitat (and site fidelity), migratory connectivity and possible carry-over effects for most species.
4. Limited understanding persists on the large-scale threats of land use change and climate change particularly for the non-breeding habitats for most aerial insectivores.

KEY RECOMMENDATIONS

Here we outline a set of ***key recommendations*** based on the outcomes of the workshop.

1. Form an aerial insectivore working group, with an immediate objective to implement the recommendations outlined below.
2. Establish an aerial insectivore website and ListServ to facilitate communication and outreach, both internally and externally.
3. Develop and implement a roadmap to aerial insectivore conservation in Canada, considering the Global Roadmap to insect conservation as a template. This should seek to implement immediate “no regrets” actions to benefit the environment, clarify threats to aerial insectivores and identify solutions and conservation actions needed to directly respond to population declines.
4. Undertake research to characterize spatiotemporal changes in land cover, pesticide use, climate variability and change, and phenology over the Western Hemisphere, 1960-present, with direct linkages to population modelling. A comprehensive large-scale analysis should aim to pinpoint how these factors affect aerial insectivore populations, thus informing conservation actions with higher likelihood of success.
5. Conduct strategic monitoring to better understand demography of “at-risk” species and develop a more complete understanding of full annual cycle ecology to facilitate where and how to allocate conservation actions. Wintering or migration surveys may be more effective than breeding season surveys estimating trends of some swift and nightjar species.
6. Strengthen and expand existing networks and collaboration in the Western Hemisphere and with European countries to achieve cross-border engagement, coordinated monitoring, research, policy and conservation goals.
7. Apply advanced technologies for monitoring to obtain new fundamental information about migratory routes and the non-breeding period, such as locations of important

wintering sites and key roosting sites, diets, and habitat types and potential changes or degradation of habitat conditions at these sites.

8. Conduct research on aerial insects – declines of insects have been reported from around the world and efforts are underway to evaluate the robustness and scale of these trends. Further work is needed to determine whether and how aerial insects and aerial insectivores are similarly affected by land use change and climate change and the possible interactions.
9. Develop a communications strategy to mobilize knowledge about using aerial insectivores and insects as indicators of environmental health, targeting a wide range of audiences. This should aim to improve the public's understanding of how birds and insects warn us about environmental threats, as well as build support for implementing policy to take action.
10. Improve mechanisms of engaging and disseminating information to policy makers and resource managers, as well as to the Committee on the Status of Endangered Wildlife in Canada. Such mechanisms would improve communications, especially in translating research results into actions, like policy transformations and program delivery.
11. Develop more effective partnerships within ECCC and among key government departments (e.g., Agriculture and Argi-Food Canada, International Affairs) as well as international organizations (BirdLife, Trilateral Committee for Wildlife and Ecosystem Conservation and Management, Trinational Monarch Conservation Science Partnership). This would strengthen information flow, leading to transnational agreements that address issues of habitat loss and environmental degradation in Canada and other countries.
12. Expand citizen science initiatives, including with Indigenous partners, and develop better mechanisms for building consistent collaborations with stakeholders, including with the agricultural and forest industries, municipal planners, and research partners (e.g., universities, NSERC, NGOs) to support conservation actions.
13. Identify and implement transformative strategies to produce policy improvements urgently needed in Canada to protect and restore environmental health and habitats – wetlands, grasslands, forests – especially in agricultural and forested regions, seeking co-benefits for biodiversity, the public, and industries.

1. Sommaire

Les populations d'insectivores aériens migrateurs ont diminué d'environ 59 % depuis les années 1970 au Canada et d'environ 32 % en Amérique du Nord. Cette guilde diversifiée d'oiseaux comprend des hirondelles, des martinets, des engoulevents et des moucherolles, des espèces qui se nourrissent toutes d'insectes volants. En 2020, 9 des 31 espèces de cette guilde étaient inscrites à la *Loi sur les espèces en péril* du Canada. En mars 2020, des universitaires ainsi que des représentants gouvernementaux et d'un organisme sans but lucratif se sont réunis à l'occasion d'un atelier de deux jours à Saskatoon, en Saskatchewan, afin d'évaluer de façon critique les mécanismes sous-jacents au déclin des populations d'insectivores aériens, avec les objectifs suivants :

1) synthétiser les données probantes attestant de menaces hypothétiques pour les populations d'insectivores aériens, et recommander des besoins hautement prioritaires en matière de recherche et de conservation;
2) recommander des mesures de gestion et des initiatives;
3) déterminer des domaines de collaboration et de coordination entre les chercheurs et les autres intervenants dans l'hémisphère occidental.

La synthèse des données probantes indique que les recherches récentes et d'autres initiatives ont fait des progrès significatifs pour combler d'importantes lacunes sur le plan des connaissances. Bon nombre de ces lacunes ont déjà été soulignées lors d'un atelier de 2012 sur les insectivores aériens, auxquelles s'ajoutent ***les nouvelles perspectives et conclusions générales*** suivantes :

- Les nouveaux résultats de la modélisation indiquent que les déclins des insectivores aériens sont complexes : il y a de grandes variations spatiotemporelles et une synchronie limitée des tendances touchant les populations à l'intérieur des espèces et entre celles-ci en Amérique du Nord.
- La compréhension de la connectivité migratoire et des habitats autres que ceux de reproduction s'est améliorée pour plusieurs espèces d'hirondelles et d'engoulevents.
- Les données probantes sur les déclins à long terme de l'abondance d'insectes aériens en Amérique du Nord demeurent vagues, et une recherche coordonnée sur de vastes régions est nécessaire.
- Des études récentes montrent que les insectes aériens aquatiques émergents peuvent être plus nutritifs que les insectes terrestres, ce qui souligne encore plus l'importance vitale des milieux humides et d'autres habitats aquatiques dans la production de ressources alimentaires essentielles pour de nombreuses espèces d'insectivores aériens.
- De meilleures estimations de la survie et de l'expansion des oiseaux adultes et juvéniles sont maintenant disponibles, en particulier pour les hirondelles.
- Des recherches actives sur les menaces que les activités agricoles et forestières posent donnent à penser que les insectivores aériens peuvent être touchés de manières complexes par les pesticides, la perte de nourriture et les déclins des habitats clés.

- Des modèles intégrés et d’autres modèles de population ont été élaborés pour repérer les étranglements de la population des Hirondelles bicolores, et des modèles intégrés de population sont étendus aux Hirondelles rustiques.
- Plusieurs études récentes ont permis de localiser et d’évaluer les principaux sites de repos et de rassemblement utilisés pendant les saisons de reproduction et internuptiales pour un éventail d’espèces.
- Des études démographiques comparatives sur l’Hirondelle bicolore et l’Hirondelle rustique ont été effectuées, et d’autres se poursuivent. Des progrès substantiels ont été réalisés sur le plan de la recherche à la suite de plusieurs recommandations hautement prioritaires, en particulier en ce qui concerne des espèces d’hirondelles. Il faudra redoubler d’efforts pour des espèces de martinets, d’engoulevents et de moucherolles.

Des ***lacunes dans les connaissances*** persistent pour chacun des groupes d’insectivores aériens, ce qui crée de l’incertitude quant aux façons les plus efficaces de gérer les déclins de populations. Les lacunes communes à tous les groupes comprennent les suivantes :

1. Manque d’estimations de référence fiables ou de tendances des abondances dans le Nord, y compris dans les régions boréales, où les programmes de surveillance des oiseaux existants (p. ex. RON et eBird) ne sont pas en place ou le sont de façon restreinte.
2. Peu ou pas d’information sur les taux démographiques saisonniers, comme des estimations pour les stades du cycle annuel que l’on croit être les plus limitatifs pour les populations.
3. Incertitude au sujet de l’écologie et des événements hors saison de reproduction, y compris les routes migratoires, les haltes migratoires, les aires d’hivernage, l’habitat (et la fidélité aux sites), la connectivité migratoire et les effets persistants possibles pour la plupart des espèces.
4. Maintien d’une compréhension limitée des menaces à grande échelle que posent les changements d’affectation des terres et les changements climatiques, en particulier pour les habitats autres que ceux de reproduction de la plupart des insectivores aériens.

PRINCIPALES RECOMMANDATIONS

Nous présentons ici un ensemble de ***recommandations clés*** fondées sur les résultats de l’atelier.

1. Former un groupe de travail sur les insectivores aériens avec l’objectif immédiat de mettre en œuvre les recommandations décrites ci-dessous.
2. Établir un site Web sur les insectivores aériens et une liste de diffusion électronique pour faciliter la communication et la sensibilisation, tant à l’interne qu’à l’externe.
3. Élaborer et mettre en œuvre une feuille de route pour la conservation des insectivores aériens au Canada, en tenant compte de la feuille de route mondiale pour la conservation des insectes comme modèle. Cela devrait viser à mettre en œuvre immédiatement des mesures « sans regrets » qui seront bénéfiques pour l’environnement, à clarifier les menaces pour les insectivores aériens et à déterminer les

solutions et les mesures de conservation nécessaires afin de réagir directement aux déclins des populations.

4. Entreprendre des recherches pour caractériser les changements spatiotemporels de la couverture terrestre, de l'utilisation des pesticides, ainsi que de la variabilité et du changement climatiques; et en phénologie dans l'hémisphère occidental, de 1960 à aujourd'hui, avec des liens directs avec la modélisation des populations. Une analyse exhaustive à grande échelle devrait viser à cerner la façon dont ces facteurs influent sur les populations d'insectivores aériens, afin d'éclairer les mesures de conservation ayant de meilleures chances de réussite.
5. Assurer une surveillance stratégique afin de mieux comprendre la démographie des espèces « en péril », et acquérir une compréhension plus exhaustive de l'écologie du cycle annuel complet pour décider où et comment répartir les mesures de conservation. Les relevés d'hivernage ou de migration peuvent être plus efficaces que les relevés de la saison de reproduction pour estimer les tendances de certaines espèces de martinets et d'engoulevents.
6. Renforcer et étendre les collaborations et les réseaux existants dans l'hémisphère occidental et avec les pays européens afin d'atteindre les objectifs de mobilisation transfrontalière, de surveillance coordonnée, de recherche, stratégiques et de conservation.
7. Appliquer des technologies de pointe aux fins de la surveillance pour obtenir de nouveaux renseignements fondamentaux sur les routes migratoires et la période de non-reproduction, comme l'emplacement des sites d'hivernage importants et des principaux sites de repos; les régimes alimentaires; les types d'habitats et les changements potentiels ou la dégradation des conditions de l'habitat à ces sites.
8. Réaliser des recherches sur les insectes aériens. Des déclins d'insectes ont été signalés dans le monde entier, et des efforts sont déployés pour évaluer la fiabilité et l'ampleur de ces tendances. D'autres travaux sont nécessaires pour établir si et comment les insectes aériens et les insectivores aériens sont touchés de la même façon par les changements d'affectation des terres, le changement climatique et les interactions possibles.
9. Élaborer une stratégie de communication afin de mobiliser les connaissances sur l'utilisation des insectivores et des insectes aériens comme indicateurs de la santé environnementale, en ciblant un large éventail de publics. Cela devrait permettre d'améliorer la compréhension du public sur la façon dont les oiseaux et les insectes nous mettent en garde contre les menaces environnementales, ainsi que d'obtenir un soutien pour la mise en œuvre de politiques visant à prendre des mesures.
10. Améliorer les mécanismes de mobilisation et de diffusion de l'information à l'intention des décideurs et des gestionnaires des ressources, ainsi qu'au Comité sur la situation des espèces en péril au Canada. De tels mécanismes amélioreraient les communications, surtout en traduisant les résultats de la recherche en mesures, notamment au chapitre de la transformation des politiques et de la prestation des programmes.
11. Établir des partenariats plus efficaces au sein d'Environnement et Changement climatique Canada et entre des ministères clés (p. ex. Agriculture et Agroalimentaire Canada et Affaires mondiales Canada) et des organismes internationaux (BirdLife,

Comité trilatéral de conservation et de gestion des espèces sauvages et des écosystèmes et Partenariat scientifique trinational pour la conservation du monarque). Cela renforcerait la circulation de l’information et mènerait à la conclusion d’accords transnationaux visant à régler les problèmes de perte d’habitats et de dégradation de l’environnement au Canada et dans d’autres pays.

12. Élargir les initiatives de science citoyenne, y compris avec les partenaires autochtones, et élaborer de meilleurs mécanismes pour établir des collaborations cohérentes avec les intervenants, notamment avec les industries agricoles et forestières, les planificateurs municipaux et les partenaires de recherche (p. ex. universités, CRSNG et ONG) afin d’appuyer les mesures de conservation.
13. Déterminer et mettre en œuvre des stratégies de transformation pour apporter de toute urgence les améliorations nécessaires aux politiques au Canada afin de protéger et de restaurer la santé environnementale et les habitats (terres humides, prairies et forêts), en particulier dans les régions agricoles et forestières, en cherchant à obtenir des avantages connexes pour la biodiversité, le public et les industries.

2. 2020 Workshop on Aerial Insectivores - Objectives and Deliverables

Populations of migratory aerial insectivores, a diverse guild of birds including swallows, swifts, nightjars, and flycatchers that feed on flying insects, have experienced steep declines in parts of North America (Figure 1; Smith et al 2015; Michel et al 2016). Recent reports from the North American Bird Conservation Initiative Canada (2019) indicate that as a guild, aerial insectivores have experienced declines of 59%, which is greater than any other bird populations. Of the 31 species in the guild, 73% are experiencing declines in parts of North America (Rosenberg et al 2019). Consequently, nine species are designated as "species-at-risk" under the Canadian Species at Risk Act and are in urgent need of conservation actions to stabilize or reverse their declines.

Given the diverse ecology of species within the guild, it was originally hypothesized that the one trait shared among all the species, their dependence of on flying insects, may be the cause of their declines (Nebel et al 2010). However, neither declines in insect abundance, nor any other threat has been conclusively identified as the main driver across all species in the guild. Aerial insectivores experience multiple threats throughout the annual cycle at breeding, migrating and wintering locations (Spiller & Dettmers 2019) — locations which are widely separated throughout the western hemisphere – but which threats, where they are acting, and how they affect population trends are unknown.

From 10-11 March 2020, a group of 24 researchers and 3 remote participants from academia, government, and a conservation organization attended a workshop at the University of Saskatchewan in Saskatoon (Appendix 1-4) building on the previous aerial insectivore workshop held in 2012 on "Research Priorities for Canada's Aerial Insectivores" (Calvert 2012). Workshop participants provided updates on aerial insectivore research that has occurred since 2012 (Tables 1-4, Appendix 5), reviewed available evidence to support or refute hypotheses on the causes of declines (Table 5, Appendix 6), and identified new or refined high-priority research needs to understand species- and region-specific population trends for appropriate conservation actions.

The main **objectives** of the workshop were to:

1) Synthesize evidence of hypothesized threats to aerial insectivore populations and recommend high-priority research needs.
2) Make recommendations for management/policy actions to reverse declining trends.
3) Identify areas for collaboration and coordination among researchers and other stakeholders across the Western Hemisphere.

Following this workshop, the group successfully produced several **outputs** intended to launch and guide future research and conservation efforts on aerial insectivores:

1) A report from the workshop including research priorities for conserving aerial insectivores in Canada with a set of comprehensive recommendations that can be used immediately as a guide to prioritize research and conservation action.

2) Editorial paper in the journal Avian Conservation and Ecology on the state of aerial insectivores and priority research recommendations (Nebel et al. 2020 available at http://www.ace-eco.org/vol15/iss1/art23).
3) Formation of an Aerial Insectivore Working Group, that includes Science and Policy Sub-Committees, to tackle priority research questions, connect researchers, and help guide conservation, policies, actions and programs.

3. Current Population Status of Aerial Insectivore Status

Adam Smith presented new Breeding Bird Survey (BBS) model results for aerial insectivores as a guild and for individual species at regional, national, and continental scales. These new results use Bayesian models that allow for non-linear fluctuations in population abundance during the time-series, such as the negative change-point that occurred for aerial insectivores in the 1980's (Smith et al 2015; Smith & Edwards 2020). This new modelling approach provides more reliable estimates for population trends of individual species. Examples of BBS analysis results conducted by Adam Smith can be found in Appendix 7, and more detailed results for individual species can be found on the GitHub repository: https://github.com/AdamCSmithCWS/Aerial_Insectivores.

As a guild, aerial insectivores have declined in Canada, and in North America, however, the degree of declines varies by species (Figure 1). Birds belonging to the groups of swallows, swifts and nightjars (Figure 2a) have declined more steeply then flycatchers (Figure 2b). Although aerial insectivores have declined as a guild since 1970's, trends for some species appear to have stabilized at much lower abundances, are showing overall increases or may have begun to reverse declines in recent years (Figure 2).

At the continental scale, the greatest declines in aerial insectivores are occurring in northeastern parts of North America (Figure 2), as suggested by others (Nebel et al 2010). However, species-specific population trends vary spatiotemporally across North America (Figure 3). For instance, Tree Swallow populations are stable or increasing in the west but declining in the east (Michel et al 2016), and Purple Martins and Vaux's Swifts are experiencing declines in the northern part of their ranges but increasing in the southern part of their ranges (Pomfret et al 2012). Understanding population trajectories of individual species across their range and how they differ from trends of other species or guild-wide will enable researchers to formulate hypotheses and test mechanisms underlying the different change-points and trajectories observed. Ultimately, this will allow for the prioritization of conservation actions towards species or subspecies experiencing declines.

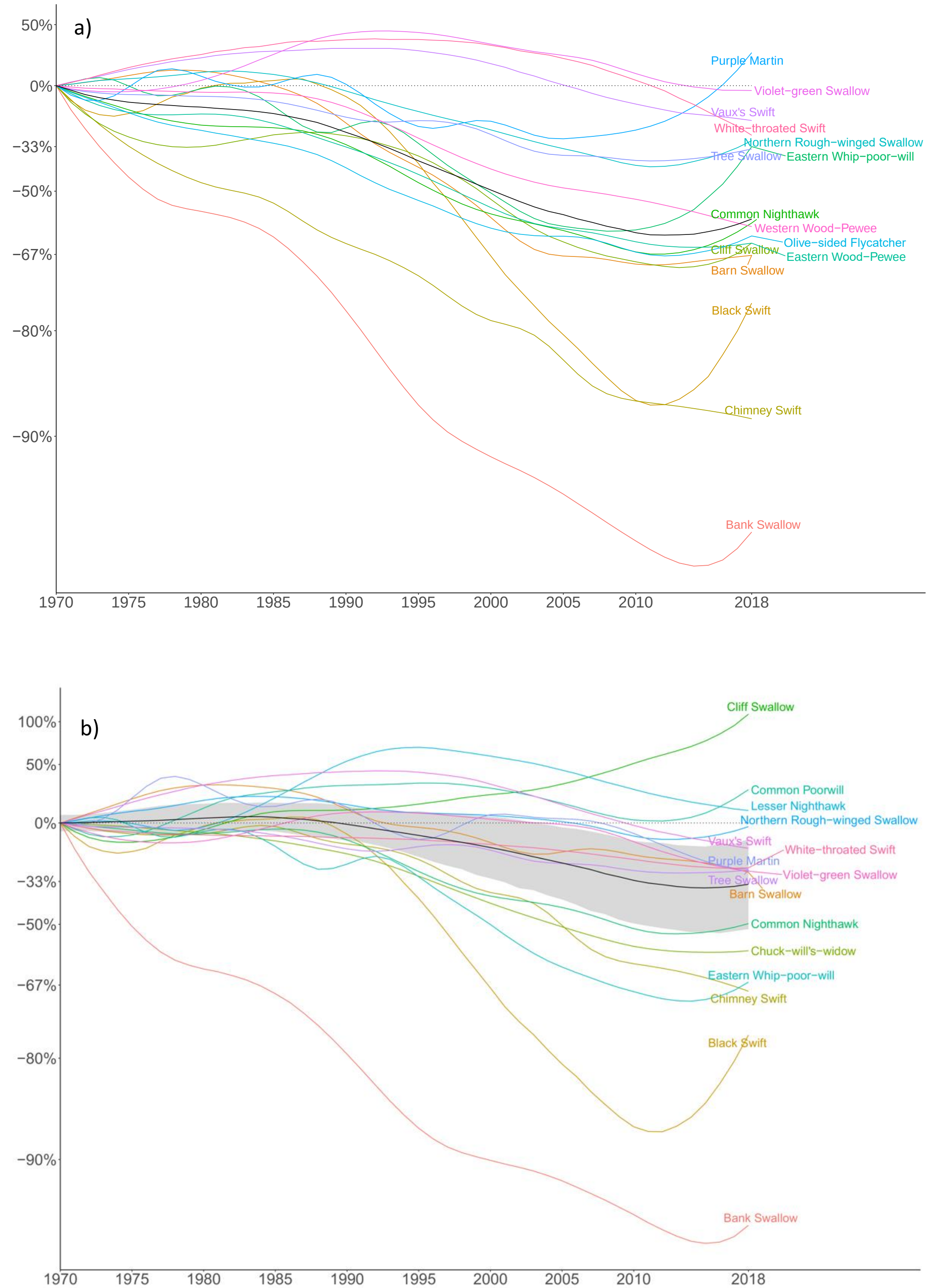
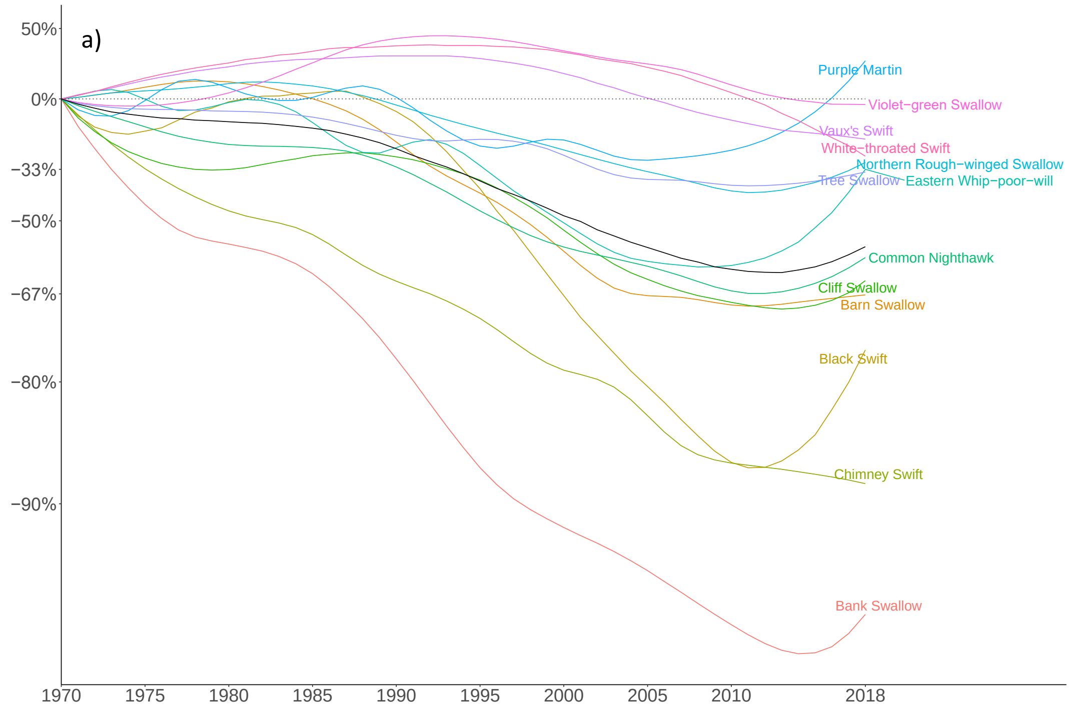


Figure 1. ‘Spaghetti’ plot for the guild of aerial insectivores (excluding Cave Swallows) in a) Canada and b) North America from 1970 to 2018. Shown is the composite trajectory (State of Birds indicator line) in black with +/- 95% credible interval in grey. Color lines show the species-level patterns within the indicator. Figure courtesy of Adam Smith (CWS).



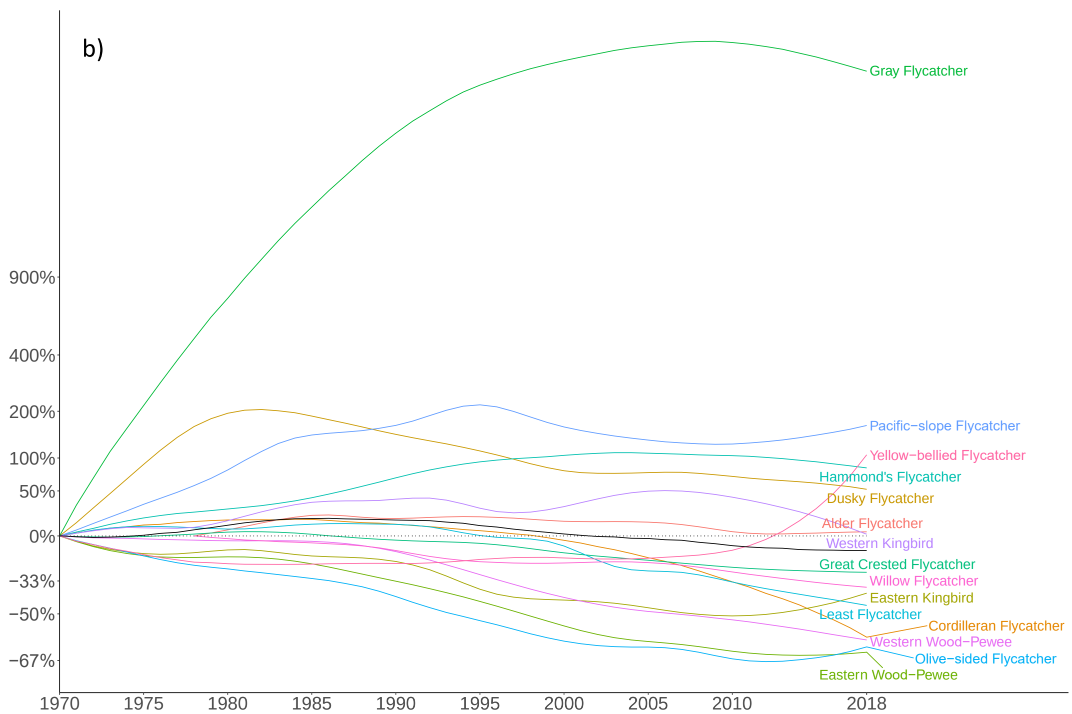
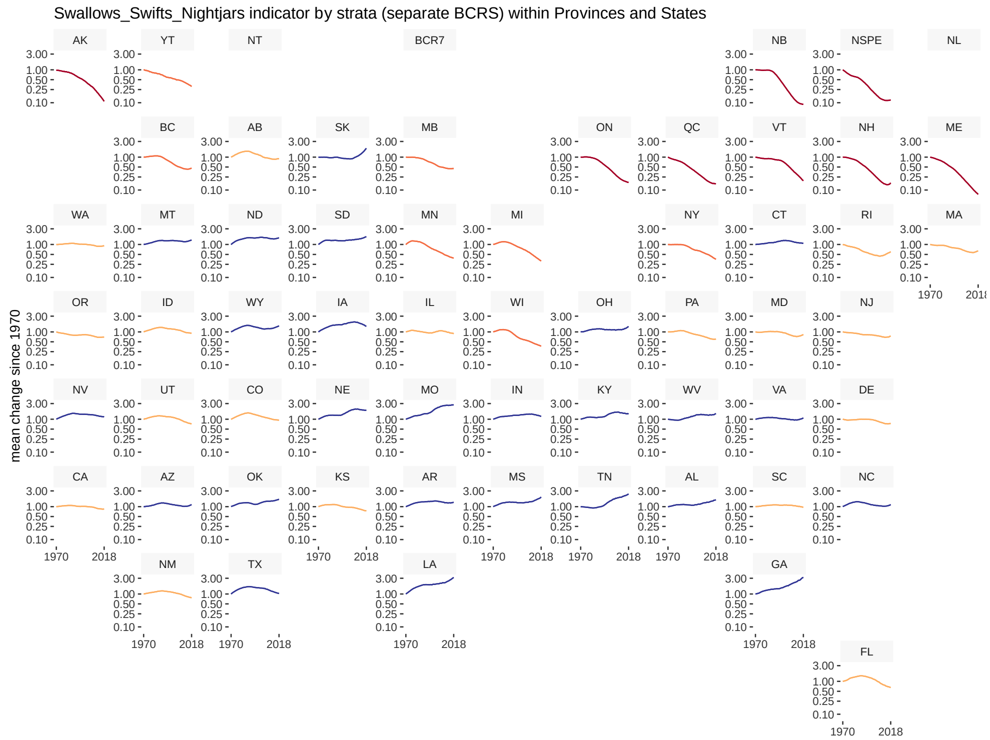


Figure 2. 'Spaghetti' plot for a) swallows, swifts, and nightjars (excluding Cave Swallows) and b) flycatchers in Canada from 1970 to 2018. Shown is the composite trajectory (State of Birds indicator line) in black with +/- 95% credible interval in grey. Color lines show the species-level patterns within the indicator. Figure courtesy of Adam Smith (CWS).

a)



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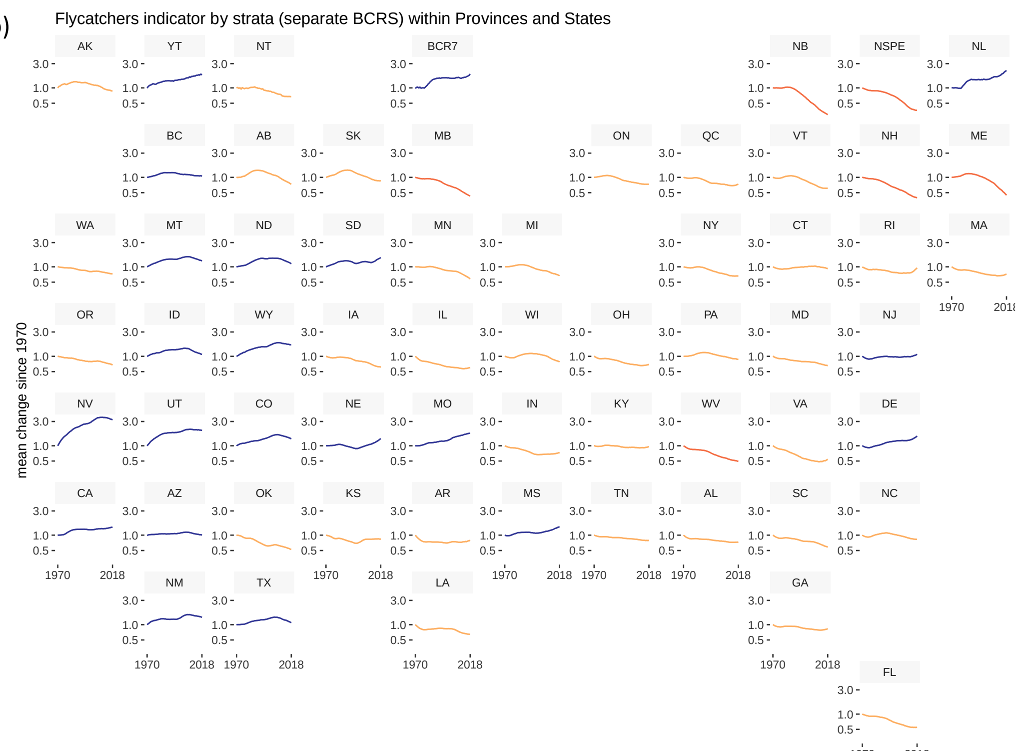

Figure 3. Geographic variation in population trends by province or state for a) swallows, swifts, and nightjars (excluding Cave Swallows) and b) flycatchers from 1970 to 2018. Color continuum from red (largest decreases since 1970) to orange to blue (largest increases since 1970). Figure courtesy of Adam Smith (CWS).

4. Overview of Research Progress on Aerial Insectivores in North America since 2012

4.1. High priority research recommendations from the 2012 Aerial Insectivore workshop

The 2012 aerial insectivore research workshop report (Calvert 2012) identified several hypotheses as potential drivers of aerial insectivore declines (Appendix 6) and listed 9 recommendations for high priority research to better understand aerial insectivore population trends in North America. These recommendations are listed below, with an indication (**yes/no**) if research progress has been made, and key references if available (see also Tables 1-5).

- **Improve understanding of migratory connectivity and non-breeding habitats**
    - **Yes**, most research is on Tree, Barn, Bank and Cliff Swallows, see García-Pérez & Hobson 2014, Hobson et al 2015, Fraser et al 2017, Knight et al 2018, Imlay et al 2018a, Knight et al 2019, but there are a few studies on nightjars, see English et al 2017a, Ng et al 2019, Knight et al in review.

- **Examine population trends across spatial scales with various analytical methods**
    - **Yes**, population trends for aerial insectivore species have been modelled (Smith et al 2015) and new modelling approaches provide information on geographic variation in population trends, see Smith and Edwards (2020) and Section 3.

- **Evaluate evidence for long-term declines in aerial insect abundance**
    - **Yes**, research is currently underway, for instance, Dunn et al (unpublished) using long-term data collected at Tree Swallow research sites, as well as a new study using malaise taps across North America (see section 4.2.5).

- **Improve estimates of survivorship and dispersal of adult and juvenile birds**
    - **Yes**, research conducted only on Tree and Barn Swallows, see García-Pérez et al 2014, Weegman et al 2017, Clark et al 2018, Cox et al 2018, Taylor et al 2018, Boynton et al 2020, Evans et al 2020.

- **Investigate correlations in spatial and temporal patterns of declines across species**
    - **Yes**, research by Michel et al (2016) for five aerial insectivore species show that declines are not synchronous across North America.

- **Assess impacts across wintering habitats through an overlay of distribution maps**
    - **No**

- **Locate and assess key roosting and congregation sites used during non-breeding**
    - **Yes**, one study on Purple Martins identified key roosting sites at winter locations using fine-scale global positioning (gps) units, see Fraser et al 2017.

- **Develop a detailed life-cycle population model for Tree Swallows**
  - **Yes**, population models for Tree Swallows from several population have been developed, see Weegman et al 2017, Cox et al 2018, Taylor et al 2018. A population model for Barn Swallows is currently being developed, see Wilson et al in prep.

- **Establish a comparative demographic study between Tree and Barn Swallows**
  - **Yes**, comparative studies between Tree, Barn and other swallows have been conducted, see Imlay et al 2017, Imlay et al 2018a,b, Boynton et al in review.

Substantial research progress has been made on aerial insectivores in North America since the 2012 workshop (also see Tables 1-5), with most high priority recommendations receiving at least some research attention. However, most of the research has been conducted on swallows and we still lack population modelling for species of swift, nightjar, and flycatcher, as well as fundamental information about migratory routes and the non-breeding period, such as locations of wintering and key roosting sites, migratory connectivity, and potential changes in habitat conditions at these sites; these remain research priorities (see section 6).

4.2. Presentation summaries of current state of knowledge of aerial insectivores and insects

Several researchers gave oral presentations to update participants on the current state of knowledge for each of the aerial insectivore groups: swallows, swifts, nightjars, flycatchers, as well as insects. Highlights from these presentations are summarized below and in Tables 1-4.

4.2.1. The Swallows (overview from Tara Imlay)

Studies in Tree Swallows have shown that populations across North America are likely currently limited by juvenile survival and recruitment, and female survival (Weegman et al 2019, Cox et al 2018, Taylor et al 2018) then by breeding productivity (Imlay et al 2018b, but see Cox et al 2020; Table 1). However, the extent to which other swallow species are limited by the same processes is not clear. A population model, presented by Scott Wilson at the workshop for Barn Swallows similarly suggests that population fluctuations are driven by adult female survival and offspring recruitment rather than breeding productivity (Wilson et al. In prep), but more research on the other swallow species is needed.

Evidence from studies examining the effect of food availability, i.e., abundance and quality, on swallow populations are mixed. The abundance of insects measured at some Tree Swallow study sites does not appear to be declining (also Section 4.2.5). Additionally, there is mixed evidence showing that insect abundance affects nestling quality or fledging success (Table 5; Imlay et al 2017, McClenaghan et al 2019a; Berzins et al in prep). Recently, the nutritional content of aquatic versus terrestrial insects was shown to differ (Section 4.2.5), with aquatic insects being more nutritious (i.e. higher quality) given their greater content of long-chain omega-3 polyunsaturated fatty acid (Twining et al 2016). Studies on Tree Swallows have shown the importance of wetlands in agricultural landscapes (Michelson et al 2018; Elgin et al in press) and that aquatic insects improve nestling development and breeding success (Twining et al 2018). Whether aquatic insects are beneficial to other swallow species, for instance Barn Swallows which depend less on wetlands for foraging, is undetermined.

Habitat quality, including level of agricultural intensification and environmental contaminants, have mixed effects on aerial insect abundance and swallow breeding success (Table 5). Generally intensive cropping negatively affects the abundance of insects, especially later in the season (Rioux Paquette et al 2013), as well as the availably of prey (Bellavance et al 2018), and Tree Swallow breeding success (Ghilain & Bélisle 2008), but instances of positive effects on nestling quality and post-fledging habitat use in Barn Swallows have also been documented (Boynton et al 2020; Kusack et al 2020). Environmental contaminants, such as pesticides (eg. neonicotinoids) and toxic metals have been detected in insects and food bolus samples of tree swallows (Haroune et al 2015); although to date, no effect has been detected on nestling quality (Beck et al 2015; Elgin 2019). Effects of contaminants on breeding success and population trends in North America remain unknown.

Local weather conditions, such as temperature and precipitation, at the breeding sites appear to be more important for adult survival and fledging success than continental climate, at least in Tree Swallows (Table 1; Weegman et al 2017; Clark et al 2018). There is some evidence that survival of adult Barn Swallows is related to continental climate, but effects may vary spatially (García-Pérez et al 2014). Nevertheless, only one study has reported long-term deterioration of local weather conditions (i.e. fewer days without rain and warm weather during the nestling period) coinciding with lower fledging success in a declining tree swallow population in Ontario (Cox et al 2020). More research is needed to understand climatic conditions on migration routes and wintering grounds and how they influence survival and population dynamics of swallow species.

Less is known about non-breeding periods of the annual cycle (Table 1). Wintering locations have recently been identified for a few swallow species and populations, but information is lacking on changes in habitat quality occurring at these areas. Tree Swallows and Purple Martins appear to use multiple winter areas with movements between areas driven by food resources and competition, but it is unknown if all swallow species make large movements during the non-breeding period. Key knowledge gaps for swallows are post-fledging survival, stopover and roost sites, as well as timing of migration and routes and wintering areas used by different populations.

4.2.2. The Swifts (overview from Joe Nocera)

There is very little research published for North American swifts, with fewer than 30 publications between 2012 and March 2020. Much of the basic ecology and the potential drivers of population declines are unknown (Tables 2 and Table 5). Only a few hypothesized drivers of declines in swifts, including limited breeding and roosting habitats, or changes in food availability have been tested, and only in Chimney and Vaux's Swifts. In Chimney Swifts, there is no support for the breeding habitat-loss hypothesis, as not all suitable chimneys are occupied (Fitzgerald et al 2014). Further research is needed to determine if roost sites are limiting populations. Evidence from stable isotopes collected from guano of Chimney and Vaux's Swifts suggest that the quality of insect prey has declined over the past 26-48 years (Nocera et al 2012; Pomfret et al 2012). For Vaux's Swifts, quality of insect prey is negatively correlated with BBS population estimates, suggesting a possible mechanism for declines (Pomfret et al 2012). Very little is known about the non-breeding season, including migratory routes, stopover sites and wintering locations (Table 2). Overall, more research on this group is needed, as aspects of their basic ecology are unknown (Table 2). Comparative studies on the drivers of population fluctuations between stable and declining populations would prove valuable.

4.2.3. The Nightjars (overview from Mark Brigham)

New survey methods occurring at night when nightjars are active have improved estimates of their population abundance, and while they are more abundant than previously thought, this group is still experiencing declines. There is relatively little information on the basic ecology of nightjars, with all research coming from studies on Common Nighthawks and Eastern Whip-poor-wills (Table 3). Very little is known about the non-breeding season (Table 3) but wintering locations have been identified (English et al 2017a; Ng et al 2018, Knight et al in review). Recent work showing low connectivity between the breeding and wintering areas for 12 common nighthawk populations suggests populations may be limited by factors occurring at breeding sites, spring stopover sites in northern South America, or when crossing the Gulf of Mexico (Knight et al in review).

Other recent research shows higher abundance or occupancy of sites by Common Nighthawks and Eastern Whip-poor-wills in early succession open-canopy forest and wetlands (Table 3; English et al 2017b; Farrell et al 2019), but they have similar preference for burned forest stands and clear cuts (Farrell et al 2017). The abundance and reproduction of Eastern Whip-poor-wills is positively related to moth abundance (English et al 2017b; English et al 2018b), but stable isotopes from claw and feather samples of museum samples from 1880 to 2005 and birds breeding from 2011-2013 indicate a dietary shift towards lower tropic level prey (English et al 2018a).

4.2.4. The Flycatchers (overview from Junior Tremblay)

There is very little research on the basic breeding and non-nonbreeding ecology of many flycatcher species in North America (Table 4), despite the fact that some species are experiencing declines and are listed as Species-at-Risk (e.g., Acadian Flycatcher, Olive-sided Flycatcher and Eastern Wood Pewee). Recent research focusing on Olive-sided Flycatchers breeding in managed boreal forests documented low nesting success due to predation and extreme weather conditions (Anctil et al 2017). However, it is unknown whether breeding success of Olive-sided Flycatchers has declined over the last several decades. A recent paper by Cadieux et al (2020) modelled future population abundances of several flycatcher species and showed variable changes in population abundance under different forest harvest and climate change scenarios. During the non-breeding season, threats experienced by flycatchers are unknown (Table 4, Table 5), but winter habitat of Acadian Flycatcher, Western Wood Pewee, Olive-sided Flycatcher, and Great Crested Flycatcher, identified using eBird count data, coincided with mining operations in Colombia, Ecuador, and Peru suggesting possible loss of habitat at wintering areas.

4.2.5. Insects (overview from Peter Dunn and Cornelia Twining)

Evidence in Germany, and Europe more generally, suggests that insects may be declining (Hallman et al 2017), but there is little comprehensive spatial or temporal information about aerial insect abundance and biomass in North America (Table 5). Preliminary analyses from a new ongoing study across North American standardized using malaise traps (led by Peter Dunn) suggest high variation in total insect biomass, though it does not appear to be lower in the east than west. Unpublished data from long-term Tree Swallow study sites (US: New York, Wisconsin; Canada: Ontario, Saskatchewan, British Columbia) suggests that insect abundance has not declined since 1975, nor is it lower in the east where swallows are more steeply declining. However, these estimates are based on different sampling methods (tow-nets, suction traps, etc), and only total biomass (mass of aquatic and terrestrial orders combined), but it is unclear if certain key taxa such as aquatic species, which are important for Tree Swallow breeding success (Twining et al 2018), are less abundant.

Long-term studies from the Cornell Ponds in New York show that the hatching of Tree Swallow nestlings occurs when the peak of aquatic insects occurs, and not the peak of terrestrial or total insects (Twining et al 2018). Additionally, higher aquatic insect biomass during the nestling period is associated with increased nestling body mass and fledging success, but no such effects were found for terrestrial or total insect biomass (Twining et al 2018). Laboratory studies showed that aquatic insects are more nutritious to nestling Tree Swallows than terrestrial insects, containing greater content of long-chain omega-3 polyunsaturated fatty acid (LCPUFA: Twining et al 2016). A 2x2 experimental design that varied the quality (high or low LCPUFA) and quantity (high or low) of diet confirmed the quality and not quantity of food fed to nestling Tree Swallows influenced their growth (Twinning et al 2016). Nestlings fed high LCPUFA diets during growth were heavier than nestlings fed diets low in LCPUFA or a high quantity of food (Twinning et al 2016). Therefore, Tree Swallows (possibly other species) benefit from obtaining LCPUFA from aquatic insect resources that emerge from freshwaters. Further research exploring these patterns in other aerial insectivore species similarly associated with wetlands and those with more terrestrial diets would determine how generalizable this is across the guild.

4.3. Synthesis of Current Knowledge on Aerial Insectivores in North America

As noted in sections 4.1 and 4.2, a substantial amount of research has been conducted on aerial insectivores since the workshop in 2012. To help identify research priorities for groups and species, information from the literature was synthesized and is presented in Tables 1-4. These tables are intended to provide an overview of what is known about the ecology of species in each of the four main groups of aerial insectivores, identify major gaps in our understanding of their ecology, and help identify priorities for future research. Overall, the information summarized in Tables 1-4 clearly shows that we still have a poor understanding of the basic ecology for many species, with most groups having only have information for a few (1-2) species and populations. Aside from swallows, we know very little about the non-breeding season, including migratory routes and stopover sites, roost sites, and wintering locations, as well as wintering site fidelity, migratory connectivity, and carry over effects. Ultimately, we need effective monitoring of species to understand their demography, research focused on more aerial insectivore species during key life stages, and an improved understanding of full annual cycle ecology and survival to facilitate where and how to focus conversation actions.

4.3.1. Current State of Knowledge for the Swallows

Summarized in Table 1 is the current state of knowledge of the basic ecology of swallows, with an indication of the species for which the information is known, as well as key references.

Table 1. Summary of the Current State of Knowledge of the Swallows[a].

	Knowledge	Species	Key references
Population trend	-Decline, but population declines are not synchronous across North America.	TRES, BARS, PUMA, NRSW	Michel et al 2016
Demography			
Population model	-Demographic rates appear to be limited by adult survival (especially females), juvenile survival and recruitment, and immigration. Population specific.	TRES	Weegman et al 2017, Cox et al 2018 Taylor et al 2018, Cox et al 2020
Breeding productivity	-Breeding success is unchanged or not limiting in declining or stable populations. -However, one declining TRES population shows long-term declines in fledging success. -BANS (1 population) has smaller clutches and broods, and lower nestling survival in recent years.	TRES, BARS, BANS, CLSW	Rioux Paquette et al 2014, Imlay et al 2018b, Taylor et al 2018, but see Cox et al 2018, 2020
Adult survival	-Estimates of apparent survival of TRES range from 30 to 60% and BARS range from 34 to 64%. Annual variation and population specific. -No strong association in 7 TRES populations across North America between putative wintering location and survival.	TRES, BARS, BANS, CLSW, PUMA	García-Pérez et al 2014, Clark et al 2018, Taylor et al 2018, Imlay & Leonard 2019

	-Little evidence for factors influencing adult survival, but weather conditions (see below) and pond abundance in the prairies are likely important.		
Juvenile survival	-Estimates of post-fledging survival range from 42-44%, and recruitment probability is lower 5-6%. Population specific.	TRES, BARS	Weegman et al 2017, Taylor et al 2018, Boynton et al 2020, Evans et al 2020
Adult site fidelity			
Breeding	-High, but higher in males.	TRES	Winkler et al. 2004, Clark et al 2018
Wintering	-Possibly high for BARS, but not BANS and CLSW. -Feather samples from large group of BARS across North America showed consistent over wintering in south-central South America. -Limited evidence from feather samples in eastern populations of BARS showed high repeatability in probable wintering habitat.	BARS, BANS, CLSW	Hobson & Kardynal 2015, Imlay et al 2018a
Diet	-Diet of TRES and BARS is flexible. -Annual, seasonal, and nest-level variation. -TRES diet is mostly comprised of Dipterans. -Consists of terrestrial and aquatic insects. -Evidence that aquatic insects are more nutritious given the higher content of omga-3 highly unsaturated fatty acids. -VGSW diet found to be similar to TRES breeding at the same study area -Mainly Diptera and Hemiptera. -Samples from BARS from July to September consisted of Hymenoptera (40%), Diptera (31%), Hemiptera (15%) and Coleoptera (12%) of intermediate size. -BARS shift diets in some agricultural areas after oil-seed rape harvest from oil-seed rape pests to other aerial insect species. -Energetic model estimates that PUMA eat 412 (± 104) billion insect/year, which equates to 115,860 (± 29,192) metric tonnes per year. -Breeding season estimate is 36,000 insects per km^3.	TRES, BARS, VGSW, PUMA	Kelly et al 2013, Garlick et al 2014, Orłowski et al 2014, Law et al 2017, Bellavance et al 2018, Michelson et al 2018, Twining et al 2018, Godwin et al 2019, McClenaghan et al 2019b
Breeding season habitat			
Nest sites	- Some species build nests, others use secondary cavities or human-made structures, such as boxes and barns. -Social cues do not increase use of shed-like structures for nesting BARS . -Newer infrastructure, such metal roofs on barns lead to over-heating and lower reproductive success for CLSW.	BARS, CLSW	Campomizzi et al 2019, Imlay et al 2019b
Roost sites	-Use of nocturnal roosts away from the colony is common, limited by local weather conditions and thermoregulatory needs of nestlings. -Possibly to avoid predation. -Locations are wetlands and marches within in the proximity of the breeding colony.	BANS, PUMA	Falconer et al 2016, Saldanha et al 2019
Post-fledging habitat	-In agricultural areas in British Columbia, crop habitats are more frequently used by juveniles.	BARS	Boynton et al. 2020

Non-breeding habitats	-Visited between mid-September to mid-April. -Breeding latitude influences timing of migration to non-breeding sites and departure to breeding sites. -Limited evidence from 33 repeated tracked PUMA showed high individual variability in timing in timing of migration.	TRES, PUMA	Knight et al 2018, Fraser et al 2019, Gow et al 2019a
Migratory routes and Stopovers	-TRES: 3 migratory flyways used for 12 populations across North America: western, central and eastern. -BARS (5 populations across North America): swallows from Washington state migrated down the Pacific Coast; Saskatchewan swallows mostly migrated through the Great Plains towards Central America; eastern swallows from Ontario, New Brunswick and Alabama migrated directly south or along the east coast of the US through Florida and the Caribbean Islands to South America (eastern birds migrate further than birds in west). - BANS (1 population in northeastern North America): most travel along Atlantic coast, with some using an inland route. -PUMA (6 populations across North America): stopover locations were on the eastern coast of the Yucatan Peninsula, Honduras, and Nicaragua. -Stopover duration was related to the breeding latitude of the population, but not habitat quality. -TRES, BARS, BANS and CLSW undertake migratory movements during the day, and BANS likely forage while migrating.	TRES, BARS, BANS, CLSW, PUMA	Hobson et al 2015, Van Loon et al 2017, Knight et al 2018, Imlay & Taylor 2020, Imlay et al 2020
Roost sites	-Swallows roost communally during migration forming large aggregations, TRES and PUMA that can be identified using weather surveillance and radar — early in the morning before sunrise they appear as ring ('roost-ring'). <u>Late summer/early fall</u> -TRES use wetland reed beds (*Typha or Phragmites*) or sugarcane fields in southeastern Louisiana to roost. - PUMA: -radar throughout North America in fall showed preference for cropland to roost, although a variety of habitat types less often used, such as forest, urban, and water. -12 populations tracked with GPS showed fall and spring roosts in patches of forest surrounded by unsuitable habitat, i.e., 'forest islands', possibly to reduce predation during migration, followed by agricultural land, few associated with urban areas. <u>Winter</u> -Wintering roost sites occur on small habitat islands containing water in Brazil (Amazon Basin). -Few winter roost sites identified occurred in protected areas.	TRES, PUMA	Laughlin et al 2013, Bridge et al 2016, Laughlin et al 2016, Fraser et al 2017, Kelly & Pletschet 2018, Chilson et al 2019, Fournier et al 2019

Wintering sites	-Some individuals use multiple non-breeding sites. -TRES (12 populations across North America): 3 wintering locations- western Mexico (western flyway), Gulf of Mexico (central flyway), and Florida and the Caribbean (eastern flyway). -BARS (5 populations across North America): western population winter in Central America and northwestern South America (Mexico, Guatemala, Honduras, Panama, northwestern Columbia) and eastern populations winter in central South America (Bolivia, Brazil, Argentina). -BANS, CLSW (1 population in northeastern North America): probable areas are central and southern South America (the Cerrado, La Plata Basin, and the Pampas). -PUMA (7 population across North America): Brazil. -Majority of PUMA tracked were found in northern Brazil near the Amazon River. Mostly in the forest, not in the agricultural areas of southern Brazil.	TRES, BARS, BANS, CLSW, PUMA	Fraser et al 2012, Hobson et al 2015, Fraser et al 2017, Knight et al 2018, Imlay et al 2018a, Knight et al 2019
Movements	-Multiple movements made during non-breeding season. -Movement driven by food resources and competition.	TRES, BANS, CLSW, PUMA	Stutchbury et al 2016, Fraser et al 2017, Imlay et al 2018a, Knight et al 2019
Migratory connectivity	-Weak. -But, for BARS, migratory divide largely between east and west breeding populations.	TRES, BARS, BANS, CLSW, PUMA	Fraser et al 2012, García-Pérez & Hobson 2014, García-Pérez et al 2014, Hobson et al 2015, Fraser et al 2017, Imlay et al 2018a, Knight et al 2018
Carry over effects (from non-breeding)	-Carry over effects reported for body condition, breeding phenology, and fledging production. -Effects are species-, sex-, and flyway-specific. -Long-term study in a Quebec population of TRES reported a decline in body condition not associated with breeding site quality, suggesting a carryover effect from the non-breeding period.	TRES, BARS, BANS, CLSW	Rioux Paquette et al 2014, Gow et al 2019b, Imlay et al 2019a
Climate variability and change	-Warmer temperatures and declining windiness have led to advances in laying dates in TRES, BARS, CLSW, and PUMA. -Associated with increased breeding success in TRES, BARS, PUMA, or no change in breeding success in CLSW. -BANS have not advanced their laying date and also have lower breeding success. -Local weather conditions during breeding season (e.g. cold, wind, rain), negatively affect abundance/availability of insects, fledging success, and adult and nestling survival. -Nestling body mass is lower following rainy conditions and nestlings have reduced survival during cold snaps. -Population specific.	TRES, BARS, BANS, CLSW	Dunn et al 2011, Winkler et al 2013, García-Pérez et al 2014, Beck et al 2015, Bourret et al 2015, Irons et al 2017, Weegman et al 2017, Clark et al 2018, Imlay et al 2018a, Cox et al 2019, Griebel & Dawson 2019, Imlay et al 2019a, Godwin et al 2019, Shave et al 2019, Cox et al 2020

	-In a declining population of TRES in Ontario, increased rain and decreased good weather days led to lower fledging success over a 43-year period, but El Niño Southern Oscillation (ENSO) which was linked to juvenile survival was unchanged over the same period. -Local weather is more important for TRES survival and fledging success than continental climate. -Continental climate during breeding and non-breeding seasons appear to have little influence on TRES population demography. -Winter North Atlantic Oscillation (NAO) has population specific effects on adult survival. -Continental climate, e.g., ENSO and NAO, has population specific effect on survival of adult BARS.		

[a]Species abbreviations TRES = Tree Swallow, BARS = Barn Swallow, BARNS = Bank Swallow, CLSW = Cliff Swallow, VGSW = Violet-green Swallow, NRSW = Northern Rough-winged Swallow, PUMA = Purple Martin.

4.3.2. Current State of Knowledge for the Swifts

Summarized in Table 2 is the current state of knowledge of the basic ecology of the swifts, with an indication of the species for which the information is known, as well as key references.

Table 2. Summary of the Current State of Knowledge of the Swifts[a].

Ecology	Knowledge	Species	Key references
Population trend	-Decline — range-wide for CHSW, specially populations in the northern part of the range.	CHSW	Nebel et al 2010, Michel et al 2016
Demography			
Population model	-Unknown.		
Breeding productivity	-Clutch size = 4-5 eggs. Lacking info on hatching and fledging success.	CHSW	Fischer 1958, Dexter 1981, Peck & James 1983
Adult survival	-Average male lifespan = 5.5 year, females = 4.8 year. -Annual mortality rates of adults estimated at 37%.		Fischer 1958, Dexter 1969, Henry 1972
Juvenile survival	-Body mass is directly related to survival.	CHSW	Goodpaster & Ritchison 2014
Adult site fidelity			
Breeding	-High for BLSW. For CHSW, strong fidelity to breeding site. In Ohio, 96% of those that returned and nested with the same mate used the same nest site (chimney).	BLSW	Dexter 1992, Leveque 2015
Wintering	-Unknown.		
Diet	-Forage on a wide variety of insect taxa and species-specific preference for prey size. -In Colorado, diet mainly consisted of Hemiptera, Ephemeroptera, Hymenoptera, and Diptera. -In Venezuela, diet was mainly comprised of Diptera and Hymenoptera, and spider. -Guano samples suggest a shift from Coleoptera to Hemiptera diet of VASW and CHSW over the last 26-48 years. -Possibly due to DDT altering the structure of insect communities.	VASW, CHSW, BLSW, GRSW	Nocera et al 2012, Pomfret et al 2014, Collins 2015
Breeding season habitat			
Nesting	-Some species nest in human-made structures, such as wells, silos, barns and old masonry chimneys, but may use tree cavities. -CHSW not limited loss of chimneys as nesting habitat. -Chimney occupancy is not influenced by minimum temperature, but is negatively to maximum and mean temperatures suggesting preference for cooler chimneys. -2 BLSW active nests found in southern BC at a creek and waterfall. -Study in Colorado measuring nest microclimate indicated nests of cool temperature and high humidity.	CHSW, BLSW	Finity & Nocera 2012, Gunn et al 2012, Wheeler 2013, Fitzgerald et al 2014, Levesque & Rock 2017, le Roux et al 2019

Roost sites	-Roosts in human-made structures, such as such as wells, silos, barns and old masonry chimneys, but also tree cavities found in several types of deciduous and coniferous trees. -CHSW form clusters in chimney roosts during warm temperatures, possibly to lower energy costs. -Regular roost switching, even in breeding season.	CHSW	Zanchetta et al 2014, Farquhar et al 2018, le Roux & Nocera in Review
Non-breeding habitat			
Migratory routes and Stopovers	-Roosting chimneys, located predominantly in urban and suburban areas, are important during migration. Some roosts used on an annual basis, both spring and fall.		Coffey 1936, Calhoun & Dickinson 1942, Lowery 1943, Bowman 1952
Roost sites	-Spring roost sites identified on Vancouver Island, British Columbia. -Overwinters in open terrain but found roosting in chimneys, churches, and caves. -Peak in migratory usage highest in spring.	VASW	Fjeldså & Krabbe 1990, Farquhar 2018, Smith et al 2019
Wintering locations	-BLSW (1 population, n = 3) -from Colorado to western Brazil. -Visited between mid-September and late-May. -Habitat -closed to open broadleaved evergreen or semi-deciduous forest. -Isotopic signatures from VASW at a spring roost site in British Columbia suggest 2-3 wintering locations or habitat types. -Overwinters in open terrain but found roosting in chimneys, churches, and caves. Occupies the low strata in mixed-species flocks.	VASW, BLSW	Fjeldså and Krabbe 1990, Marin 1993 Beason et al 2012, Reudink et al 2015
Movements	-Unknown.		
Migratory connectivity	-Weak, but depends on clusters analyzed.	VASW	Smith et al 2019
Carry over effects (from non-breeding)	-Unknown.		
Climate variability and change	-Unknown.		

[a]Species abbreviations CHSW = Chimney Swift, BLSW = Black Swift, VASW = Vaux's Swift, GRSW = Grey-rumped Swift.

4.3.3. Current State of Knowledge for the Nightjars

Summarized in Table 3 is the current state of knowledge of the basic ecology of the nightjars, with an indication of the species for which the information is known, as well as key references.

Table 3. Summary of the Current State of Knowledge of the Nightjars[a].

Ecology	Knowledge	Species	Key references
Population trend	-Decline. Some species declines are across the range, while others are only declining in the northern part of their range (EWPW).	EWPW	COSEWIC 2009, English et al 2017b
Demography			
Population model	-Unknown.		
Breeding productivity	-Nest survival in northern Alberta is ~75%.	CONI	Knight unpublished
Adult survival	-Return rate of males 63% (n = 19).	EWPW	English et al 2017a
Juvenile survival	-Unknown.		
Adult site fidelity			
Breeding	-High.	CONI, EWPW	English et al 2017a, Ng et al 2018,
Wintering	-Limited evidence from 3 EWPW males tracked for two years suggests wintering site fidelity is high.	EWPW	English et al 2017a,
Breeding season diet	- CONI diet in the boreal forest is mostly comprised of Coleoptera. - EWPW diet is mainly moth and beetles. -EWPW abundance and reproduction is positively related to moth abundance. -Museum samples suggest long-term dietary changes in EWPW (i.e., feeding on insects from lower trophic levels than in the past).	CONI, EWPW	English et al 2017b, English et al 2018a, Knight et al 2018
Breeding season habitat			
Nesting	-Nests in open-canopy forests and also man-made structures, such as pebble rooftops. -Well-drained soils/surfaces (i.e., mineral soils or bedrock) and bare ground appears to be an important nest site characteristic across the family. Breeding ground occurrence -Abundance is positively associated with forest area and fragmentation —open-canopy early succession forests and forest edges are preferred. -Abundance is negatively related to amount of urban area. -Site occupancy is positively related to influenced by the proportion and amount of open wetland in the surrounding landscape. -EWPW have similar preference for natural and managed open sites providing early successional habitat, such as burned stands, clear cuts, and open wetlands. -Suggests clearcuts and fire may increase abundance or occupancy of EWPW. -Occupancy is not influenced by the amount of clearcut in surrounding landscape.	CONI, EWPW	Tozer et al 2014, Akresh & King 2016, English et al 2017b, Farrell et al 2017, Farrell et al 2019, Knight unpublished,

	-CONI negatively related to agricultural cover in multiple analyses from different datasets. -In the boreal, presence strongly predicted by jack pine forest, fire, and clearcuts, and soil moisture is important. -Probability of occupancy declines with time since disturbance for both forest fires and clearcuts.		
Roost sites	-Roost sites in western Massachusetts were located in managed shrublands, such as scrub oak barrens and heavily thinned stands on pine.	EWPW	Akresh & King 2016
Post-fledging habitat	-Unknown.		
Non-breeding habitat	-CONI: Visited from early and mid-November to mid-March. -EWPW: Ontario -visited from mid-November to mid-March; Ohio -visited early October to late-March.	CONI, EWPW	English et al 2017a Ng et al 2018
Migratory routes and Stopovers	-CONI -Loop migration. -1 population migrated from northern Manitoba through Florida, across the Gulf of Mexico, and to South America via Ecuador, Columbia, or Venezuela and then east to Brazil. -12 populations across North America shared migration route towards central/Mississippi flyway and across the Gulf of Mexico to Brazil. -EWPW (7 individuals) mostly migrated at night, and avoided crossing the Gulf of Mexico as it required flying during daylight. -EWPW (4 populations): migrate from central Ontario to the north coast of the Gulf of Mexico and then to the Gulf coast of Mexico, south western Mexico or Central America (note: females did not cross the Gulf (n=2)); leaf from migration with birds in northern part of the range migrating further than more southern birds.	CONI, EWPW	English et al 2017a, Ng et al 2018, Korpach et al 2019, Knight et al in review
Roost sites	-Winter roost sites in forest or open landscapes composed of cropland or grassland	CONI	Ng et al 2018
Wintering locations	-CONI (1 population + 12 populations): Brazil (the Cerrado and Amazon biome), but also as far south as northern Argentina. -EWPW (4 populations [Ontario, CA], 1 population [Ohio, USA]): from Texas to Costa Rica, most individuals located in central and southern Mexico -Habitat consisted of various amounts of forest, shrub, open and develop area.	CONI, EWPW	English et al 2017a, Ng et al 2018, Tonra et al 2019, Knight et al in review
Movements	-Unknown.		
Migratory connectivity	-Weak (12 populations).	CONI	Knight et al in review
Carry over effects (from non-breeding)	-Unknown.		
Climate variability and change	-Unknown.		

[a]Species abbreviations CONI = Common Nighthawk, EWPW = Easter Whip-poor-will.

4.3.4. Current State of Knowledge for the Flycatchers

Summarized in Table 4 is the current state of knowledge of the basic ecology of the flycatchers, with an indication of the species for which the information is known, as well as key references.

Table 4. Summary of the Current State of Knowledge of the Flycatchers[a].

Ecology	Knowledge	Species	Key references
Population trend	-Decline. Some species declines are higher in the east. - Decline of OLSF and YBFL in spruce-fir forests of the eastern United States (from point counts took place within the period from 1989 to 2013). -Decline of OSFL in San Juan Island National Historical Park and Lewis and Clark National Historical Park (from landbird point-count surveys from 2005 to 2016).	OSFL	Ralston et al 2015, ECCC 2017, Ray et al 2019
Demography			
Population model	-Unknown.		
Breeding productivity	-Unknown.		
Adult survival	-Unknown.		
Juvenile survival	-Unknown.		
Adult site fidelity			
Breeding	-Unknown.		
Wintering	-Unknown.		
Breeding season diet	-May forage on insects (i.e., pollinators) from flowering vegetation during inclement weather .	OSFL	Hagalin et al 2015
Breeding season habitat			
Nesting	-Nests on edges of predominantly coniferous forests and forested wetlands. -In the Maritimes, nests were found in *Picea mariana*, and population density was higher in tree stands dominated by *Picea* species (except *Picea glauca*) and lowest in areas dominated by *Pinus* species and deciduous trees. -Population density was negatively affected by anthropogenic disturbance and proximity to roads and was slightly higher in protected areas. -Nest box occupancy and reproductive success of ATFL in California, USA were fragmented habitats with less grassland. -Female OSFL preferred to forage from shorter perch trees than males, and females' perches were shorter than other available perch trees. -Song rate can be used as an indirect measurement of breeding status in the OSFL when using a hierarchical modeling approach. -Other studies agree that YBFL is one of the most ubiquitous species among the conifer- and wetland-dominated habitats of the boreal while OSFL had a clear association with lowland conifer embedded within landscapes containing high proportions of nonforest (i.e. cutover areas and shrub- or sedge-dominated wetlands).	OSFL, ATFL, YBFL	Robertson et al 2012, Milligan & Dickinson 2016, Anctil et al 2017, Westwood et al 2019, Upham-Mills et al 2020
Roost sites	-Unknown.		
Post-fledging habitat	-Unknown.		

Non-breeding habitat			
Migratory routes and Stopovers	-Unknown.		
Roost sites	-Unknown.		
Wintering locations	-Visited between early-November to mid-March -ALFL & WIFL: Argentina (rivers in Chaco region and forests of Yungas) -ACFL, OSFL, and GCFL present respectively 12.52, 10.70 and 0.55% of their Global population in mining concessions in the Northern Andes -Habitat: stands of palo bobo (*Tessaria integrifolia*) along the Río Bermejo and tributaries, associated with sparse shrubs of chila (*Baccharis salicifolia*) or less often with canebreake (*Gynerium sagittatum*). -OSFL: Central and South America (Brazil: Amazon, Cerrado, Atlantic forest; 61 sightings)	ALFL, WIFL, OSFL	Areta et al 2016, de Lima Pereira 2016, Rodewald et al 2019
Movements	-Unknown.		
Migratory connectivity	-Unknown.		
Carry over effects (from non-breeding)	-Unknown.		
Climate variability and change	-Nest failure is the most likely caused by adverse weather conditions	OSFL	Anctil et al 2017

[a]Species abbreviations OSFL = Oliver-sided Flycatcher, ATFL = Ash-throated Flycatcher, WIGL= Willow Flycatcher, YBFL = Yellow-bellied Flycatcher.

5. Evaluation of Hypothesized Threats to Aerial Insectivore Populations

Day 1 of the workshop, participants discussed hypothesized threats identified from the 2012 workshop (see Appendix 5). These were proposed to explain: (i) initial population declines (or spatial variation in population fluctuations) and (ii) persistently low populations (in some regions). Research conducted since the 2012 meeting was synthesized to determine whether the current evidence is sufficient to support any of the hypothesized threats to aerial insectivores. Provided below is a table summarizing the evidence for the hypothesized threats to aerial insectivores throughout the annual cycle. An indication of the likeliness of the hypothesis (Likely or Unlikely) and the certainty given the evidence (Certain or Uncertain) is provided. Threats that are 'Likely', but where the evidence to support or refute the hypothesis is 'Uncertain" should be considered top priorities for future research.

Table 5. Synthesis of hypothesized threats to aerial insectivores at each stage of the annual cycle[a]. For each threat, the evidence to support or refute the hypothesis has been summarized, if available. An indication of the likeliness of the hypothesis (Likely or Unlikely) and certainty (Certain or Uncertain) given the evidence is also provided. A full description of hypothesized threats identified at the 2012 aerial insectivore workshop are provided in Appendix 5.

Hypothesized threat	**Evidence to support or refute hypothesis throughout the annual cycle**		
	Breeding season	**Migration**	**Wintering grounds/movements**
Declines in aerial insect populations	**LIKELY/UNCERTAIN** -Global declines of insects reported (e.g., Sánchez-Bayo & Wyckhuys 2019, Wagner 2020), but see (Macgregor et al 2019). -Caution in certainty of declines given biased taxonomic sampling, methodological limitations, restricted geographic areas sampled, limited long-term studies, and habitat variation (Macgregor et al 2019, Didham et al 2020, Saunders et al 2020). -Most reports of insect declines from Europe (Powney et al 2019, Thomas et al 2019, Møller et al 2020). -Unclear if aerial insects are declining in North America. -Evidence for declines in aquatic-emergent insects (Stephanian et al 2020). -Evidence for changes in insect diet of EWPW & CHSW over the last century (Nocera et al 2012; English et al 2018a). -No evidence of long-term decline in insect biomass at several TRES study sites, nor is insect biomass lower in regions with steeper declines (Dunn et al unpublished data). -Intensification of agricultural practises negatively influences insect abundance (Rioux Paquette et al 2013) and Tree Swallow reproductive success (Ghilain & Bélisle 2008).	**LIKELY/UNCERTAIN** -Abundance and quality of insects prior to and during migration, and at stop over sites is unknown.	**LIKELY/UNCERTAIN** -Diet of few aerial insectivores is known at wintering location. -Unknown whether insect abundance or quality has changed over time.

	-Little evidence for phenological mismatch between insect emergence/ availability and reproduction in TRES, BARS, and CLSW, but possible in BANS (Imlay et al 2018b). -Mixed evidence in TRES and BARS on effects of insect quantity (abundance/biomass) on nestling quality (Harriman et al 2017, Imlay et al 2017, Berzins et al In prep) and breeding success (McClenaghan et al 2019a). -Strong evidence of insect quality (aquatic insects) on breeding success and nestling quality in TRES only (Twining et al 2016, 2018). -Stable isotope studies in EWPW and VASW samples suggest declines in abundance or quality of insects (Pomfret et al 2012, English et al 2018a). -Negatively correlated with population abundance in VASW. -Abundance and presence of EWPW is positively associated with the abundance of moths (English et al 2017b). -Survival of EWPW chicks is positively related to moth abundance (English et al 2018b). -Evidence that TRES and BARS have flexible diets (Michelson et al 2018; McClenaghan et al 2019b).		
Habitat loss/degradation	**LIKELY/UNCERTAIN** -Habitat loss continues (e.g., wetlands, older forests, natural cavities, and even urban habitats (rooftops)). -Some aerial insectivores with specific habitat requirements have lost or experience degraded habitat. -Other aerial insectivores use a wide variety of breeding habitats. -No evidence of nest site limitation for several species, even those with declining populations. -Suitable nest sites are unoccupied by populations of CHSW in Ontario (Fitzgerald et al 2014). -TRES unoccupied nest boxes present at sites with declining populations (e.g., Cox et al 2020). -Mixed evidence on the effect of agricultural intensification on TRES and BARS. -In an Ontario population of BARS, row-cropping agriculture had positive effect on body condition and number of young fledged (Kusack et al 2020). -In a British Columbia population of BARS, fledglings used crop habitat more frequently than pasture (Boynton et al 2020) and no effect of natal habitat type on breeding success (Boynton et al in review). -In a Quebec population of TRES, intensive cropping is associated with lower insect abundance (in some years), especially later in the season (Rioux Paquette et al 2013), altered availability of insect prey (Bellavance et al 2018), lower reproductive success (Ghilain & Bélisle 2008). -No evidence long-term decline in TRES body mass associated with intensive crop agricultural in a Quebec population of TRES (Rioux Paquette et al 2014). -In prairie population of TRES, intensive cropping is associated with lower adult and nestling body condition (Michelson et al 2018), higher food provisioning rates, but less time at the nest (Stanton et al 2016), and lower adult return rates (Stanton et al	**LIKELY/UNCERTAIN** -Habitat conversion and degradation may affect the quality of habitats used during migration. -Little knowledge of habitat needs for most aerial insectivores during migration. -No evidence that PUMA stopover duration was linked to habitat quality (Van Loon et al 2017).	**LIKELY/UNCERTAIN** -Habitat conversion and degradation in Central and South America may affect wintering habitat. -Wintering locations are not identified for many aerial insectivores (Table 1). -Declining populations of PUMA in the north part of the range were not more exposed to agricultural areas than stable populations in the south as most tracked birds were found in the forest near Amazon River, not in the agricultural areas in southern Brazil (Fraser et al. 2012). -But few winter roost sites occur in protect areas so could be susceptible to deforestation (Fraser et al 2017). -Abundance data for ACFL, OSFL, WEWP, and GCFL show overlap between mining concessions and non-breeding

	2017). -Loss of ponds (flooded wetland basins) in the prairies may negatively affect lifetime reproductive success, nestling quality, and adult survival and juvenile recruitment of TRES (Clark et al 2018, Berzins et al In review, Berzins et al in prep).		areas for declining species (Rodewald et al 2019).
Environmental contaminants	**LIKELY/UNCERTAIN** -Aerial insectivores are exposed to contaminants in the environment, sources included agriculture, wastewater treatment plants, coal plants, oil sands. Pesticides -Increased use of agricultural pesticides, such as neonicotinoids. -Neonicotinoids affect timing of aquatic insect emergence (Cavallaro et al 2019). -TRES nestling boluses frequently contain >1 agricultural pesticide (Haroune et al 2015) -No effect of neonicotinoid concentration on nestling quality (Elgin 2019). -Effects on agricultural pesticides on breeding success are unknown. -Unclear if agricultural pesticides influence insect diet quality. -But diets, at least in TRES and BARS, are diverse and flexible (Michelson et al 2018; Godwin et al 2019, McClenaghan et al 2019b). -Evidence for increased abundance of aerial insectivores on organic farms (Kirk & Lindsay 2017). Toxic metals -Whether toxic metal exposure from agriculture is higher or lower in areas with intensive agriculture is mixed. -BARS and COSW higher exposure to toxic metals in crop habitats (Orłowskiet al 2015), whereas BANS and TRES had higher mercury in grassland-dominated landscapes relative to cropland, but BARS and PUMA did not (Kardynal et al In prep). -No evidence on whether it affects breeding success. -Low levels of mercury in adult ACFL are not related to adult body condition, but negatively affect reproductive success (i.e., lower number of fledglings produced, Rowse et al 2014). -No evidence that toxic metal exposure in blood and eggs of TRES influence reproductive success or nestling quality (Beck et al 2015).	**LIKELY/UNCERTAIN** -Overlap between migratory routes and stopover sites of some aerial insectivores and agriculture or other industrial activities (e.g., Bridge et al 2016) suggests exposure to contaminants is likely. -Migration habitats are not identified for many aerial insectivores (Tables 1-5) and effects of contaminants during non-breeding is unknown.	**LIKELY/UNCERTAIN** -Overlap between wintering locations of some aerial insectivores and agriculture, mining, and other industrial activities (e.g., Rodewald et al 2019) on wintering grounds suggests exposure to contaminants is likely. -Wintering locations are not identified for many aerial insectivores (Tables 1-5) and effects of contaminants during non-breeding is unknown.
Changes in weather severity (frequency)	**LIKELY/UNCERTAIN** -Little evidence that advancing lay dates due to climate warming result in phenological mismatch between insect emergence/ availability and reproduction in TRES, BARS, and CLSW but possible in BANS (Imlay et al 2018b). -Earlier breeding, however may expose nestlings to more adverse spring weather conditions (Cox et al 2020). -Warmer, wetter conditions in the prairies for the last 40 years is associated with greater abundance of aerial insectivores (Mantyka-Pringle et al 2019). -Evidence from several populations of TRES suggest that local weather conditions (e.g. temperature, wind, rain) influence breeding success and nestling survival (Table 1). -Population specific —may be more important than continental climate (Weegman et al 2017).	**LIKELY/UNCERTAIN** -Increased storms, severe or atypical weather events, or changes in wind vectors during migration may influence costs of flight during migration, survival, or migratory timing/routes. -Wind speeds and direction influence spring departure timing in PUMA (Abdulle & Fraser 2018), and evidence for European	**LIKELY/UNCERTAIN** -Continental climate conditions show mixed effects on survival and demography. -Annual apparent survival of 1 population of BARS was high in years preceded by ENSO winters and more positive NAO (García-Pérez et al 2014). -Mixed evidence for strong effects of winter NAO and

	-Unclear if weather affects are changing in frequency or severity. -In one declining population of TRES in ON, long-term deteriorating weather conditions were linked to decreased fledging success over a 43-year period (Cox et al 2018). -Influence of climatic conditions (e.g., El Niño Southern Oscillation [ENSO], North Atlantic Oscillation [NAO]) at breeding and wintering grounds on survival are species and population specific in TRES and BARS.	population of swallows and martins to experience in-flight mortality due to adverse weather (see Newton et al 2007). -Unknown if weather during migration is increasing in severity in North America.	Bivariate ENSO time series (BEST) on annual apparent survival of TRES from 7 populations across North America (Clark et al 2018). -Non-breeding climate conditions BEST did not explain demographic rates in 3 populations of TRES (Weegman et al 2017). -Juvenile survival of TRES was greater in years with lower winter ENSO, but winter ENSO values, while variable, did not change throughout the 43-year study period (Cox et al 2020).
Persecution/anthropogenic mortality	**UNLIKELY/UNCERTAIN**	**UNLIKELY/UNCERTAIN**	**UNLIKELY/UNCERTAIN**
Competition	**UNLIKELY/UNCERTAIN** - Nest box occupancy of swallows is lower in agricultural areas with greater densities of sparrows (Robillard et al 2013).	**UNLIKELY/UNCERTAIN**	**UNLIKELY/UNCERTAIN** -Limited studies provide evidence of movements on wintering ground being driven by resource availability. -Unknown if there is increased density-dependence at non-breeding locations over time.
Increased susceptibility to parasites/diseases	**UNLIKELY/UNCERTAIN**	**UNLIKELY/UNCERTAIN**	**UNLIKELY/UNCERTAIN**
Predation	**UNLIKELY/UNCERTAIN** -Observations of species such as herring gulls depredating aerial insectivores have been reported (Evans et al 2017). -No evidence that this has increased over time. -Evidence of BARS nest predation by Barred Owls in BC (Mahony 2017) but unlikely to have population level effects.	**UNLIKELY/UNCERTAIN**	**UNLIKELY/UNCERTAIN**

[a]Species abbreviations TRES = Tree Swallow, BARS = Barn Swallow, BANS = Barn Swallow, CLSW = Cliff Swallow, CHSW = Chimney Swift, COSW = Common Swift, VASW = Vaux’s Swift, EWPW = Eastern Whip-poor-will.

A synthesis of research focusing on threats to aerial insectivores since 2012, suggests that multiple factors may have contributed to their declines, as opposed to a single driver (Spiller and Dettmers 2019). However, conclusive evidence is still lacking to refute any hypothesized threat. Research is needed to rigorously test each hypothesis across the guild of aerial insectivores, as well as comparing populations of the same species experiencing different trends (i.e., declining versus stable or increasing). Furthermore, since evidence for threats occurring during the breeding season do not unequivocally limit breeding success in populations experiencing declines (but see Cox et al 2020), aerial insectivore populations may be experiencing (multiple) threats co-occurring during all periods of the annual cycle (Imlay et al 2018b, Spiller & Dettmers 2019). Additionally, a lack of synchrony in declines across of the breeding range of species (Michel et al 2016) and reports of carryover effects from the non-breeding, such as low body condition (see Table 1; Rioux Paquette et al 2014, Imlay et al 2019a), further suggest that aerial insectivores may be experiencing threats at other periods of the annual cycle. Nevertheless, given that the majority of evidence comes from research on Tree and Barn Swallows, the extent to which threats experienced during the breeding season, such as insect abundance, habitat loss and degradation, and contaminants, may limit the productivity or survival of other species in the guild is uncertain. Ultimately, identifying non-breeding locations, habitat conditions, and migratory connectivity is needed to understand the full range of threats aerial insectivores are exposed to throughout the annual cycle.

6. Summary of Main Highlights

Day 2 of the workshop, participants discussed and identified high-priority research needs and *possible* management actions for aerial insectivores (Appendix 6). Resulting from this discussion, is this 'Summary of Main Highlights' section, which is intended to guide the next 5+ years of aerial insectivore research to address the most important information needs (Table 1-5) and identify conservation actions that could be taken – and evaluated for their effectiveness – right now. The main points highlighted in this section include

- Effective communication and collaboration between researchers and conservation organizations working on aerial insectivores, and levels of government.
- A continental approach to collaboration and research with the US and South America.
- Addressing knowledge gaps on full annual cycle movements/connectivity (Tables 1-4) and threats experienced by aerial insectivores throughout this time, with particular focus on changes in insects, habitat and weather (Table 5).
- Greater use of existing data sets and sources to address key knowledge gaps.

More details are summarized below in sections 6.1 Communication, Collaboration, Knowledge Mobilization and Networks and 6.2 Monitoring, Data Analysis, Management Actions, and Technology Needs.

6.1. Strategies for Communication, Collaboration, Knowledge Mobilization and Networks

Below we document the strategies for enhancing communication, collaboration, knowledge mobilization and networks. These topics are comprised of cross-cutting ideas and actions that are common to the four main groups of aerial insectivores (swallows, swifts, nightjars, and flycatchers).

6.1.1. Communicating Challenges, Opportunities and Results

1. Create a formal Listserve tied to a newly-formed aerial insectivore working group.
2. A Policy sub-committee was formed (Chair: Silke Nebel) to develop communication strategies, communication products and advance policy to support conservation of aerial insectivores (and possibly insects).
3. A Science sub-committee was formed (Co-Chairs: Lisha Berzins, Christy Morrissey) to summarise and communicate key findings, help form networks, and advance studies to support conservation.
4. Develop communications strategies tailored to target audiences, such as:
    a. talks to public, industry, policy makers/regulators.
    b. infographics for regulators, policy makers, and the public.

6.1.2. Collaborations to Support Research and Policy Activities

1. Expand existing networks and collaboration in US and South America, as determined by lists that are specific to individual research or policy goals (e.g., improving eBird data, deploying tags on the wintering grounds) at the onset of specific projects.
2. Collaborate with European colleagues who work on same species.
3. Work with collaborators in South America, especially in Brazil and northern Argentina to determine the feasibility of expanding the use of radar systems to detect roosts.

6.1.3. Knowledge Mobilization

1. Improve mechanisms of transferring information to policy makers and resource managers, as well as to COSEWIC; actively involve government/managers in projects.
2. Develop a roadmap to aerial insectivore conservation in Canada (e.g., Global Roadmap to insect conservation as a template; formulate a Canadian response).
3. Launch a communication campaign highlighting the importance of aerial insectivores and insects, targeting the most influential or important audiences.
4. Improve policy/international government collaboration – more active cross-border engagement with Latin America.
5. Develop more effective communications and interactions within ECCC and among key government departments (AAFC, International Affairs). Design case studies – barn swallow, swift, common nighthawk – to illustrate the scope and scale of conservation challenges that will require a large-scale coordinated response to seek solutions.
6. North American Trinational Committee – engage the wildlife / ecosystem conservation and management group.
7. Rebrand 'aerial insectivores' with another name that is more appealing to the public and represents all species within this group (subject to further discussion).

6.1.4. Networks

1. Review and expand existing networks and collaboration in US and South America.
2. Work with European colleagues on same species, seek solutions to common challenges.
3. Work with people in South America on determining feasibility of using and expanding radar to detect birds (e.g., roosts); ensure co-benefits with South American partners.
4. Build NSERC alliance grant (aerial insectivores). https://www.nserc-crsng.gc.ca/Innovate-Innover/alliance-alliance/index_eng.asp
5. Expand Citizen Science, including Indigenous partners, and develop better mechanisms for constant and consistent collaborations, including with industry partners.

6.2 Monitoring, Data Analysis, Management Actions, and Technology Needs

Below we document strategies for improving our efforts towards monitoring, data analysis, management, and technology needs for aerial insectivores organized according to the four main groups of aerial insectivores (swallows, swifts, nightjars, and flycatchers). In each section, participants identified research questions and priorities that will contribute to improved understanding of (i) population status and trends (using targeted or strategic monitoring), (ii) main threats and demographic drivers or mechanisms to explain population fluctuations and (iii) help guide decisions and conservation actions, when appropriate.

6.2.1. The swallows

1) Strategic monitoring to fill information gaps; improve our understanding of status and trends.

<u>Higher priorities</u>

a. Breeding: Canadian surveys of Bank and Northern Rough-winged Swallows, including surveys of areas in the north and in boreal regions.
b. Wintering: initiate a winter ground distribution and habitat association project for aerial insectivores. As a first step, work with eBird personnel and others to assess the use of eBird and Christmas Bird Count data, singly and in combination, to determine distribution and abundances. Additionally, incorporate habitat data from Central and South America. These steps would help in identifying a range of goals related to habitat needs and priority areas for conservation and can be aligned with other layers either on past land use change or future projections of land use change. However, there are still coverage gaps, particularly in some areas of South America like the Amazon basin and so another important component could be emphasizing additional survey work in these regions where feasible.
c. Migration: assess the feasibility of using radar (or other options such as localized spring tagging in eastern North America) to detect roosts during the annual cycle, and locate areas of potential conservation concern.

<u>Moderate-Lower priorities</u>

d. Develop a strategy to monitor insect biomass (availability, if possible) at key times and locations during the annual cycle; determine main drivers of insect abundance.
e. Assess the availability of existing purple martin data, determine whether or not they have been summarized and are now available for distribution and analysis.
f. Ascertain whether volunteer/citizen science can ensure continuity of long-term data sets for understanding population trends in situations where long-term monitoring programs have ended (e.g., Barn Swallows).

2) Data analyses: immediate needs to inform next steps

a. Integrate covariates into population trend analyses of BBS, CBC, eBird, and Atlas data sets.
b. Expand use of integrated population models to understand drivers of population fluctuations throughout annual cycle. Explore the integration of multiple population estimates from different sources (e.g., eBird in winter, BBS in spring) to improve trend

analyses, while explicitly including land cover, weather and other covariates to enable robust tests of competing hypotheses.

Specific examples:

- Update and expand on Nicole Michel's work examining drivers (e.g. weather, climate) of population change to include more species (link to 2a).
- Complete an inventory of long-term studies and harness long-term demographic data sets, such as Seattle Zoo data set on Barn Swallows. (link to 2b).
- Consider retrospective analyses and data mining, e.g., of existing nest record schemes.
- Overlay trends in changes in landscape with BBS population trends and Atlas data to examine drivers of population fluctuations.
- Use NDVI partitioned to areas of the Western Hemisphere to determine correlates with population trends, possibly using eBird.
- Use pesticide use data for Central and South America to examine levels of exposure of wintering and migrating swallows (to complement growing information from North America).

3) Management actions linked to research and conservation needs

a. Determine use and importance of different wetland types for foraging and roosting, to support management/conservation actions - restore and (or) conserve key wetlands and wetland complexes. See comment above (1b) eBird habitat variable importance.
b. Review current studies of migratory connectivity across species, and prioritize future connectivity studies to identify appropriate action(s) – in the correct places - on the basis of known or emerging threats to populations.
c. Measure survival throughout the annual cycle to identify bottlenecks, and thus help to guide appropriate actions. LifeTags and dual-mode Motus networks could provide the technological platform to complete this work. The time is now to do this work!
d. Re-evaluate and(or) consider new approaches to nesting structures for Barn Swallows or other priority species.

4) Technology needs

a. Develop better tags (e.g. smaller, longer lasting, transmit data [e.g., to cell towers]).
b. Implement better coverage and more strategic placement of Motus towers in western North America, Florida, Louisiana, Central America (including Caribbean) and wintering areas, where feasible.
c. Evaluate existing and new intrinsic markers to help understand migratory connectivity and threats.
d. Improve isoscapes for Central and South America, and use them singly and in combination with other markers (see 5c), as is most appropriate.

6.2.2. The swifts

1) Strategic monitoring to fill information gaps; improve our understanding of status and trends.

Breeding data is needed for Black Swifts; very little wintering data (locations, habitats, movements, survival) for all species. Suggest prioritizing:

a. Winter ground monitoring.
b. Spatial and population trend data to inform prioritization, highlighting importance of BBS and Atlas data, and compiling/digitizing existing historical data.

2) Data analyses: immediate needs to inform next steps

There are no existing datasets; could compile Swift Watch data, chimney swift nest survey data, national roost count data to get an index of population trends. Suggest prioritizing:

a. Use data from the Monitoring Avian Productivity & Survival (MAPS) program, and migration monitoring, to assess changes in vital rates and demography of swifts.
b. Combine 2a with BBS data to formulate integrated population models.
c. Assess how habitat has changed throughout the annual cycle.
d. Assess the importance of wetlands (e.g., aquatic food quantity and quality) to species.

3) Management actions linked to research and conservation needs

Management and protection of roost sites (e.g., not protected or need repair); need research on roost replacement. Suggest prioritizing:

a. Improve landscape diversity – evaluate breeding and wintering incentives (e.g., for habitat conservation), best management practises (including certification incentives).
b. Consider pros:cons of a Canadian insect strategy (insect availability/quality).
c. Immediate wetland protection in all Canadian jurisdictions, and more broadly where possible.

4) Technology needs

The following tools and data products are needed to better understand major threats such as landscape changes and climate variability over the annual cycle:

a. Improved tracking and detection tools, e.g., RADAR, MOTUS.
b. Improved landscape/habitat mapping products, e.g., LIDAR.
c. Meta-barcoding to assess diets across species. Obtain samples from MAPS stations or other networks that are capturing/accessing birds/faeces.

6.2.3. The nightjars

1) Strategic monitoring to fill information gaps; improve our understanding of status and trends.

Limited breeding and very little wintering data (locations, habitats, movements, survival) for all species. Suggest prioritizing:

a. Winter ground monitoring.
b. Boreal monitoring.
c. Spatial and population trend data to inform prioritization, highlighting importance of BBS and Atlas data, and compiling/digitizing existing historical data.

New nightjar surveys have been developed. Challenges exist to survey in northern areas and acquire data for wintering areas but tracking opportunities may be improving in some cases (large scale tracking is underway or completed for Common Nighthawks, Eastern Whip-poor-will). For specific new information needs, there is a need to launch an initiative for major tagging on the wintering grounds, with detections of birds returning to North America. Technological advances have created new opportunities for year-round tracking of nightjars (e.g., LifeTags; Icarus).

2) Data analyses: immediate needs to inform next steps

Some GPS work is being done. There is a need to develop standardized survey protocols, but there are no reliable survival or recruitment data. There is a need to prioritize:

a. Assess how habitat has changed throughout the annual cycle.
b. Assess the importance of wetlands (e.g. aquatic food quantity and quality) to species, particularly in the north.

3) Management actions linked to research and conservation needs

Need habitat heterogeneity incorporated into land use planning; protection of nest sites; better understanding of fire suppression impacts. Suggest prioritizing:

a. Improving landscape diversity – evaluate breeding and wintering incentives (e.g., for habitat conservation), best management practises (including certification incentives).
b. Consider pros and cons of a Canadian insect strategy (insect availability/quality).
c. Immediate wetland protection in all Canadian jurisdictions, and more broadly where possible.

4) Technology needs – same as SWIFTS.

6.2.4. The flycatchers

1) Strategic monitoring to fill information gaps; improve our understanding of status and trends.

There is a need for improved monitoring to better determine population fluctuations and rates of decline; compile and digitize existing data for breeding and wintering areas. Suggest prioritizing:

a. Winter ground monitoring.
b. Boreal monitoring.
c. Spatial and population trend data to inform prioritization, highlighting importance of BBS and Atlas data, and compiling/digitizing existing historical data.

2) Data analyses: immediate needs to inform next steps

Some data exist from MAPS, migration data, Atlas data and these could be compiled and used as productivity data for developing population models. Suggest the following:

a. Use data from the Monitoring Avian Productivity & Survival (MAPS) program, and migration monitoring, to assess changes in vital rates and demography of flycatchers.
b. Assess how habitat has changed throughout the annual cycle.
c. Assess the importance of wetlands (e.g., aquatic food quantity and quality) to species.

3) Management actions linked to research and conservation needs

Immediate actions can be taken to conserve flycatchers including:

a. Improve landscape diversity – evaluate breeding and wintering incentives (e.g., for habitat conservation), best management practises (including certification incentives).
b. Consider pros and cons of a Canadian insect strategy (insect availability/quality).
c. Immediate wetland protection in all Canadian jurisdictions, and more broadly where possible.
d. Evaluate whether ecological traps are created by harvest clear-cuts in forests;
e. Work with landowners at stop-over sites during migration and on wintering grounds for beneficial management practises.

4) Technology needs – same as SWIFTS.

7. Conclusion

This report resulting from our workshop synthesizes the current progress, new research and actions that are needed immediately to help conserve aerial insectivores. Discussions among participants identified key knowledge gaps that limit our understanding of threats to aerial insectivore populations. Although knowledge gaps exist for each of the groups of aerial insectivores, those common to all groups include:

- Species abundances in the north and boreal regions.
- Demography, including which stages of the annual cycle limit populations.
- Non-breeding season ecology, including migratory routes, stopover sites, wintering locations and migratory connectivity for most species.

We present a **Summary of Main Highlights** (Section 6) with recommendations to fill in these knowledge gaps for improving our understanding of the threats to aerial insectivores. Some of the highest priority recommendations include:

- Expand collaboration in the US and South America and take a continental approach to research, conservation and policy.
- Improve mechanisms of communication within and across levels of government and transferring information to policy makers.
- Understand wintering ground locations, distribution, and habitat associations.
- Detect roost sites throughout the annual cycle and locate areas of potential conservation concern.
- Assess trends in landscape change and pesticide use to determine relationship with population trends.
- Determine use and importance of different wetland types for foraging and roosting.

To conserve aerial insectivore populations in Canada, research over the full annual cycle that takes a hemispheric approach and integrates data on breeding and wintering areas and migration is needed. This would enable conservation efforts to be prioritized to locations and times of the annual cycle deemed most urgent to effectively mitigate threats to aerial insectivores. It is hoped that this report, and subsequent communications products, play a key role in helping managers, decision- and policy-makers understand the importance of a full annual cycle, continental approach to mitigating threats to aerial insectivores to slow or reverse their declines.

8. Acknowledgements

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Appendix 1: Agenda for the 2020 Aerial Insectivore Workshop

2020 AERIAL INSECTIVORE WORKSHOP, 10-11 MARCH 2020
UNIVERSITY CLUB, UNIVERSITY OF SASKATCHEWAN, SASKATOON

Tuesday, 10 March 2020 (WebEx – 8:00 until lunch – details by email Day 1)

08:00 Welcome and logistics. *Christy Morrissey* and *Elsie Krebs*

08:15 Introductions.
08:30 Brief review of 2012 Workshop. *Nancy Mahony*
08:45 Review Current Workshop Objectives. *Kevin Kardynal*
09:00 Where are we now? Population status and trends. *Adam Smith* and *Nicole Michel* (Webex)
10:00 *Break and Coffee at University Club*
10:20 What is the current state of knowledge? Brief review of major findings/confidence in results.

Moderator: *Keith Hobson*

[Annual life cycles and population trends, recognizing guild and species-specific issues.]

- Swallows (25 min; *Tara Imlay*)
- Swifts (15 min; *Joe Nocera*)
- Caprimulgids (15 min; *Mark Brigham*)
- Flycatchers (15 min; *Junior Tremblay*)
- Insects (25 min; *Peter Dunn & Cornelia Twining (webex))*

12:10 *Lunch (Buffet provided at the University Club)*
13:15 General discussion (All); Moderator – *Keith Hobson*
13:30 Break-out sessions explained. *Bob Clark*
13:40 Break-out session #1. (3 groups, split among life-cycle periods, but set with "loose" boundaries)

- Late spring, breeding season. Leads - *Greg Mitchell* & *Marc Bélisle*
- Late summer, fall migration, early winter movements. Leads – *Christine Bishop* & *David Winkler*
- Wintering areas, spring migration, carry-over effects. Leads - *Erica Nol* & *Keith Hobson*

15:00 *Break and Coffee at University Club*
15:30 Break-out session #1, summarize your key points (*continued…*)
16:20 Brief reporting from each group (5-10 min highlights). Moderator: *Elsie Krebs*
17:15 End
19:00 Group supper (location TBA) - Assemble in hotel lobby at 18:30

2020 AERIAL INSECTIVORE WORKSHOP, 10-11 MARCH 2020

UNIVERSITY CLUB, UNIVERSITY OF SASKATCHEWAN, SASKATOON

Wednesday, 11 March 2020 (WebEx – 8:00 until lunch – details by email Day 2)

08:30 Review Day 1 – general discussion/round table; revised or new hypotheses in an annual cycle

context - unique or unifying? Ideas missed? Moderator: *Organizing team*

09:00 Integration – synthesize information, organize thinking, pinpoint gaps, test hypotheses, and generate new predictions via retrospective and predictive analyses. *Scott Wilson*
09:45 Plans for the remainder of the day – group discussion. Moderator: *Bob Clark*
10:00 *Break and Coffee at University Club*
10:30 Break-out session #2 – integration (species, guilds); prioritize hypotheses, research and *possible* management actions or policy implications. [Adjust based on group discussion.]

- Late spring, breeding season. Leads –*Silke Nebel* & *Mark Brigham*
- Non-breeding season, wintering areas/movements. Leads - *Peter Thomas* & *Laura Tranquilla*

12:00 *Lunch (provided at the University Club)*
13:10 Break-out session #2, summarize the main points (*continued*…)
14:15 Review break-out session #2 (5-10 min per group). Moderator: *Christy Morrissey*
15:00 *Break and Coffee at University Club*
15:30 General discussion. Moderators: *Elsie Krebs, Nancy Mahony* and *Kevin Kardynal*
WebEx Session (details TBA)

- Quick round-table: other ideas arising.
- Aerial insectivore review paper, ACE (*Keith Hobson*)
- Review major conclusions
- Set action items around the priorities
- Identify leads and timelines

16:30 Thank-you and End. *Christy Morrissey*

Appendix 2: Day 1 Break-out Session

Break-out session #1.

Group 1. Breeding season. Leads - *Greg M* & *Marc B; Silke, Nancy, Peter T, Mike, Joe.*
Group 2. Fall migration & winter movements. Leads – *Christine B* & *David W; Elsie, Lisha, Scott, Laura, Kevin.* *Group 3. Spring migration and carry-over effects*. Leads - *Erica N* & *Keith H; Christine, Peter D, Tara, Junior, Elly*

The main objective of this session is to consider recent information and discuss hypotheses proposed to account for: (i) initial population declines (or spatial variation in population fluctuations) and (ii) persistently low populations (in some regions). [Note. A list of hypotheses is appended to help guide initial discussions; you are encouraged to consider new ones.]. This break-out session is also intended to help set the stage for the second break-out session (day 2) which will focus more on management and(or) research needs, priorities and plans.

Step 1. Each group should choose a recorder and reporter (for Step 3 below).

Step 2. For the period of the annual life cycle assigned to your group, review and address the following questions and(or) record the most pertinent issues discussed:

Question 1. Which hypotheses seem most plausible given recent information?
As examples only, you could rank these in terms of relative plausibility (3 point scale ranging from low to high) and also indicate quality of information/certainty (3 point scale ranging from uncertain to certain). You could also rank all hypotheses from High to Low plausibility; annotate with comments to clarify your group's ranking decisions.

Question 2. How do these relate to species or guilds – and what mechanism(s) could be involved (e.g., how are survival or reproductive success affected by these factors)?

Question 3. Again - depending on species or guild - what new ideas do you want to advance and discuss? Begin to compile a list of the most serious information gaps (we will return to this topic on day 2).

Step 3. Review your main points and nominate 3-5 highlights for presentation (within ~10 min) and discussion with all workshop participants.

Appendix 3: Day 2 Break-out Session

Break-out session 2. Looking forward – roadmaps to progress…

Group 1. Spring migration, breeding season. Leads –*Silke N & Mark B; Elly, Mike, Greg, Marc, Keith, Erica, Peter D, Elsie, Christine*

Group 2. Late summer, non-breeding season, wintering areas/movements. Leads – *Peter T & Laura T; Joe, David, Laura, Kevin, Junior, Scott, Nancy, Tara*

The main objective of this break-out session is refine and prioritize hypotheses, research needs and *possible* management actions or policy implications. This break-out session is also intended to help set the stage for a 5+ year research program to address the most important information needs and identify actions that could be taken – and evaluated for effectiveness - now.

Step 1. Each group should choose a recorder and reporter.

Step 2. For the period of the annual life cycle assigned to your group, briefly review hypotheses and evidence from day 1, and then focus most on the following questions and record the outcome(s) of your needs assessment and prioritization discussions:

Question 1. In order of priority, what are the most important information gaps for this period of the annual life-cycle? Prioritize the research needs.

Question 2. How would new information address mechanism(s) of population change (e.g., how are migratory connectivity, carry-over effects, survival or reproductive success related to these mechanisms)?

Question 3. Can these mechanisms be related to practical actions – in what way(s)? If management actions or policy recommendations seem feasible, what are they?

Step 3. Review your main points and nominate 3-5 highlights for presentation (within ~10 min) and discussion with all workshop participants.

Appendix 4: List of workshop participants

Name	Affiliation
Robert Clark	ECCC - Wildlife Research Division
Greg Mitchell	ECCC - Wildlife Research Division
Nancy Mahony	ECCC - Wildlife Research Division
Elsie Krebs	ECCC - Wildlife Research Division
Junior Trembly	ECCC - Wildlife Research Division
Scott Wilson	ECCC - Wildlife Research Division
Kevin Kardynal	ECCC - Wildlife Research Division
Keith Hobson	ECCC - Wildlife Research Division
Christine Bishop	ECCC - Wildlife Research Division
Mike Cadman	ECCC - Canadian Wildlife Service
Tara Imlay	ECCC - Canadian Wildlife Service
Peter Thomas	ECCC - Canadian Wildlife Service
Christy Morrissey	University of Saskatchewan
Lisha Berzins	University of Saskatchewan
Marc Bélisle	University of Sherbroooke
Elly Knight	University of Alberta
Mark Brigham	University of Regina
Peter Dunn	University of Wisconsin
Joe Nocera	University of New Brunswick
Silke Nebel	Birds Canada
David Winkler	Cornell University
Laura Tranquilla	Birds Canada
Erica Nol	Trent University
Ana Diaz	University of Saskatchewan
Mercy Harris	University of Saskatchewan
Dominic Cormier	ECCC - Wildlife Research Division
Adam Smith (remote)	ECCC - Wildlife Research Division
Nicole Michel (remote)	National Audubon Society
Cornelia Twining (remote)	University of Konstanz

Appendix 5: List of hypothesized drivers of Aerial Insectivore declines*

- **Monitoring techniques –** species (e.g., clumped distributions, nocturnal) are not being monitored appropriately using current approaches (e.g. BBS), creating uncertainty about population status and trends.
- **Redistribution** – shifts of breeding birds to new areas (including those not adequately surveyed), taking advantage of more favourable conditions there.
- **Declines in aerial insect populations**, particularly those species important in the diets of aerial insectivores on breeding, migration and/or wintering grounds.
- **Habitat loss on breeding, migration and/or wintering grounds**, reflecting loss of wetlands and grasslands, changes in agricultural and forestry practices, and loss of certain types of **nesting structures**. Loss of nesting sites may be particularly important to a few species (Barn Swallow, Chimney Swift, Common Nighthawk, Eastern Whip-poor-will).
- **Habitat degradation** resulting in reduced productivity or survival via changes such as altered food availability or phenology, or increased predation.
- **Environmental contaminants** including acid rain (and associated declines in availability of calcium needed for the production of eggs and the growth of bones in young birds), pesticides, heavy metals, flame retardants, and endocrine disrupters.
- **Changes in weather severity (frequency)**, including but not limited to droughts, increasing frequency of cold and/or wet periods, extreme weather events in the breeding season, and hurricane and storm frequency during migrations. **Indirect climatic effects** could include asynchrony between timing of peak insect food emergence and timing of peak resource needs (e.g., food demand by hatchlings), or a reduction in food availability during critical periods in late summer, migration or winter.
- Heightened direct human **persecution**, increases in levels of **anthropogenic mortality** (e.g., collisions with infrastructure and vehicles; cats).
- **Competition** (intra and interspecific) for resources, triggering **density dependence**.
- **Increased susceptibility to parasites or diseases.**
- **Predation** – higher predation throughout the annual cycle associated with increases in falcons and accipiters; other predators.

* Based on the 2012 Aerial Insectivore Workshop Report (Calvert et al. 2012); Spiller & Dettmers. 2019. Condor: Ornithological Applications); Imlay & Leonard. 2019. Bird Study.

Appendix 6: Literature Review

Aerial Insectivore papers (2012 – 2020) (Insect papers appended after)

TRENDS, CAUSES FOR TRENDS

1) Mantyka-Pringle, C., Leston, L., Messmer, D., Asong, E., Bayne, E.M., Bortolotti, L.E., Sekulic, G., Wheater, H., Howerter, D.W., Clark, R.G. Antagonistic, synergistic and direct effects of land use and climate on Prairie wetland ecosystems: Ghosts of the past or present? (2019) *Diversity and Distributions*, 25 (12), pp. 1924-1940. DOI: 10.1111/ddi.12990

Aim: Wetland loss and degradation threaten biodiversity to an extent greater than most ecosystems. Science-supported responses require understanding of interacting effects of land use and climate change on wetland biodiversity. Location: Alberta, Canada. Methods: We evaluated how current climate, climate change (as a ghost of the past), land use and wetland water quality relate to aquatic macroinvertebrates and birds. Results: Climatic relationships and climate–land use interactions were observed on chironomid abundance, but not macroinvertebrate taxa richness (MTR) or odonate abundance, which responded to land use and water chemistry. Chironomid abundance was positively associated with cropland and negatively associated with total precipitation. Higher cropland cover and dissolved organic carbon synergistically interacted with total precipitation to affect chironomids. MTR was negatively related to salinity, yet greater area of non-woody riparian vegetation attenuated salinity effects on MTR. Odonate abundance was negatively related to total phosphorus. Higher grassland cover also increased the negative relationship of total phosphorous to odonate abundance. Climatic relationships and climate–land use interactions were observed on bird species richness (BSR) and abundance of several bird functional groups. Higher BSR and abundances of several bird groups were positively related to average rainfall and greater warming temperatures over time. Area of non-crop cover and wetlands was positively associated with most bird groups and BSR. Warming temperatures over time ameliorated the negative relationship of higher cropland or less shrubland on aerial insectivores and other bird groups. Main conclusions: Climate patterns and climate change are as important as land use pressures with stronger impacts on birds. Climate change was more influential than current climate and provided novel empirical evidence that progressively warmer, wetter conditions is benefiting some bird groups, including aerial insectivores, a group of conservation concern. Riparian vegetation ameliorated the negative impacts of climate and water quality gradients on MTR and could mitigate global change impacts in agricultural systems.
Keywords: agriculture; antagonistic; aquatic macroinvertebrates; birds; climate change; functional group; interaction; synergistic; water quality; wetlands

2) Spiller, K.J., Dettmers, R. Evidence for multiple drivers of aerial insectivore declines in North America (2019) *Condor*, 121 (2), art. no. duz010, . DOI: 10.1093/condor/duz010

Aerial insectivores (birds that forage on aerial insects) have experienced significant population

declines in North America. Numerous hypotheses have been proposed for these declines, but current evidence suggests multiple factors could be operating in combination during their annual migratory cycles between breeding and nonbreeding areas. Potential drivers include decreased prey abundance, direct or indirect impacts of environmental contaminants, habitat loss, phenological changes due to warming climate, and conditions on migratory stopover or wintering grounds. While no single threat appears to be the cause of aerial insectivore declines, existing evidence suggests that several of these factors could be contributing to the declines at different times in the annual lifecycle. Breeding productivity for most of these species does not appear to be limited by overall prey abundance, contaminants, or habitat loss, which suggests that similar issues on nonbreeding grounds or carryover effects could play important roles. However, a better understanding of the importance of prey quality throughout the lifecycle is critically needed. Based on current evidence, we propose that changes in availability of high-quality prey, with variability across breeding and nonbreeding grounds, reduce various combinations of fledging success, post-fledging survival, and nonbreeding season body condition of aerial insectivores, resulting in species and geographic differences in population trends. We encourage others to use this hypothesis as a starting point to test specific mechanisms by which availability of high-quality prey influences demographic parameters. We suggest that future research focus on defining prey quality, monitoring insect abundance in conjunction with birds, comparing demographic models across local populations experiencing different population growth rates, and using tracking technology to document important migratory and nonbreeding areas. Considerable research progress already has been made, but additional research is needed to better understand the complex web of potential causes driving aerial insectivore declines.
Keywords: Aerial insectivores; Carryover effects; Contaminants; Population declines; Prey quality

3) Imlay, T.L., Leonard, M.L. A review of the threats to adult survival for swallows (Family: Hirundinidae) (2019) *Bird Study*, 66 (2), pp. 251-263. DOI: 10.1080/00063657.2019.1655527

Capsule: For declining migratory birds, including many aerial insectivores, such as swallows, there is evidence that adult survival is a demographic process with strong effects on population trends. Aims: The aim was to identify and quantify the effect of threats affecting adult survival and potentially driving population declines for five well-studied swallow species: Barn Swallow Hirundo rustica, Cliff Swallow Petrochelidon pyrrhonota, Tree Swallow Tachycineta bicolor, Sand Martin Riparia riparia, and Purple Martin Progne subis. Methods: We reviewed the literature to identify the threats to adult survival, quantified the magnitude of the effect and identified whether threats had a direct or indirect effect on survival. Results: We identified habitat change, weather, competition, incidental loss, contaminants, insect availability, disease, and predation as threats to adult survival in swallows, although for many of these threats there was limited information to quantify their impact. However, weather, particularly cold snaps and precipitation, had negative effects on survival for many populations of four species, either directly or indirectly through effects on insect availability. When there was a relationship, weather was associated with a 13–53% decrease in survival. Conclusion: Based on the available research, weather conditions throughout the annual cycle is a key threat to adult survival for several swallow species. However, future research on the threats to these species should consider examining the effect of insect availability and the effect of threats during the non-breeding period on survival. Finally, we suggest that new research should be devoted to understanding the importance of adult survival for declining bird populations.

4) Cox, A.R., Robertson, R.J., Lendvai, A.Z., Everitt, K., Bonier, F. Rainy springs linked to poor nestling growth in a declining avian aerial insectivore (Tachycineta bicolor) (2019) *Proceedings of the Royal Society B: Biological Sciences*, 286 (1898), . DOI: 10.1098/rspb.2019.0018

As species shift their ranges and phenology to cope with climate change, many are left without a ready supply of their preferred food source during critical life stages. Food shortages are often assumed to be driven by reduced total food abundance, but here we propose that climate change may cause short-term food shortages for foraging specialists without affecting overall food availability. We frame this hypothesis around the special case of birds that forage on flying insects for whom effects mediated by their shared food resource have been proposed to cause avian aerial insectivores' decline worldwide. Flying insects are inactive during cold, wet or windy conditions, effectively reducing food availability to zero even if insect abundance remains otherwise unchanged. Using long-term monitoring data from a declining population of tree swallows (Tachycineta bicolor), we show that nestlings' body mass declined substantially from 1977 to 2017. In 2017, nestlings had lower body mass if it rained during the preceding 3 days, though females increased provisioning rates, potentially in an attempt to compensate. Adult body mass, particularly that of the males, has also declined over the long-term study. Mean rainfall during the nestling period has increased by 9.3+0.3 mm decade-1, potentially explaining declining nestling body mass and population declines. Therefore, we suggest that reduced food availability, distinct from food abundance, may be an important and previously overlooked consequence of climate change, which could be affecting populations of species that specialize on foraging on flying insects.
Keywords: body condition; climate change; insect availability; parental investment; tree swallow

5) Cox, A.R., Robertson, R.J., Fedy, B.C., Rendell, W.B., Bonier, F. Demographic drivers of local population decline in Tree Swallows (Tachycineta bicolor) in Ontario, Canada
(2018) *Condor*, 120 (4), pp. 842-851. DOI: 10.1650/CONDOR-18-42.1

Bird species around the world are threatened with extinction. In North America, aerial insectivores are experiencing particularly severe population declines. To conserve these species, we need to know which life stages have the largest influence on population growth. We monitored a box-nesting population of Tree Swallows (Tachycineta bicolor) from 1975 to 2017. From this long-term dataset, we derived estimates of 9 vital rates: clutch size, reproductive attempts, and overwinter return for 2 age classes of adult females, and hatching, fledging, and juvenile recruitment rates. We conducted a life-stage simulation analysis on this population based on a 3-stage, female-based population projection matrix to determine which of these vital rates had the greatest influence on overall population growth rate. We determined each vital rate's sensitivity (i.e. the effect of a small change in each vital rate on

population growth), elasticity (i.e. the effect of a proportional change in each vital rate on population growth), and ability to explain variation in population growth rate. Juvenile recruitment, female return for both age classes, and fledging success determine population growth because they have high sensitivity, elasticity, and explained large amounts of variation in population growth rate. Contrary to expectations, the number of nesting attempts, clutch size, and hatch rate have little impact on population growth rate. To stem Tree Swallow decline, and potentially the declines we see across the aerial insectivores, fledging success or overwinter survival must increase.
Keywords: avian aerial insectivore; life-stage simulation; long-term monitoring; population decline; Tree Swallow; vital rates

6) Taylor, L.U., Woodworth, B.K., Sandercock, B.K., Wheelwright, N.T. Demographic drivers of collapse in an island population of Tree Swallows (2018) *Condor*, 120 (4), pp. 828-841. DOI: 10.1650/CONDOR-18-75.1

Diagnosing causes of population declines requires an understanding of the contributions of demographic vital rates to interannual variability and long-term changes in population size. At Kent Island, New Brunswick, Canada, an isolated population of Tree Swallows (Tachycineta bicolor) collapsed between 1987 and 2010, providing a unique opportunity to reconstruct how demographic rates drive population dynamics. We fit an integrated population model to 24 yr of population count, reproductive success, and capture-recapture data to generate annual estimates of productivity, juvenile and adult survival, immigration, and the finite rate of population change (λ). The Kent Island population declined from 202 to 12 breeding adults over 24 yr, with a geometric mean decline of 11.6% per year. Annual apparent survival of adults averaged 56% across sexes, whereas annual survival and recruitment of juveniles never exceeded 6%. Transient life table response experiments revealed that variation in male and female immigration rates were the major contributors to both overall and interannual variation in λ, followed by female and male adult survival. Local recruitment and reproductive rates had little effect on variation in λ. Given broad-scale regional declines in Tree Swallows, our study shows how declines of isolated populations can be driven by reductions in immigration, especially when coupled with variation in adult survival and low local recruitment.
Keywords: aerial insectivore; immigration; integrated population models; life table response experiments; population dynamics; recruitment; survival

7) Clark, R.G., Winkler, D.W., Dawson, R.D., Shutler, D., Hussell, D.J.T., Lombardo, M.P., Thorpe, P.A., Dunn, P.O., Whittingham, L.A. Geographic variation and environmental correlates of apparent survival rates in adult tree swallows *Tachycineta bicolor* (2018) *Journal of Avian Biology*, 49 (6), art. no. e01659, . DOI: 10.1111/jav.01659

Determining demographic rates in wild animal populations and understanding why rates vary are important challenges in population ecology and conservation. Whereas reproductive success is reported frequently for many songbird species, there are relatively few corresponding estimates of annual survival for widespread populations of the same migratory species. We incorporated mark–recapture data into Cormack–Jolly–Seber models to estimate

annual apparent survival and recapture rates of adult male and female tree swallows Tachycineta bicolor in eight local breeding populations across North America for periods of 7–33 yr. We found strong site-specific and annual variation in apparent survival rates of adult swallows, and evidence of higher survival or site fidelity among males than females. There were no strong associations between putative overwintering region and survival. Strength and patterns of winter climate-apparent survival relationships varied across four sites monitored for >15 yr; at one site, spring pond conditions, local spring precipitation and, to a lesser extent, winter North Atlantic Oscillation Index were credible predictors of annual apparent survival. Further work is needed to evaluate how survival is related to environmental conditions throughout the annual cycle and how these factors affect population dynamics of swallows and related species of conservation concern.
Keywords: aerial insectivore; climate cycles; population ecology; recapture rates

8) Imlay, T.L., Mills Flemming, J., Saldanha, S., Wheelwright, N.T., Leonard, M.L. Breeding phenology and performance for four swallows over 57 years: relationships with temperature and precipitation
(2018) *Ecosphere*, 9 (4), art. no. e02166. DOI: 10.1002/ecs2.2166

Climate change can drive population declines for many species, often through changes to their food supply. These changes can involve a mis-timing between periods of high food demand and peak food availability, typically from advances in breeding phenology, and/or an overall reduction in food availability. Aerial insectivores, birds that feed on insects caught in flight, are experiencing steep population declines possibly because of shifts in the timing and/or abundance of aerial insects. We determined whether changes in breeding performance over time could account for declines in Bank Riparia riparia, Barn Hirundo rustica, Cliff Petrochelidon pyrrhonota, and Tree Tachycineta bicolor Swallows, and if so, whether changes were related to shifts in breeding phenology and/or climate change. We compared breeding performance and phenology in Maritime Canada before (1962–1972) and after (2006–2016) the onset of steep population declines during the mid-1980s, to determine whether breeding performance was reduced or phenology was advanced. Then, we modeled relationships between temperature, precipitation, breeding phenology, and performance for Barn and Tree Swallows, the only species with sufficient data, from 1960 to 2016, to determine whether phenology and performance were related to climatic conditions. Between the two time periods, we found significantly lower performance in Bank Swallows, higher performance in Barn and Tree Swallows, and unchanged performance in Cliff Swallows. We also found clutch initiation dates advanced by 8–10 d for all species except Bank Swallows. On the breeding grounds, warmer winter temperatures for Tree Swallows and less winter precipitation for Barn and Tree Swallows in a given year were associated with earlier breeding, and for Tree Swallows, changes in nestling survival. Otherwise, Barn and Tree Swallow breeding performance was unaffected by winter temperature and precipitation. Our results suggest that in this region poorer breeding performance could contribute to population declines for Bank Swallows but not for the other three species. © 2018 The Authors.

Keywords: citizen science; climate change; Hirundo rustica; historical ecology; insect availability; Petrochelidon pyrrhonota; reproductive success; Riparia riparia; Tachycineta bicolor

9) Stanton, R.L., Morrissey, C.A., Clark, R.G. Analysis of trends and agricultural drivers of farmland bird declines in North America: A review (2018) *Agriculture, Ecosystems and Environment*, 254, pp. 244-254. DOI: 10.1016/j.agee.2017.11.028

Globally, agriculture has intensified during the past 50 years due to increased mechanization, changes in the timing of farming operations, grassland conversion to cropland, and increased agrochemical inputs. Birds associated with farmlands and grasslands in North America have experienced severe declines over the last several decades, prompting the need for a comprehensive review of the drivers, mechanisms and magnitude of effects on bird populations. Here we evaluated changes in North American farmland bird populations over time and conducted a systematic review and analysis of the published literature to identify the major causes. Based on North American Breeding Bird Survey data, populations of 57 of 77 (74%) farmland-associated species decreased from 1966 to 2013. Multiple species exhibited highly congruent declines during the 1960s-1980s − a period with rapid changes in farming practices to low tillage systems, heavy pesticide use and widespread conversion of grassland habitat to cropland. The most severe declines occurred in aerial insectivorous birds (average change of −39.5% from 1966 to 2013), followed by grassland (-20.8%) and shrubland (-16.5%) bird species. Direct agricultural drivers impacting bird abundance, survival, and reproduction include loss of natural habitats, interference from farming equipment, and direct mortality or sublethal effects from pesticide exposure. Subtle interference with behaviour or physiology are reported through indirect drivers such as reduced food supplies, sublethal pesticide toxicity, habitat fragmentation and alteration, and disturbance. Indirect effects are likely significant for many species, particularly aerial insectivores, but detailed mechanistic studies are lacking. Our review of 122 studies found that pesticides (42% of all studies), followed by habitat loss or alterations (27%), were most predominant in negatively affecting farmland birds, with pesticides (93% negative) and mowing/harvesting (81% negative) having the most consistently negative effects. Modifications to farmland management such as reducing pesticide inputs through integrated pest management and maintaining or restoring uncultivated field margins and native habitat could positively influence farmland birds without significantly reducing agricultural crop yields.
Keywords: Aerial insectivores; Agricultural intensification; Avian declines; Farmland birds; Grassland birds; Habitat loss; Pesticides

10) English, P.A., Green, D.J., Nocera, J.J. Stable isotopes from museum specimens may provide evidence of long-term change in the trophic ecology of a migratory aerial insectivore (2018) *Frontiers in Ecology and Evolution*, 6 (FEB), art. no. 14. DOI: 10.3389/fevo.2018.00014

Identifying the mechanisms of ecological change is challenging in the absence of long-term data, but stable isotope ratios of museum specimen tissues may provide a record of diet and habitat change through time. Aerial insectivores are experiencing the steepest population

declines of any avian guild in North America and one hypothesis for these population declines is a reduction in the availability of prey. If reduced prey availability is due to an overall reduction in insect abundance, we might also expect populations of higher trophic level insects to have declined most due to their greater sensitivity to a variety of disturbance types. Because nitrogen isotope ratios (δ15N) tend to increase with trophic-level, while δ13C generally increases with agricultural intensification, we used δ15N and δ13C values of bird tissues grown in winter (claw) and during breeding (feathers) from museum specimens spanning 1880-2005, and contemporary samples from breeding birds (2011-2013) to test for diet change in a migratory nocturnal aerial insectivore, Eastern Whip-poor-will (Antrostomus vociferus) breeding in Ontario, Canada. To test if environmental baselines have changed as a result of synthetic N fertilizer use, habitat conversion or climate, we also sampled δ15N values of three potential prey species collected from across the same geographic region and time period. Over the past 100 years, we found a significant decline in δ15N in tissues grown on both the breeding and wintering grounds. Prey species did not show a corresponding temporal trend in δ15N values, but our power to detect such a trend was limited due to higher sample variance. Amongst contemporary bird samples, δ15N values did not vary with sex or breeding site, but nestlings had lower δ15N values than adults. These results are consistent with the hypothesis that aerial insectivore populations are declining due to changes in abundance of higher trophic-level prey, but we caution that museum-based stable isotope studies of terrestrial food chains will require new approaches to assessing baseline change. Once addressed, an ability to decode the `al record locked inside museum collections could enhance our understanding of ecological change and inform conservation decisions.
Keywords: Antrostomus vociferus; Diet change; Museum collections; Nightjar; Nitrogen fertilizer; Population declines; Trophic-level; Whip-poor-will

11) Weegman, M.D., Arnold, T.W., Dawson, R.D., Winkler, D.W., Clark, R.G. Integrated population models reveal local weather conditions are the key drivers of population dynamics in an aerial insectivore (2017) *Oecologia*, 185 (1), pp. 119-130. DOI: 10.1007/s00442-017-3890-8

Changes to weather patterns under a warming climate are complex: while warmer temperatures are expected virtually worldwide, decreased mean precipitation is expected at mid-latitudes. Migratory birds depend on broad-scale weather patterns to inform timing of movements, but may be more susceptible to local weather patterns during sedentary periods. We constructed Bayesian integrated population models (IPMs) to assess whether continental or local weather effects best explained population dynamics in an environmentally sensitive aerial insectivorous bird, the tree swallow (Tachycineta bicolor), along a transcontinental gradient from British Columbia to Saskatchewan to New York, and tested whether population dynamics were synchronous among sites. Little consistency existed among sites in the demographic rates most affecting population growth rate or in correlations among rates. Juvenile apparent survival at all sites was stable over time and greatest in New York, whereas adult apparent survival was more variable among years and sites, and greatest in British Columbia and Saskatchewan. Fledging success was greatest in Saskatchewan. Local weather conditions explained significant variation in adult survival in Saskatchewan and fledging success in New

York, corroborating the hypothesis that local more than continental weather drives the population dynamics of this species and, therefore, demographic synchrony measured at three sites was limited. Nonetheless, multi-population IPMs can be a powerful tool for identifying correlated population trajectories caused by synchronous demographic rates, and can pinpoint the scale at which environmental drivers are responsible for changes. We caution against applying uniform conservation actions for populations where synchrony does not occur or is not fully understood.
Keywords: Capture-mark-recapture; Climate change; Demography; Horvitz–Thompson estimator; Long-distance migrant bird

12) Michel, N.L., Smith, A.C., Clark, R.G., Morrissey, C.A., Hobson, K.A. Differences in spatial synchrony and interspecific concordance inform guild-level population trends for aerial insectivorous birds (2016) *Ecography*, 39 (8), pp. 774-786. DOI: 10.1111/ecog.01798

Many animal species exhibit spatiotemporal synchrony in population fluctuations, which may provide crucial information about ecological processes driving population change. We examined spatial synchrony and concordance among population trajectories of five aerial insectivorous bird species: chimney swift Chaetura pelagica, purple martin Progne subis, barn swallow Hirundo rustica, tree swallow Tachycineta bicolor, and northern rough-winged swallow Stelgidopteryx serripennis. Aerial insectivores have undergone severe guild-wide declines that were considered more prevalent in northeastern North America. Here, we addressed four general questions including spatial synchrony within species, spatial concordance among species, frequency of declining trends among species, and geographic location of declining trends. We used dynamic factor analysis to identify large-scale common trends underlying stratum-specific annual indices for each species, representing population trajectories shared by spatially synchronous populations, from 46 yr of North American Breeding Bird Survey data. Indices were derived from Bayesian hierarchical models with continuous autoregressive spatial structures. Stratum-level spatial concordance among species was assessed using cross-correlation analysis. Probability of long-term declining trends was compared among species using Bayesian generalized linear models. Chimney swifts exhibited declining trends throughout North America, with less severe declines through the industrialized Mid-Atlantic and Great Lakes regions. Northern rough-winged swallows exhibited declining trends throughout the west. Spatial concordance among species was limited, the proportion of declining trends varied among species, and contrary to previous reports, declining trends were not more prevalent in the northeast. Purple martins, barn swallows, and tree swallows exhibited synchrony across smaller spatial scales. The extensive within-species synchrony and limited concordance suggest that population trajectories of these aerial insectivores are responding to large-scale but complex and species- and region-specific environmental conditions (e.g. climate, land use). A single driver of trends for aerial insectivores as a guild appears unlikely.

13) Smith, A.C., Hudson, M.-A.R., Downes, C.M., Francis, C.M. Change points in the population trends of aerial-insectivorous birds in North America: Synchronized in time across species and regions (2015) *PLoS ONE*, 10 (7), art. no. 0130768, . DOI: 10.1371/journal.pone.0130768

North American populations of aerial insectivorous birds are in steep decline. Aerial insectivores (AI) are a group of bird species that feed almost exclusively on insects in flight, and include swallows, swifts, nightjars, and flycatchers. The causes of the declines are not well understood. Indeed, it is not clear when the declines began, or whether the declines are shared across all species in the group (e.g., caused by changes in flying insect populations) or specific to each species (e.g., caused by changes in species' breeding habitat). A recent study suggested that population trends of aerial insectivores changed for the worse in the 1980s. If there was such a change point in trends of the group, understanding its timing and geographic pattern could help identify potential causes of the decline. We used a hierarchical Bayesian, penalized regression spline, change point model to estimate group-level change points in the trends of 22 species of AI, across 153 geographic strata of North America. We found evidence for group-level change points in 85% of the strata. Change points for flycatchers (FC) were distinct from those for swallows, swifts and nightjars (SSN) across North America, except in the Northeast, where all AI shared the same group-level change points. During the 1980s, there was a negative change point across most of North America, in the trends of SSN. For FC, the group-level change points were more geographically variable, and in many regions there were two: a positive change point followed by a negative change point. This group-level synchrony in AI population trends is likely evidence of a response to a common environmental factor(s) with similar effects on many species across broad spatial extents. The timing and geographic patterns of the change points that we identify here should provide a spring-board for research into the causes behind aerial insectivore declines.

14) García-Pérez, B., Hobson, K.A., Albrecht, G., Cadman, M.D., Salvadori, A. Influence of climate on annual survival of Barn Swallows (Hirundo rustica) breeding in North America (2014) *Auk*, 131 (3), pp. 351-362. DOI: 10.1642/AUK-13-145.1

Population dynamics of migratory birds are influenced by both local weather and larger-scale patterns in climate that can operate at various stages of their annual cycle. We investigated correlations between (1) annual climatic indices and weather during the breeding season and (2) the annual survival of Barn Swallows (Hirundo rustica) breeding at 2 sites in North America. Mark-recapture data collected during a 10-yr period for each of the 2 colonies in eastern and western North America were analyzed to model annual survival probabilities. Annual survival rates of Barn Swallows breeding in Seattle, Washington, USA, were higher in years preceded by El Niño Southern Oscillation (ENSO) winters and higher in years with more positive North Atlantic Oscillation (NAO) values. ENSO was expected to primarily influence wintering conditions through rainfall amount, and NAO was expected to influence climate on the breeding grounds; thus, climatic conditions on both breeding and wintering grounds likely affected the survival of these Seattle-breeding birds. By contrast, annual survival of swallows breeding in southern Ontario, Canada, remained constant over time and were not affected by any of the climatic parameters studied, which suggests that NAO did not have a strong effect on climatic conditions there and/or that these birds winter in regions where ENSO is not strongly correlated with local weather conditions. Alternatively, there may be less geographic variation in wintering-ground locations for Barn Swallows breeding in Seattle, resulting in stronger ENSO

effects on survival for the Seattle population. Our results demonstrate how correlations between climate patterns on wintering grounds and annual survival can provide information on migratory connectivity at continental scales and underline the importance of local weather conditions throughout the annual cycle on survivorship and population dynamics of aerial insectivorous birds.
Keywords: Aerial insectivore; Barn Swallow; El Niño Southern Oscillation; Hirundo rustica; Long-distance migration; Mark-recapture data; North Atlantic Oscillation; Survivorship

15) Pomfret, JK; Nocera, JJ; Kyser, TK; Reudink, MW. Linking Population Declines with Diet Quality in Vaux's Swifts Northwest Science: 88 (4): 305-313 DOI: 10.3955/046.088.0405 2014

Over the past 50 years, a range of environmental stressors has resulted in aerial insectivores throughout North America experiencing sharp population declines. Vaux's swifts (Chaetura vauxi) are small, long-distance migratory birds that are currently experiencing range-wide population declines, especially at the their northern range limit. Many studies attribute the Vaux's swift's population decline to a loss in nesting habitat; however, other potentially exacerbating factors, such as changes in insect composition and diet, remain unstudied. Here, we examine a similar to 26 year dietary archive of Vaux's swift guano to ask whether diet composition has changed over time. Vaux's swifts roost communally at the same roost sites each year when migrating, often within decommissioned brick chimneys. As a result, guano accumulates at the base of these roost sites, providing a chronostratified snapshot of the bird's historic diet. We obtained a vertical core sample from a Vaux's swift guano deposit in a chimney on Vancouver Island, BC, Canada. We symmetrically stratified the guano and assessed diet composition by visually analyzing egested arthropod exoskeletons, identifying them to order, and measuring delta N-15 signatures at each layer. Our 26-year data set revealed an increase in the ratio of Hemiptera to Coleoptera corresponding with an increase in delta N-15, suggesting a possible decline in diet quality through time because Hemipterans tend towards higher trophic status than Coleopterans, but are of less caloric value per capita. In addition, delta N-15 was significantly negatively correlated with an annual population index (Breeding Bird Survey). We suggest a reduction in diet quality may be contributing to the decline of Vaux's swift populations, and could be contributing to more declines in other aerial insectivore species.
Keywords: Vaux's Swift; insectivore; stable isotope; diet; population decline

16) Hallmann, C.A., Foppen, R.P.B., Van Turnhout, C.A.M., De Kroon, H., Jongejans, E. Declines in insectivorous birds are associated with high neonicotinoid concentrations
(2014) *Nature*, 511 (7509), pp. 341-343. DOI: 10.1038/nature13531

Recent studies have shown that neonicotinoid insecticides have adverse effects on non-target invertebrate species. Invertebrates constitute a substantial part of the diet of many bird species during the breeding season and are indispensable for raising offspring. We investigated the hypothesis that the most widely used neonicotinoid insecticide, imidacloprid, has a negative impact on insectivorous bird populations. Here we show that, in the Netherlands, local population trends were significantly more negative in areas with higher surface-water concentrations of imidacloprid. At imidacloprid concentrations of more than 20 nanograms per litre, bird populations tended to decline by 3.5 per cent on average annually. Additional analyses revealed that this spatial pattern of decline appeared only after the introduction of imidacloprid to the Netherlands, in the mid-1990s. We further show that the recent negative relationship remains after correcting for spatial differences in land-use changes that are known to affect bird populations in farmland. Our results suggest that the impact of neonicotinoids on the natural environment is even more substantial than has recently been reported and is reminiscent of the effects of persistent insecticides in the past. Future legislation should take into account the potential cascading effects of neonicotinoids on ecosystems.

17) Paquette, SR; Garant, D; Pelletier, F; Belisle, M Seasonal patterns in Tree Swallow prey (Diptera) abundance are affected by agricultural intensification ECOLOGICAL APPLICATIONS 23 (1): 122-133 DOI: 10.1890/12-0068.1 2013

In many parts of the world, farmland bird species are declining at faster rates than other birds. For aerial insectivores, this decline has been related to a parallel reduction in the abundance of their invertebrate prey in agricultural landscapes. While the effects of agricultural intensification (AI) on arthropod communities at the landscape level have been substantially studied in recent years, seasonal variation in these impacts has not been investigated. To assess the contention that intensive cultures negatively impact food resources for aerial insectivorous birds, we analyzed the spatiotemporal distribution patterns of Diptera, the main food resource for breeding Tree Swallows (Tachycineta bicolor), across a gradient of AI in southeastern Quebec, Canada. Linear mixed models computed from a data set of 5000 samples comprising >150 000 dipterans collected over three years (2006-2008) suggest that both Diptera abundance and biomass varied greatly during swallow breeding season, following a quadratic curve. Globally, AI had a negative effect on Diptera abundance (but not biomass), but year-by-year analyses showed that in one of three years (2008), dipterans were more abundant in agro-intensive landscapes. Analyses also revealed a significant interaction between the moment in the season and AI: In early June, Diptera abundances were similar regardless of the landscape, but differences increased as the season progressed, with highly intensive landscapes harboring fewer prey, possibly creating an "ecological trap" for aerial insectivores. While global trends in our results are in agreement with expectations (negative impact of AI on insect abundance), strong discrepancies in 2008 highlight the difficulty of predicting the abundance of insect communities. Our study indicates that predicting the effects of AI may prove more challenging than generally assumed, even when large data sets are collected, and that temporal variation within a season is important to take into consideration. While further work is required to assess the direct impacts of these seasonal trends in Diptera abundance on bird breeding success and post-fledging survival, management strategies in agricultural landscapes may need to consider the phenology of breeding birds and their dipteran prey in order to mitigate the potentially negative effects of AI late in the breeding season.
Keywords: agro-intensive landscapes; biomass; Diptera abundance; linear mixed modeling; southeastern Canada; spatiotemporal analyses; Tachycineta bicolor; Tree Swallow

18) Nocera, JJ; Blais, JM; Beresford, DV; Finity, LK, Grooms, C; Kimpe, LE; Kyser, K; Michelutti, N (Michelutti, Neal); Reudink, MW; Smol, JP Historical pesticide applications coincided with an altered diet of aerially foraging insectivorous chimney swifts (2012) PROCEEDINGS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES 279 (1740): 3114-3120 DOI: 10.1098/rspb.2012.0445

Numerous environmental pressures have precipitated long-term population reductions of many insect species. Population declines in aerially foraging insectivorous birds have also been detected, but the cause remains unknown partly because of a dearth of long-term monitoring data on avian diets. Chimney swifts (Chaetura pelagica) are a model aerial insectivore to fill such information gaps because their roosting behaviour makes them easy to sample in large numbers over long time periods. We report a 48-year-long (1944-1992) dietary record for the chimney swift, determined from a well-preserved deposit of guano and egested insect remains in Ontario (Canada). This unique archive of palaeo-environmental data reflecting past chimney swift diets revealed a steep rise in dichlorodiphenyltrichloroethane (DDT) and metabolites, which were correlated with a decrease in Coleoptera remains and an increase in Hemiptera remains, indicating a significant change in chimney swift prey. We argue that DDT applications decimated Coleoptera populations and dramatically altered insect community structure by the 1960s, triggering nutritional consequences for swifts and other aerial insectivores.
Keywords: aerial insectivores; dichlorodiphenyltrichloroethane; diet reconstruction; guano

19) Shutler, D, Hussell, DJT, Norris, DR, Winkler, DW, Robertson, RJ; Bonier, F, Rendell, WB, Belisle, M, Clark, RG, Dawson, RD; Wheelwright, NT, Lombardo, MP, Thorpe, PA; Truan, MA; Walsh, R; Leonard, ML, Horn, AG; Vleck, CM; Vleck, D; Rose, AP, Whittingham, LA, Dunn, PO; Hobson, KA; Stanback, MT. Spatiotemporal Patterns in Nest Box Occupancy by Tree Swallows Across North America (2012) AVIAN CONSERVATION AND ECOLOGY 7 (1): 3 DOI: 10.5751/ACE-00517-070103

Data from the North American Breeding Bird Survey (BBS) suggest that populations of aerial insectivorous birds are declining, particularly in northeastern regions of the continent, and particularly since the mid-1980s. Species that use nest boxes, such as Tree Swallows (Tachycineta bicolor), may provide researchers with large data sets that better reveal finer-scale geographical patterns in population trends. We analyzed trends in occupancy rates for ca. 40,000 Tree Swallow nest-box-years from 16 sites across North America. The earliest site has been studied intensively since 1969 and the latest site since 2004. Nest box occupancy rates declined significantly at five of six (83%) sites east of -78 degrees W longitude, whereas occupancy rates increased significantly at four of ten sites (40%) west of -78 degrees W longitude. Decreasing box occupancy trends from the northeast were broadly consistent with aspects of a previous analysis of BBS data for Tree Swallows, but our finding of instances of increases in other parts of the continent are novel. Several questions remain, particularly with respect to causes of these broad-scale geographic changes in population densities of Tree Swallows. The broad geographic patterns are consistent with a hypothesis of widespread changes in climate on wintering, migratory, or breeding areas that in turn may differentially affect populations of aerial insects, but other explanations are possible. It is also unclear whether these changes in occupancy rates reflect an increase or decrease in overall populations

of Tree Swallows. Regardless, important conservation steps will be to unravel causes of changing populations of aerial insectivores in North America.
Keywords: avian aerial insectivore; migrant; nest boxes; North American Breeding Bird Survey; population trends; Tree Swallow

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BREEDING SEASON

1) Kusack, J.W., Mitchell, G.W., Evans, D.R., Cadman, M.D., Hobson, K.A. Effects of agricultural intensification on nestling condition and number of young fledged of barn swallows (Hirundo rustica) (2020) *Science of the Total Environment*, 709, art. no. 136195. DOI: 10.1016/j.scitotenv.2019.136195

Farmland bird populations have declined with increasing agricultural intensification possibly due to putative reductions in prey insects and effects of pesticide exposure. Presence of agriculture may be especially relevant for aerial insectivorous songbirds whose primary diet is flying insects. Here, we investigated the effects of agricultural land use on nestling body condition, an important determinant of post-fledging survival, for barn swallows (Hirundo rustica), an aerial insectivore breeding within an agro-ecosystem in southern Ontario, Canada. Our scale-of-effect analysis revealed that nestling and pre-fledging body condition varied most strongly with the proportion of row crop within 100 m of the natal barn. Unexpectedly, this correlation was positive for both nestling body condition (2016 only) and for pre-fledging condition (2016 and 2017). We found a weak positive effect of row crop on number of young fledged. We speculate that the positive effects of agricultural row-cropping on condition and number of young fledged was due to higher prey availability and/or more open foraging habitat around barns surrounded by row crops. Alternatively, higher nestling condition in high agriculture environments could reflect an insurance policy to increase survival during the post-fledging period. Our results suggest that, in our southern Ontario study area, the degree of agricultural conversion does not negatively influence individual nestling condition and number of young produced for barn swallows. We recommend future research on this species to examine reproductive success in more intense agricultural landscapes and possible effects of pesticide exposure.
Keywords Agricultural intensification; Barn swallow; Body condition; Nestling; Number of young fledged; Scale-of-effect

2) Saldanha, S., Taylor, P.D., Imlay, T.L., Leonard, M.L. Biological and environmental factors related to communal roosting behavior of breeding bank swallow (Riparia riparia) [Facteurs biologiques et environnementaux liés au comportement de nidification communautaire de l'hirondelle de rivage (Riparia riparia) pendant la saison de reproduction] (2019) *Avian Conservation and Ecology*, 14 (2), art. no. 21. DOI: 10.5751/ACE-01490-140221

Although communal roosting during the wintering and migratory periods is well documented, few studies have recorded this behavior during the breeding season. We used automated radio telemetry to examine communal roosting behavior in breeding Bank Swallow (Riparia riparia)

and its relationship with biological and environmental factors. Specifically, we used (generalized) linear mixed models to determine whether the probability of roosting communally and the timing of departure from and arrival at the colony (a measure of time away from the nest) was related to adult sex, nestling age, brood size, nest success, weather, light conditions, communal roosting location, and date. We found that Bank Swallow individuals roosted communally on 70 ± 25% of the nights, suggesting that this behavior is common. The rate of roosting communally was higher in males than in females with active nests, increased with older nestlings in active nests, and decreased more rapidly with nestling age in smaller broods. Together, these results suggest that that communal roosting is limited by the thermoregulatory needs of the offspring. The rate of roosting communally and the total time spent away from the nest while roosting also decreased with humidity and low temperatures (total time only), supporting the conclusion that the thermoregulatory needs of both offspring and adults limit this behavior. Communal roosting was also restricted to dark nights, suggesting that the Bank Swallow may roost communally to avoid predation. Individuals also roosted communally and spent more time at the roosts as the breeding season progressed, suggesting that communal roosting may be a way of avoiding the growing number of ectoparasites at the colony or taking advantage of prospecting opportunities in the morning. The Bank Swallow is listed as Threatened in Canada, so understanding the factors that relate to communal roosting is essential for identifying the critical habitat of this declining species.
Keywords: Automated telemetry; Communal roost; Habitat use; Predator avoidance; Radio telemetry; Sand Martin; Thermoregulation; Weather

3) Purves, E.F., Falconer, C.M., Tozer, D.C., Richardson, K. Timing matters: Cloud cover and date influence probability of detecting nesting chimney swifts (*Chaetura pelagica*) [Le choix du moment: La couverture nuageuse et la date ont une influence sur la probabilité de détecter les Martinets ramoneurs nicheurs] (2019) *Avian Conservation and Ecology*, 14 (1), art. no. 8. DOI: 10.5751/ACE-01339-140108

One third of bird species in North America need immediate conservation action. Effective management and recovery actions for species of conservation concern require accurate methods of monitoring species occurrence that limit the incidence of nondetection error (when a species is falsely recorded as absent when it is present). The Chimney Swift (Chaetura pelagica) is experiencing widespread population declines in North America, possibly, in part, because chimneys used for nesting or roosting are being capped or demolished. In particular, the presence of nesting swifts in a chimney can be difficult to determine, and thus, it is important to design survey protocols that limit the incidence of nondetection error. Here, we used data from Bird Studies Canada’s Citizen Science program, Ontario SwiftWatch, and dynamic occupancy models to examine factors influencing the probability of detecting Chimney Swifts at nest sites. We found that the probability of detecting Chimney Swifts at nest chimneys decreased with increasing cloud cover. We also found some support suggesting that detection increased moderately with date over the course of the nesting period (June-July). Based on our findings, we recommend that surveys aiming to identify Chimney Swift nest sites in southern Ontario, Canada should be conducted for at least one hour under clear skies, and as late in the nesting period as possible. The results of this study will inform survey design to reduce the

incidence of false negatives during chimney surveys for nest occupancy, and as a result, help reduce Chimney Swift nesting habitat disturbance and loss.
Keywords: Aerial insectivore; Chaetura pelagica; Chimney Swift; Citizen Science; Detection probability; Dynamic occupancy model; Habitat loss

4) Farrell, CE; Fahrig, L; Mitchell, G; Wilson, S Local habitat association does not inform landscape management of threatened birds. (2019) *Landscape Ecology* 34(6): 1313-1327 DOI: 10.1007/s10980-019-00843-6

Context Species that use open patches in forested landscapes often select clearcuts. However, it is unknown whether local associations with clearcuts translate to an effect of clearcut amount in the surrounding landscape on occupancy or abundance at local sites. This question is important because forest management decisions are made at landscape scales.ObjectivesWe examined whether the amount of clearcut in the surrounding landscape influenced site occupancy of two threatened aerial insectivores, Common Nighthawk and Eastern Whip-poor-will. Both species nest in/near clearcuts at a local-scale.MethodsWe used acoustic recorders placed on edges of recent clearcuts (<= 15years old, n=49 sites) to measure presence-absence. We estimated occupancy in relation to the proportion of clearcut and open wetland within the surrounding landscapes at spatial extents between 0.5 and 5.0km.ResultsOccupancy of Eastern Whip-poor-will was not related to clearcut amount in the surrounding landscape at any scale. Common Nighthawk occupancy was lower in sites surrounded by landscapes with higher proportion of older (11-15years old) clearcuts. Both species' occupancy was higher in sites where the surrounding landscapes had higher proportions of open wetland.ConclusionsTwo possible mechanisms for our results include multi-scale selection of breeding sites or demographic responses to higher productivity in wetlands than clearcuts; both need further study. Our results show how the association of species with clearcut habitats at a local scale does not necessarily translate to a higher occurrence of those species at the landscape scale at which management decisions are made.

5) Westwood, A.R., Staicer, C., Sólymos, P., Haché, S., Fontaine, T., Bayne, E.M., Mazerolle, D. Estimating the conservation value of protected areas in maritime canada for two species at risk: The olive-sided flycatcher (*Contopus cooperi*) and canada warbler (*Cardellina canadensis*) [Évaluation de la valeur de conservation d'aires protégées dans les Maritimes, Canada, pour deux espèces en péril: Le Moucherolle à côtés olive (Contopus cooperi) et la Paruline du Canada (Cardellina canadensis)]
(2019) *Avian Conservation and Ecology*, 14 (1), art. no. 16. DOI: 10.5751/ACE-01359-140116

The Olive-sided Flycatcher (Contopus cooperi) and Canada Warbler (Cardellina canadensis) are threatened landbirds in Canada and parts of the U.S. Both species are subjects of recent conservation and management interest. Protected areas are a key tool for managing populations of species at risk, and Canadian national parks may serve as important refuges in an increasingly fragmented landscape. However, the potential role that Canadian national parks may play in the recovery of these species is unclear. We used the Boreal Avian Modelling Project point count database to build Poisson log-linear models using forward stepwise variable

selection to predict population density and distribution of these two threatened species in four national parks in Maritime Canada. We also predicted population density in areas of equivalent size in the same ecoregions outside the parks for comparison. Because forested wetlands, a key habitat for these species in this region, are difficult to represent with available spatial data, we tested the effectiveness of different remote sensing products. We tested GIS layers based on aerial photography wetlands (WETLANDS), depth to water table (WETNESS), and WETNESS as interacted with forest cover from aerial photography (WETxFOR). The bestperforming models for the Olive-sided Flycatcher used WETxFOR, whereas WETNESS performed best for the Canada Warbler. Anthropogenic disturbance and proximity to roads had a negative effect on predicted density for both species. Protected areas showed slightly higher Olive-sided Flycatcher population densities than nearby areas, but not so for the Canada Warbler. Our results provide the first population density and population size estimates for these species in these parks, and novel information on the impacts of anthropogenic disturbance on predicted population density. These results can inform conservation and management in this region and our approach can be replicated in other regions to support ongoing recovery efforts.
Keywords: Canada Warbler; Conservation; Olive-sided Flycatcher; Parks and protected areas; Species at risk; Species distribution models

6) Godwin, CM; Barclay, RMR; Smits, JEG. Tree Swallow (Tachycineta bicolor) nest success and nestling growth near oil sands mining operations in northeastern Alberta, Canada (2019) *Canadian Journal Of Zoology* 97(6): 547-557 DOI: 10.1139/cjz-2018-0247

Industrial development and contaminant exposure may affect reproductive success and food quality for birds. Tree Swallows (Tachycineta bicolor (Vieillot, 1808)) nesting near oil sands development in northern Alberta (Canada) potentially experience elevated environmental stressors that could influence reproduction. We measured reproductive and growth endpoints in Tree Swallows, predicting reduced reproductive success and nestling growth near oil sands operations compared with reference sites. We also identified the invertebrate prey in the stomach contents of nestlings to understand variability in the diet and its potential effect on growth and survival of nestlings. From 2012 to 2015, clutch initiation varied among years but was not influenced by proximity to oil sands operations. Hatching and fledging success decreased in response to increased precipitation, regardless of location. Measurements of nestling growth reflected the variation associated with nestling sex and possibly asynchronous hatching. The composition of the nestling diet was significantly different; birds near oil sands development consumed Odonata, whereas birds at reference sites consumed Ephemeroptera. Nestlings from all sites consumed relatively high quantities of terrestrial insects. Our results demonstrate that factors such as weather conditions, diet, hatching order, and nestling sex are important when interpreting the potential effects of oil sands development on nest success and nestling growth.

7) Shave, A., Garroway, C. J., Siegrist, J., Fraser, K. C. Timing to temperature: Egg-laying dates respond to temperature and are under stronger selection at northern latitudes (2019) Ecosphere 10(12): e02974

Global climate change produces spatially variable patterns of environmental change. This could put migratory species at risk as the synchrony between migration timing and suitable breeding conditions could become mismatched. For migratory birds, whether the timing of egg laying is a plastic trait that can vary in response to environmental change has been sparsely studied across regions and systems and thus remains poorly known. We investigated the effects of temperature variability and climate warming on the breeding phenology of purple martins (Progne subis), a long-distance migratory songbird, using a 20-yr data set comprised of 28,165 records of nest timing and fledgling success spanning the entire breeding range (25–54° N). We discovered that purple martins lay eggs earlier in warmer springs and fledge more young when they lay earlier. After controlling for spatial patterns in the data with Moran's eigenvector maps, we found that selection favored earlier breeding in most years, particularly at more northern latitudes.

However, selection pressure for earlier breeding did not increase over the 20-yr period, perhaps owing to high variability in temperature across years. Our results therefore demonstrate plasticity in the timing of egg laying in response to temperature variation and climate change over 20 yr across the range of this widely distributed, long-distance migrant. Whether these plastic responses are common or sufficiently matched to climate change among other declining migratory songbird species should be further investigated.

Key words: breeding phenology; climate change; migratory songbird; Neotropical migrant; Progne subis; purple
martin; selection

8) Moeller, K., Ritchison, G. Factors influencing pre-fledging mass recession by nestling Tree Swallows (Tachycineta bicolor) (2019) *Wilson Journal of Ornithology*, 131 (1), pp. 119-127. DOI: 10.1676/18-54

Nestlings of some aerial insectivores experience pre-fledging mass recession, possibly to achieve optimum wing loading at fledging. However, studies to date where mass recession was linked to wing loading at fledging have been limited to 2 species of swifts (Apodidae), and additional studies are needed to determine if factors contributing to prefledging mass recession vary among species. We examined factors contributing to pre-fledging mass recession by nestling Tree Swallows (Tachycineta bicolor). During the 2015 breeding season in Kentucky, nestling Tree Swallows in 29 broods were divided into half-weighted, full-weighted, and control treatment groups. Lead weights weighing either 2.5% (0.6 g) or 5% (1.2 g) of nestling mass were glued to the back feathers of half-weighted and full-weighted nestlings, respectively, between 9 and 11 days post-hatching. Video recordings were used to monitor provisioning and begging behavior. Treatment groups did not differ in mass at fledging, amount of mass lost, or wing loading at fledging, and adult provisioning rates and time spent begging by nestlings did not vary from day 11 to day 19 post-hatching. Thus, mass loss by nestling Tree Swallows prior to fledging was not due to changes in either parental or nestling behavior, but likely resulted from loss of water from maturing feathers and other tissues. In contrast, studies of 2 species of swifts (Apodidae) revealed that changes in nestling behavior influenced pre-fledging mass recession, with weighted nestlings losing more mass than control nestlings, apparently to optimize wing loading at fledging. This difference between swifts and Tree Swallows may be due to

differences in the duration of nestling periods (longer for swifts) and wing loading (higher in swifts). With greater wing loading, optimum mass at fledging may be more critical for swifts than Tree Swallows.
Keywords: aerial insectivore; begging behavior; provisioning behavior; Tachycineta bicolor; wing loading.

9) McClenaghan, B., Nol, E., Kerr, K.C.R. DNA metabarcoding reveals the broad and flexible diet of a declining aerial insectivore (2019) *Auk*, 136 (1), art. no. uky003; DOI: 10.1093/auk/uky003

Aerial insectivores are highly mobile predators that feed on diverse prey items that have highly variable distributions. As such, investigating the diet, prey selection and prey availability of aerial insectivores can be challenging. In this study, we used an integrated DNA barcoding method to investigate the diet and food supply of Barn Swallows, an aerial insectivore whose North American population has declined over the past 40 yr. We tested the hypotheses that Barn Swallows are generalist insectivores when provisioning their young and select prey based on size. We predicted that the diets of nestlings would contain a range of insect taxa but would be biased towards large prey items and that the diet of nestlings would change as prey availability changed. We collected insects using Malaise traps at 10 breeding sites and identified specimens using standard DNA barcoding. The sequences from these insect specimens were used to create a custom reference database of prey species and their relative sizes for our study area. We identified insect prey items from nestling fecal samples by using high-throughput DNA sequencing and comparing the sequences to our custom reference database. Barn Swallows fed nestlings prey items from 130 families representing 13 orders but showed selection for larger prey items that were predominantly from 7 dipteran families. Nestling diet varied both within and between breeding seasons as well as between breeding sites. This dietary flexibility suggests that Barn Swallows are able to adjust their provisioning to changing prey availability on the breeding grounds when feeding their nestlings. Our study demonstrates the utility of custom reference databases for linking the abundance and size of insect prey in the habitat with prey consumed when employing molecular methods for dietary analysis.
Keywords: aerial insectivore; Barn Swallow; código de barras de ADN; diet; DNA barcoding; Hirundo rustica; Hirundo rustica; insectívoro aéreo; meta-código de barras; metabarcoding

10) Griebel, I.A., Dawson, R.D. Predictors of nestling survival during harsh weather events in an aerial insectivore, the tree swallow (*Tachycineta bicolor*) (2019) *Canadian Journal of Zoology*, 97 (2), pp. 81-90. DOI: 10.1139/cjz-2018-0070

Extreme weather events influence the population dynamics of wild animals. For organisms whose food source is affected by environmental conditions, such as aerial insectivorous birds, periods of inclement weather can have devastating effects. Here, we examine predictors of survival of individual nestlings and whole broods in Tree Swallows (Tachycineta bicolor (Vieillot, 1808)) during an extreme, 2-day harsh weather event in central British Columbia, Canada, which co-occurred with experimental reduction of nest ectoparasite loads using an antiparasite drug (ivermectin) or heat-treating nests. A curvilinear relationship existed between survival and brood age such that middle-aged broods were least likely to survive. Survival of broods and nestlings was higher when raised by males with bluer plumage, whereas nestling survival was lower when female parents had brighter and more UV-reflective plumage. Within broods, smaller nestlings had a lower chance of surviving than their larger siblings. Nestlings in broods where half of the offspring received ivermectin injections had significantly higher chances of surviving than nestlings from nonexperimental broods, suggesting that parasite loads can influence survival during inclement weather. Our results identify several factors influencing resiliency of nestlings to harsh weather and are particularly relevant in the context of declining aerial insectivorous bird populations and climate change.

Keywords: Aerial insectivore; Antiparasite treatment; Brood age; Brood size hierarchy; Harsh weather; Plumage characteristics; Tachycineta bicolor; Tree Swallow

11) Twining, C.W., Shipley, J.R., Winkler, D.W. Aquatic insects rich in omega-3 fatty acids drive breeding success in a widespread bird. (2018) *Ecology Letters*, 21 (12), pp. 1812-1820. DOI: 10.1111/ele.13156

Ecologists studying bird foraging ecology have generally focused on food quantity over quality. Emerging work suggests that food quality, in terms of highly unsaturated omega-3 fatty acids (HUFA), can have equally important effects on performance. HUFA, which are present in aquatic primary producers, are all but absent in vascular plants, and HUFA content is also correspondingly higher in aquatic insects. Here, we show that Tree Swallow (Tachycineta bicolor) chicks rapidly accumulate HUFA from food during the nestling period. Using data sampled over 24 years, we also show that Tree Swallow breeding success is positively associated with the availability of HUFA-rich aquatic insects. Variation in aquatic insect biomass during chick development was a strong predictor of fledging success, whereas variation in terrestrial insects had little effect on fledging success. Our results highlight the potential for nutritional mismatches between insectivores and high-quality prey to affect avian reproductive performance.

Keywords: Aerial insectivores; breeding success; ecological subsidies; food quality; highly unsaturated omega-3 fatty acids; long-term ecological data; Tree Swallows

12) Dreelin, R.A., Shipley, J.R., Winkler, D.W. Flight behavior of individual aerial insectivores revealed by novel altitudinal dataloggers (2018) *Frontiers in Ecology and Evolution*, 6 (NOV), art. no. 182. DOI: 10.3389/fevo.2018.00182

Swallows and martins (Aves: Hirundinidae) are well-studied with respect to their breeding biology, but major aspects of their individual aerial movement behavior and ecology are poorly understood. Atmospheric conditions can strongly influence both the availability and distribution of flying insects that aerial insectivores rely upon. Because aerial insects are often found in distinct clusters within the aerosphere, we wanted to explore whether aerial insectivore flight altitudes were species-specific and if they were associated with atmospheric conditions. We examined these questions with novel tag technology, an altitude datalogger, on breeding populations of Purple Martin (Progne subis), Tree Swallow (Tachycineta bicolor), and Barn Swallow (Hirundo rustica) in upstate New York during the summer of 2016, providing

individual-level flight data on a per minute basis. Using mixed models, we investigated differences in flight altitudes between individuals, species, and varying atmospheric conditions. The major findings were that individuals of each species spent significantly different proportions of their time throughout the day in different aerial strata. In addition, higher flying species such as Purple Martins and Tree Swallows responded positively to greater thermal uplift whereas this predictor had no effect on Barn Swallow flight altitudes. Finally, the differing relationships for all species between their flight altitudes and weather variables suggest that each species may use different atmospheric cues for tracking their environment and/or prey. More research spanning greater time scales and a wider range of atmospheric conditions is needed to determine these relationships in finer detail. We encourage broader use of this or similar methodologies to better understand the behavior and ecology of aerial insectivores globally. Keywords:Aerial
insectivore; Aeroecology; Behavior; Datalogger; Ecology; Flight; Hirundinidae; Swallow

13) Michelson, C.I., Clark, R.G., Morrissey, C.A. Agricultural land cover does not affect the diet of Tree Swallows in wetland-dominated habitats (2018) *Condor*, 120 (4), pp. 751-764. DOI: 10.1650/CONDOR-18-16.1

Agricultural practices have intensified during the past 50 yr, increasing crop production and altering the Canadian prairie landscape by removing or degrading uncropped habitats, including wetlands. We predicted that agricultural practices would alter invertebrate communities and the diets of consumers such as insectivorous birds. Using stable isotope analysis (δ13C and δ15N), we tested for differences in the assimilated diets and isotopic niche widths of adult and nestling Tree Swallows (Tachycineta bicolor) in grassland and cropland sites with similar wetland densities in Saskatchewan, Canada. We also assessed relationships between swallow diet and body size, mass, and condition. Dietary composition and niche width differed between years and age classes but were not consistently related to agricultural land cover. Aquatic insect prey (Diptera and Odonata) made up 75% of all swallow diets, but nestlings consumed a larger proportion of terrestrial Diptera, resulting in broader isotopic niche widths compared with adults. Age-specific dietary differences could have been related to temporal shifts in the insect community or distinct foraging by adults when feeding nestlings. The body mass and condition of adult and nestling swallows were unrelated to diet, but were higher on average in grassland than cropland habitat. Overall, Tree Swallows specialized in feeding on aquatic insects, regardless of agricultural land cover, at least in wetland-dominated habitats. Food resources originating from wetlands may play a critical role in supporting insectivorous bird populations in agricultural landscapes.
Keywords: aerial insectivores; agricultural land cover; avian diet; body condition; niche width

14) Johnson, L.S., Iser, K.M., Molnar, H.A., Nguyen, A.V., Connor, C.L. Clutch and egg size of Tree Swallows along an elevational gradient (2018) *Journal of Field Ornithology*, 89 (3), pp. 234-241. DOI: 10.1111/jofo.12262

How avian reproductive behavior changes at high elevations, and whether changes are the result of adaptation or constraint remains unclear. We compared clutch and egg sizes in two

populations of Tree Swallows (Tachycineta bicolor), one at an elevation of ~2500 m a.s.l. in Wyoming's Bighorn Mountains and the other at ~1350 m at the base of these mountains. Females at the high-elevation site began laying 10 d later, on average, than females at the lower site. Females at the high site laid an average of 0.4 fewer eggs than those at the low site, a significant difference. Eggs were also slightly (2.3%), but significantly, smaller at the high site. Smaller clutches and eggs at the high site may have resulted in part from greater energetic constraints on females. Females at this site faced colder, windier weather during egg formation which would have increased thermoregulatory costs while simultaneously reducing the abundance of prey, i.e., flying insects. Laying a relatively small clutch at the high-elevation site may also be adaptive, however. Having a smaller brood could help ensure there is an adequate supply of food for each offspring during bouts of inclement weather that are more severe at higher elevations. Also, if the delay in breeding inherent at high elevations reduces the survival prospects of the young, then producing fewer young could enhance a female's chances of breeding again, perhaps at a different location.
Keywords: aerial insectivore; high elevation; inclement weather; Tachycineta bicolor

15) Knight, E.C., Ng, J.W., Mader, C.E., Brigham, R.M., Bayne, E.M. "An inordinate fondness for beetles": First description of Common Nighthawk (Chordeiles minor) diet in the boreal biome (2018) *Wilson Journal of Ornithology*, 130 (2), pp. 525-531. DOI: 10.1676/16-219.1

We present the first description of Common Nighthawk (Chordeiles minor) diet from the boreal biome. Knowledge of diet is important for this crepuscular aerial insectivore, whose population declines may be related to insect food sources. We collected 4 nestling diet samples as food boluses from 1 adult female and 3 adult males on the breeding grounds in northern Alberta, Canada. Coleopterans comprised the majority of samples, and the composition of the sample from the female differed from those collected from males. Further research is needed across the boreal forest to characterize foraging strategies and assess the potential role of food availability in population declines.
Keywords: Aerial insectivore; boreal; Common Nighthawk; diet; insect; nightjar

16) English, P.A., Nocera, J.J., Green, D.J. Nightjars may adjust breeding phenology to compensate for mismatches between moths and moonlight (2018) *Ecology and Evolution*, 8 (11), pp. 5515-5529. DOI: 10.1002/ece3.4077

Phenology match–mismatch usually refers to the extent of an organism's ability to match reproduction with peaks in food availability, but when mismatch occurs, it may indicate a response to another selective pressure. We assess the value of matching reproductive timing to multiple selective pressures for a migratory lunarphilic aerial insectivore bird, the whip-poor-will (Antrostomus vociferus). We hypothesize that a whip-poor-will's response to shifts in local phenology may be constrained by long annual migrations and a foraging mode that is dependent on both benign weather and the availability of moonlight. To test this, we monitored daily nest survival and overall reproductive success relative to food availability and moon phase in the northern part of whip-poor-will's breeding range. We found that moth abundance, and potentially temperature and moonlight, may all have a positive influence on

daily chick survival rates and that the lowest chick survival rates for the period between hatching and fledging occurred when hatch was mismatched with both moths and moonlight. However, rather than breeding too late for peak moth abundance, the average first brood hatch date actually preceded the peak moth abundance and occurred during a period with slightly higher available moonlight than the period of peak food abundance. As a result, a low individual survival rate was partially compensated for by initiating more nesting attempts. This suggests that nightjars were able to adjust their breeding phenology in such a way that the costs of mismatch with food supply were at least partially balanced by a longer breeding season.
Keywords: adaptive phenology mismatch; aerial insectivore; Antrostomus vociferus; Caprimulgidae; double brood; whip-poor-will

17) Lenske, A.K., Nocera, J.J. Field test of an automated radio-telemetry system: tracking local space use of aerial insectivores (2018) *Journal of Field Ornithology*, 89 (2), pp. 173-187. DOI: 10.1111/jofo.12254

Documenting local space use of birds that move rapidly, but are too small to carry GPS tags, such as swallows and swifts, can be challenging. For these species, tracking methods such as manual radio-telemetry and visual observation are either inadequate or labor- and time-intensive. Another option is use of an automated telemetry system, but equipment for such systems can be costly when many receivers are used. Our objective, therefore, was to determine if an automated radio-telemetry system, consisting of just two receivers, could provide an alternative to manual tracking for gathering data on local space use of six individuals of three species of aerial insectivores, including one Cliff Swallow (Petrochelidon pyrrhonota), one Eastern Phoebe (Sayornis phoebe), and four Barn Swallows (Hirundo rustica). We established automated radio-telemetry systems at three sites near the city of Peterborough in eastern Ontario, Canada, from May to August 2015. We evaluated the location error of our two-receiver system using data from moving and stationary test transmitters at known locations, and used telemetry data from the aerial insectivores as a test of the system's ability to track rapidly moving birds under field conditions. Median location error was ~250 m for automated telemetry test locations after filtering. More than 90% of estimated locations had large location errors and were removed from analysis, including all locations > 1 km from receiver stations. Our automated telemetry receivers recorded 17,634 detections of the six radio-tagged birds. However, filtering removed an average of 89% of bird location estimates, leaving only the Cliff Swallow with enough locations for analysis of space use. Our results demonstrate that a minimal automated radio-telemetry system can be used to assess local space use by small, highly mobile birds, but the resolution of the data collected using only two receiver stations was coarse and had a limited range. To improve both location accuracy and increase the percentage of usable location estimates collected, we suggest that, in future studies, investigators use receivers that simultaneously record signals detected by all antennas, and use of a minimum of three receiver stations with more antennas at each station.
Keywords: habitat use; location error; movement; small birds; swallows

18) Fernie, K.J., Letcher, R.J. Waste-water treatment plants are implicated as an important source of flame retardants in insectivorous tree swallows (Tachicyneta bicolor) (2018) *Chemosphere*, 195, pp. 29-39. DOI: 10.1016/j.chemosphere.2017.12.037

Wastewater treatment plants (WWTPs) are an important source of anthropogenic chemicals, including organic flame retardants (FRs). Limited studies indicate birds can be exposed to FRs by feeding from waters receiving WWTP effluent or in fields receiving biosolids. Expanding on our earlier study, 47 legacy and 18 new FR contaminants were characterized in the eggs of insectivorous tree swallows (Tachycineta bicolor) feeding in water bodies receiving effluent from two WWTPs and compared to those from a reference site 19 km downstream of the nearest WWTP. Of the FRs measured, polybrominated diphenyl ethers (PBDEs) dominated the FR profile, specifically BDE-47, -99, -100, -153, -154, with considerably lower concentrations of hexabromocyclododecane (HBCDD), BDE-183 and BDE-209; each detected in 96–100% of the eggs overall except HBCDD (83%). FR concentrations were usually significantly greater in eggs from the secondary WWTP versus the tertiary WWTP and/or reference site. Despite low detection rates, concentrations of new FRs, specifically pentabromobenzyl acrylate (PBBA), 1,2,-bis-(2,4,6-tribromophenoxy)ethane (BTBPE), bis(2-ethylhexyl)-tetrabromophthalate (BEHTBP), tetrabromo-o-chlorotoluene (TBCT), hexabromobenzene (HBB), α- and β-1,2-dibromo-4-(1,2-dibromoethyl)-cyclohexane (DBE-DBCH), were greater than HBCDD or BDE-209. Additional evidence that WWTPs are an important source of exposure to new FR contaminants for birds utilizing associated water bodies is that only the WTTP eggs, not the reference eggs, had measureable concentrations of PBBA, TBCT, BEHTBP, HBB, α-DBE-DBCH, 2,2′,4,5,5′-pentabromobiphenyl (BB-101), pentabromoethyl benzene (PBEB), 2,4,6-tribromophenyl allyl ether (TBPAE), and tetrabromo-p-xylene (pTBX). Our study suggests that WWTPs are an important source of legacy and new FR contaminants for birds consuming prey that are associated with WWTP out-flows.
Keywords: Halogenated flame retardants; Sewage outflow; Tachycineta bicolor; Tree swallows; Wastewater treatment plant

19) Twining, CW; Lawrence, P; Winkler, DW; Flecker, AS; Brenna, JT. Taking the Short-or Long-chain Route: Conversion Efficiency of Alpha Linolenic Acid to Long-chain Omega-3 Fatty Acids in Aerial Insectivore Chicks INTEGRATIVE AND COMPARATIVE BIOLOGY Meeting : 131-1 58: E238-E238 Supplement: 1

20) Bellavance, V; Belisle, M; Savage, J; Pelletier, F; Garant, D Influence of agricultural intensification on prey availability and nestling diet in Tree Swallows (Tachycineta bicolor) CANADIAN JOURNAL OF ZOOLOGY Volume: 96 Issue: 9 Pages: 1053-1065 DOI: 10.1139/cjz-2017-0229

Over the last decades, aerial insectivorous birds have been declining in both North America and Europe. Those declines have been hypothetically attributed to a decrease in prey availability caused by agricultural intensification, but empirical evidence remains scarce. Here, we quantify the effect of landscape composition on the abundance and diversity of potential prey of Tree Swallows (Tachycineta bicolor (Vieillot, 1808)) and on nestling diet in southern Quebec, Canada.

We collected food boluses from nestlings and compared their composition with spatiotemporally corresponding samples from traps on farms distributed along a gradient of agricultural intensification. The diet of nestlings was mostly composed of Diptera, both in biomass and abundance, but by mid-June, these decreased with increasing proportions of intensively cultivated crops within 500mof the nests. Trap catches for Diptera and all arthropods combined followed the same trends. Yet, the associations between Diptera subgroups (Nematocera, non-schizophoran Brachycera, Schizophora (Calyptratae), and Schizophora (Acalyptratae)) and landscape composition differed between traps and boluses, suggesting that prey selection was altered by agricultural intensification. Our results suggest that agriculture can alter the availability of preferred prey for aerial insectivores, and further studies should evaluate the impact of prey availability to explain the decline of aerial insectivores.
Keywords: aerial insectivorous bird; arthropods; agricultural intensification; Diptera; redundancy analysis (RDA); Tree Swallow; Tachycineta bicolor

21) Twining, C.W., Lawrence, P., Winkler, D.W., Flecker, A.S., Brenna, J.T. Conversion efficiency of α-linolenic acid to omega-3 highly unsaturated fatty acids in aerial insectivore chicks (2018) *Journal of Experimental Biology*, 221 (3), art. no. 165373, . DOI: 10.1242/jeb.165373

Food availability and quality are both critical for growing young animals. In nature, swallows (Tachycineta bicolor) and other aerial insectivores feed on both aquatic insects, which are rich in omega-3 highly unsaturated fatty acids (HUFAs), and terrestrial insects, which contain considerably lower amounts of omega-3 HUFAs. Carnivorous mammals and fishes must obtain omega-3 HUFAs from their diet, as they have lost the capacity to convert the precursor omega-3 a- linolenic acid (ALA) into omega-3 HUFAs. Thus, the relative value of aquatic versus terrestrial insects depends not only on the fatty acid composition of the prey but also on the capacity of consumers to convert ALA into omega-3 HUFAs.We used a combination of stableisotope- labeled fatty acid tracers to ask whether, and how efficiently, tree swallows can deposit newly synthesized omega-3 HUFAs into tissue. Our data show for the first time that tree swallows can convert ALA into omega-3 HUFAs deposited in liver and skeletal muscle. However, high tree swallow demand for omega-3 HUFAs combined with low ALA availability in natural terrestrial foods may strain their modest conversion ability. This suggests that while tree swallows can synthesize omega-3 HUFAs de novo, omega-3 HUFAs are ecologically essential nutrients in natural systems. Our findings thus provide mechanistic support for our previous findings and the importance of omega-3 HUFA-rich aquatic insects for tree swallows and most likely other aerial insectivores with similar niches.
Keywords: ALA; Carbon stable isotope tracer; Compound-specific stable isotopes; Energy; HUFA; Nutrients; Tree swallows

22) Imlay, T.L., Mann, H.A.R., Leonard, M.L. No effect of insect abundance on nestling survival or mass for three aerial insectivores [Absence d'effet du nombre d'insectes sur la survie et le poids des oisillons de trois insectivores aériens] (2017) *Avian Conservation and Ecology*, 12 (2), art. no. 19, 10 p. DOI: 10.5751/ACE-01092-120219

Swallows, along with other aerial insectivores, are experiencing steep population declines. Decreased insect abundance has been implicated as a potential cause of the decline. However, to determine if there is a guild-level effect of reduced insect abundance on swallows, research is needed to examine relationships between insect abundance and breeding success for multiple species. The goal of our study was two-fold. First, we determined if insect abundance during nestling rearing varied with breeding phenology for three species of swallows, Barn (Hirundo rustica), Cliff (Petrochelidon pyrrhonota), and Tree Swallows (Tachycineta bicolor), such that swallows breeding when insects are abundant have greater success. Then we determined if insect abundance was related to nestling survival and mass (as a proxy for postfledgling survival). We collected insects daily at each of three study sites during the breeding season, monitored swallow nests to determine breeding phenology and success, and weighed nestlings at or just prior to the peak of rapid nestling growth to determine mass. We found early hatching Cliff and Tree Swallow nests had higher insect abundance during nestling rearing. However, neither nestling survival nor mass were related to insect abundance. Our results suggest that breeding success in three species of swallows was not related to insect abundance in our study area. We suggest that the role of insect abundance on aerial insectivore declines may vary across their geographic range, and call for broad-scale, multispecies research on aerial insectivore declines.
Keywords: Body condition; Food availability; Reproductive success

23) English, PA, Nocera, JJ; Pond, BA; Green, DJ Habitat and food supply across multiple spatial scales influence the distribution and abundance of a nocturnal aerial insectivore (2017) LANDSCAPE ECOLOGY 32 (2): 343-359 DOI: 10.1007/s10980-016-0454-y

Conservation research often focuses on individual threats at a single spatial scale, but population declines can result from multiple stressors occurring at different spatial scales. Analyses incorporating alternative hypotheses across spatial scales allow more robust evaluation of the ecological processes underlying population declines. Populations of many aerially insectivorous birds are declining, yet conservation efforts remain focused on habitat due to an absence of data on changes in prey availability. We evaluate the potential for prey and habitat availability at multiple spatial scales to influence a population of eastern whip-poor-wills (Antrostomus vociferous). We assess relationships between landcover (topographical map and satellite imagery) and insect abundance (moths and beetles from blacklight traps), and whip-poor-will distribution and abundance within eastern Canada using Ontario breeding bird atlas data (1980s and 2000s), acoustic recordings (regional), and point counts (local). Whip-poor-will occurrence in both atlas time periods was positively associated with forest area and fragmentation, but only a delayed effect of urban area explained reductions in detection. Contemporary regional whip-poor-will presence was positively related to moth abundance, and local whip-poor-will abundance was best predicted by area of open-canopy forest, anthropogenic linear disturbance density, and beetle abundance. Our finding that bird presence and abundance were associated with human activity and insect abundance across spatial scales suggests factors beyond habitat structure are likely driving population declines in whip-poor-wills and other aerial insectivores. This study demonstrates the importance of examining

multiple hypotheses, including seasonally and locally variable food availability, across a range of spatial scales to direct conservation efforts.
Keywords: Eastern whip-poor-will Antrostomus vociferous; Population declines; Landcover change; Edge effects; Linear disturbance; Coleoptera; Lepidoptera

24) Kirk, D.A., Lindsay, K.E.F. Subtle differences in birds detected between organic and nonorganic farms in Saskatchewan Prairie Parklands by farm pair and bird functional group (2017) *Agriculture, Ecosystems and Environment*, 246, pp. 184-201. DOI: 10.1016/j.agee.2017.04.009

Organic farming may be more beneficial to biodiversity than nonorganic farming but the comparison is often confounded by regional within-farm and landscape differences. We compared breeding bird species composition and abundance on 10 farm pairs of each type matched at the site level for land cover in the prairie parklands of Saskatchewan, Canada in 1990. Land cover was measured around bird point counts at two extents; 'site' (6.3 ha area) and 'field' (16.3 ha area). We pooled species into functional groups; linear mixed models showed no significant differences between farm types for species richness but that all birds, migratory birds using crops and aerial insectivores were more abundant on organic farms. A permutational multivariate analysis of variance demonstrated that farm type did not have a significant overall effect on compositional similarity but that pairwise differences existed between about half of the farm pairs (the direction of differences in beta diversity was not consistent between organic and nonorganic farms according to tests for the homogeneity of multivariate dispersions). Farm-pair differences were more pronounced for all birds and for migratory bird species using crops, migratory birds consuming grains and ground feeders, but not grassland birds. nMDS ordinations suggested that there was more variation in species composition and abundance on organic farms than nonorganic ones but the difference was not significant. Distance-based redundancy analysis (dbRDA) was used to examine the main drivers of bird species composition and abundance and to see which extent was most important; land cover at the field extent was more important than land cover at the site extent or the farming practices measured. The most important field-extent land cover was the amount of native grassland, woodland (including shelterbelts) and wetlands. After controlling for significant field-extent land cover, seed treatment, herbicide use, and number of passes were significant. At the site extent, greater non-crop heterogeneity had a significantly positive effect on abundance and species richness of several groups (e.g., grassland birds, migratory granivores, ground feeders, ground nesters) but a negative effect on richness of woodland birds and abundance of aerial insectivores. Relationships with crop heterogeneity were mostly negative and non-significant. Overall land cover heterogeneity at the site level was positively related to the richness of grassland birds. In contrast at the field extent, non-crop heterogeneity did not have any significant effects on the richness and abundance of any functional group. Crop heterogeneity had a significantly negative effect on aerial insectivore richness and abundance. In the early 1990s, differences in birds between organic and nonorganic farms in Saskatchewan were evident but subtle and variable among farms, and apparently most related to land cover-bird assemblage interactions/relationships.

Keywords: Avian biodiversity; Canada; Farming practices; Farmland birds; Land cover heterogeneity; Landscape heterogeneity; Organic farming; Pesticides; Prairies; Saskatchewan; Variance partitioning

25) Irons, R.D., Scurr, A.H., Rose, A.P., Hagelin, J.C., Blake, T., Doak, D.F. Erratum: Correction to: Wind and rain are the primary climate factors driving changing phenology of an aerial insectivore (Proceedings. Biological sciences (2017) 284 1853 PII: 20171168) (2017) *Proceedings. Biological Sciences*, 284 (1857). DOI: 10.1098/rspb.2017.1168

26) Irons, R.D., Scurr, A.H., Rose, A.P., Hagelin, J.C., Blake, T., Doak, D.F. Wind and rain are the primary climate factors driving changing phenology of an aerial insectivore (2017) *Proceedings of the Royal Society B: Biological Sciences*, 284 (1853), art. no. 20170412, . DOI: 10.1098/rspb.2017.0412

While the ecological effects of climate change have been widely observed, most efforts to document these impacts in terrestrial systems have concentrated on the impacts of temperature. We used tree swallow (Tachycineta bicolor) nest observations from two widely separated sites in central Alaska to examine the aspects of climate affecting breeding phenology at the northern extent of this species' range. We found that two measures of breeding phenology, annual lay and hatch dates, are more strongly predicted by windiness and precipitation than by temperature. At our longest-monitored site, breeding phenology has advanced at nearly twice the rate seen in more southern populations, and these changes correspond to long-term declines in windiness. Overall, adverse spring climate conditions known to negatively impact foraging success of swallows (wet, windy weather) appear to influence breeding phenology more than variation in temperature. Separate analyses show that short windy periods significantly delay initiation of individual clutches within years. While past reviews have emphasized that increasing variability in climate conditions may create physiological and ecological challenges for natural populations, we find that long-term reductions in inclement weather corresponded to earlier reproduction in one of our study populations. To better predict climate change impacts, ecologists need to more carefully test effects of multiple climate variables, including some, like windiness, that may be of paramount importance to some species, but have rarely been considered as strong drivers of ecological responses to climate alteration.
Keywords: Breeding; Climate change; Phenology; Tachycineta bicolor; Wind

27) Stanton, R., Clark, R.G., Morrissey, C.A. Intensive agriculture and insect prey availability influence oxidative status and return rates of an aerial insectivore (2017) *Ecosphere*, 8 (3), art. no. 1746, . DOI: 10.1002/ecs2.1746

Birds breeding in agricultural landscapes contend with potential reductions in prey availability that may alter behavior and incur physiological costs. Individuals may need to increase foraging intensity, producing elevated reactive oxygen species involved in oxidative damage. Food scarcity or low food quality may also reduce levels of diet-derived antioxidants. Here, we tested whether short-term changes in insect biomass on agricultural sites produce changes in the

oxidative status of tree swallows (Tachycineta bicolor), with the potential to influence return rates. We sampled 368 adult and 374 nestling swallows at five agricultural cropland and grassland-dominated sites over three years from 2012 to 2014. Blood plasma was assessed for antioxidant capacity (OXY) and reactive oxygen metabolites (ROMs), a marker for oxidative damage. Overall, males appeared to have higher oxidative damage and therefore oxidative stress (calculated as the ratio between ROMs and OXY) than females. Consistent with our hypothesis, aerial insect biomass was a strong predictor of oxidative status in swallows. Adult plasma antioxidants were higher with greater insect biomass, while nestling plasma antioxidants, oxidative damage, and oxidative stress exhibited negative relationships with insect biomass. Annual return rates of adults were predicted by site type, age, fledging success, and oxidative status. In 2013, adult return rates were higher at grassland sites (41%) than at cropland sites (25%) and birds with lower plasma antioxidants the previous year were more likely to return. In 2014, adults were more likely to return if they had fledged more nestlings the previous season and if they had lower levels of oxidative damage the previous year. We conclude that even subtle changes in insect prey availability in agricultural landscapes caused by pesticides, intense cropping, and natural habitat loss can play a key role in swallow oxidative status, with subsequent effects on local return rates.
Keywords: Agricultural intensification; Antioxidants; Oxidative damage; Stress physiology; Tree swallows

28) Timmermann, U., Becker, N. Impact of routine Bacillus thuringiensis israelensis (Bti) treatment on the availability of flying insects as prey for aerial feeding predators (2017) *Bulletin of Entomological Research*, pp. 1-10. DOI: 10.1017/S0007485317000141

Since 1980, mosquito breeding habitats in the Upper Rhine Valley were routinely treated with Bacillus thuringiensis var. israelensis (Bti). Bti is considered to significantly reduce the number of mosquitoes, and – especially when used in higher dosages – to be toxic to other Nematocera species, e.g. Chironomidae, which could be food sources for aerial feeding predators. To investigate direct and indirect effects of routine Bti treatment on food sources for aerial feeding predators, the availability of flying insects in treated and untreated areas was compared. A car trap was used for insect collection, which allowed their exact spatiotemporal assignment. The statistical analysis revealed that insect taxa abundance was influenced differently by the factors season, temperature and time of day. Nematocera (Diptera) were the most frequently collected insects in all areas. Chironomidae were the predominant aquatic Nematocera. The comparison of treated and untreated sites did not show significant differences that would indicate any direct or indirect effect of routine Bti treatment on the availability of flying insects. Additional to food availability, food selection must be considered when investigating food resources for aerial feeding predators. In this study, food selection of Delichon urbicum (House Martin) as an example was investigated with the help of neck ring samples. The preferred prey of the investigated D. urbicum colony consisted of diurnal insects with terrestrial larvae (Aphidina, Brachycera, Coleoptera). Chironomidae were consumed, but not preferred.
Keywords: aerial insect abundance; Bacillus thuringiensis var. israelensis; car trap sampling; Chironomidae; Delichon urbicum; food web; insect behaviour; mosquito control; Upper Rhine Valley

29) Farrell, C.E., Wilson, S., Mitchell, G. Assessing the relative use of clearcuts, burned stands, and wetlands as breeding habitat for two declining aerial insectivores in the boreal forest (2017) *Forest Ecology and Management*, 386, pp. 62-70. DOI: 10.1016/j.foreco.2016.11.026

Fires are an ecological process essential for species dependent on early successional habitat in forested landscapes. In a wildlife context, clearcut forestry practices can mimic forest fires through the creation of early successional forest clearings, however, evidence that clearcuts provide the same ecological value as fire is mixed. In temperate deciduous/hardwood forests, many species that depend on early successional habitat are known to use clearcuts, including Eastern Whip-poor-wills (Antrostomus vociferous) and Common Nighthawks (Chordeiles minor), two threatened aerial insectivorous birds. However, the relative importance of recent clearcuts as breeding habitat relative to other more naturally open habitat types in the boreal forest is unknown. In May-July 2015 we studied occupancy and detectability of these two species in the boreal forest of northwestern Ontario. We first determined whether occupancy differed among three open habitats: burned stands, recent clearcuts, and open wetlands, and whether it differed in relation to the size of clearcut patches. We also examined how detectability of each species varied with time of day, season and weather conditions. Site occupancy for the Eastern Whip-poor-will and Common Nighthawk averaged 0.413 and 0.437, respectively. We found no significant difference in occupancy of either species in relation to burned stands, recent clearcuts, or open wetlands, although Eastern Whip-poor-will occupancy tended to be higher in burned stands. Occupancy did not show a linear relationship with patch size but neither species was found in the smallest open patches (<3 ha), perhaps indicating a minimum size threshold, although further study is needed. The detection of each species was positively correlated with the occurrence of the other species, suggesting that they were both selecting similar site characteristics. Detectability for Eastern Whip-poor-will was highest after sunset and increased over the course of the breeding season, while for Common Nighthawk, detectability was similar during and after sunset and decreased over the season. Our results suggest that Eastern Whip-poor-will and Common Nighthawk show similar preference for natural and managed open sites and that recent clearcuts may provide early successional habitat in the absence of burned stands. Our results also extend the known breeding range of Eastern Whip-poor-will, which further emphasizes the need for future research on these poorly studied species in the boreal forest.
Keywords: Aerial insectivore; Boreal ecology; Caprimulgidae; Clearcut silviculture; Forest management; Species-at-risk

30) Kreisinger, J., Kropáčková, L., Petrželková, A., Adámková, M., Tomášek, O., Martin, J.-F., Michálková, R., Albrecht, T. Temporal stability and the effect of transgenerational transfer on fecal microbiota structure in a long distance migratory bird (2017) *Frontiers in Microbiology*, 8 (FEB), art. no. 50. DOI: 10.3389/fmicb.2017.00050

Animal bodies are inhabited by a taxonomically and functionally diverse community of symbiotic and commensal microorganisms. From an ecological and evolutionary perspective, inter-individual variation in host-associated microbiota contributes to physiological and

immune system variation. As such, host-associated microbiota may be considered an integral part of the host's phenotype, serving as a substrate for natural selection. This assumes that host-associated microbiota exhibits high temporal stability, however, and that its composition is shaped by trans-generational transfer or heritable host-associated microbiota modulators encoded by the host genome. Although this concept is widely accepted, its crucial assumptions have rarely been tested in wild vertebrate populations. We performed 16S rRNA metabarcoding on an extensive set of fecal microbiota (FM) samples from an insectivorous, long-distance migratory bird, the barn swallow (Hirundo rustica). Our data revealed clear differences in FM among juveniles and adults as regards taxonomic and functional composition, diversity and co-occurrence network complexity. Multiple FM samples from the same juvenile or adult collected within single breeding seasons exhibited higher similarity than expected by chance, as did adult FM samples over two consecutive years. Despite low effect sizes for FM stability over time at the community level, we identified an adult FM subset with relative abundances exhibiting significant temporal consistency, possibly inducing long-term effects on the host phenotype. Our data also indicate a slight maternal (but not paternal) effect on FM composition in social offspring, though this is unlikely to persist into adulthood. We discuss our findings in the context of both evolution and ecology of microbiota vs. host interactions and barn swallow biology.
Keywords: Barn swallow; Fecal microbiota; Gastrointestinal tract; Metagenome; Microbiome; Symbiosis

31) Davy, C.M., Ford, A.T., Fraser, K.C. Aeroconservation for the fragmented skies (2017) Conservation Letters 10(6):773-780. doi: 10.1111/conl.12347

From birds to bacteria, airborne organisms face substantial anthropogenic impacts. The airspace provides essential habitat for thousands of species, some of which spend most of their lives airborne. Despite recent calls to protect the airspace, it continues to be treated as secondary to terrestrial and aquatic habitats in policy and research. Aeroconservation integrates recent advances in aeroecology and habitat connectivity, and recognizes aerial habitats and threats as analogous to their terrestrial and aquatic counterparts. Aerial habitats are poorly represented in the ecological literature and are largely absent from environmental policy, hindering protection of aerial biodiversity. Here, we provide a framework for defining aerial habitats to advance the study of aeroconservation and the protection of the airspace in environmental policy. We illustrate how current habitat definitions explicitly disadvantage aerial species relative to non-aerial species, and review key areas of conflict between aeroconservation and human use of the airspace. Finally, we identify opportunities for research to fill critical knowledge gaps for aeroconservation. For example, aerial habitat fragmentation may impact biodiversity and ecosystem function similarly to terrestrial habitat fragmentation, and we illustrate how this can be investigated by extending existing methods and paradigms from terrestrial conservation biology up into the airspace.
Key words: Airspace, aerial habitat, habitat connectivity, habitat classification scheme, habitat fragmentation, IUCN, status assessment

32) Law, A.A., Threlfall, M.E., Tijman, B.A., Anderson, E.M., McCann, S., Searing, G., Bradbeer, D. Diet and prey selection of Barn Swallows (Hirundo rustica) at Vancouver International Airport (2017) *Canadian Field-Naturalist*, 131 (1), pp. 26-31. DOI: 10.22621/cfn.v131i1.1777

The Barn Swallow (Hirundo rustica) is the most widely distributed aerial insectivore in North America, but has declined appreciably in recent decades. reasons for these declines are largely unknown, though presumably relate mainly to changes in prey availability. To help inform conservation priorities for this species, we assessed their diet and prey selection using birds lethally struck by aircraft at Vancouver International Airport (yVr). esophagi and gizzards of 31 Barn Swallows collected from June 2013 to October 2013 contained insects mainly from the orders hymenoptera (mean across birds = 40% of insect numbers), Diptera (31%), hemiptera (15%), and coleoptera (12%). To assess prey selection, we compared the esophagi and gizzard contents of 20 swallows collected from July 2013 to September 2013 to populations of aerial insects we sampled during the same period using Malaise traps. Barn Swallows selected strongly for insects in the order hymenoptera (mainly formicidae, which comprised 29% of diet), and selected against insects in the orders coleoptera, Diptera, and Lepidoptera. for all prey taxa combined, Barn Swallows displayed strong selection for insects of length 4-8 mm (body length excluding appendages). conversely, they selected against smaller and larger insects, despite the fact that smaller insects comprised about 80% of all insects sampled in Malaise traps. combined with past studies, our results suggest that Barn Swallows select among available aerial insects within local feeding sites for taxa that (i) are of intermediate size, (ii) occur at relatively high density, and (iii) have poor flight performance.
Keywords: Aerial insectivore; Barn Swallow; British Columbia; Diet; Hirundo rustica; Prey selection

33) Levesque, P.G., Rock, C.A. Searching for black swift (Cypseloides niger) nests in southern British Columbia (2017) *Canadian Field-Naturalist*, 131 (2), pp. 144-150. DOI: 10.22621/cfn.v131i2.1805

Black Swifts (Cypseloides Niger) are thought to breed throughout southern British Columbia, however few nests have been described in the region. Population trend estimates from British Columbia show significant declines, prompting the Committee on the Status of endangered Wildlife in Canada (CoSeWiC) to assess Black Swift as endangered in Canada. We identified potential nesting locations and searched for nests at 16 sites in southern British Columbia between 2001 and 2015. two active Black Swift nests were discovered during surveys: Brandywine Falls south of Whistler, and highfalls Creek Falls northwest of Squamish. The Brandywine Falls nest was revisited annually from 2009 to 2015, and the nest was active during at least five of the seven years of monitoring. evening surveys were not effective for detecting Black Swift nest attendance.
Keywords: Aerial insectivore; Black swift; Brandywine falls; British Columbia; Cypseloides Niger; Highfalls creek; Nesting

34) Madliger, C.L., Love, O.P. Do baseline glucocorticoids simultaneously represent fitness and environmental quality in a declining aerial insectivore? (2016) *Oikos*, 125 (12), pp. 1824-1837. DOI: 10.1111/oik.03354

Glucocorticoids (GCs) are often interpreted as indicators of disturbance, habitat quality, and fitness in wild populations. However, since most investigations have been unable to examine habitat variability, GC levels, and fitness simultaneously, such interpretations remain largely unvalidated. We combined a quantification of two habitat types, a manipulation of foraging ability (feather-clipping just prior to nestling rearing), multiple baseline plasma GC measures, and multi-year reproductive monitoring to experimentally examine the linkages between habitat quality, GCs, and fitness in female tree swallows Tachycineta bicolor. Control females experiencing the higher early-season food resources of inland–pasture habitat laid larger clutches, but fledged an equal number but lower mass offspring compared to those in riparian–cropland habitat. Despite these differences in reproductive success, females nesting in the two habitat types did not differ in baseline GC levels at the early- or late-breeding stage. Feather-clipping reduced provisioning rate in both habitat types. However, baseline GC levels were affected in a habitat-specific way; only individuals in inland–pasture habitats showed an increase in GCs. Despite this difference in GC levels, the manipulation did not influence offspring mass, reproductive output, adult return rate (a proxy for survival) to the following year, or reproductive success in the subsequent year. Nonetheless, regardless of treatment, individuals with higher GC levels during the late breeding stage returned in the following year with higher GC levels at incubation, indicating a long-term effect on future GC levels. Our results indicate that environmental changes (e.g. foraging conditions) can have consequences for body condition, behaviour, and current and future baseline GC levels without concomitant influences on fitness, and that differences in fitness components between habitats may not be reflected in baseline GC levels. These results illustrate that baseline GCs may not simultaneously reflect environmental quality and fitness, potentially limiting their application in ecological and conservation settings.

35) Erratum: Omega-3 long-chain polyunsaturated fatty acids support aerial insectivore performance more than food quantity (Proceedings of the National Academy of Sciences of the United States of America (2016) 113:39 (10920-10925) DOI: 10.1073/pnas.1603998113) (2016) *Proceedings of the National Academy of Sciences of the United States of America*, 113 (46), p. E7347. DOI: 10.1073/pnas.1616962113

ECOLOGY: Correction for "Omega-3 long-chain polyunsaturated fatty acids support aerial insectivore performance more than food quantity," by Cornelia W. Twining, J. Thomas Brenna, Peter Lawrence, J. Ryan Shipley, Troy N. Tollefson, and David W. Winkler, which appeared in issue 39, September 27, 2016, of Proc Natl Acad Sci USA (113:10920-10925; first published September 16, 2016; 10.1073/pnas.1603998113). The authors note that Fig. 3 appeared incorrectly. The corrected figure and its legend appear below.

36) Twining, C.W., Brenna, J.T., Lawrence, P., Shipley, J.R., Tollefson, T.N., Winkler, D.W. Omega-3 long-chain polyunsaturated fatty acids support aerial insectivore performance more

than food quantity (2016) *Proceedings of the National Academy of Sciences of the United States of America*, 113 (39), pp. 10920-10925. DOI: 10.1073/pnas.1603998113

Once-abundant aerial insectivores, such as the Tree Swallow (Tachycineta bicolor), have declined steadily in the past several decades, making it imperative to understand all aspects of their ecology. Aerial insectivores forage on a mixture of aquatic and terrestrial insects that differ in fatty acid composition, specifically long-chain omega-3 polyunsaturated fatty acid (LCPUFA) content. Aquatic insects contain high levels of both LCPUFA and their precursor omega-3 PUFA, alpha-linolenic acid (ALA), whereas terrestrial insects contain much lower levels of both. We manipulated both the quantity and quality of food for Tree Swallow chicks in a full factorial design. Diets were either high-LCPUFA or low in LCPUFA but high in ALA, allowing us to separate the effects of direct LCPUFA in diet from the ability of Tree Swallows to convert their precursor, ALA, into LCPUFA. We found that fatty acid composition was more important for Tree Swallow chick performance than food quantity. On high-LCPUFA diets, chicks grew faster, were in better condition, and had greater immunocompetence and lower basal metabolic rates compared with chicks on both low LCPUFA diets. Increasing the quantity of high-LCPUFA diets resulted in improvements to all metrics of performance while increasing the quantity of low-LCPUFA diets only resulted in greater immunocompetence and lower metabolic rates. Chicks preferentially retained LCPUFA in brain and muscle when both food quantity and LCPUFA were limited. Our work suggests that fatty acid composition is an important dimension of aerial insectivore nutritional ecology and reinforces the importance of high-quality aquatic habitat for these declining birds.
Keywords: aerial insectivores; Nutritional ecology; Omega-3 long-chain polyunsaturated fatty acids

37) Milligan, M.C., Dickinson, J.L. Habitat quality and nest-box occupancy by five species of oak woodland birds (2016) *Auk*, 133 (3), pp. 429-438. DOI: 10.1642/AUK-15-187.1

Habitat quality can have important consequences for avian communities through impacts on survival and annual reproductive success. However, habitat quality is often hard to measure, leading to the use of occupancy as a proxy. We compared habitat use of 5 avian species that used nest boxes in the oak woodlands of central coastal California, USA, to determine which habitat characteristics best predicted box occupancy. We focused on the relationship between habitat characteristics and occupancy for five species-Ash-throated Flycatcher (Myiarchus cinerascens), House Wren (Troglodytes aedon), Oak Titmouse (Baeolophus inornatus), Violet-green Swallow (Tachycineta thalassina), and Western Bluebird (Sialia mexicana)-for which we had 12 consecutive years of data on nest boxes spread over a 700 ha study area. We also examined whether the physical habitat characteristics and box occupancy rates were good predictors of reproductive success, to infer whether they were useful indicators of habitat quality. The habitat characteristics influencing nest-box occupancy differed among the 5 species. Ash-throated Flycatchers were associated with fragmented habitats with less grassland. House Wrens were associated with riparian vegetation, as were Oak Titmice, which were also associated with chaparral. Violet-green Swallows were associated with chaparral but tended to nest farther from riparian corridors than Oak Titmice. Western Bluebirds nested

away from riparian corridors and in areas with more grassland and oak woodland. Finally, occupancy rate was a better predictor than habitat characteristics of reproductive success, which suggests that occupancy can be a valuable proxy for habitat quality for these 5 species.
Keywords: habitat; habitat quality; habitat use; nest box; oak woodland; occupancy

38) Falconer, C.M., Mitchell, G.W., Taylor, P.D., Tozer, D.C. Prevalence of disjunct roosting in nesting bank swallows (Riparia riparia) (2016) *Wilson Journal of Ornithology*, 128 (2), pp. 429-434. DOI: 10.1676/1559-4491-128.2.429

Bank Swallows (Riparia riparia) congregate in large nocturnal roosts during the non-breeding season. Scant evidence suggests that Bank Swallows may also congregate regularly in nocturnal roosts during the breeding period. To help clarify the issue, we used automated radio-telemetry to document the roosting behavior of 11 males and 11 females that were tending nests with young at two nesting colonies. Nineteen of the 22 birds (86%) spent at least one night roosting away from the colony, and 13 of the 22 birds (59%) spent at least one night roosting likely within a large marsh located ∼30 km away from the colonies. Females tended to roost overnight at the colony more than males. The proportion of nights birds spent roosting away from the colony was highly variable between individuals. Minimum flight speeds to an evening roost site (∼30 km distant) were significantly greater than return flights back to the colony in the morning. Our study confirms that breeding Bank Swallows do in fact regularly roost away from the colony during the nestling period. Our study also highlights some new and intriguing questions regarding how Bank Swallows use the landscape during the breeding season, and the potential importance of wetland roost sites in the proximity of breeding colonies.
Keywords: Bank Swallow; movements; radio telemetry; Riparia riparia; Sand Martin

39) O'Brien, E.L., Dawson, R.D. Life-history and phenotypic traits of insectivorous songbirds breeding on reclaimed mine land reveal ecological constraints (2016) *Science of the Total Environment*, 553, pp. 450-457. DOI: 10.1016/j.scitotenv.2016.02.146

Studies assessing impacts of industrial activities on wildlife typically examine population- or community-level responses. However, changes in measures such as species abundance or diversity are driven by cumulative responses of individuals to disturbance, and may take time to detect. Quantifying individual responses could allow us to foresee and mitigate future population declines resulting from industrial activities, while providing ecologically informative indices to assess quality of reclaimed land. We examined life-history and phenotypic traits of mountain bluebirds (Sialia currucoides) and tree swallows (Tachycineta bicolor) breeding on reclaimed copper mine lands in Canada over two years in comparison to a nearby undisturbed reference area. Bluebirds feed on terrestrial invertebrates, whereas swallows feed on adult forms of insects with aquatic larvae, allowing us to assess quality of both reclaimed terrestrial and aquatic systems as habitat for insectivorous birds. Supplemental feeding of bluebirds also was used to experimentally assess nutritional limitation of birds feeding on terrestrial invertebrates. Bluebirds on reclaimed land initiated clutches later, and in one year had lower fledging success compared to birds on the reference area. Tree swallows also bred later in the season on reclaimed land, but were otherwise comparable to or exceeded performance of birds

on the reference area. Annual differences in responses of nestling bluebirds on the mine to supplemental feeding revealed an apparent switch in life-history strategy of parents between years, from brood reduction to brood survival, suggesting greater annual fluctuations in ecological conditions within terrestrial systems on reclaimed land. Sex differences in response of nestling bluebirds to food supplementation additionally suggested high within-brood competition for food on reclaimed land. We suggest that measures of avian life-history and phenotypic traits, particularly when assessed over multiple years using experimental approaches such as food supplementation, are informative and sensitive indices of the health of reclaimed terrestrial and aquatic systems.
Keywords: Ecological indicator; Food supplementation; Impact assessment; Land reclamation; Mountain bluebird Sialia currucoides; Tree swallow Tachycineta bicolor

40) Musitelli, F., Romano, A., Møller, A.P., Ambrosini, R. Effects of livestock farming on birds of rural areas in Europe (2016) *Biodiversity and Conservation*, 25 (4), pp. 615-631. DOI: 10.1007/s10531-016-1087-9

In the last decades, profound modifications of agricultural practices occurred in Europe, including the introduction of modern livestock farming. These modifications negatively affected the fauna of rural areas, as indicated by the large demographic declines suffered by several populations of birds typical of these habitats. The impact of agricultural practices on bird populations has been widely investigated, while the effect of livestock farming has seldom been assessed. To fill this gap, we carried out a quantitative meta-analysis of the existing scientific literature and evaluated the size of the effects of livestock farming on birds of rural areas in Europe. We only found 26 papers on this topic, from which 72 effect sizes could be estimated. The barn swallow (Hirundo rustica) was the species on which most studies focused. Livestock farming positively influenced presence and distribution of barn swallows in breeding habitats, while it did not significantly affect reproduction of this species. Effects on other bird species typical of rural habitats were non-significant. The positive effect on the insectivorous barn swallow might be mediated by the enhanced insect abundance where livestock is reared. In addition, habitat features typical of rural settings where livestock is reared (e.g. cattle-sheds or large hayfields) positively affected barn swallows independently of actual presence of livestock at a setting. Presence of livestock at rural setting therefore seems beneficial to barn swallows, but not significantly to other bird species typical of rural habitats. The effect of livestock farming on birds of rural habitats has been under-investigated to date.
Keywords: Agricultural intensification; Barn swallow; Farmlands; Hierarchical linear models; Livestock farming; Meta-analysis

41) Akresh, M.E., King, D.I. Eastern whip-poor-will breeding ecology in relation to habitat management in a pitch pine-scrub oak barren (2016) *Wildlife Society Bulletin*, 40 (1), pp. 97-105. DOI: 10.1002/wsb.621

Numerous wildlife species are dependent on the creation and maintenance of early successional forests, yet little is known about the effects of habitat management on some threatened species. One such species is the eastern whip-poor-will (Antrostomus vociferous), a

nocturnal bird of conservation concern. We examined the effects of heavy thinning, mowing, burning, and herbicide treatments on this species by conducting point counts and nest searches on a pitch pine-scrub oak (Pinus rigida-Quercus ilicifolia) barren in western Massachusetts, USA, between 2006 and 2013. Our point-count data showed that the abundance of calling birds was greater in managed shrublands such as scrub oak barrens and heavily thinned pitch pine stands, compared to closed-canopy pitch pine and deciduous forest. We found a high number of whip-poor-will nests (n = 26) and roosts (n = 59), which we located primarily within managed shrublands. We did not search for nests in closed-canopy forests, and we were unable to determine the extent of their use of the forest edge for nesting. Nevertheless, birds selected nest sites under residual deciduous trees within the early successional forests; therefore, canopy cover appears to be important for nest placement at the nest-patch spatial scale, but not necessarily at a broader scale. Nests were found in both dense and sparse understory vegetation; none were found in vegetation patches that were <2 years since treatment. Estimated nest survival was 63% through incubation (daily survival rate = 0.977, n = 21), consistent with other published studies of nightjars in the United States and Canada. Creating and maintaining open-canopy early successional forests in pitch pine-scrub oak barrens, with the retention of some residual deciduous trees, should increase the amount of habitat suitable for courtship, roosting, and nesting by eastern whip-poor-wills.
Keywords: aerial insectivore; Antrostomus vociferous; Caprimulgiformes; fire; nest survival; nightjar; population limitation; shrubland; thinning

42) Stanton, R.L., Morrissey, C.A., Clark, R.G. Tree swallow (Tachycineta bicolor) foraging responses to agricultural land use and abundance of insect prey (2016) *Canadian Journal of Zoology*, 94 (9), pp. 637-642. DOI: 10.1139/cjz-2015-0238

Throughout North America, many species of aerial insectivorous birds have exhibited steep declines. The timing of these declines coincides with changes in agriculture, perhaps signaling a causal link. Increased agrochemical use, wetland drainage, and cropping intensity may indirectly influence insectivores by reducing the abundance of insect prey. Our objective was to determine whether changes in insect abundance and biomass on agricultural landscapes in the Canadian Prairies influence the foraging behaviour of breeding Tree Swallows (Tachycineta bicolor (Vieillot, 1808)). Swallows were studied at five sites with varying levels of agricultural intensity in Saskatchewan, where insect abundance and biomass were monitored daily with passive aerial samplers. Radio-frequency identification (RFID) technology was employed at Tree Swallow nest boxes to investigate adult foraging behaviour. Foraging rates (number of nest visits/h) were slightly higher on agricultural sites than at grassland sites, and were positively related to daily insect biomass and nestling age. Tree Swallows, especially males, breeding at agricultural sites spent more time away from the nest box, presumably foraging, resulting in reduced nest attentiveness. RFID technology provides an effective technique to measure behaviour in birds and these findings suggest mechanisms by which prey abundance and agricultural land use may affect declining aerial insectivorous bird populations.
Keywords: Aerial insectivore; Agricultural intensification; Radio-frequency identification; RFID; Tachycineta bicolor; Tree swallow

43) Orłowski, G., Kamiński, P., Karg, J., Baszyński, J., Szady-Grad, M., Koim-Puchowska, B., Klawe, J.J. Variable contribution of functional prey groups in diets reveals inter- and intraspecific differences in faecal concentrations of essential and non-essential elements in three sympatric avian aerial insectivores: A re-assessment of usefulness of bird faeces in metal biomonitoring (2015) *Science of the Total Environment*, 518-519, pp. 407-416. DOI: 10.1016/j.scitotenv.2015.02.078

Aerial insectivores through their insect diet can contribute to biotransfer of elements across habitats. We investigate the relationship between dietary composition as expressed by the contributions of six functional invertebrate prey groups (primarily of agriculturally subsidised invertebrates characteristic of agricultural areas in temperate regions of Europe) and concentrations of essential (Na, K, Ca, Mg, Fe, Cu, Zn, Mn, Co) and non-essential (As, Cd, Pb) elements of environmental concern in the faeces of nestlings of three species of avian aerial insectivores - Common Swift Apus apus, Barn Swallow Hirundo rustica and House Martin Delichon urbicum - which breed sympatrically and use apparently similar resources of flying insect prey. There were significant differences between the species for 7 of the 12 elements (Ca, Zn, Cu, Co, As, Pb, Cd); these differences were attributable to the variable dietary composition, even though the concentrations of the elements varied enormously between the faecal samples from the individual species. Partial correlation analysis between the biomass (expressed in mg dry weight) of the six functional prey groups and faecal concentrations of elements showed the highest number of significant relationships for toxic metals (As, Pb and Cd). The results of the General Regression Model explaining faecal element concentrations revealed the different explanatory power of the effects of PCA (of six functional prey groups) dietary scores. A significant fit of GRM was obtained for 7 elements (Na, Mg, Fe, Mn, As, Pb, Cd) for Barn Swallows, 2 elements (Cu, As) for House Martins and 1 element (Mn) for Common Swifts. Overall, the results confirmed our predictions that the biomass of consumed coprophilous taxa and insects from crop habitats was positively correlated with the faecal concentrations of toxic elements. Unexpectedly, however, the faecal samples (primarily those of Common Swifts) that contained many oil-seed rape insect pests had lower Ca, Pb and Cd levels and a higher As level. Our study implies that the cross-boundary transfer of contaminants, primarily non-essential elements, by aerially foraging birds through the considerable accumulation of their faeces has potential consequences for the local biogeochemical cycle and environmental quality.
Keywords: Aerial insects; Aerially foraging vertebrates; Faecal deposits; Food chain; Minerals; Oil-seed rape; Toxic elements

44) Hagelin, J.C., Busby, S., Harding-Scurr, A., Brinkman, A.R. Observations on Fecal Sac Consumption and Near-ground Foraging Behavior in the Olive-sided Flycatcher (Contopus cooperi) (2015) *Wilson Journal of Ornithology*, 127 (2), pp. 332-336. DOI: 10.1676/wils-127-02-332-336.1

We present details on parental care and foraging behavior of Olive-sided Flycatchers (Contopus cooperi) in central Alaska. We document the first evidence of fecal sac consumption in this

species. Both sexes exhibited this behavior while tending chicks less than one week old. Adults with older nestlings (1.5-2 weeks) removed fecal sacs only. The general pattern of reduced fecal sac consumption with chick age is consistent with other passerines and may supplement parental nutrition. Near-ground foraging behavior in C. cooperi is rarely reported, as birds typically sally for aerial insects near or above the canopy. Two breeding females fed multiple times from 1-3 m perches, hovering over, flying directly above or disappearing into low vegetation (<0.5 m) for up to 15 secs. Low stumps and saplings in a wood cutting area and in undisturbed forest provided access to patches of flowering vegetation that appeared to concentrate pollinator prey during cool or inclement weather. Given the conservation concerns for this species, its low productivity, dietary specialization, and hypothesized early-season reliance on insect prey, flowering vegetation presents a testable visual stimulus that may govern settlement behavior of breeding adults.
Keywords: aerial insectivore; breeding; Contopus cooperi; fecal sac; flower phenology; foraging; Olive-sided Flycatcher

45) Beck, M.L., Hopkins, W.A., Jackson, B.P., Hawley, D.M. The effects of a remediated fly ash spill and weather conditions on reproductive success and offspring development in tree swallows (2015) *Environmental Monitoring and Assessment*, 187 (3), 25 p. DOI: 10.1007/s10661-015-4333-9

Animals are exposed to natural and anthropogenic stressors during reproduction that may individually or interactively influence reproductive success and offspring development. We examined the effects of weather conditions, exposure to element contamination from a recently remediated fly ash spill, and the interaction between these factors on reproductive success and growth of tree swallows (Tachycineta bicolor) across nine colonies. Females breeding in colonies impacted by the spill transferred greater concentrations of mercury (Hg), selenium (Se), strontium, and thallium to their eggs than females in reference colonies. Parental provisioning of emerging aquatic insects resulted in greater blood Se concentrations in nestlings in impacted colonies compared to reference colonies, and these concentrations remained stable across 2 years. Egg and blood element concentrations were unrelated to reproductive success or nestling condition. Greater rainfall and higher ambient temperatures during incubation were later associated with longer wing lengths in nestlings, particularly in 2011. Higher ambient temperatures and greater Se exposure posthatch were associated with longer wing lengths in 2011 while in 2012, blood Se concentrations were positively related to wing length irrespective of temperature. We found that unseasonably cold weather was associated with reduced hatching and fledging success among all colonies, but there was no interactive effect between element exposure and inclement weather. Given that blood Se concentrations in some nestlings exceeded the lower threshold of concern, and concentrations of Se in blood and Hg in eggs are not yet declining, future studies should continue to monitor exposure and effects on insectivorous wildlife in the area.
Keywords: Element; Interactive effects; Nestling growth; Reproductive success; Tree swallow; Weather

46) Orłowski, G., Karg, J., Karg, G. Functional invertebrate prey groups reflect dietary responses to phenology and farming activity and pest control services in three sympatric species of aerially foraging insectivorous birds (2014) *PLoS ONE*, 9 (12), art. no. e114906, DOI: 10.1371/journal.pone.0114906

Farming activity severely impacts the invertebrate food resources of farmland birds, with direct mortality to populations of above-ground arthropods thorough mechanical damage during crop harvests. In this study we assessed the effects of phenological periods, including the timing of harvest, on the composition and biomass of prey consumed by three species of aerial insectivorous birds. Common Swifts Apus apus, Barn Swallows Hirundo rustica and House Martins Delichon urbica breed sympatrically and most of their diet is obtained from agricultural sources of invertebrate prey, especially from oil-seed rape crops. We categorized invertebrate prey into six functional groups, including oil-seed rape pests; pests of other arable crops; other crop-provisioned taxa; coprophilous taxa; and taxa living in non-crop and mixed crop/non-crop habitats. Seasonality impacted functional groups differently, but the general direction of change (increase/decrease) of all groups was consistent as indexed by prey composition of the three aerial insectivores studied here. After the oil-seed rape crop harvest (mid July), all three species exhibited a dietary shift from oil-seed rape insect pests to other aerial invertebrate prey groups. However, Common Switfts also consumed a relative large quantity of oil-seed rape insect pests in the late summer (August), suggesting that they could reduce pest insect emigration beyond the host plant/crop. Since these aerially foraging insectivorous birds operate in specific conditions and feed on specific pest resources unavailable to foliage/ground foraging avian predators, our results suggest that in some crops like oil-seed rape cultivations, the potential integration of the insectivory of aerial foraging birds into pest management schemes might provide economic benefits. We advise further research into the origin of airborne insects and the role of aerial insectivores as agents of the biological control of crop insect pests, especially the determination of depredation rates and the cascading effects of insectivory on crop damage and yield.

47) Tozer, D.C., Hoare, J.C., Inglis, J.E., Yaraskavitch, J., Kitching, H., Dobbyn, S. Clearcut with seed trees in red pine forests associated with increased occupancy by Eastern Whip-poor-wills (2014) *Forest Ecology and Management*, 330, pp. 1-7. DOI: 10.1016/j.foreco.2014.06.038

Forest management is often used to increase and maintain early-successional forest habitat for breeding birds by emulating natural disturbance with harvesting. However, quantified habitat-use relationships are often lacking, which makes forest management planning challenging for some species. One such species is the Eastern Whip-poor-will (Antrostomus vociferus), a crepuscular, insectivorous, neotropical, migrant bird, designated as a species at risk throughout most of its breeding range. Thus, we determined occupancy of Eastern Whip-poor-wills at 37 sampling points in red pine (Pinus resinosa)-dominated stands harvested using clearcut with seed trees and in white pine (P. strobus)-dominated stands harvested using uniform shelterwood in June 2013 in eastern Algonquin Provincial Park, Ontario. In red pine stands, we found that model-predicted site occupancy increased by 3.3 times from 0.23 where young (<16. years since harvest) clearcuts were absent to 0.76 where young clearcuts were present.

Shelterwood harvesting in white pine stands, by contrast, was unassociated with occupancy. Our data suggest that an aggregated mean total of 12. ha of clearcuts per 100. ha (interquartile range: 1.5-18. ha) of mature pine-dominated forest is associated with significantly higher occupancy by breeding Eastern Whip-poor-wills, and that the clearcuts can be composed of various sizes (interquartile range: 3-42. ha) and ages (interquartile range: 5-24. years since harvest). Given that similar relationships have been found by others elsewhere, clearcuts may increase the occupancy and abundance of breeding Eastern Whip-poor-wills in other regions and forest types throughout northeastern North America.
Keywords: Aerial forager; Forest management planning; Goatsucker; Logging; Nightjar; Silviculture

48) Rowse, L.M., Rodewald, A.D., Sullivan, S.M.P. Pathways and consequences of contaminant flux to Acadian flycatchers (Empidonax virescens) in urbanizing landscapes of Ohio, USA (2014) *Science of the Total Environment*, 485-486 (1), pp. 461-467. DOI: 10.1016/j.scitotenv.2014.03.095

A prevalent environmental contaminant, mercury (Hg) is mobile and persistent in aquatic systems, where it often occurs in its bioavailable form methylmercury. Because methylmercury can bioaccumulate in aquatic insects and then transfer to terrestrial food webs, riparian consumers reliant upon aquatic emergent insects, should be disproportionately affected. Using the aerial insectivore Acadian flycatcher (Empidonax virescens) as a focal species, we examined (1) the extent to which total Hg loads in breeding flycatchers affected body condition and reproductive output and (2) potential pathways of contaminant flux in 19 riparian forest fragments distributed across an urban-to-rural landscape gradient in Ohio, USA. From April-August 2011-2012, we collected blood samples from adult (n=76) and nestling (n=17 from 7 nests) flycatchers, monitored their annual reproductive success (i.e., total number of fledglings), and sampled water, sediment, and aquatic emergent insects at each site. Hg concentrations in adult flycatcher blood (47 to 584μg/kg, x-=211.8, SD=95.5) were low relative to published advisory levels and not related to body condition. However, even at low concentrations, blood Hg was negatively related to reproductive success, with a 0.83 decline in the number of fledglings per μg/kg (log<inf>e</inf>) increase of blood Hg. Adult flycatchers had 11× greater concentrations of blood Hg than their offspring. Hg levels in flycatcher blood were not predicted by Hg concentrations in sediment, water, or aquatic emergent insects, with the exception of rural landscapes alone, in which flycatcher Hg was negatively related to sediment Hg. In addition to illustrating the difficulty of predicting exposure pathways that may vary among landscape contexts, our study provides evidence that even trace levels of contaminants may impair reproductive success of free-living songbirds.
Keywords: Acadian Flycatcher; Mercury; Reproductive success; Riparian; Rural; Urban

49) Zanchetta, C., Tozer, D.C., Fitzgerald, T.M., Richardson, K., Badzinski, D. Tree cavity use by chimney swifts: Implications for forestry and population recovery [utilisation de cavités d'arbres par le martinet ramoneur: Incidence sur les plans de l'exploitation forestière et du rétablissement des populations] (2014) *Avian Conservation and Ecology*, 9 (2), . DOI: 10.5751/ACE-00677-090201

The Chimney Swift (Chaetura pelagica) is an aerial insectivore and a cavity-nesting/roosting specialist designated as threatened in several jurisdictions. As the occurrence of suitable chimneys declines, Chimney Swifts may increasingly nest and roost in tree cavities. It is therefore important to identify characteristics of suitable nest or roost trees and assess their frequency of occurrence. We reviewed 59 historic and modern records of trees used by Chimney Swifts to understand characteristics of suitable nest or roost trees. Chimney Swifts used at least 13 different deciduous and coniferous tree species. All of the trees were greater than 0.5 m diameter at breast height (DBH) and were described as hollow or having cavities. Nest or roost tree height was 12.7 ± 7.0 m (mean ± SD; range: 3.6-28.0 m; n = 25) and DBH was 1.0 m ± 0.5 m (range 0.5-2.1 m; n = 21). According to our description of used trees, the number of suitably hollow Chimney Swift nest or roost trees may be two to three times higher, although still rare, in most unlogged compared to logged hardwood forests. Whether the current total supply of suitable nest or roost trees is sufficient to carry the anticipated increase in use by Chimney Swifts as chimney habitat is modified or deteriorates is unknown. Monitoring the frequency of use of tree cavities by nesting and roosting Chimney Swifts over time, and more robustly quantifying the availability of suitable tree cavities in different forest types for nesting and roosting Chimney Swifts, particularly in unlogged versus logged forests, are fruitful areas for future research.
Keywords: Aerial insectivore; Cavity nesting; Cavity roosting; Chaetura pelagic; CHIMNEY Swift; Ecological specialization; Forest management; Population decline

50) Fitzgerald, T.M., van Stam, E., Nocera, J.J., Badzinski, D.S. Loss of nesting sites is not a primary factor limiting northern Chimney Swift populations (2014) *Population Ecology*, 56 (3), pp. 507- 512. DOI: 10.1007/s10144-014-0433-6

Aerially-foraging insectivorous bird populations have been declining for several decades in North America and habitat loss is hypothesized as a leading cause for the declines. Chimney Swifts (Chaetura pelagica) are a model species to test this hypothesis because nest site use and availability is easily assessed. To determine if nest site availability is a limiting factor for Chimney Swifts, we established a volunteer-based survey to inventory and describe chimneys (n = 928) that were used or unused by swifts. A logistic regression model showed that swifts preferred chimneys with a greater length exposed above the roofline and greater inside area, which were not associated with residential buildings. The average chimney used by swifts extended 2.86 m above the roofline with an internal area of 10,079 cm2. The regression model represents the range of nest-site conditions that swifts will tolerate; this was used to build a linear discriminant function (ldf) that had an I-index of 82 % (measure of prediction success). We applied the ldf coefficients to predict chimney occupancy in three southern Ontario communities. Of 366 open chimneys, the ldf classified 139 as suitable but only 24.4 % were occupied by swifts. Given that >75 % of suitable sites were unoccupied, swifts are likely not experiencing competition from habitat saturation. Our results suggest that Chimney Swift populations, and likely other aerially-foraging insectivorous birds, are limited primarily by other processes not measured in this study, such as changes in prey.

Keywords: Aerial insectivores; Chaetura pelagica; Citizen Science; Habitat loss; Population declines

51) Garlick, N.W., Newberry, G.N., Rivers, J.W. An assessment of nestling diet composition in the violet-green swallow (Tachycineta thalassina) (2014) *Northwest Science*, 88 (1), pp. 49-54. DOI: 10.3955/046.088.0109

Aerial insectivores have undergone marked population declines in recent decades, including members of the Hirundinidae (swallows), which have long served as sentinels of environmental change. In contrast to other swallow species that breed in North America, we have a poor understanding of most aspects of the basic ecology and life history of the violetgreen swallow (Tachycineta thalassina), a widespread species found throughout the Pacific Northwest. In this study, we investigated the diet composition of violet-green swallow nestlings to document the consumption of food resources by offspring during adult feeding visits. We identified arthropods from 13 taxonomic orders in feeding boluses and found that representation of taxonomic groups was highly uneven and dominated by Diptera and Hemiptera. Although swallows did provision some large prey, the great majority (i.e., 92.6% of 1047) of food items were < 5 mm in length. Feeding boluses collected from the congeneric tree swallow (T. bicolor) at the same study area and during the same time period revealed similar patterns of size and taxonomic representation of diet composition of violet-green nestlings, raising questions as to how these species partition critical resources in areas of sympatry.
Keywords: nestling diet; offspring provisioning; swallows; Tachycineta bicolor; Tachycineta thalassina

52) Kelly, J.F., Bridge, E.S., Frick, W.F., Chilson, P.B. Ecological Energetics of an Abundant Aerial Insectivore, the Purple Martin (2013) *PLoS ONE*, 8 (9), art. no. e76616. DOI: 10.1371/journal.pone.0076616

The atmospheric boundary layer and lower free atmosphere, or aerosphere, is increasingly important for human transportation, communication, environmental monitoring, and energy production. The impacts of anthropogenic encroachment into aerial habitats are not well understood. Insectivorous birds and bats are inherently valuable components of biodiversity and play an integral role in aerial trophic dynamics. Many of these insectivores are experiencing range-wide population declines. As a first step toward gaging the potential impacts of these declines on the aerosphere's trophic system, estimates of the biomass and energy consumed by aerial insectivores are needed. We developed a suite of energetics models for one of the largest and most common avian aerial insectivores in North America, the Purple Martin (Progne subis). The base model estimated that Purple Martins consumed 412 (± 104) billion insects*y-1 with a biomass of 115,860 (± 29,192) metric tonnes*y-1. During the breeding season Purple Martins consume 10.3 (+ 3.0) kg of prey biomass per km3 of aerial habitat, equal to about 36,000 individual insects*km-3. Based on these calculations, the cumulative seasonal consumption of insects*km-3 is greater in North America during the breeding season than during other phases of the annual cycle, however the maximum daily insect consumption*km-3 occurs during fall migration. This analysis provides the first range-wide quantitative estimate of the magnitude of the trophic impact of this large and common aerial insectivore. Future studies could use a similar modeling approach to estimate impacts of the entire guild of aerial insectivores at a variety of temporal and spatial scales. These analyses would inform our understanding of the impact of population declines among aerial insectivores on the aerosphere's trophic dynamics.

53) Robillard, A; Garant, D; Belisle, M The Swallow and the Sparrow: how agricultural intensification affects abundance, nest site selection and competitive interactions LANDSCAPE ECOLOGY 28 (2): 201-215 **DOI:** 10.1007/s10980-012-9828-y FEB 2013

Intensification of farming practices is a key factor in population declines of many species, including aerial insectivores. Of these species, Tree Swallow populations have been declining rapidly in Canada, likely in response to increased pesticide use (depleting insect prey) and destruction of marginal habitats (limiting cavity-nesting opportunities). Agricultural intensification may however be favourable to other species. House Sparrows for instance could benefit from abundant nesting sites (farm buildings) and food resources (grains) in intensive landscapes. Competition for nesting sites between these two species has been observed, and could be another factor in the decline of Tree Swallows. In a 400 nest-box study system embedded along a gradient of agricultural intensification of Southern Quebec, Canada, we first assessed effects of intensification on abundance of House Sparrows by analysing 5,200 min of point counts. From these results, we modeled influence of competition and habitat on Tree Swallow nest site selection. Density of sparrows and proximity to buildings reduced the nest-box occupancy of swallows. Therefore, agricultural intensification had opposite influences on these two species, directly affecting House Sparrow abundance, but indirectly exacerbating competition pressure on swallows through competitor abundance. These results provide evidence of interspecific competition between these species, highlighting the indirect role of anthropogenic alterations on agro-ecosytems and illustrating a landscape-mediated avian competition pressure that has, to our knowledge, never been documented in farmscapes. Keywords: Abundance; Agricultural intensification; House sparrow; Interspecific nest-site competition; Landscape structure; Nest-box occupancy; Passer domesticus; Tachycineta bicolor; Tree swallow

54) Boynton, CK; Mahony, NA; Williams, TD. Barn Swallow (Hirundo rustica) fledglings use crop habitat more frequently in relation to its availability than pasture and other habitat types. CONDOR. 122, 2020. pp.1-14. DOI: 10.1093/condor/duz067

Populations of birds that forage on aerial insects have been declining across North America for several decades, but the main causes of and reasons for geographical variation in these declines remains unclear. We examined the habitat use and survival of post-fledging Barn Swallows (Hirundo rustica) near Vancouver, British Columbia, Canada, using VHF radio telemetry. We predicted that fledgling Barn Swallows hatched in higher-quality natal habitat (pasture) would fledge at higher quality, stay closest to the nest, disproportionately use higher-quality habitat during
the post-fledge stage, and have higher survival rates in the region. Contrary to our predictions, we found that natal habitat (crop, pasture, or non-agriculture) had no effect on fledgling quality

or movement distance. Barn Swallow fledglings used crop habitat more frequently in relation to its availability than other habitat types, including pasture. Barn Swallows had low post-fledging survival rates (0.44; 95% CI: 0.35–0.57), which could negatively influence the population trend of the species in this region. While natal habitat had only minor effects, crop habitat appears to be important for fledgling Barn Swallows and, therefore, a decline in this habitat type could have further negative implications for an already declining species.
Keywords: Barn Swallow, habitat use, *Hirundo rustica*, post-fledging, radio-telemetry, survival

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FALL MIGRATION/WINTER MOVEMENTS

1) Korpach, AM; Mills, A; Heidenreich, C; Davy, CM; Fraser, KC Blinded by the light? Circadian partitioning of migratory flights in a nightjar species JOURNAL OF ORNITHOLOGY 160 Issue: 3 Pages: 835-840 DOI: 10.1007/s10336-019-01668-5

Circadian migration patterns for most migratory birds can be partitioned into day and night flights, but can be flexible at barrier crossings. Whether obligate nocturnal species opportunely use some daylight during migration has not been previously investigated. We tested the night constraint hypothesis using autumn Global Positioning System (GPS) tracking of a migratory nightjar species (Eastern Whip-poor-will, Antrostomus vociferus), and found that a minimum of 89% of travel occurred in darkness. All seven GPS-tracked individuals avoided crossing the Gulf of Mexico, which would have required some daytime flight. Future research should investigate the mechanisms and implications of light restrictions on the migratory movements of nocturnal species.
Keywords: Wild clocks; Migration timing; Migration phenology; Antrostomus; Global Positioning System; Whip-poor-will

2) Fournier, A.M.V., Shave, A., Fischer, J., Siegrist, J., Ray, J., Cheskey, E., MacIntosh, M., Ritchie, A., Pearman, M., Applegate, K., Fraser, K. Precise direct tracking and remote sensing reveal the use of forest islands as roost sites by Purple Martins during migration (2019) *Journal of Field Ornithology*, 90 (3), pp. 258-265. DOI: 10.1111/jofo.12298

Direct tracking methods in combination with remote sensing data allow examination of habitat use by birds during migration. Species that roost communally during migration, such as some swallows, form large aggregations that can attract both avian and terrestrial predators. However, the extent to which they might use patchy habitats that could reduce predation risk during migration is unknown. We tested the hypothesis that Purple Martins (Progne subis) use forest islands (patches of suitable forest habitat surrounded by unsuitable habitat) as roost sites during migration between breeding sites in North America and overwintering sites in South America. We used high-precision (< 10 m), archival GPS units deployed and retrieved during the 2015 and 2016 breeding seasons, respectively, at 12 colonies located across eastern North America. We found that Purple Martins roosted in forest islands more often than expected based on availability during both spring and fall migration. Despite an apparent association with urban habitats by Purple Martins based on observational and radar data in North America

during the fall, the roost locations we identified during spring and fall migration were not more closely associated with urban areas than random locations. The use of forest islands during both spring and fall migration suggest that Purple Martins may use these habitats to reduce predation risk during migration. Our results suggest that some species of birds may use similar habitats as stopover sites during migration and that patches of forest habitat may be important conservation targets for Purple Martins and other species. Identifying habitat use during migration represents an important advance in support of full annual-cycle conservation of Purple Martins and other migratory species with declining populations.
Keywords: archival GPS; biologging; direct tracking; Progne subis; stopover ecology

3) Chilson, C., Avery, K., McGovern, A., Bridge, E., Sheldon, D., Kelly, J. Automated detection of bird roosts using NEXRAD radar data and Convolutional Neural Networks (2019) *Remote Sensing in Ecology and Conservation*, 5 (1), pp. 20-32. DOI: 10.1002/rse2.92

Although NEXRAD radars have proven to be an effective tool for detecting airborne animals, detecting biological phenomena in radar images often involves a manual, time- consuming data-extraction process. This paper focuses on applying machine learning to automatically find radar data that snapshots large aggregations of birds (specifically Purple Martins and Tree Swallows) as they depart en masse from roosting sites. These aggregations are evident in radar images as rings of elevated reflectivity that appear early in the morning as birds depart from roost sites. Our goal was to develop an algorithm that could determine whether an individual radar image contained at least one Purple Martin or Tree Swallow roost. We use a dataset of known roost locations to train three machine learning algorithms that employed (1) a traditional Artificial Neural Network (ANN), (2) a sophisticated preexisting Convolutional Neural Network (CNN) called Inception-v3, and (3) a shallow CNN built from scratch. The resulting programs were all effective at finding bird roosts, with both the shallow CNN and the Inception-v3 network making correct determinations about 90 per cent of the time with an AUC above.9. To the best of our knowledge, this study is the first to apply neural networks in the analysis of bird roosts in radar imagery, and these analytical tools offer new avenues of research into the ecology and behavior of flying animals, with practical applications to wind farm placement, air traffic administration and wildlife conservation. The NEXRAD radar network offers a tremendous archive of continental-scale data and has the potential to capture entire vertebrate populations. We apply existing machine learning models to a new dataset which constitutes a valuable approach to extracting information from this archive.
Keywords: Aeroecology; bird roosts; deep learning; machine learning

4) Kelly, J.F., Pletschet, S.M. Accuracy of swallow roost locations assigned using weather surveillance radar (2018) *Remote Sensing in Ecology and Conservation*, 4 (2), pp. 166-172. DOI: 10.1002/rse2.66

Weather surveillance radars (WSR) have been used to detect roosting aggregations of swallows since the 1950s. We provide the first quantitative assessment of the accuracy of roost locations derived from WSR images. We found 265 swallow roosts in WSR images from the Eastern US (east of 100oW) between June and September over 7 years (2010–2016). We quantified error

in WSR-based roost locations of 72 of these roosts by comparing them to ground-truth locations. Purple Martins (Progne subis) formed 67 (93%) of ground-truthed roosts. Tree Swallows (Tachycineta bicolor) and Bank Swallows (Riparia riparia) formed the other 5 roosts (7%); all of which were in the northeastern U.S. (north of 41oN and east of 80oW). Magnitude of roost-location error was 2.94 kilometers (SD = 1.63 km, N = 72, range = 0–7.3). This error increased slightly, but significantly, with distance from the WSR (R2 = 0.13, P = 0.002). Location error was not influenced by wind speed. Directions of location errors (from confirmed to estimated location) were clumped in a southeasterly direction ($\bar{x}$ = 128.9°, SD = 1.32, N = 72, P < 0.05). Similarly, prevailing wind direction ($\bar{x}$ = 180.0°, SD = 1.28, N = 71, P < 0.01) tended to come from the south. Wind direction and direction to the nearest WSR were not correlated with direction of the location error. Magnitude and direction of error associated with using WSR images to assign geographic locations to swallow roosts is small. This error is largely unaffected by variation in distance and direction to WSR stations and prevailing wind conditions. These results enable future studies that seek automated approaches to roost identification and permit association with other environmental data at the appropriate level of spatial precision.
Keywords: Aeroecology; migration; roost locations; swallow roosts; weather radar; WSR

5) Bayly, N.J., Rosenberg, K.V., Easton, W.E., Gómez, C., Carlisle, J., Ewert, D.N., Drake, A., Goodrich, L.
Major stopover regions and migratory bottlenecks for Nearctic-Neotropical landbirds within the Neotropics: A review (2018) *Bird Conservation International*, 28 (1), pp. 1-26.
DOI: 10.1017/S0959270917000296

Summary Nearly 300 species of landbirds, whose populations total billions, migrate between the Neotropics and North America. Many migratory populations are in steep decline, and migration is often identified as the greatest source of annual mortality. Identifying birds' needs on migration is therefore central to designing conservation actions for Nearctic-Neotropical migratory birds; yet migration through the Neotropics is a significant knowledge gap in our understanding of the full annual cycle. Here, we synthesise current knowledge of Neotropical stopover regions and migratory bottlenecks, focusing on long-distance, migratory landbirds that spend the boreal winter in South America. We make the important distinction between true stopover - involving multi-day refuelling stops - and rest-roost stops lasting < 24 hours, citing a growing number of studies that show individual landbirds making long stopovers in just a few strategic areas, to accumulate large energy reserves for long-distance flights. Based on an exhaustive literature search, we found few published stopover studies from the Neotropics, but combined with recent tracking studies, they describe prolonged stopovers for multiple species in the Orinoco grasslands (Llanos), the Sierra Nevada de Santa Marta (Colombia), and the Yucatan Peninsula. Bottlenecks for diurnal migrants are well described, with the narrowing Central American geography concentrating millions of migrating raptors at several points in SE Mexico, Costa Rica, Panama and the Darién. However, diurnally migrating aerial insectivores remain understudied, and determining stopover/roost sites for this steeply declining group is a priority. Despite advances in our knowledge of migration in the Neotropics, we conclude that major knowledge gaps persist. To identify stopover sites and habitats and the threats they face,

we propose a targeted and collaborative research agenda at an expanded network of Neotropical sites, within the context of regional conservation planning strategies.

6) Loon, A.V., Ray, J.D., Savage, A., Mejeur, J., Moscar, L., Pearson, M., Pearman, M., Hvenegaard, G.T., Mickle, N., Applegate, K., Fraser, K.C. Migratory stopover timing is predicted by breeding latitude, not habitat quality, in a long-distance migratory songbird (2017) *Journal of Ornithology*, 158 (3), pp. 745-752. DOI: 10.1007/s10336-017-1435-x

The timing of migration can have important survival impacts, as birds must synchronize their movements with favourable environmental conditions to reach their destination. The timing of arrival at and duration of migratory stopover may be largely governed by environmental conditions experienced en route as well as by endogenous factors, but our understanding of these processes is limited. We used light-level geolocators to collect start-to-finish spatio-temporal migration data for a declining aerial insectivore, the Purple Martin (Progne subis), that travels seasonally between North and South America. Using data obtained for birds originating from range-wide breeding populations, our objectives were to test intrinsic and extrinsic hypotheses for migration stopover duration as well as to identify important stopover regions during fall migration. We examined whether breeding latitude, fall migration timing, age, sex or habitat quality at stopover sites (measured using Normalized Difference Vegetation Index) influenced the duration of stopovers. We found that most individuals rely on the eastern coast of the Yucatan Peninsula, Honduras, and Nicaragua for stopovers during fall migration, where duration ranged from 1 to 36 days (average 6.8 ± 8.2). Stopovers in these regions were later and of longer duration for more northern breeding populations. Only breeding latitude predicted stopover duration, and not habitat quality at stopovers, lending support to the hypothesis that duration is prescribed by endogenous factors. The important core stopover regions we documented could be targeted for conservation efforts, particularly for steeply-declining, more northern breeding populations that have greater stopover duration in these areas.
Keywords: Aerial insectivore; Direct-tracking; Geolocator; Migration behaviour; Migration phenology

7) Stutchbury, B.J., Siddiqui, R., Applegate, K., Hvenegaard, G.T., Mammenga, P., Mickle, N., Pearman, M., Ray, J.D., Savage, A., Shaheen, T., Fraser, K.C. Ecological Causes and Consequences of Intratropical Migration in Temperate-Breeding Migratory Birds (2016) *The American naturalist*, 188, pp. S28-S40. DOI: 10.1086/687531

New discoveries from direct tracking of temperate-breeding passerines show that intratropical migration (ITM) occurs in a growing number of species, which has important implications for understanding their evolution of migration, population dynamics, and conservation needs. Our large sample size ([Formula: see text]) for purple martins (Progne subis subis) tracked with geolocators to winter sites in Brazil, combined with geolocator deployments at breeding colonies across North America, allowed us to test hypotheses for ITM, something which has not yet been possible to do for other species. ITM in purple martins was not obligate; only 44% of individuals exhibited ITM, and movements were not coordinated in time or space. We found no

evidence to support the resource hypothesis; rainfall and temperature experienced by individual birds during their last 2 weeks at their first roost site were similar to conditions at their second roost site after ITM. Birds generally migrated away from the heavily forested northwestern Amazon to less forested regions to the south and east. ITM in this aerial insectivore appears to support the competition-avoidance hypothesis and may be triggered by increasing local density in the core wintering region. Full life cycle models and migratory networks will need to incorporate ITM to properly address seasonal carryover effects and identify which wintering regions are most important for conservation.
Keywords: intratropical migration; migration; seasonality; temperate bias; wintering grounds

WINTERING AREAS, MIGRATORY CONNECTIVITY

1) López-Calderón, C., Hobson, K.A., Balbontín, J., Reviriego, M.I., Magallanes, S., García-Longoria, L., Relinque, C., De Lope, F., Møller, A.P., Marzal, A. Rainfall at African wintering grounds predicts age-specific probability of haemosporidian infection in a migratory passerine bird (2019) *Ibis*, 161 (4), pp. 759-769. DOI: 10.1111/ibi.12680

In migratory species breeding in temperate zones and wintering in tropical areas, the prevalence of blood parasites may be affected by migratory strategies and winter habitat choice. We explored whether African winter habitat was linked to the probability of haemosporidian infection in the House Martin Delichon urbicum breeding in Spain, and tested for potential differences between age-classes. As a proxy for winter habitat features, we analysed stable isotope (δ2H, δ13C and δ15N) values of winter-grown feathers moulted in tropical Africa. Rainfall at the African winter grounds was related to the probability of being infected with haemosporidians and this effect differed among age-classes. We found that haemosporidian prevalence was similar for young and experienced birds wintering in habitats of higher rainfall (2H-depleted), whereas there were great differences in winter habitats of lower rainfall (2H-enriched), with young having a much higher prevalence compared with experienced birds. Likewise, experienced birds wintering in habitats of higher rainfall had a higher probability of haemosporidian infection compared with experienced birds wintering in habitats of lower rainfall. By contrast, young birds wintering in habitats of lower rainfall had a higher probability of haemosporidian infection compared with young birds wintering in habitats of higher rainfall. These outcomes highlight the interaction of age with haemosporidian infection in the migratory ecology of the House Martin, which may drive carry-over effects in this long-distance aerial insectivore.
Keywords: blood parasites; carry-over effects; Delichon urbicum; House Martin; migration; stable isotopes

2) Knight, S.M., Gow, E.A., Bradley, D.W., Clark, R.G., Bélisle, M., Berzins, L.L., Blake, T., Bridge, E.S., Burke, L., Dawson, R.D., Dunn, P.O., Garant, D., Holroyd, G.L., Hussell, D.J.T., Lansdorp, O., Laughlin, A.J., Leonard, M.L., Pelletier, F., Shutler, D., Siefferman, L., Taylor, C.M., Trefry, H.E., Vleck, C.M., Vleck, D., Whittingham, L.A., Winkler, D.W., Ryan Norris, D. Nonbreeding season movements of a migratory songbird are related to declines in resource availability (2019) *Auk*, 136 (3), art. no. ukz028. DOI: 10.1093/auk/ukz028

There have been an increasing number of observations of itinerancy in migratory songbirds, where individuals move among 2 or more widely separated areas during the "stationary" nonbreeding season. Knowledge of such movements and an understanding of what drives them are important for predicting how migratory populations will respond to environmental change. In this study, we investigated nonbreeding movements of the Tree Swallow (Tachycineta bicolor), an aerial insectivore that breeds across North America and spends the nonbreeding season around the Gulf of Mexico, Florida, Mexico, Central America, and the Caribbean. With year-round tracking data obtained from 133 light-level geolocators deployed at 12 breeding sites ranging from Alaska to Nova Scotia to North Carolina, we show that 44% of individuals made at least one large-scale movement (range: 301-1,744 km) within the nonbreeding range. The frequency of itinerancy decreased with longitude, such that 75% of individuals made a movement in the western portion of the nonbreeding range compared to only 31% in the east. Using the Normalized Difference Vegetation Index (NDVI) as a proxy for resource availability, we found that when individuals did move, they were more likely to move from sites where resources were deteriorating faster (a more negative change in NDVI prior to departure) than their destination sites. There was also evidence that individuals moved to destination sites with higher NDVI and temperature in the autumn, but not in the winter. Our results suggest movements of Tree Swallows during the nonbreeding season are influenced by resource availability, but because not all individuals used multiple nonbreeding sites, the density of individuals at a site and the level of competition may have also been a factor influencing nonbreeding season movements.\

Keywords: aerial insectivore; itinerancy; light-level geolocator; migration; NDVI; Tachycineta bicolor; Tree Swallow

3) Smith, E.L., Reudink, M.W., Marra, P.P., McKellar, A.E., Van Wilgenburg, S.L. Breeding origins and migratory connectivity at a northern roost of Vaux's Swift, a declining aerial insectivore (2019) *Condor*, 121 (3), . DOI: 10.1093/condor/duz034

Populations of Vaux's Swift (Chaetura vauxi), like those of many aerial insectivores, are rapidly declining. Determining when and where populations are limited across the annual cycle is important for their conservation. Establishing the linkages between wintering and breeding sites and the strength of the connections between them is a necessary first step. In this study, we analyzed 3 stable isotopes (δ13C, δ15N, δ2H) from feathers collected during spring migration from Vaux's Swifts that perished during a stopover on Vancouver Island, British Columbia, Canada. We previously analyzed claw tissue (grown during winter) from the same individuals, revealing that the swifts likely wintered in 2 or 3 locations/habitats. Here, we used stable isotope analysis of flight feathers presumed to have been grown on, or near, the breeding grounds to determine the likely previous breeding locations and presumed destinations for the swifts. Stable isotope values (δ13C, δ15N, δ2H) showed no meaningful variation between age classes, sexes, or with body size. Surprisingly, ~26% of the birds sampled had feather isotope values that were not consistent with growth on their breeding grounds. For the remaining birds, assigned breeding origins appeared most consistent with molt origins on Vancouver Island. Overall, migratory connectivity of this population was relatively weak (rM =

0.07). However, the degree of connectivity depended on how many winter clusters were analyzed; the 2-cluster solution suggested no significant connectivity, but the 3-cluster solution suggested weak connectivity. It is still unclear whether low migratory connectivity observed for Vaux's Swift and other aerial insectivores may make their populations more or less vulnerable to habitat loss; therefore, further efforts should be directed to assessing whether aerial insectivores may be habitat limited throughout the annual cycle.
Keywords: Aerial insectivores; Chaetura vauxi; Migration; Migratory connectivity; Population declines; Stable isotopes; Stopover; Vaux's Swift

4) Ng, J.W., Knight, E.C., Scarpignato, A.L., Harrison, A.-L., Bayne, E.M., Marra, P.P. First full annual cycle tracking of a declining aerial insectivorous bird, the common nighthawk (Chordeiles minor), identifies migration routes, nonbreeding habitat, and breeding site fidelity (2018) *Canadian Journal of Zoology*, 96 (8), pp. 869-875. DOI: 10.1139/cjz-2017-0098

Over one third of North American bird species are in decline, and for many species, we still lack fundamental biogeographic information such as migration routes and nonbreeding areas. Identifying causes of declines is limited because tracking many species throughout their annual cycle with high precision and accuracy is challenging. Common Nighthawks (Chordeiles minor (J.R. Forster, 1771)) have declined throughout much of their range and have yet to have their migratory and nonbreeding areas identified and characterized. We tracked Common Nighthawks by deploying a new 3.5 g Pinpoint GPS-Argos tag on adult males. Seven of 10 (70%) tags uploaded locations, providing the first data on migration, nonbreeding habitat, and annual site fidelity to breeding areas. Birds used similar loop migration routes and overwintered in Brazil’s Cerrado and Amazon regions. Nonbreeding season roosting home ranges were 148.22 ± 121 ha (mean ± SE) and included forest, grassland, and cropland. Breeding home-range fidelity was high; all tracked birds returned to within 1.27 ± 0.27 km of original capture locations. Our study is the first tracking of Common Nighthawks throughout their full annual cycle. Continued miniaturization of tracking technology, like the GPS-Argos transmitters used, is critical for identifying the causes of population declines of previously enigmatic migratory species.
Keywords: Aerial insectivore; Caprimulgidae; Chordeiles minor; Full annual cycle; Habitat; Migration; Migratory connectivity; Nightjar

5) Fraser, K.C., Shave, A., Savage, A., Ritchie, A., Bell, K., Siegrist, J., Ray, J.D., Applegate, K., Pearman, M.
Determining fine-scale migratory connectivity and habitat selection for a migratory songbird by using new GPS technology (2017) *Journal of Avian Biology*, 48 (3), pp. 339-345. DOI: 10.1111/jav.01091

Migratory aerial insectivores are among the fastest declining avian groups, but our understanding of these trends has been limited by poor knowledge of migratory connectivity and the identification of critical habitat across the vast distances they travel annually. Using new, archival GPS loggers, we tracked individual purple martins Progne subis from breeding colonies across North America to determine precise (< > 10 m) locations of migratory and overwintering roost locations in South America and to test hypotheses for fine-scale migratory connectivity and habitat use. We discovered weak migratory connectivity at the roost scale, and extensive, fine-scale mixing of birds in the Amazon from distant (> 2000 km) breeding sites, with some individuals sharing the same roosting trees. Despite vast tracts of contiguous forest in this region, birds occupied a much more limited habitat, with most (56%) roosts occurring on small habitat islands that were strongly associated with water. Only 17% of these roosts were in current protected areas. These data reflect a critical advance in our ability to remotely determine precise migratory connectivity and habitat selection across vast spatial scales, enhancing our understanding of population dynamics and enabling more effective conservation of species at risk.

6) English, P.A., Mills, A.M., Cadman, M.D., Heagy, A.E., Rand, G.J., Green, D.J., Nocera, J.J. Tracking the migration of a nocturnal aerial insectivore in the Americas (2017) *BMC Zoology*, 2 (1), art no. 5, . DOI: 10.1186/s40850-017-0014-1

Background Populations of Eastern Whip-poor-will (Antrostomus vociferous) appear to be declining range-wide. While this could be associated with habitat loss, declines in populations of many other species of migratory aerial insectivores suggest that changes in insect availability and/or an increase in the costs of migration could also be important factors. Due to their quiet, nocturnal habits during the non-breeding season, little is known about whip-poor-will migration and wintering locations, or the extent to which different breeding populations share risks related to non-breeding conditions. Results We tracked 20 males and 2 females breeding in four regions of Canada using geolocators. Wintering locations ranged from the gulf coast of central Mexico to Costa Rica. Individuals from the northern-most breeding site and females tended to winter furthest south, although east-west connectivity was low. Four individuals appeared to cross the Gulf of Mexico either in spring or autumn. On southward migration, most individuals interrupted migration for periods of up to 15 days north of the Gulf, regardless of their subsequent route. Fewer individuals showed signs of a stopover in spring. Conclusions Use of the southeastern United States for migratory stopover and a concentration of wintering locations in Guatemala and neighbouring Mexican provinces suggest that both of these regions should be considered potentially important for Canadian whip-poor-wills. This species shows some evidence of both "leapfrog" and sex-differential migration, suggesting that individuals in more northern parts of their breeding range could have higher migratory costs.
Keywords: Antrostomus vociferous; Geolocator; Leapfrog; Migration; Nightjar; Recapture rate; Sex-differential migration; Stopover; Trans-Gulf; Whip-poor-will

7) Areta, J.I., Mangini, G.G., Gandoy, F.A., Gorleri, F., Gomez, D., Depino, E.A., Jordan, E.A. Ecology and behavior of alder flycatchers (Empidonax alnorum) on their wintering grounds in Argentina (2016) *Wilson Journal of Ornithology*, 128 (4), pp. 830-845. DOI: 10.1676/15-188.1

The Alder (Empidonax alnorum) and Willow (E. traillii) flycatchers are cryptic species, and their distribution outside the breeding season is poorly known, owing mostly to identification difficulties. Our new records suggest that large numbers of Alder Flycatchers overwinter in rivers crossing the Chaco region and in the foothill forests of the Yungas of Argentina, significantly increasing their southern wintering range. Records in northern Argentina span 3

November to 23 March. Key habitat for overwintering Alder Flycatchers in Argentina included stands of palo bobo (Tessaria integrifolia) along the Río Bermejo and tributaries, either in association with sparse shrubs of chilca (Baccharis salicifolia) or more rarely with canebrake (Gynerium sagittatum). Other habitats used were old shrubby 'madrejones' with Tessaria scrub and sacha café (Sesbania virgata), very dense Baccharis salicifolia scrub next to flowing creeks in foothill Yungas and dry Chaco, and riparian forests dominated by palo flojo (Albizia inundata) and timbó (Enterolobium contortisiliquum). Seasonal flooding of these habitats did not affect the presence of Alder Flycatchers. Small territories of c. 20 × 20 or 25 × 25 m were defended in Tessaria stands. Alder Flycatchers fed mostly on insects in flight (aerial hawking), but also on green Lepidoptera larvae (upward sally-strikes), and on insects on leaves, and ripe fruits of tala (Celtis cf. ehrenbergiana) in forest understory (clinging). Vocalizations given by overwintering birds (fee-bee-oo, zwee-oo, wee-oo, churr, pit, double-peak, and kitter) were similar to those used while breeding. Alder Flycatchers collected in Argentina had significantly longer wings and wider bills than specimens from the sympatric Euler's Flycatchers (Lathrotriccus euleri) from Argentina with which it has been confused in museum specimens.
Keywords: Argentina; Chaco; cryptic species; distribution; seasonality; South America

8) de Lima Pereira, K.D. Olive-sided flycatcher, *Contopus cooperi*, in the cerrado biome, and a review of records in Brazil (2016) *Revista Brasileira de Ornitologia*, 24 (1), pp. 46-52.

The Olive-sided Flycatcher, Contopus cooperi (Nuttall, 1831), is a long distance migrant bird from North America. This Tyrannidae bird has wintering areas in Central and South America, and such as other long distance migrants, has decreased their populations, probably due to the use of pesticides, which in turn decrease the abundance of aerial insects, their main food supply. Little is known about the wintering distribution range of the species, mainly in South America. In Brazil its known distribution includes 11 states and 36 municipalities at the Amazon and Atlantic Foresst, occurring between October and April. This study reviews the distribution area of this species in Brazil, reporting for the first time, its occurrence in the Goiás state and the Cerrado biome.
Keywords: Geographical distribution; Migratory bird; North American migrant; Occurrence

9) Reudink, M.W., Van Wilgenburg, S.L., Steele, L.S., Pillar, A.G., Marra, P.P., McKellar, A.E. Patterns of migratory connectivity in Vaux's Swifts at a northern migratory roost: A multi-isotope approach (2015) *Condor*, 117 (4), pp. 670-682. DOI: 10.1650/CONDOR-15-82.1

The strength of migratory connectivity between breeding, stopover, and wintering areas can have important implications for population dynamics, evolutionary processes, and conservation. For example, patterns of migratory connectivity may influence the vulnerability of species and populations to stochastic events. For many migratory songbirds, however, we are only beginning to understand patterns of migratory connectivity. We investigated the potential strength of migratory connectivity within a population of Vaux's Swifts (Chaetura vauxi). Like many aerial insectivores, this species is currently experiencing population declines. In 2012, a mass mortality event at a spring migratory roost on Vancouver Island, British Columbia, Canada, resulted in the deaths of > 1,000 individuals (~2% of the British Columbia population). In

these individuals, we examined variation in 3 stable isotopes (δ 2H, δ 13C, and δ 15N) from claw samples to determine whether spring migrants showed inherent isotopic similarity in the habitats they used on their Mexican and Central American wintering grounds. Our results indicated the presence of 2 or 3 broad isotopic clusters, which suggests that Vaux's Swifts that migrated through Vancouver Island most likely originated from 2 or 3 overwintering locales or habitat types. We found no evidence of sex- or morphology-based segregation, which suggests that these groups likely share a similar overwintering ecology and, thus, may be equally vulnerable to stochastic events or habitat loss on the wintering grounds. Our results highlight the need for more studies on the nonbreeding-season ecology and migratory connectivity of this species.
Keywords: Cluster analysis; Conservation; Migratory connectivity; Roost; Stable isotope; Vaux's Swift

10) Hobson, K.A., Kardynal, K.J., Van Wilgenburg, S.L., Albrecht, G., Salvadori, A., Cadman, M.D., Liechti, F., Fox, J.W. A continent-wide migratory divide in North American breeding barn swallows (Hirundo rustica)
(2015) *PLoS ONE*, 10 (6), art. no. e0129340. DOI: 10.1371/journal.pone.0129340

Populations of most North American aerial insectivores have undergone steep population declines over the past 40 years but the relative importance of factors operating on breeding, wintering, or stopover sites remains unknown. We used archival light-level geolocators to track the phenology, movements and winter locations of barn swallows (Hirdundo rustica; n = 27) from populations across North America to determine their migratory connectivity. We identified an east-west continental migratory divide for barn swallows with birds from western regions (Washington State, USA (n = 8) and Saskatchewan, Canada (n = 5)) traveling shorter distances to wintering areas ranging from Oregon to northern Colombia than eastern populations (Ontario (n = 3) and New Brunswick (n = 10), Canada) which wintered in South America south of the Amazon basin. A single swallow from a stable population in Alabama shared a similar migration route to eastern barn swallows but wintered farther north in northeast Brazil indicating a potential leap frog pattern migratory among eastern birds. Six of 9 (67%) birds from the two eastern populations and Alabama underwent a loop migration west of fall migration routes including around the Gulf of Mexico travelling a mean of 2,224 km and 722 km longer on spring migration, respectively. Longer migration distances, including the requirement to cross the Caribbean Sea and Gulf of Mexico and subsequent shorter sedentary wintering periods, may exacerbate declines for populations breeding in north-eastern North America.

11) Collins, C.T. Food habits and resource partitioning in a guild of Neotropical swifts
(2015) *Wilson Journal of Ornithology*, 127 (2), pp. 239-248. DOI: 10.1676/wils-127-02-239-248.1

The Coastal Cordillera of Venezuela has a rich avifauna including swifts. The aerial arthropod prey of three species found there, Gray-rumped Swift (Chaetura cinereiventris), Vaux's Swift (Chaetura vauxi), and White-tipped Swift (Aeronautes montivagus), included spiders plus nine orders and 110 families of insects. Diptera and Hymenoptera were the most numerous prey

taxa (>60%) taken by all three swifts. Prey size ranged from 0.5-17.9 mm body length, and averaged 2.69 mm for Gray-rumped Swifts, 2.91 mm for Vaux's Swifts, and 5.52 mm for White-tipped Swifts. Niche breadth was similar in Gray-rumped and Vaux's Swifts (2.4 and 3.13), and niche overlap was also high (0.98). Niche breadth was higher in White-tipped Swifts (8.49) and niche overlap was <60 with both Gray-rumped and Vaux's swifts. Observed elevational differences in foraging habitat and altitudinal foraging zones are proposed as resource partitioning mechanisms for this guild of sympatric aerial insectivores.
Keywords: Aeronautes montivagus; Apodidae; Chaetura cinereiventris; Chaetura vauxi; food habits; Neotropics; prey size; resource partitioning

12) Hobson, K.A., Kardynal, K.J. An isotope (δ34s) filter and geolocator Results constrain a dual feather isoscape (δ2h, δ13C) to identify the wintering grounds of North American Barn Swallows (2015) Auk 133 (1), 86-98

The discovery of spatial patterns in naturally occurring isotopes (e.g., δ2H, δ13C) at continental scales has been tremendously important in providing a method to infer potential breeding and wintering origins of migratory animals through assignment to tissue-specific isoscapes. Single-isotope (i.e. δ2H) assignments of birds to molting origins in South America have been limited by the lack of strong spatial gradients in precipitation δ2H there. We integrated an mvnpdf (multivariate normal probability density function) approach using δ2H and δ13C values in tail feathers to determine wintering origins of adult Barn Swallows (Hirundo rustica) breeding in eastern Canada (n = 208). Spatial assignments were conducted using precipitation (δ2H) and theoretical plant-based (δ13C) isoscapes for South America calibrated for feathers of Nearctic-Neotropical migrant songbirds. We also measured feather δ34S values of Barn Swallows equipped with geolocators (n = 9) and of a larger group of Barn Swallows (n =121) of unknown molt origin to assess the possibility of using this isotope to identify birds molting in coastal habitats and for which the terrestrial d2H isoscapes would potentially be invalid. We constrained the mvnpdf assignment to areas generally south of the Amazon basin, based on data retrieved from Barn Swallows fitted with archival light-level geolocators from Ontario (n = 3) and New Brunswick (n = 11), Canada, which showed consistent overwintering fidelity to south-central South America. The majority of birds from our breeding populations were assigned to south-central Brazil. Results from the δ34S analysis indicate that a threshold of 11% may be appropriate to constrain the use of terrestrial δ2H isoscapes in South America. Our results refine the toolbox available to examine migratory connectivity in species that molt on their South American wintering grounds and underline the value of using multiple proxies for assignments of animals to spatial origin.
Keywords: Carbon-13, Deuterium, Geolocators, Isoscape, Isotopic assignment, Migratory connectivity, Multivariate normal probability density function, Sulfur-34

13) Fraser, KC; Stutchbury, BJM; Silverio, C; Kramer, PM; Barrow, J; Newstead, D; Mickle, N; Cousens, BF; Lee, JC; Morrison, DM; Shaheen, T; Mammenga, P; Applegate, K; Tautin, J. Continent-wide tracking to determine migratory connectivity and tropical habitat associations of a declining aerial insectivore PROCEEDINGS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES 279 (1749): 4901-4906 DOI: 10.1098/rspb.2012.2207 2012

North American birds that feed on flying insects are experiencing steep population declines, particularly long-distance migratory populations in the northern breeding range. We determine, for the first time, the level of migratory connectivity across the range of a songbird using direct tracking of individuals, and test whether declining northern populations have higher exposure to agricultural landscapes at their non-breeding grounds in South America. We used light-level geolocators to track purple martins, Progne subis, originating from North American breeding populations, coast-to-coast (n = 95 individuals). We show that breeding populations of the eastern subspecies, P. s. subis, that are separated by ca. 2000 km, nevertheless have almost completely overlapping non-breeding ranges in Brazil. Most (76%) P. s. subis overwintered in northern Brazil near the Amazon River, not in the agricultural landscape of southern Brazil. Individual non-breeding sites had an average of 91 per cent forest and only 4 per cent agricultural ground cover within a 50 km radius, and birds originating from declining northern breeding populations were not more exposed to agricultural landscapes than stable southern breeding populations. Our results show that differences in wintering location and habitat do not explain recent trends in breeding population declines in this species, and instead northern populations may be constrained in their ability to respond to climate change.
Keywords: geolocator; songbird; South America

SPRING MIGRATION, CARRY-OVER EFFECTS

1) Imlay, T.L., Angelier, F., Hobson, K.A., Mastromonaco, G., Saldanha, S., Leonard, M.L. Multiple intrinsic markers identify carry-over effects from wintering to breeding sites for three Nearctic-Neotropical migrant swallows (2019) *Auk*, 136 (4), art. no. ukz053, . DOI: 10.1093/auk/ukz053

Carry-over effects from one stage of the annual cycle to subsequent stages can have profound effects on individual fitness. In migratory birds, much research has been devoted to examining such effects from the nonbreeding to the breeding period. We investigated potential carry-over effects influencing spring body condition, breeding phenology, and performance for 3 species of sympatric, declining Nearctic-Neotropical migratory swallows: Bank Swallow (Riparia riparia), Barn Swallow (Hirundo rustica), and Cliff Swallow (Petrochelidon pyrrhonota). To examine carry-over effects, we used structural equation modeling and several intrinsic markers, including stable isotope (δ2H, δ13C, and δ15N) and corticosterone (CORTf) values from winter molted-feathers, and changes in telomere length between breeding seasons. We found support for carry-over effects for all 3 species, however, the specific relationships varied between species and sexes. Effects leading to lower breeding performance were only observed in male Bank, female Barn, and female and male Cliff Swallows. In most cases, carry-over effects were attributed to differences in stable isotope values (most commonly with δ2H) presumably related to differences in winter habitat use, but, for Cliff Swallows, negative carry-over effects were also linked to higher CORTf values and greater rates of telomere shortening. This work provides further support for the potential role of nonbreeding conditions on population declines, and indicates how multiple intrinsic markers can be used to provide information on ecological conditions throughout the annual cycle.

Keywords: análisis de rutas; ciclo anual; corticosterona; corticosterone; efecto de arrastre; Hirundo rustica; Hirundo rustica; isótopo estable; path analysis; Petrochelidon pyrrhonota; Petrochelidon pyrrhonota; Riparia riparia; Riparia riparia; sand martin; stable isotope; telomere; telómero

2) Fraser, K.C. Shave, A., de Greef, E., Siegrest, J. Garroway, C. Individual variability in migration timing can explain long-term, population-level Songbird (2019) Frontiers in Ecology and Evolution

Migratory animals may be particularly at-risk due to global climate change, as they must match their timing with asynchronous changes in suitable conditions across broad, spatiotemporal scales. It is unclear whether individual long-distance migratory songbirds can flexibly adjust their timing to varying inter-annual conditions. Longitudinal data for individuals sampled across migration are ideal for investigating phenotypic plasticity in migratory timing programs, but remain exceptionally rare. Using the largest, repeat-tracking data set available to date for a songbird (n = 33, purple martin Progne subis), we investigated individual variability in migration timing across 7,000–14,000 km migrations between North American breeding sites and South American overwintering sites. In contrast to previous studies of songbirds, we found broad, within-individual variability between years in the timing of spring departure (0–20 days), spring crossing of the Gulf of Mexico (0–20 days), and breeding site arrival (0–18 days). Spring departure and arrival dates were fairly repeatable across years (depart r = 0.39; arrive r = 0.32). Fall migration timing was more variable at the individual level (depart range = 0–19 days; gulf crossing range = 1–15 days; arrive range = 0–24 days) and less repeatable, with fall crossing of the Tropic of Cancer being the least repeatable (r = 0.0001). In this first, repeat-tracking study of a diurnal migratory songbird, the high within-individual variability in timing that we report may reflect the greater influence of environmental and social cues on migratory timing, as compared to the migration of more solitary, nocturnally migrating songbirds. Further, large, within-individual variability in migration dates (0–24 days) suggest that advances in spring arrival dates with climate change that have been reported for multiple songbird species (including purple martins) could potentially be explained by intra-individual flexibility in migration timing. However, whether phenotypic plasticity will be sufficient to keep up with the pace of climate change remains to be determined.
Key words: phenotypic plasticity, spring phenology, repeatability, climate change, avian, long-distance migration, songbird

3) Szép, T., Dobránszky, J., Møller, A.P., Dyke, G., Lendvai, Á.Z. Older birds have better feathers: A longitudinal study on the long-distance migratory Sand Martin, *Riparia riparia* (2019) *PLoS ONE*, 14 (1), art. no. e0209737. DOI: 10.1371/journal.pone.0209737

Feather quality is of critical importance to long-distance migratory birds. Here, we report a series of analyses of a unique data set encompassing known-age individuals of the long-distance migratory Sand Martin (Riparia riparia). Sampling over 17 years along the Tisza River, eastern Hungary, has resulted in the recapture of numerous individuals enabling longitudinal and cross-sectional investigation of the role of adaptation to variable environmental conditions on feather morphology. We show that older individuals tend to possess better quality feathers, measured using bending stiffness, feather length and thickness as proxies. Bending stiffness and feather thickness do not change with individual age, in contrast with increases in feather length and declines in daily feather growth versus age of individual alongside moult duration. Individuals who live to older ages tend to have similar, or higher, feather growth rates and better feather quality than individuals captured at younger ages. Thus, on the basis of strong selection against individuals with slow feather growth, as seen in other species of swallows and martins, which causes a delay in moult completion, the results of this analysis highlight the potential cost of producing better quality feathers when this depends on moult duration. Feather length also does change during the lifetime of the individual and thus enabled us to further investigate influence of individual and environmental conditions during the moult. The results of this analysis provide important insights on the adaptive significance of these traits, and the potential use of physical characteristics in unravelling the reasons why long distance migratory bird populations are in global decline.

4) Fairhurst, G.D., Berzins, L.L., Bradley, D.W., Laughlin, A.J., Romano, A., Romano, M., Scandolara, C., Ambrosini, R., Dawson, R.D., Dunn, P.O., Hobson, K.A., Liechti, F., Marchant, T.A., Norris, D.R., Rubolini, D., Saino, N., Taylor, C.M., Whittingham, L.A., Clark, R.G. Assessing costs of carrying geolocators using feather corticosterone in two species of aerial insectivore (2015) *Royal Society Open Science*, 2 (5), art. no. 150004, 10 p. DOI: 10.1098/rsos.150004

Despite benefits of using light-sensitive geolocators to track animal movements and describe patterns of migratory connectivity, concerns have been raised about negative effects of these devices, particularly in small species of aerial insectivore.Geolocators may act as handicaps that increase energetic expenditure, which could explain reported effects of geolocators on survival.We tested this ‘Energetic Expenditure Hypothesis’ in 12 populations of tree swallows (Tachycineta bicolor) and barn swallows (Hirundo rustica) from North America and Europe, usingmeasurements of corticosterone from feathers (CORTf) grown after deployment of geolocators as a measure of physiology relevant to energetics. Contrary to predictions, neither among- (both species) nor within-individual (tree swallows only) levels of CORTf differed with respect to instrumentation. Thus, to the extent that CORTf reflects energetic expenditure, geolocators apparently were not a strong handicap for birds that returned post-deployment. While this physiological evidence suggests that information about migration obtained from returning geolocator-equipped swallows is unbiased with regard to levels of stress, we cannot discount the possibility that corticosterone played a role in reported effects of geolocators on survival in birds, and suggest that future studies relate corticosterone to antecedent factors, such as reproductive history, and to downstream fitness costs. ©2015 The Authors.
Keywords: Energetic expenditure hypothesis; Feather corticosterone; Hormone biomarkers; Light-level geolocators; Migration physiology; Swallows

5) Rioux Paquette, S., Pelletier, F., Garant, D., Bélisle, M. Severe recent decrease of adult body mass in a declining insectivorous bird population (2014) *Proceedings of the Royal Society B: Biological Sciences*, 281 (1786), art. no. 20140649, . DOI: 10.1098/rspb.2014.0649

Migratory bird species that feed on air-borne insects are experiencing widespread regional declines, but these remain poorly understood. Agricultural intensification in the breeding range is often regarded as one of the main drivers of these declines. Here, we tested the hypothesis that body mass in breeding individuals should reflect habitat quality in an aerial insectivore, the tree swallow (Tachycineta bicolor), along a gradient of agricultural intensity. Our dataset was collected over 7 years (2005-2011) and included 2918 swallow captures and 1483 broods. Analyses revealed a substantial decline of the population over the course of the study (219% occupancy rate), mirrored by decreasing body mass. This trend was especially severe in females, representing a total loss of 8% of their mass. Reproductive success was negatively influenced by intensive agriculture, but did not decrease over time. Interestingly, variation in body mass was independent of breeding habitat quality, leading us to suggest that this decline in body mass may result from carry-over effects from non-breeding areas and affect population dynamics through reduced survival. This work contributes to the growing body of evidence suggesting that declines in migratory aerial insectivores are driven by multiple, complex factors requiring better knowledge of year-round habitat use
Keywords: Aerial insectivores; Agricultural intensification; Body mass; Breeding success; Phenotypic plasticity; Tree swallow

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INSECT DECLINES

1) Wu, C.-H., Lin, C.-L., Wang, S.-E., Lu, C.-W. Effects of imidacloprid, a neonicotinoid insecticide, on the echolocation system of insectivorous bats (2020) Pesticide Biochemistry and Physiology, 163, pp. 94-101.

Imidacloprid, a widely used neonicotinoid insecticide, has led to a decline in the honey bee population worldwide. An invertebrate insect prey with neonicotinoid toxicity can adversely affect insectivores, such as echolocating bats. The aim of the current study was to examined whether imidacloprid toxicity may interfere echolocation system such as vocal, auditory, orientation, and spatial memory systems in the insectivorous bat. By comparing the ultrasound spectrum, auditory brainstem-evoked potential, and flight trajectory, we found that imidacloprid toxicity may interfere functions in vocal, auditory, orientation, and spatial memory system of insectivorous bats (Hipposideros armiger terasensis). As suggested from immunohistochemistry and western blots evidences, we found that insectivorous bats after suffering imidacloprid toxicity may decrease vocal-related FOXP2 expressions in the superior colliculus, auditory-related prestin expressions in the cochlea, and the auditory-related otoferlin expressions in the cochlea and the inferior colliculus, and cause inflammation and mitochondrial dysfunction-related apoptosis in the hippocampal CA1 and medial entorhinal cortex. These results may provide a reasonable explanation about imidacloprid-induced interference of echolocation system in insectivorous bats.
Keywords: Apoptosis; Echolocation system; FOXP2; Imidacloprid; Inflammation; Insectivorous bats; Otoferlin; Prestin; Spatial memory

2) Wagner, D.L. Insect declines in the Anthropocene (2020) Annual Review of Entomology, 65, pp. 457-480.

Insect declines are being reported worldwide for flying, ground, and aquatic lineages. Most reports come from western and northern Europe, where the insect fauna is well-studied and there are considerable demographic data for many taxonomically disparate lineages. Additional cases of faunal losses have been noted from Asia, North America, the Arctic, the Neotropics, and elsewhere. While this review addresses both species loss and population declines, its emphasis is on the latter. Declines of abundant species can be especially worrisome, given that they anchor trophic interactions and shoulder many of the essential ecosystem services of their respective communities. A review of the factors believed to be responsible for observed collapses and those perceived to be especially threatening to insects form the core of this treatment. In addition to widely recognized threats to insect biodiversity, e.g., habitat destruction, agricultural intensification (including pesticide use), climate change, and invasive species, this assessment highlights a few less commonly considered factors such as atmospheric nitrification from the burning of fossil fuels and the effects of droughts and changing precipitation patterns. Because the geographic extent and magnitude of insect declines are largely unknown, there is an urgent need for monitoring efforts, especially across ecological gradients, which will help to identify important causal factors in declines. This review also considers the status of vertebrate insectivores, reporting bias, challenges inherent in collecting and interpreting insect demographic data, and cases of increasing insect abundance. Copyright © 2020 by Annual Reviews. All rights reserved.
Keywords: agricultural intensification; bees; climate change; drought; insect decline; pollinator decline; precipitation extremes; vertebrate insectivores

3) Lewis-Phillips, J., Brooks, S.J., Sayer, C.D., Patmore, I.R., Hilton, G.M., Harrison, A., Robson, H., Axmacher, J.C. Ponds as insect chimneys: Restoring overgrown farmland ponds benefits birds through elevated productivity of emerging aquatic insects (2020) Biological Conservation, 241, art. no. 108253, .

Farmland bird populations have experienced severe declines across Europe and elsewhere. Agricultural intensification is believed to be a main factor behind these declines, with losses of non-cropped features, such as farmland ponds, identified as a key driver. Since the 1950s, many European farmland ponds have been in-filled or, through lack of management, become terrestrialised. Restoring terrestrialised farmland ponds has been shown to significantly increase the abundance and diversity of local farmland bird communities. It has been hypothesised that farmland birds are specifically attracted to open-canopy ponds due to increased emergent aquatic insect availability, but this link has hitherto been little explored. This study investigates how farmland pond management influences emergent aquatic insects, and how emergent insect abundance and biomass is linked to local bird assemblages. Insect emergences showed an 18-fold higher abundance and a 25-fold higher biomass at managed open-canopy ponds in comparison to their unmanaged overgrown counterparts, with day-to-day fluctuations in pond water temperature a key predictor of insect emergences. Species

richness and abundance of birds at farmland ponds were strongly positively linked to the abundance of emergent insects. Furthermore, insect emergence peaks occurred on different days in different restored ponds such that the pond landscape afforded extended feeding opportunities for birds. Our findings suggest that restoring networks of terrestrialised farmland ponds to open-canopy macrophyte-dominated conditions could be a highly effective way of increasing the availability of aquatic insect prey for birds. This study highlights an urgent need to re-evaluate pond restoration and management within agri-environmental schemes in Europe and beyond.
Keywords: Aquatic habitat restoration; Aquatic insect emergence; Biodiversity conservation; Trophic links; Wetland subsidies

4) Manu E Saunders, Jasmine K Janes, James C O'Hanlon Moving On from the Insect Apocalypse Narrative: Engaging with Evidence-Based Insect Conservation (2020) BioScience 70 (1): 80–89, https://doi.org/10.1093/biosci/biz143

Recent studies showing temporal changes in local and regional insect populations received exaggerated global media coverage. Confusing and inaccurate science communication on this important issue could have counterproductive effects on public support for insect conservation. The insect apocalypse narrative is fuelled by a limited number of studies that are restricted geographically (predominantly the United Kingdom, Europe, the United States) and taxonomically (predominantly some bees, macrolepidoptera, and ground beetles). Biases in sampling and analytical methods (e.g., categorical versus continuous time series, different diversity metrics) limit the relevance of these studies as evidence of generalized global insect decline. Rather, the value of this research lies in highlighting important areas for priority investment. We summarize research, communication, and policy priorities for evidence-based insect conservation, including key areas of knowledge to increase understanding of insect population dynamics. Importantly, we advocate for a balanced perspective in science communication to better serve both public and scientific interests.
Keywords: population biology, biodiversity, insect ecology, science communication, conservation

5) Møller, A.Pape. Quantifying rapidly declining abundance of insects in Europe using a paired experimental design (2020) Ecology and Evolution https://doi.org/10.1002/ece3.6070

The abundance of insects has decreased for the last decades in many parts of the world although so far few studies have quantified this reduction because there have only been few baseline studies dating back decades that have allowed comparison of ancient and recent population estimates. Such a paired design is particularly powerful because it reduces or eliminates bias caused by differences in identity and experience of observers, identity of study sites, years, time of season, and time of day, and it ensures identity of sampling procedures. Here, I compiled information on the reduction in abundance of insects in Europe and Algeria by the same persons compiling the abundance of insects from the same 21 study sites during 1951–1997 and again a second time in 1998–2018. There was a reduction by 47% in the abundance of insects. The difference in abundance in old compared to new samples declined

with latitude, with a significant variance among taxa. This reduction in abundance of insects was of such a magnitude that it must have consequences for insectivores and the role that insects play in ecosystems.
Key words: declining abundance, insects, land-use, latitudinal decline

6) Harvey, J.A. et al. International scientists formulate a roadmap for insect conservation and recovery (2020) Natural Ecology and Evolution 4, 174-176. https://doi.org/10.1038/s41559-019-1079-8

A growing number of studies are providing evidence that a suite of anthropogenic stressors - habitat loss and fragmentation, pollution, invasive species, climate change and overharvesting - are seriously reducing insect and other invertebrate abundance, diversity and biomass across the biosphere1–8. These declines affect all functional groups: herbivores, detritivores, parasitoids,
predators and pollinators. Insects are vitally important in a wide range of ecosystem services9 of which some are vitally important for food production and security (for example, pollination and
pest control)10. There is now a strong scientific consensus that the decline of insects, other arthropods and biodiversity as a whole, is a very real and serious threat that society must urgently address11–13. In response to the increasing public awareness of the problem, the German government is committing funds to combat and reverse declining insect numbers13. This funding
should act as a clarion call to other nations across the world — especially wealthier ones — to follow suit and to respond proactively to the crisis by addressing the known and suspected threats
and implementing solutions.
7) Macgregor, C.J., Williams, J.H., Bell, J.R., Thomas, C.D. Moth biomass increases and decreases over 50 years in Britain (2019) Nature Ecology and Evolution, 3 (12), pp. 1645-1649.

Steep insect biomass declines ('insectageddon') have been widely reported, despite a lack of continuously collected biomass data from replicated long-term monitoring sites. Such severe declines are not supported by the world's longest running insect population database: annual moth biomass estimates from British fixed monitoring sites revealed increasing biomass between 1967 and 1982, followed by gradual decline from 1982 to 2017, with a 2.2-fold net gain in mean biomass between the first (1967–1976) and last decades (2008–2017) of monitoring. High between-year variability and multi-year periodicity in biomass emphasize the need for long-term data to detect trends and identify their causes robustly.

8) Powney, G.D., Carvell, C., Edwards, M., Morris, R.K.A., Roy, H.E., Woodcock, B.A., Isaac, N.J.B. Widespread losses of pollinating insects in Britain (2019) Nature Communications, 10 (1), art. no. 1018, .

Pollination is a critical ecosystem service underpinning the productivity of agricultural systems across the world. Wild insect populations provide a substantial contribution to the productivity of many crops and seed set of wild flowers. However, large-scale evidence on species-specific trends among wild pollinators are lacking. Here we show substantial inter-specific variation in pollinator trends, based on occupancy models for 353 wild bee and hoverfly species in Great Britain between 1980 and 2013. Furthermore, we estimate a net loss of over 2.7 million occupied 1 km 2 grid cells across all species. Declines in pollinator evenness suggest that losses were concentrated in rare species. In addition, losses linked to specific habitats were identified, with a 55% decline among species associated with uplands. This contrasts with dominant crop pollinators, which increased by 12%, potentially in response agri-environment measures. The general declines highlight a fundamental deterioration in both wider biodiversity and non-crop pollination services.

9) Harris, J.E., Rodenhouse, N.L., Holmes, R.T. Decline in beetle abundance and diversity in an intact temperate forest linked to climate warming (2019) Biological Conservation, 240, art. no. 108219, .

Insect abundances are declining in many areas around the world, but the causes of those declines are seldom clear. Here we report a dramatic decline in the abundance and diversity of Coleoptera (beetle) taxa in a large tract of intact northern hardwood forest during the last 45 years, and provide evidence supporting winter warming as the primary cause. Beetles were sampled using the same method (window traps) and in the same locations within the Hubbard Brook Experimental Forest, New Hampshire, in 1973–1977 and again in 2015–2017. The mean (±SE) number of beetles captured per 48-h fell from 23.2 (±3.89) to 3.9 (±1.19), a decline of 83% over this 45-year period. The number of beetle taxa captured decreased by 39%, with 19 beetle families disappearing entirely. Beetle capture rate was least when and where climate was warmest. Capture rate was significantly lower in the 2010s when mean daily temperature was about 1.8 °C warmer, and sampling during 2016–2017 at low, mid and high elevations (320, 540, and 810 m asl, respectively) revealed lowest beetle captures at low elevation where climate was warmest. Most importantly, beetle capture rate was significantly lower after winters with less snow cover during the previous winter, indicating that snow cover in northern hardwood forest is essential for sustaining the beetle community. These results imply that additional climate warming might further reduce the abundance and diversity of beetles and other arthropods inhabiting the forest-floor, potentially affecting critical ecosystem processes such as decomposition and carbon storage.
Keywords: Climate change; Coleoptera; Forest-floor; Hubbard Brook; Insect decline; Temperate deciduous forest

10) Habel, J.C., Trusch, R., Schmitt, T., Ochse, M., Ulrich, W. Long-term large-scale decline in relative abundances of butterfly and burnet moth species across south-western Germany (2019) Scientific Reports, 9 (1), art. no. 14921, .

Current studies have shown a severe general decline in insect species diversity, their abundance, and a biomass reduction of flying insects. Most of previous studies have been performed at single sites, or were spatially restricted at the landscape level. In this study, we analyse trends of species richness and shifts in species composition of butterflies and burnet moth species across the federal state of Baden-Württemberg in south-western Germany, covering an area of 35,750 km2. The data set consists of 233,474 records and covers a period from 1750 until today. We grouped species according to their species´ specific functional traits and analyse how species with different habitat requirements and behaviour respond to land-use changes over time. Our data document a significant loss of relative abundance for most species, especially since the 1950s until today. Species demanding specific habitat requirements are more seriously suffering under this trend than generalists. This in particular affects taxa adapted to extensively used xerothermic grasslands, bogs or other habitats maintained by traditional low-productivity agricultural practices of the past. Our data indicate large-scale decline in relative abundance of many butterfly and burnet moth species, which happened in particular during the past few decades.

11) Uhl, P., Brühl, C.A. The Impact of Pesticides on Flower-Visiting Insects: A Review with Regard to European Risk Assessment (2019) Environmental Toxicology and Chemistry, 38 (11), pp. 2355-2370.

Flower-visiting insects (FVIs) are an ecologically diverse group of mobile, flying species that should be protected from pesticide effects according to European policy. However, there is an ongoing decline of FVI species, partly caused by agricultural pesticide applications. Therefore, the risk assessment framework needs to be improved. We synthesized the peer-reviewed literature on FVI groups and their ecology, habitat, exposure to pesticides, and subsequent effects. The results show that FVIs are far more diverse than previously thought. Their habitat, the entire agricultural landscape, is potentially contaminated with pesticides through multiple pathways. Pesticide exposure of FVIs at environmentally realistic levels can cause population-relevant adverse effects. This knowledge was used to critically evaluate the European regulatory framework of exposure and effect assessment. The current risk assessment should be amended to incorporate specific ecological properties of FVIs, that is, traits. We present data-driven tools to improve future risk assessments by making use of trait information. There are major knowledge gaps concerning the general investigation of groups other than bees, the collection of comprehensive data on FVI groups and their ecology, linking habitat to FVI exposure, and study of previously neglected complex population effects. This is necessary to improve our understanding of FVIs and facilitate the development of a more protective FVI risk assessment. Environ Toxicol Chem 2019;38:2355–2370. © 2019 The Authors. Environmental Toxicology and Chemistry published by Wiley Periodicals, Inc. on behalf of SETAC. © 2019 The Authors. Environmental Toxicology and Chemistry published by Wiley Periodicals, Inc. on behalf of SETAC
Keywords: Bees; Effects; Exposure; Pollinator insects; Regulatory deficits; Regulatory development

12) Kunin, W.E. Robust evidence of declines in insect abundance and biodiversity (2019) Nature, 574 (7780), pp. 641-642.

Recent reports of local extinctions of arthropod species1, and of massive declines in arthropod biomass2, point to land-use intensification as a major driver of decreasing biodiversity.

However, to our knowledge, there are no multisite time series of arthropod occurrences across gradients of land-use intensity with which to confirm causal relationships. Moreover, it remains unclear which land-use types and arthropod groups are affected, and whether the observed declines in biomass and diversity are linked to one another. Here we analyse data from more than 1 million individual arthropods (about 2,700 species), from standardized inventories taken between 2008 and 2017 at 150 grassland and 140 forest sites in 3 regions of Germany. Overall gamma diversity in grasslands and forests decreased over time, indicating loss of species across sites and regions. In annually sampled grasslands, biomass, abundance and number of species declined by 67%, 78% and 34%, respectively. The decline was consistent across trophic levels and mainly affected rare species; its magnitude was independent of local land-use intensity. However, sites embedded in landscapes with a higher cover of agricultural land showed a stronger temporal decline. In 30 forest sites with annual inventories, biomass and species number—but not abundance—decreased by 41% and 36%, respectively. This was supported by analyses of all forest sites sampled in three-year intervals. The decline affected rare and abundant species, and trends differed across trophic levels. Our results show that there are widespread declines in arthropod biomass, abundance and the number of species across trophic levels. Arthropod declines in forests demonstrate that loss is not restricted to open habitats. Our results suggest that major drivers of arthropod decline act at larger spatial scales, and are (at least for grasslands) associated with agriculture at the landscape level. This implies that policies need to address the landscape scale to mitigate the negative effects of land-use practices.
Long-term standardized monitoring reveals the scale of biodiversity losses.
Keywords: Conservation biology

13) Goulson, D. The insect apocalypse, and why it matters (2019) Current Biology, 29 (19), pp. R967-R971.

Though threats to charismatic animals, such as birds and mammals, garner most of the public's attention, Goulson makes the case that much more attention should be paid to insects, which provide many important ecosystem services and have experienced dramatic declines recently. The majority of conservation efforts and public attention are focused on large, charismatic mammals and birds such as tigers, pandas and penguins, yet the bulk of animal life, whether measured by biomass, numerical abundance or numbers of species, consists of invertebrates such as insects. Arguably, these innumerable little creatures are far more important for the functioning of ecosystems than their furry or feathered brethren, but until recently we had few long-term data on their population trends. Recent studies from Germany and Puerto Rico suggest that insects may be in a state of catastrophic population collapse: the German data describe a 76% decline in biomass over 26 years, while the Puerto Rican study estimates a decline of between 75% and 98% over 35 years. Corroborative evidence, for example from butterflies in Europe and California (which both show slightly less dramatic reductions in abundance), suggest that these declines are not isolated. The causes are much debated, but almost certainly include habitat loss, chronic exposure to pesticides, and climate change. The consequences are clear; insects are integral to every terrestrial food web, being food for numerous birds, bats, reptiles, amphibians and fish, and performing vital roles such as pollination, pest control and nutrient recycling. Terrestrial and freshwater ecosystems will collapse without insects. These studies are a warning that we may have failed to appreciate the full scale and pace of environmental degradation caused by human activities in the Anthropocene.

14) Hopkins, J. Comment: The insect decline - Time to limit pesticide use? (2019) British Wildlife, 31 (1), pp. 40-45.

15) Bowler, D.E., Heldbjerg, H., Fox, A.D., de Jong, M., Böhning-Gaese, K. Long-term declines of European insectivorous bird populations and potential causes (2019) Conservation Biology, 33 (5), pp. 1120-1130.

Evidence of declines in insect populations has recently received considerable scientific and societal attention. However, the lack of long-term insect monitoring makes it difficult to assess whether declines are geographically widespread. By contrast, bird populations are well monitored and often used as indicators of environmental change. We compared the population trends of European insectivorous birds with those of other birds to assess whether patterns in bird population trends were consistent with declines of insects. We further examined whether declines were evident for insectivores with different habitats, foraging strata, and other ecological preferences. Bird population trends were estimated for Europe (1990–2015) and Denmark (1990–2016). On average, insectivores declined over the study period (13% across Europe and 28% in Denmark), whereas omnivores had stable populations. Seedeaters also declined (28% across Europe; 34% in Denmark), but this assessment was based on fewer species than for other groups. The effects of insectivory were stronger for farmland species (especially grassland species), for ground feeders, and for cold-adapted species. Insectivory was associated with long-distance migration, which was also linked to population declines. However, many insectivores had stable populations, especially habitat generalists. Our findings suggest that the decline of insectivores is primarily associated with agricultural intensification and loss of grassland habitat. The loss of both seed and insect specialists indicates an overall trend toward bird communities dominated by diet generalists.
Keywords: agricultural intensification; bioindicadores; bioindicators; cambio climático; climate change; declinaciones de insectos; insect declines; intensificación agrícola; population trends; tendencias poblacionales

16) Habel, J.C., Ulrich, W., Biburger, N., Seibold, S., Schmitt, T. Agricultural intensification drives butterfly decline (2019) Insect Conservation and Diversity, 12 (4), pp. 289-295.

Severe losses of insects have taken place over major parts of Europe. This negative trend is assumed to be largely the result of agricultural intensification. To analyse potential factors causing this loss of species, we assessed butterfly communities at 21 grassland patches. Seventeen of these were distributed across an agricultural landscape dominated by crop fields; four were embedded in two adjoining managed semi-natural grassland areas. We assessed environmental parameters such as patch size and habitat quality for each grassland patch. We further incorporated the surrounding land-cover considering different degrees of land-use

intensity. We classified butterfly species into generalists and specialists according their ecological and behavioural characteristics. As in the managed semi-natural reference grasslands, species richness and abundance were higher in patches surrounded by extensively used grasslands and unsprayed crop fields, and lower in patches surrounded by sprayed crop fields. Furthermore, blossom density positively affected butterfly occurrence. Our data revealed that specialised butterfly species mainly occur in managed semi-natural grassland sites, and are largely absent from other grassland plots embedded in the agricultural matrix. Our study underlines the negative impacts of intense conventional agriculture on butterfly species richness and abundance and reveals the urgent need for more nature-friendly cultivation methods. In situ experiments may help to understand and disentangle single drivers causing this negative trend.
Keywords: Agricultural intensification; butterflies; insect decline; pesticides; semi-natural grasslands

17) Mupepele, A.-C., Bruelheide, H., Dauber, J., Krüß, A., Potthast, T., Wägele, W., Klein, A.-M. Insect decline and its drivers: Unsupported conclusions in a poorly performed meta-analysis on trends—A critique of Sánchez-Bayo and Wyckhuys (2019) (2019) Basic and Applied Ecology, 37, pp. 20-23.

18) Møller, A.P. Parallel declines in abundance of insects and insectivorous birds in Denmark over 22 years (2019) Ecology and Evolution, 9 (11), pp. 6581-6587.

Farmers in most western countries have increased use of fertilizer and pesticides with impact on wild animals and plants, including the abundance of insects and their predators. I used 1,375 surveys of insects killed on car windscreens as a measure of insect abundance during 1997–2017 at two transects in Denmark. I cross-validated this method against three other methods for sampling insect abundance, and I investigated the effects of this measure of insect abundance on the abundance of breeding insectivorous birds. The abundance of flying insects was quantified using a windscreen resulting in reductions of 80% and 97% at two transects of 1.2 km and 25 km, respectively, according to general additive mixed model. Insect abundance increased with time of day, temperature, and June date, but decreased with wind resulting in a reduction by 54%. The abundance of insects killed on a car windscreen was strongly positively correlated with the abundance of insects caught in sweep nets and on sticky plates in the same study areas and at the same time as when insects were sampled using windscreens. The decline in abundance of insects on windscreens predicted the rate at which barn swallows Hirundo rustica fed their nestlings, even when controlling statistically for time of day, weather, and age and number of nestlings. The abundance of breeding pairs of three species of aerially insectivorous birds was positively correlated with the abundance of insects killed on windscreens at the same time in the same study area. This suggests a link between two trophic levels as affected by the temporal reduction in the abundance of flying insects. These findings are consistent with recent dramatic declines in insect abundance in Europe and North America with consequences for the rate of food provisioning of barn swallow offspring, the abundance of aerially insectivorous birds and bottom-up trophic cascades.
Keywords: agriculture; Diptera; farming practice; insectivorous birds; land use; windscreen

19) Wagner, D.L. Global insect decline: Comments on Sánchez-Bayo and Wyckhuys (2019) (2019) Biological Conservation, 233, pp. 332-333.

The recently published review by Sánchez-Bayo and Wyckhuys (2019) in Biological Conservation provides a needed review of global insect decline. There is much in the study to recommend it: this is the first attempt to review the magnitude, geographic nature, and taxonomic scope of the insect decline phenomenon. Their focus on traits that are correlated with declines, their conclusion that specialists are losing ground to ecological generalists, and their systematic quantifications of declines are valuable contributions.

20) Sanchez-Bayo, F., Wyckhuys, K.A.G. Response to “Global insect decline: Comments on Sánchez-Bayo and Wyckhuys (2019)” (2019) Biological Conservation, 233, pp. 334-335.

21) Simmons, B.I., Balmford, A., Bladon, A.J., Christie, A.P., De Palma, A., Dicks, L.V., Gallego-Zamorano, J., Johnston, A., Martin, P.A., Purvis, A., Rocha, R., Wauchope, H.S., Wordley, C.F.R., Worthington, T.A., Finch, T.
Worldwide insect declines: An important message, but interpret with caution (2019) Ecology and Evolution, 9 (7), pp. 3678-3680.
Keywords: entomofauna; invertebrates; population trends; systematic review

22) Sánchez-Bayo, F., Wyckhuys, K.A.G. Worldwide decline of the entomofauna: A review of its drivers (2019) Biological Conservation, 232, pp. 8-27.

Biodiversity of insects is threatened worldwide. Here, we present a comprehensive review of 73 historical reports of insect declines from across the globe, and systematically assess the underlying drivers. Our work reveals dramatic rates of decline that may lead to the extinction of 40% of the world's insect species over the next few decades. In terrestrial ecosystems, Lepidoptera, Hymenoptera and dung beetles (Coleoptera) appear to be the taxa most affected, whereas four major aquatic taxa (Odonata, Plecoptera, Trichoptera and Ephemeroptera) have already lost a considerable proportion of species. Affected insect groups not only include specialists that occupy particular ecological niches, but also many common and generalist species. Concurrently, the abundance of a small number of species is increasing; these are all adaptable, generalist species that are occupying the vacant niches left by the ones declining. Among aquatic insects, habitat and dietary generalists, and pollutant-tolerant species are replacing the large biodiversity losses experienced in waters within agricultural and urban settings. The main drivers of species declines appear to be in order of importance: i) habitat loss and conversion to intensive agriculture and urbanisation; ii) pollution, mainly that by synthetic pesticides and fertilisers; iii) biological factors, including pathogens and introduced species; and iv) climate change. The latter factor is particularly important in tropical regions, but only affects a minority of species in colder climes and mountain settings of temperate zones. A rethinking of current agricultural practices, in particular a serious reduction in pesticide usage and its substitution with more sustainable, ecologically-based practices, is urgently needed to slow or reverse current trends, allow the recovery of declining insect populations and safeguard the

vital ecosystem services they provide. In addition, effective remediation technologies should be applied to clean polluted waters in both agricultural and urban environments.
Keywords: Agriculture; Aquatic insects; Ecosystem services; Extinction; Global change ecology; Pesticides; Pollinators

23) Liu, Y., Dietrich, C.H., Braxton, S.M., Wang, Y. Publishing trends and productivity in insect taxonomy from 1946 through 2012 based on an analysis of the Zoological Record for four species-rich families (2019) European Journal of Taxonomy, 2019 (504), pp. 1-24.

Insect taxonomy is fundamental to global biodiversity research, but few studies have been conducted to track progress in this field using objective criteria. This study reports publishing trends in the taxonomy of four diverse, globally-distributed insect families from 1946 to 2012 to elucidate recent progress and the current status of insect taxonomy. Publications included in the Zoological Record online literature database were analyzed for Cicadellidae (leafhoppers), Miridae (plant bugs), Pyralidae (moths) and Staphylinidae (rove beetles). Data on numbers of new species, article length, species description length, authorship and collaborations, and taxonomic journals were extracted and compiled for each year. The results showed that (1) the number of taxonomic papers increased before 1980, followed by a steep decline with subsequent partial recovery; (2) the number of papers describing new species generally mirrored the trend in numbers of new species, suggesting no overall change in the proportion of larger, synthetic works (monographs) and more such work is encouraged; (3) the average number of new species described per publication decreased over the time period investigated, but with an increase in the average description pages per new species; (4) researchers from Europe and North America continue to produce the most taxonomic research on three of the four families, but the main center for Cicadellidae taxonomy has recently shifted to Asia; (5) collaboration among authors within and across continents has increased as indicated by increases in coauthored papers; and (6) journal prevalence differed for the four families and the top 10 most utilized journals for each family were given out for reference. Based on the analysis of the publication trend of the four families, we found that the overall trend toward increasing rates of species discovery is encouraging. But more human resources training and financial support on taxonomic work are required in order to complete a global faunistic inventory in a reasonable timeframe. Future study that conducts more in-depth and comprehensive analysis based on more families is required to reflect the overall trend of the insect taxonomy.
Keywords: Biodiversity; Cicadellidae; Miridae; Pyralidae; Staphylinidae

24) Hall, D.M., Steiner, R. Insect pollinator conservation policy innovations: Lessons for lawmakers (2019) Environmental Science and Policy, 93, pp. 118-128.

Global insect pollinator declines are caused by human behaviors of land uses, habitat alteration, pesticides, and others. Policies—as mutually agreed-upon limits to behaviors to achieve shared values—are necessary for addressing complex social-ecological problems like declines of insect pollinator diversity and abundance. Despite scientific calls and public outcry to develop policy that addresses declines, multi-state agreements have not delivered such legislation nor met basic monitoring needs recommended by experts. In the absence of

sweeping international agreements targeting pollinator declines, national and sub-national governments are actively deploying policies to address the pollinator health crisis. Although global monitoring and conservation agreements are needed, small-scale policy innovations represent advances in laws. These sub-national actions are effectively piloting new policy instruments in terms that have proven amenable to polarized political parties. To showcase the spectrum of policy innovations, we examine pollinator-relevant polices passed by US state-level legislatures from 2000 to 2017. This timeframe captures pre- and post-publicity of pollinator declines via colony collapse disorder, the evolving research on neonicotinoids, and highly-visible bee kills. We found 109 new laws covering apiculture, pesticides, awareness, habitat, and research. Together, they narrate an evolution of bureaucratic thinking on insects. Yet when compared to policies proposed by biologists, legislators failed to address four of ten policy targets. In politically divided nations, policies that have successfully appealed to and passed laws through sub-national assemblies are predictive of large-scale conservation bills that could win broad support for national laws and international agreements.
Keywords: Bees; Biodiversity; Butterfly; Conservation policy; Insect biodiversity conservation; Sustainability science

25) Settele, J. Decline in insect populations, insect loss, insect mortality? (2019) Biologie in Unserer Zeit, 49 (4), p. 231.

26) Habel, J.C., Samways, M.J., Schmitt, T. Mitigating the precipitous decline of terrestrial European insects: Requirements for a new strategy (2019) Biodiversity and Conservation, .

Severe decline in terrestrial insect species richness, abundance, flying biomass, and local extinctions across Europe are cause for alarm. Here, we summarize this decline, and identify species affected most. We then focus on the species that might respond best to mitigation measures relative to their traits. We review apparent drivers of decline, and critically reflect on strengths and weaknesses of existing studies, while emphasising their general significance. Generality of recent scientific findings on insect decline have shortcomings, as results have been based on irregular time series of insect inventories, and have been carried out on restricted species sets, or have been undertaken only in a particular geographical area. Agricultural intensification is the main driver of recent terrestrial insect decline, through habitat loss, reduced functional connectivity, overly intense management, nitrogen influx, and use of other fertilisers, as well as application of harmful pesticides. However, there are also supplementary and adversely synergistic factors especially climate change, increasingly intense urbanisation, and associated increase in traffic volume, artificial lighting and environmental pollution. Despite these various synergistic impacts, there are mitigating factors that can be implemented to stem the precipitous insect decline. Science can provide the fundamental information on potential synergistic and antagonistic mechanisms of multiple drivers of insect decline, while implementation research can help develop alternative approaches to agriculture and forestry to mitigate impacts on insects. We argue for more nature-friendly land-use practices to re-establish Europe’s insect diversity.

Keywords: Abundance; Agricultural intensification; Biodiversity crisis; Climate change; Habitat degradation; Habitat fragmentation; Insect conservation; Insect decline; Pesticides; Species richness

27) Owens, A.C.S., Cochard, P., Durrant, J., Farnworth, B., Perkin, E.K., Seymoure, B. Light pollution is a driver of insect declines (2019) Biological Conservation, art. no. 108259, .

Insects around the world are rapidly declining. Concerns over what this loss means for food security and ecological communities have compelled a growing number of researchers to search for the key drivers behind the declines. Habitat loss, pesticide use, invasive species, and climate change all have likely played a role, but we posit here that artificial light at night (ALAN) is another important—but often overlooked—bringer of the insect apocalypse. We first discuss the history and extent of ALAN, and then present evidence that ALAN has led to insect declines through its interference with the development, movement, foraging, and reproductive success of diverse insect species, as well as its positive effect on insectivore predation. We conclude with a discussion of how artificial lights can be tuned to reduce their impact on vulnerable populations. ALAN is unique among anthropogenic habitat disturbances in that it is fairly easy to ameliorate, and leaves behind no residual effects. Greater recognition of the ways in which ALAN affects insects can help conservationists reduce or eliminate one of the major drivers of insect declines.
Keywords: ALAN; Insect apocalypse; Insect conservation; Insect declines; Light pollution; Skyglow

28) Braby, M.F. Are insects and other invertebrates in decline in Australia? (2019) Austral Entomology, 58 (3), pp. 471-477.

29) Skaldina, O., Sorvari, J. Ecotoxicological effects of heavy metal pollution on economically important terrestrial insects (2019) Environmental Science and Engineering, pp. 137-144.

Pollution is among the major anthropogenically induced drivers of environmental change. Heavy metals, released from industry and transport, can contaminate aquatic and terrestrial environments, inducing further ecotoxicological effects in different organisms. Insects play crucial ecological roles in maintenance of ecosystem structure and functioning and deliver such ecosystem services as food provisioning, plant pollination, dung burial, pest control and wildlife nutrition. Economically important terrestrial insects vary in an ability to accumulate heavy metals and demonstrate substantial difference in heavy metal tolerance. Despite global pollinator decline, only limited information is available about effects of heavy metals on wild bees. Ants, wasps and beetles are key-predatory insect groups in many terrestrial ecosystems. Responses in ants are investigated to higher extent than in wasps and revealed ecotoxicological effects of heavy metal pollution in beetles are biased to model species. Insect pests such as aphids and butterfly larvae respond to heavy metal pollution with modifications in their morphology and physiology, however more studies are needed to understand general directions of adaptations in this functional group of economically important insects. When investigated the problem of insect decline, heavy metal pollution should be thoroughly

considered. In addition to natural habitat transformation, use of insecticides and modifications in agriculture, ecotoxicological effects of heavy metals on useful insects might have direct consequences to food security, agricultural economy and human welfare.
Keywords: Ecosystem services; Ecotoxicology; Heavy metals; Insecta; Pests; Pollinators; Predators

30) Engels, S., Medeiros, A.S., Axford, Y., Brooks, S.J., Heiri, O., Luoto, T.P., Nazarova, L., Porinchu, D.F., Quinlan, R., Self, A.E. Temperature change as a driver of spatial patterns and long-term trends in chironomid (Insecta: Diptera) diversity (2019) Global Change Biology.

Anthropogenic activities have led to a global decline in biodiversity, and monitoring studies indicate that both insect communities and wetland ecosystems are particularly affected. However, there is a need for long-term data (over centennial or millennial timescales) to better understand natural community dynamics and the processes that govern the observed trends. Chironomids (Insecta: Diptera: Chironomidae) are often the most abundant insects in lake ecosystems, sensitive to environmental change, and, because their larval exoskeleton head capsules preserve well in lake sediments, they provide a unique record of insect community dynamics through time. Here, we provide the results of a metadata analysis of chironomid diversity across a range of spatial and temporal scales. First, we analyse spatial trends in chironomid diversity using Northern Hemispheric data sets overall consisting of 837 lakes. Our results indicate that in most of our data sets, summer temperature (Tjul) is strongly associated with spatial trends in modern-day chironomid diversity. We observe a strong increase in chironomid alpha diversity with increasing Tjul in regions with present-day Tjul between 2.5 and 14°C. In some areas with Tjul > 14°C, chironomid diversity stabilizes or declines. Second, we demonstrate that the direction and amplitude of change in alpha diversity in a compilation of subfossil chironomid records spanning the last glacial–interglacial transition (~15,000–11,000 years ago) are similar to those observed in our modern data. A compilation of Holocene records shows that during phases when the amplitude of temperature change was small, site-specific factors had a greater influence on the chironomid fauna obscuring the chironomid diversity–temperature relationship. Our results imply expected overall chironomid diversity increases in colder regions such as the Arctic under sustained global warming, but with complex and not necessarily predictable responses for individual sites.
Keywords: Arctic; biodiversity; climate warming; freshwater ecosystems; insects; palaeoecology; Quaternary

31) Deacon, C., Samways, M.J., Pryke, J.S. Aquatic insects decline in abundance and occupy low-quality artificial habitats to survive hydrological droughts (2019) Freshwater Biology, 64 (9), pp. 1643-1654.

Hydrological extremes have negative impacts on natural, agricultural, and urban landscapes and place substantial ecological pressure on freshwater habitats. However, the role of artificial freshwater habitats during hydrological drought is poorly understood. Insects make up much of total aquatic fauna and lend themselves to understanding how drought impacts freshwater ecosystems. Using the Greater Cape Floristic Region as an example of a drought-prone area, we

determined the effects of a severe drought on a subset of insects occupying lentic habitats in terms of their species richness, diversity, and assemblage composition. Here, we: (1) calculated the percentage change in average precipitation between a record dry season and the last consistently wet decade; (2) identified the environmental variables driving aquatic insect species richness, diversity and composition; (3) identified the environmental differences between natural ponds and artificial reservoirs; (4) determined whether artificial reservoirs act as suitable habitats for focal taxa during drought; and (5) compared these results to other, pre-drought studies. Environmental variables related to water chemistry and physical characteristics were drivers of species richness, diversity, and composition, yet vegetation cover remained a major driver. In terms of marginal vegetation cover, most artificial reservoirs did not resemble natural ponds, yet overall 38.4% of sampled aquatic insect species were shared between natural ponds and artificial reservoirs. We found some rare endemic species in artificial reservoirs that had never before been recorded in this habitat during wet years. When our drought findings were compared to earlier, wet years, species richness did not change significantly, although abundance was much lower during the drought year. We postulate that historically, these aquatic insects, which have been through many ecological filters such as drought, must have sought low-quality habitats to survive water stress periods. Artificial reservoirs, being novel landscape features, cannot fully replace natural ponds, but enable some aquatic insects to survive drought. Artificial reservoirs can be attractive habitats to aquatic insects when they resemble natural ponds, with specific reference to their marginal vegetation characteristics.
Keywords: climate change; community; conservation; invertebrates; physical environment; ponds

32) Delpon, G., Vogt-Schilb, H., Munoz, F., Richard, F., Schatz, B. Diachronic variations in the distribution of butterflies and dragonflies linked to recent habitat changes in Western Europe (2019) Insect Conservation and Diversity, 12 (1), pp. 49-68.

In the context of ongoing global changes, it is crucial to characterise and understand the species distribution dynamics. Despite increasing emphasis on insects' conservation issues, evidence of distribution changes in insects over a wide range of bioclimatic conditions remains scarce in Western Europe. We examined distribution changes in butterflies and dragonflies in three European countries over 34 years, determined the influence of environmental changes, especially land cover, and assessed how of species ecology related to distinct responses. We analysed the diachronic variations by compiling occurrence data in France, Belgium, and Luxembourg for 240 butterfly and 95 dragonfly taxa. We found contrasting patterns of diachronic variation in butterfly and dragonfly distributions, i.e. a strong gradient of disappearance for butterflies (from northwest to southeast with significantly higher rate of disappearance in urbanised and intensive agriculture areas of north-western France), whereas dragonflies showed lower and heterogeneous variation in occurrences, mainly related to alteration and regression of aquatic habitats. Species responses appeared closely linked to their ecological preferences, with greater decline in habitat specialist species. Butterfly and dragonfly species are constrained by their dependence to host plant species and to aquatic habitats, respectively, and proved to convey complementary insights on the influence of environmental

changes in biodiversity dynamics. Conservation priorities were identified across species and administrative units, revealing that almost 80% of the declining taxa were not listed on the current protection lists. Our results support the need to update current French policies in terms of insect conservation.
Keywords: Diachronic analysis; ecological attributes; insect conservation; land-cover changes; null models; range changes

33) Barmentlo, S.H., Vriend, L.M., van Grunsven, R.H.A., Vijver, M.G. Environmental levels of neonicotinoids reduce prey consumption, mobility and emergence of the damselfly *Ischnura elegans* (2019) Journal of Applied Ecology, 56 (8), pp. 2034-2044.

Freshwaters are among the most endangered ecosystems in the world as a result of anthropogenic interference such as pollution. Pollution in the form of neonicotinoids has been intensively studied, but data thus far is often conflicted by contrasting responses between laboratory and field experiments. In addition, toxicity data are scarce and contradictory for insects such as Odonates (dragonflies and damselflies) and a potential risk to them may therefore be overlooked. We investigate the potential risk of neonicotinoids to Odonates by exposing nymphs of the blue-tailed damselfly Ischnura elegans to environmentally relevant concentrations of the neonicotinoid thiacloprid. We consider I. elegans as an indicator species for other Odonates as it is an abundant, widespread and eurytopic species. We analyse the effects of thiacloprid on multiple endpoints (survival, consumption, growth, molting, mobility and emergence), using cage-experiments as well as controlled field observations in naturally colonized experimental ditches. In addition, we assess sensitivity by either feeding the damselfly nymphs with lab-cultured prey or by letting them feed freely on natural aquatic invertebrates. All sublethal endpoints of I. elegans are affected to some degree, and strongly depend on the food offered; free-feeding nymphs are more sensitive than culture-fed nymphs. Environmental relevant concentrations of thiacloprid strongly reduce the emergence of I. elegans and this effect is more substantial in the natural populations compared to the caged damselflies. This is likely explained by exclusion of additional biotic pressures such as predation in the caged experiment. Policy implications. Literature reports that one out of seven Odonates is threatened and 24% of the species have declining populations. Our observations show that current risks of neonicotinoids to Odonates are underestimated in laboratory experiments as the toxicity is governed by multiple biotic factors such as food quantity/quality and predation. Given the widespread abundance of blue-tailed damselfly Ischnura elegans, the observed sensitivity to neonicotinoids and current population trends of this species, these results indicate neonicotinoids play a central role in the Odonate decline in general.
Keywords: biomonitoring; freshwater; insect decline; insecticide; neonicotinoids; odonata; zygoptera

34) Piano, E., Souffreau, C., Merckx, T., Baardsen, L.F., Backeljau, T., Bonte, D., Brans, K.I., Cours, M., Dahirel, M., Debortoli, N., Decaestecker, E., De Wolf, K., Engelen, J.M.T., Fontaneto, D., Gianuca, A.T., Govaert, L., Hanashiro, F.T.T., Higuti, J., Lens, L., Martens, K., Matheve, H., Matthysen, E., Pinseel, E., Sablon, R., Schön, I., Stoks, R., Van Doninck, K., Van Dyck, H., Vanormelingen, P., Van Wichelen, J., Vyverman, W., De Meester, L., Hendrickx, F.

Urbanization drives cross-taxon declines in abundance and diversity at multiple spatial scales (2019) Global Change Biology.

The increasing urbanization process is hypothesized to drastically alter (semi-) natural environments with a concomitant major decline in species abundance and diversity. Yet, studies on this effect of urbanization, and the spatial scale at which it acts, are at present inconclusive due to the large heterogeneity in taxonomic groups and spatial scales at which this relationship has been investigated among studies. Comprehensive studies analysing this relationship across multiple animal groups and at multiple spatial scales are rare, hampering the assessment of how biodiversity generally responds to urbanization. We studied aquatic (cladocerans), limno-terrestrial (bdelloid rotifers) and terrestrial (butterflies, ground beetles, ground- and web spiders, macro-moths, orthopterans and snails) invertebrate groups using a hierarchical spatial design, wherein three local-scale (200 m × 200 m) urbanization levels were repeatedly sampled across three landscape-scale (3 km × 3 km) urbanization levels. We tested for local and landscape urbanization effects on abundance and species richness of each group, whereby total richness was partitioned into the average richness of local communities and the richness due to variation among local communities. Abundances of the terrestrial active dispersers declined in response to local urbanization, with reductions up to 85% for butterflies, while passive dispersers did not show any clear trend. Species richness also declined with increasing levels of urbanization, but responses were highly heterogeneous among the different groups with respect to the richness component and the spatial scale at which urbanization impacts richness. Depending on the group, species richness declined due to biotic homogenization and/or local species loss. This resulted in an overall decrease in total richness across groups in urban areas. These results provide strong support to the general negative impact of urbanization on abundance and species richness within habitat patches and highlight the importance of considering multiple spatial scales and taxa to assess the impacts of urbanization on biodiversity.
Keywords: biodiversity; biotic homogenization; diversity partitioning; insect decline; land use; spatial scale; urban ecology

35) Graham A. Montgomery, Dunn, R.R., Fox, R., Jongejanse, E. Leatherf, S.R., Saundersg, M.E., Shortalli, C.R., Tingley, M.W., Wagner, D.L. Is the insect apocalypse upon us? How to find out. Biological Conservation, In press. https://doi.org/10.1016/j.biocon.2019.10832

In recent decades, entomologists have documented alarming declines in occurrence, taxonomic richness, and geographic range of insects around the world. Additionally, some recent studies have reported that insect abundance and biomass, often of common species, are rapidly declining, which has led some to dub the phenomenon an “Insect Apocalypse”. Recent reports are sufficiently robust to justify immediate actions to protect insect biodiversity worldwide. We caution, however, that we do not yet have the data to assess large-scale spatial patterns in the severity of insect trends. Most documented collapses are from geographically restricted studies and, alone, do not allow us to draw conclusions about insect declines on continental or global scales, especially with regards to future projections of total insect biomass, abundance, and extinction. There are many challenges to understanding insect declines: only a small fraction of

insect species have had any substantial population monitoring, millions of species remain unstudied, and most of the long-term population data for insects come from human-dominated landscapes in western and northern Europe. But there are still concrete steps we can take to improve our understanding of potential declines. Here, we review the challenges scientists face in documenting insect population and diversity trends, including communicating their findings, and recommend re-search approaches needed to address these challenges.
Key words: Insect declines, Biodiversity crisis, Biomass Monitoring, Entomology

36) Komonen, A., Halme, P., Kotiaho, Janne S. Alarmist by bad design: Strongly popularized unsubstantiated claims undermine credibility of conservation science (2019). Rethinking Ecology 4: 17–19 (2019)doi: 10.3897/rethinkingecology.4.34440

Keywords: Insect, decline, extinction

37) Thomas, C.D., Jones, Jones, T.H., Hartley, S.E. “Insectageddon”: A call for more robust data and rigorous analyses (2019) Global Change Biolgogy (Invited Letter) https://doi.org/10.1111/gcb.14608

As members of that subset of the human population who love in-sects, we have been alarmed by a recent publication reporting their global decline and impending extinction (Sánchez-Bayo & Wyckhuys,2019), and the accompanying media furore. Indeed, there has been a growing tide of concern over the magnitude and potential con-sequences of diminishing insect populations (e.g., Hallmann et al., 2017; Lister & Garcia, 2018). However, we respectfully suggest thataccounts of the demise of insects may be slightly exaggerated. Bad things are happening—we agree—but this is not the whole story. We call for hard-nosed, balanced, and numerical analysis of the changes taking place, and for calm and even-handed interpretation of the changes, rather than rushing headlong into the hyperbole of impend-ing apocalypse.

38) Hallmann, C.A., Zeegers, T. van Klink, R. Vermeulen, R. van Wielink, P. Spijkers, H., van Deijk, van Steenis, J.W., Jongejans, E. Declining abundance of beetles, moths and caddisflies in the Netherlands. (2019) Insect Conservation and Diversity doi: 10.1111/icad.12377

1. Recently, reports of insect declines prompted concerns with respect to the state of insects at a global level. Here, we present the results of longer-term insect monitoring from two locations in the Netherlands: nature development area De Kaaistoep and nature reserves near Wijster.2. Based on data from insects attracted to light in De Kaaistoep, macro-moths (macro-Lepidoptera), beetles (Coleoptera), and caddisflies (Trichoptera) have declined in the mean number of individuals counted per evening over the period of 1997–2017, with annual rates of decline of 3.8, 5.0 and 9.2%, respectively. Other orders appeared stable [true bugs (Hemiptera: Heteroptera and Auchenorrhyncha) and mayflies (Ephemeroptera)] or had uncertainty in their trend estimate [lacewings (Neuroptera)].3. Based on 48 pitfall traps near Wijster, ground beetles (Coleoptera: Carabidae) showed a mean annual decline of 4.3% in total numbers over the period of 1985–2016.Nonetheless, declines appeared stronger after 1995.4. For macro-moths, the mean of the trends of individual species was comparable to the annual trend in total

numbers. Trends of individual ground beetle species, however suggest that abundant species performed worse than rare ones.5. When translated into biomass estimates, our calculations suggest a reduction in total biomass of approximately 61% for macro-moths as a group and at least 42% forground beetles, by extrapolation over a period of 27 years. Heavier ground beetles and macro-moths did not decline more strongly than lighter species, suggesting that heavy species did not contribute disproportionately to biomass decline.6. Our results broadly echo recent reported trends in insect biomass in Germany and elsewhere.
Keyword: Beetles, collecting at light, insect declines, macro-moths, pitfall trap, trend analysis.

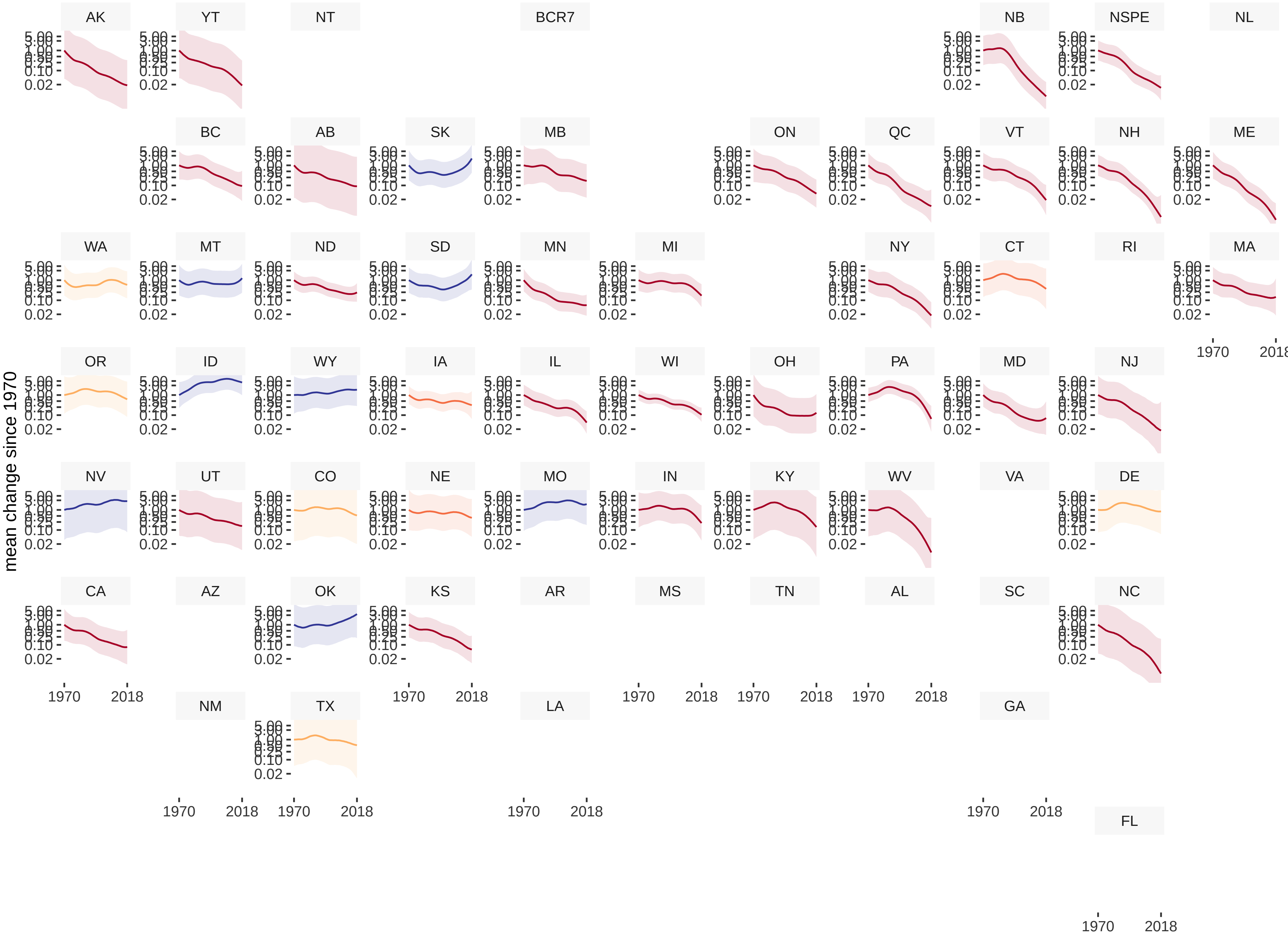
39) Hallmann CA, Sorg M, Jongejans E, Siepel H, Hofland N, Schwan H, et al. More than 75 percent decline over 27 years in total flying insect biomass in protected areas (2017) PLoS ONE 12(10): e0185809. https://doi.org/10.1371/journal.pone.0185809

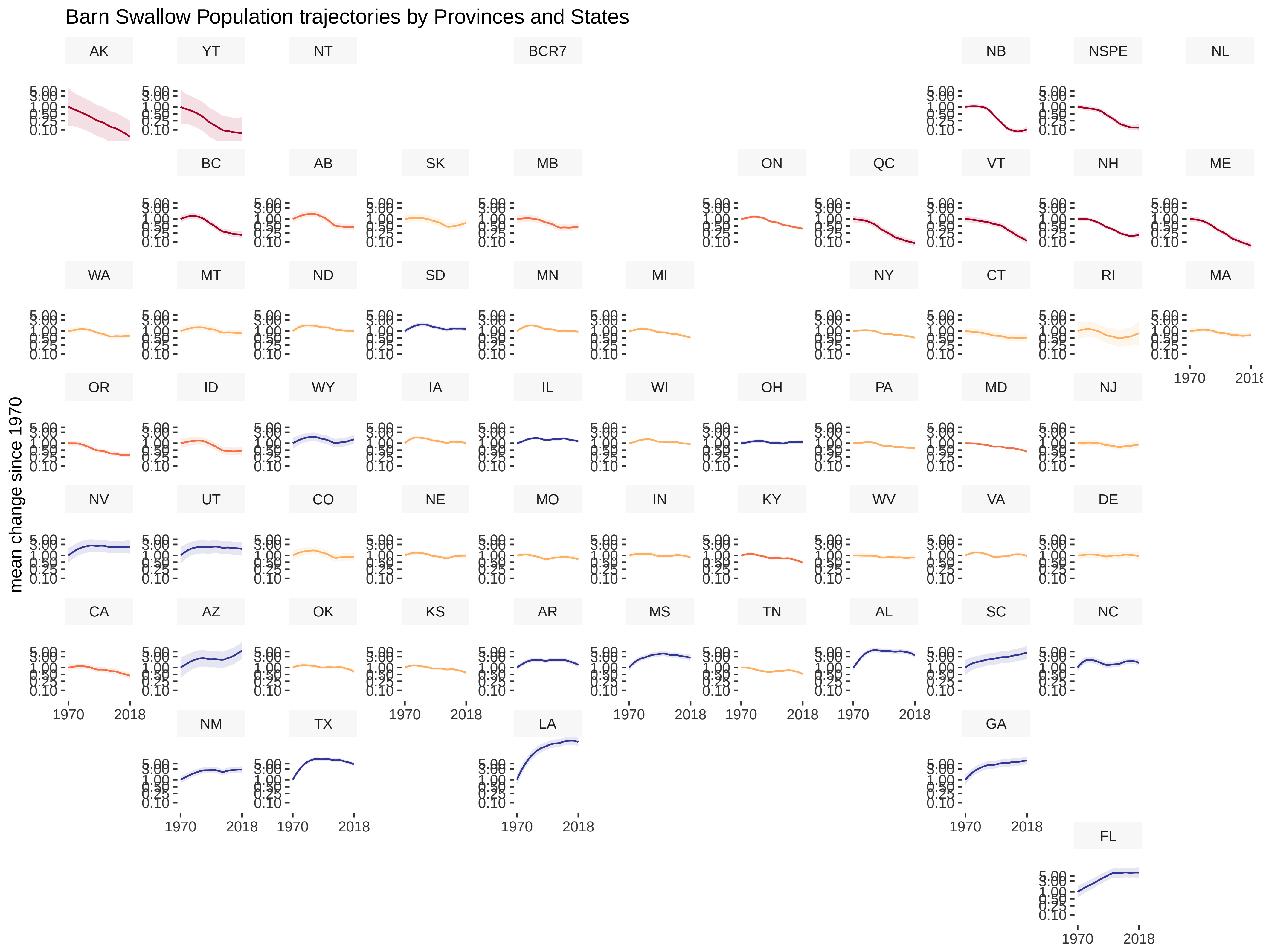
Global declines in insects have sparked wide interest among scientists, politicians, and the general public. Loss of insect diversity and abundance is expected to provoke cascading effects on food webs and to jeopardize ecosystem services. Our understanding of the extent and underlying causes of this decline is based on the abundance of single species or taxonomic groups only, rather than changes in insect biomass which is more relevant for ecological functioning. Here, we used a standardized protocol to measure total insect biomass using Malaise traps, deployed over 27 years in 63 nature protection areas in Germany (96 unique location-year combinations) to infer on the status and trend of local entomofauna. Our analysis estimates a seasonal decline of 76%, and mid-summer decline of 82% in flying insect biomass over the 27 years of study. We show that this decline is apparent regardless of habitat type, while changes in weather, land use, and habitat characteristics cannot explain this overall decline. This yet unrecognized loss of insect biomass must be taken into account in evaluating declines in abundance of species depending on insects as a food source, and ecosystem functioning in the European landscape.

Appendix 7: Aerial Insectivore Breeding Bird Survey analysis results, Data-version 2018

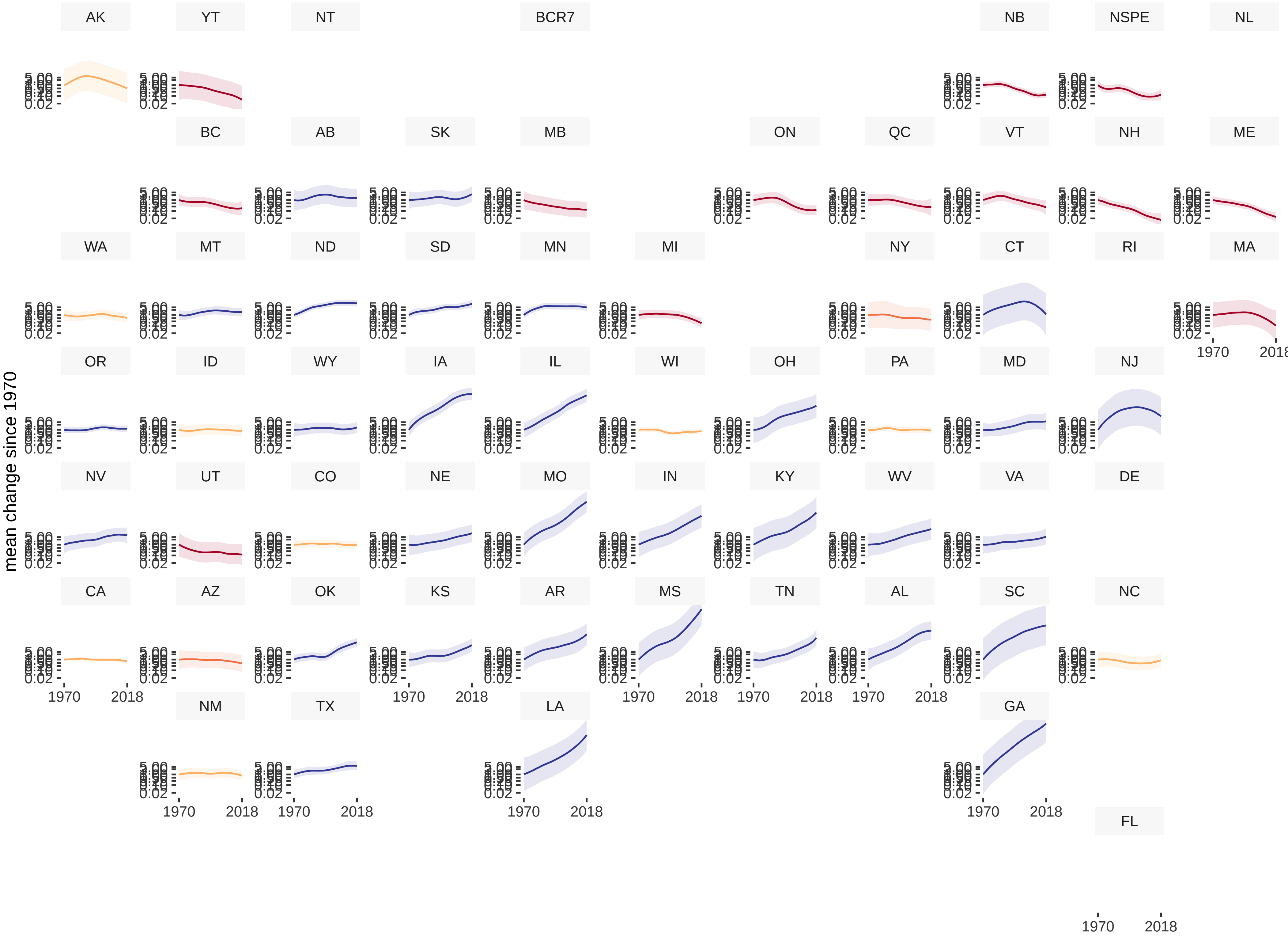
This appendix contains Breeding Bird Survey (BBS) analysis results provided by Adam Smith to the Aerial Insectivore workshop held in Saskatoon, Canada in March 2020. These figures show geographic variation in population trends by province or state for species from 1970 to 2018. Color continuum from red (largest decreases since 1970) to orange to blue (largest increases since 1970). Figures courtesy of Adam Smith (CWS). First presented are the swallows, swifts and nightjars followed by flycatchers.

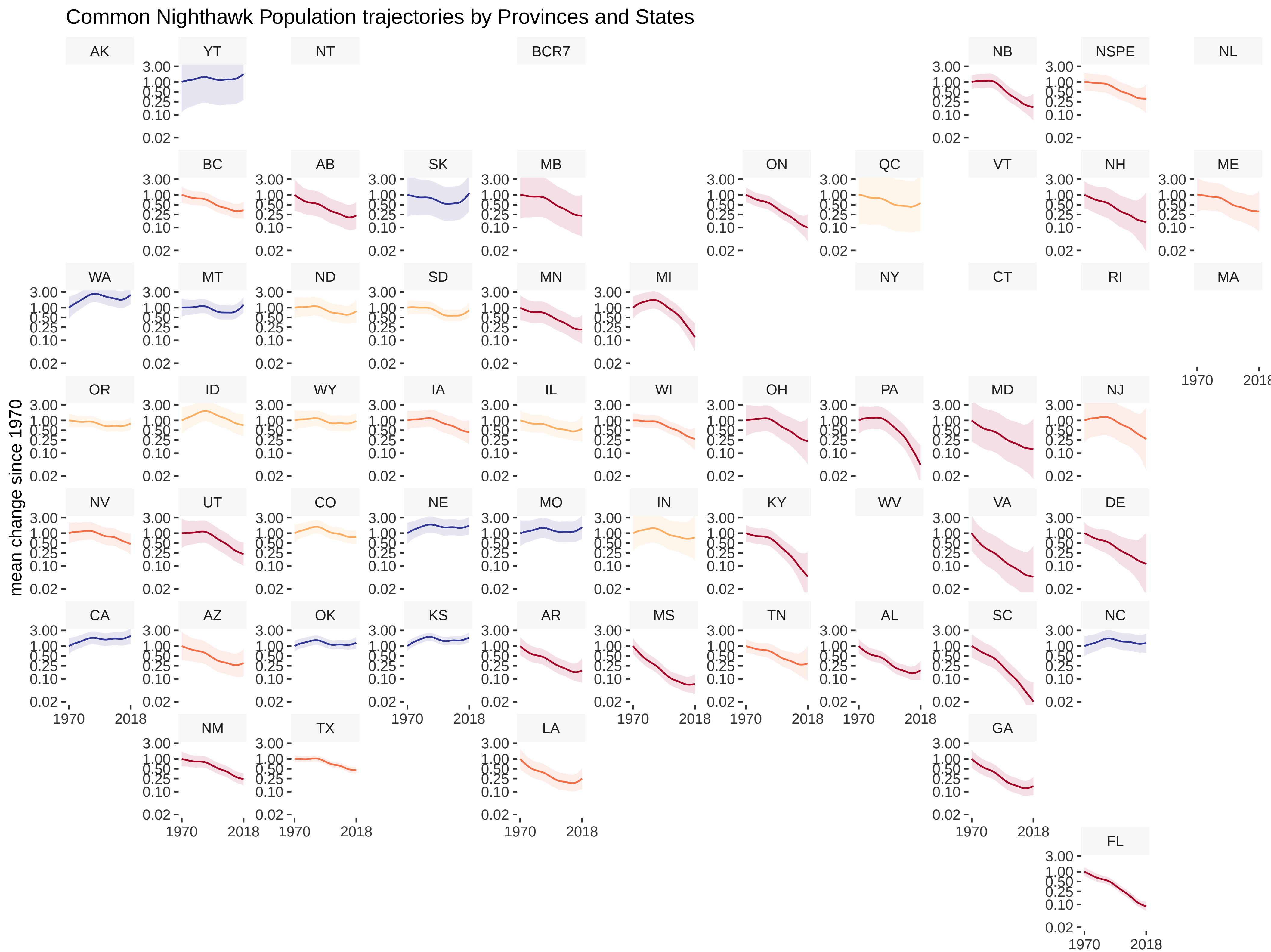
Bank Swallow Population trajectories by Provinces and States




Barn Swallow Population trajectories by Provinces and States
AK
YT
NT
BCR7
NB
NSPE
NL
BC
AB
SK
MB
ON
QC
VT
NH
ME
WA
MT
ND
SD
MN
MI
NY
CT
RI
MA
OR
ID
WY
IA
IL
WI
OH
PA
MD
NJ
NV
UT
CO
NE
MO
IN
KY
WV
VA
DE
CA
AZ
OK
KS
AR
MS
TN
AL
SC
NC
NM
TX
LA
GA
FL
mean change since 1970
5.00
3.00
1.00
0.50
0.25
0.10
1970
2018

Cliff Swallow Population trajectories by Provinces and States





Common Nighthawk Population trajectories by Provinces and States
mean change since 1970
AK
YT
NT
BCR7
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NSPE
NL
BC
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SK
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VT
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CA
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TN
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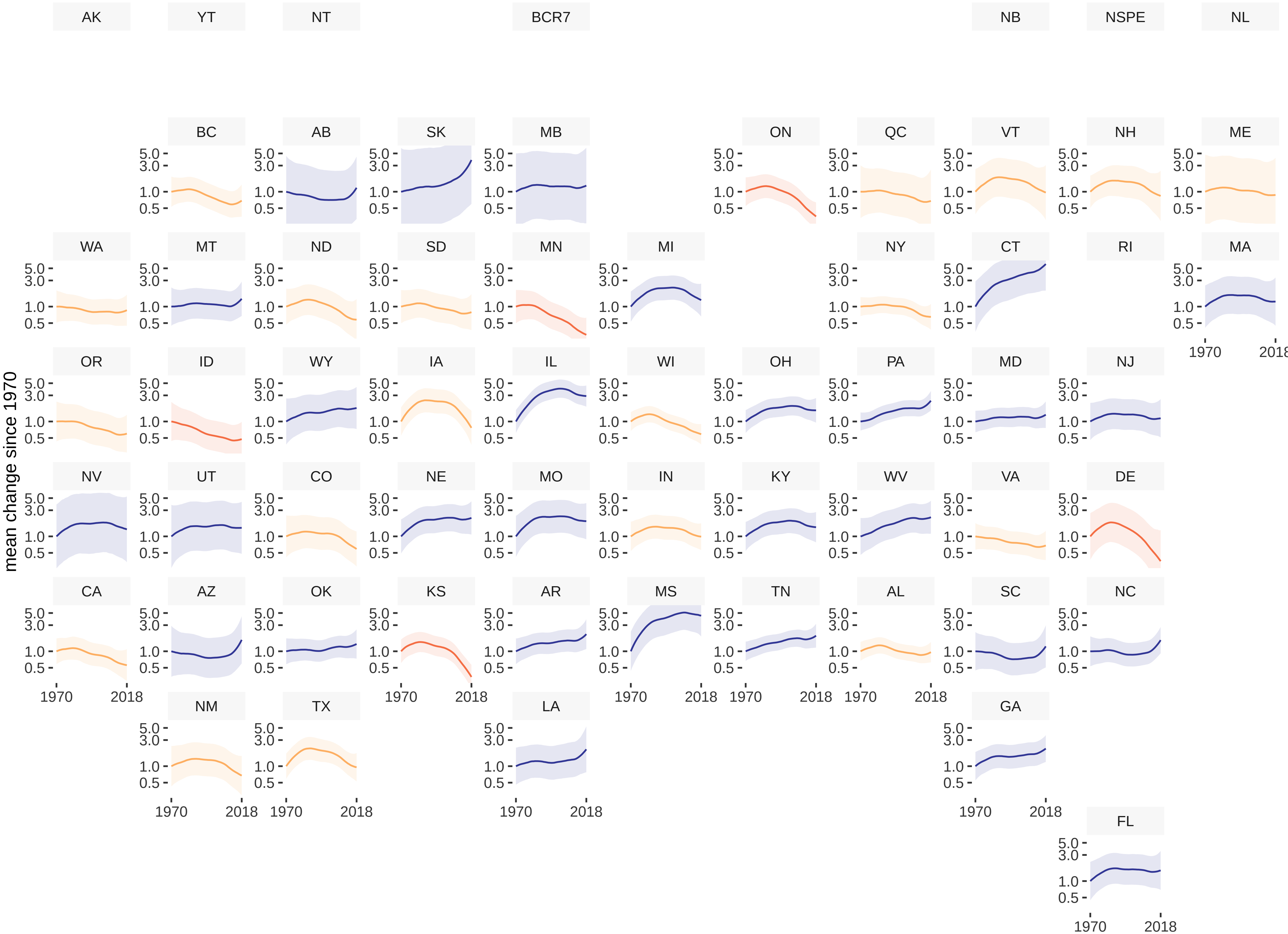
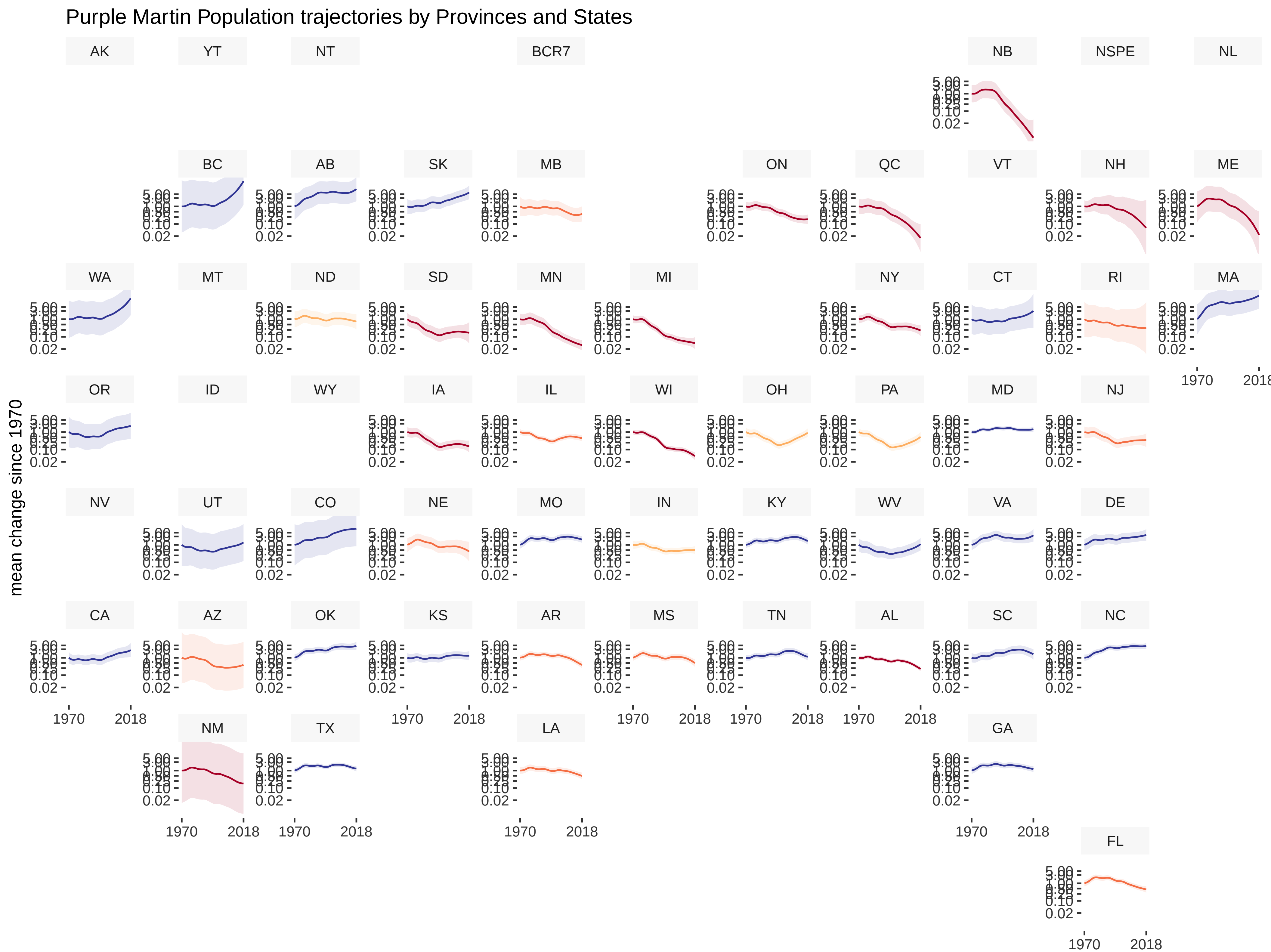
SC
NC
NM
TX
LA
GA
FL
3.00
1.00
0.50
0.25
0.10
0.02
1970
2018

Northern Rough−winged Swallow Population trajectories by Provinces and States





Purple Martin Population trajectories by Provinces and States
mean change since 1970
AK
YT
NT
BCR7
NB
NSPE
NL
BC
AB
SK
MB
ON
QC
VT
NH
ME
WA
MT
ND
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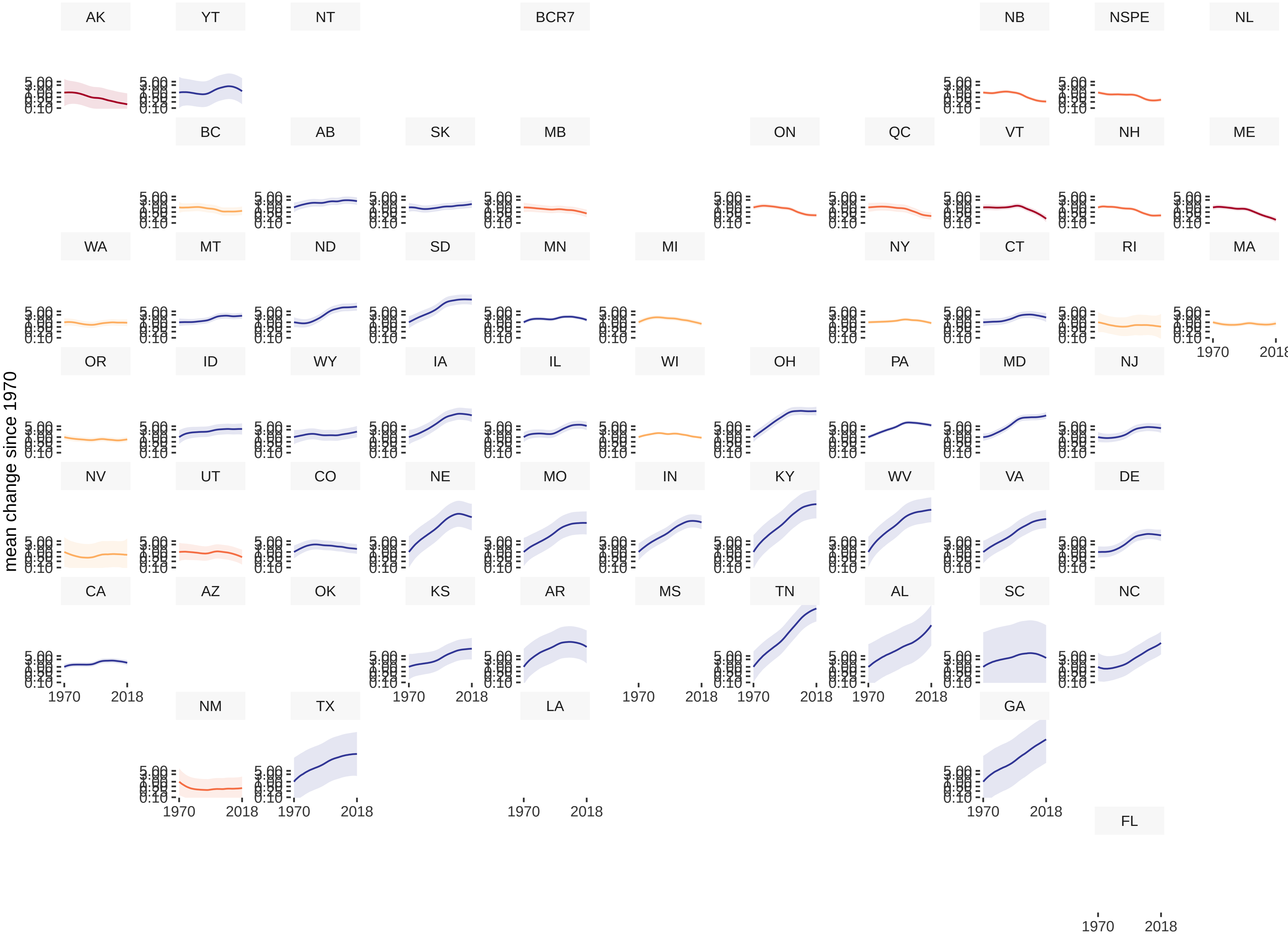
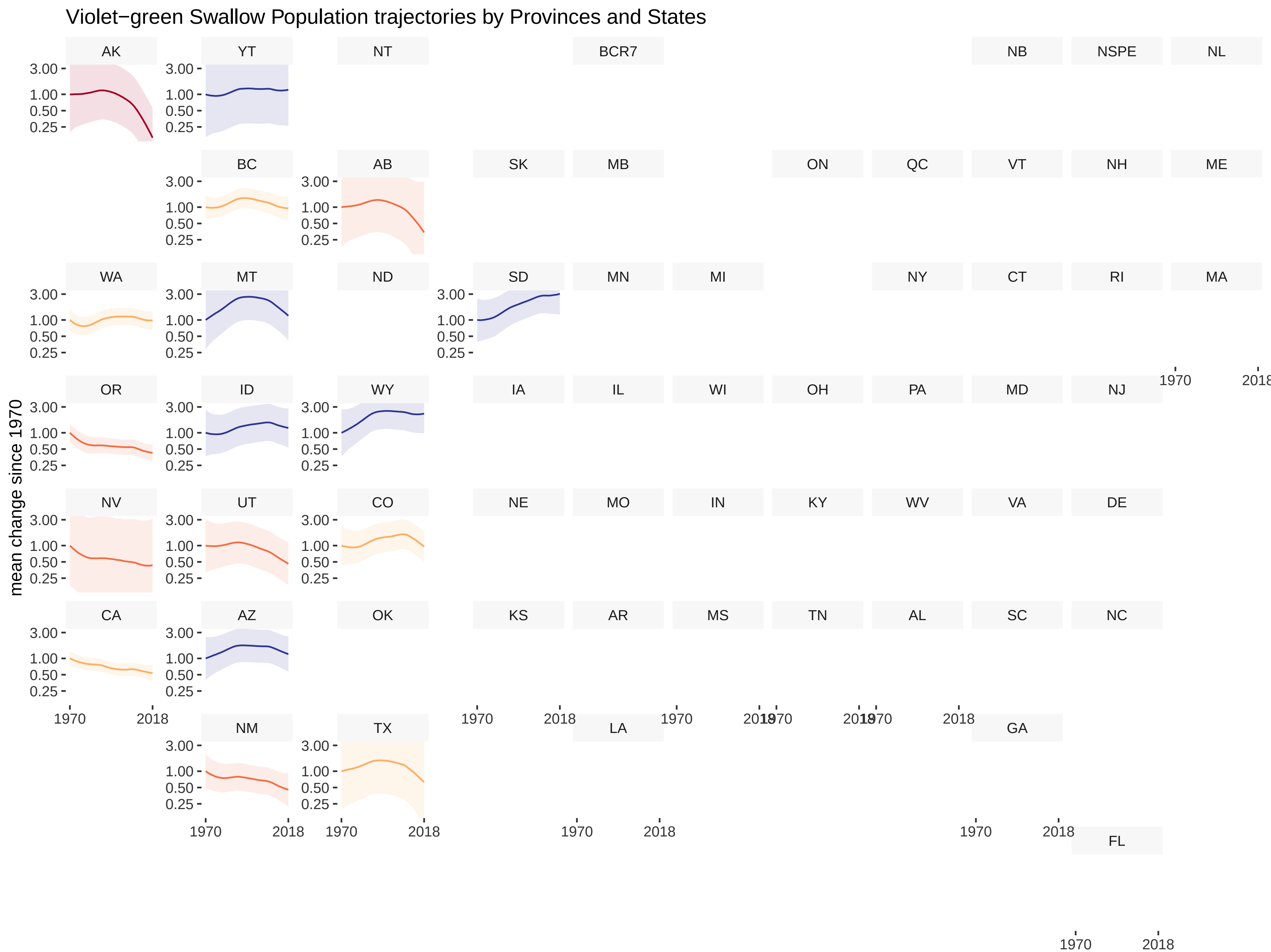
AZ
OK
KS
AR
MS
TN
AL
SC
NC
NM
TX
LA
GA
FL
5.00
3.00
1.00
0.50
0.25
0.10
0.02
1970
2018

Tree Swallow Population trajectories by Provinces and States




Violet−green Swallow Population trajectories by Provinces and States
AK
YT
NT
BCR7
NB
NSPE
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MO
IN
KY
WV
VA
DE
CA
AZ
OK
KS
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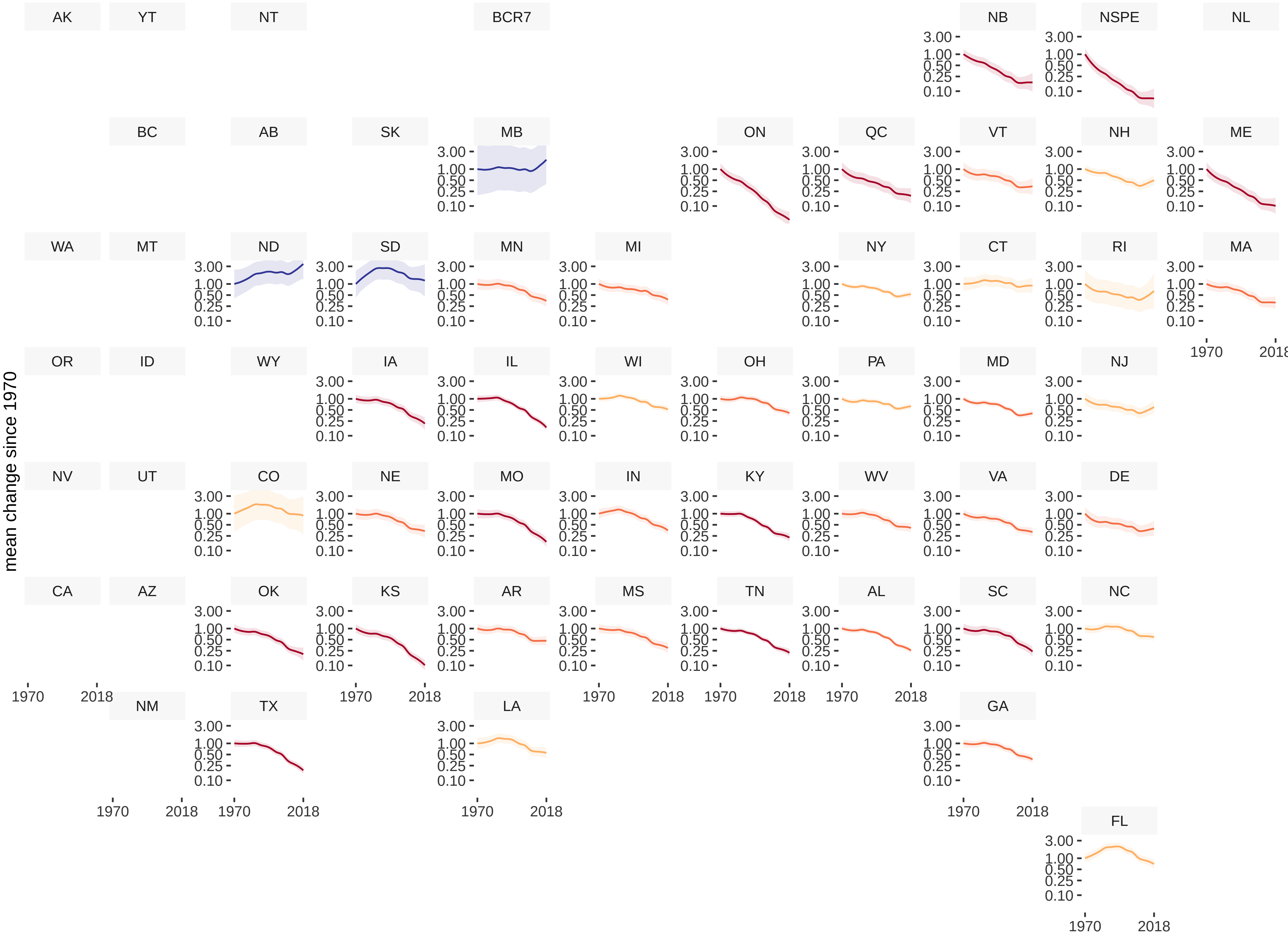
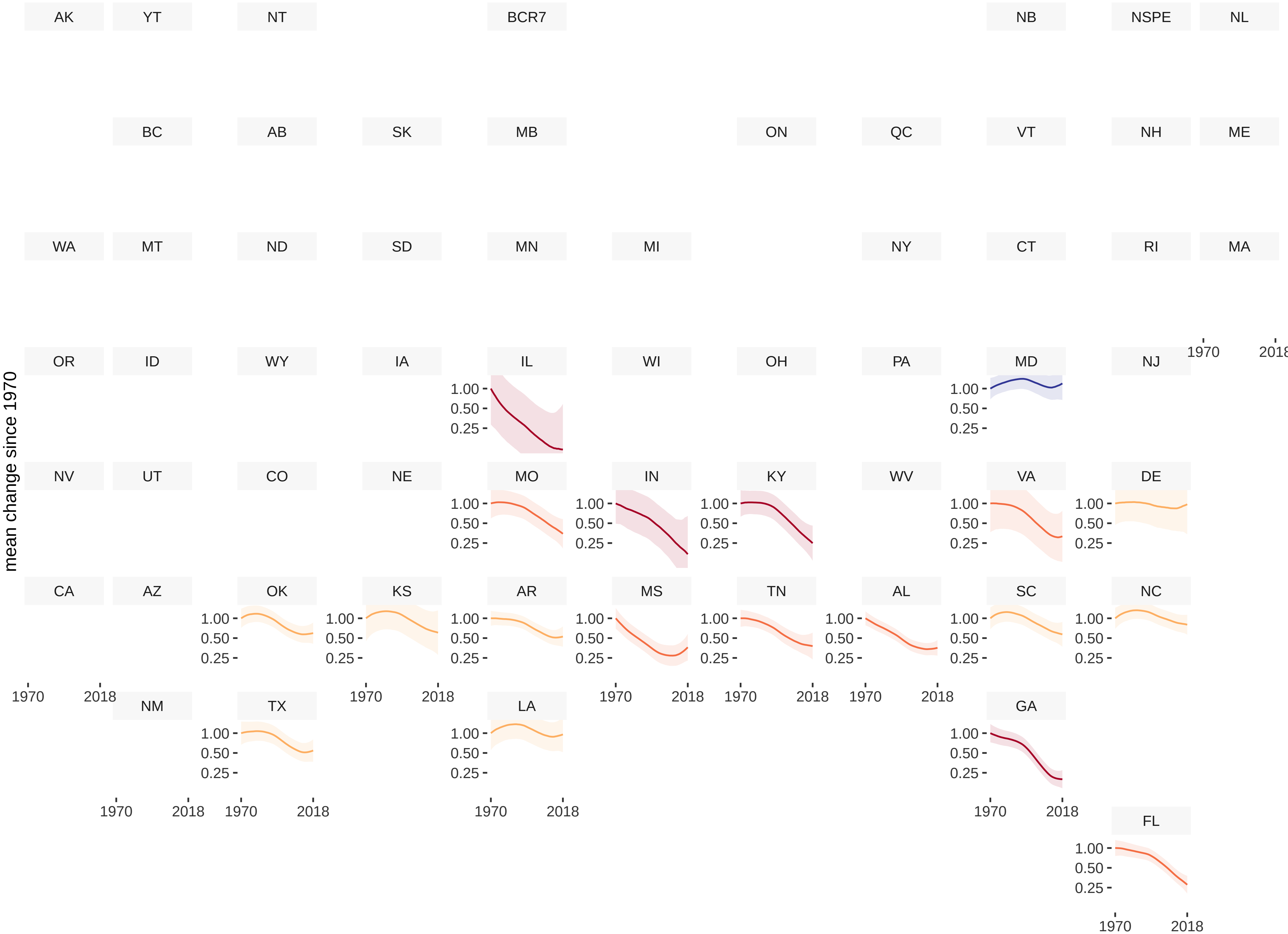
MS
TN
AL
SC
NC
NM
TX
LA
GA
FL
mean change since 1970
3.00
1.00
0.50
0.25
1970
2018

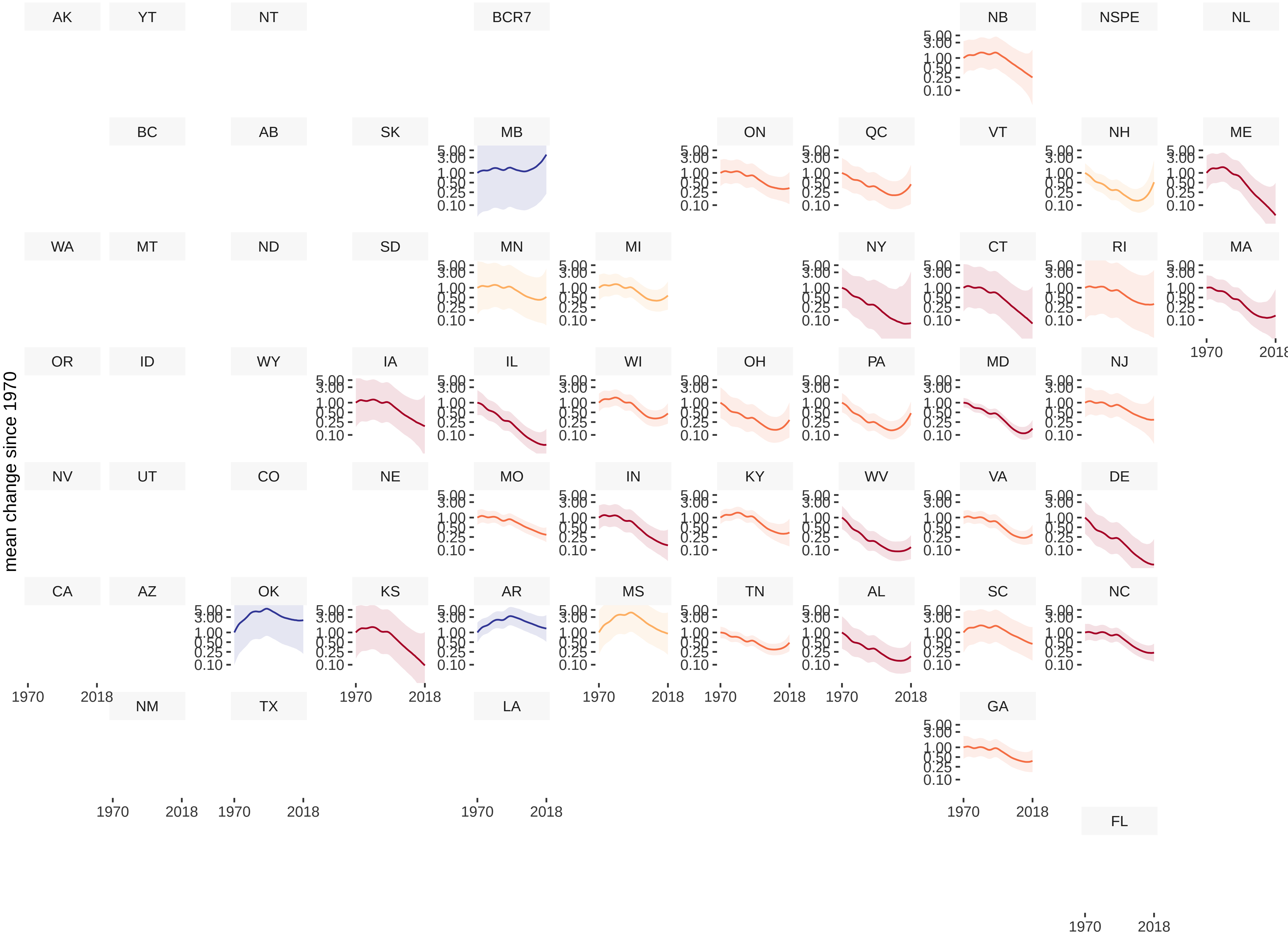
Chimney Swift Population trajectories by Provinces and States



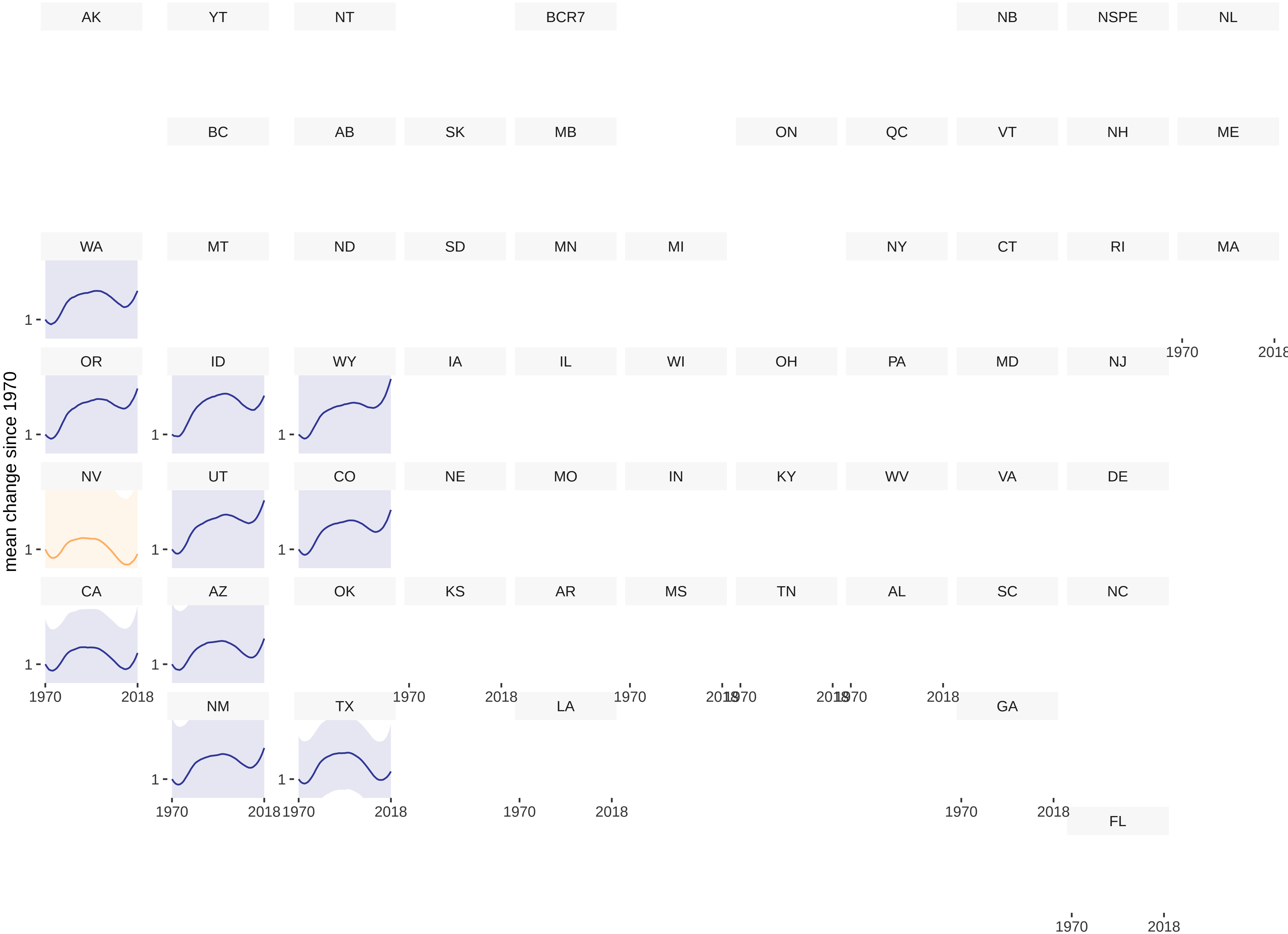
Chuck−will's−widow Population trajectories by Provinces and States

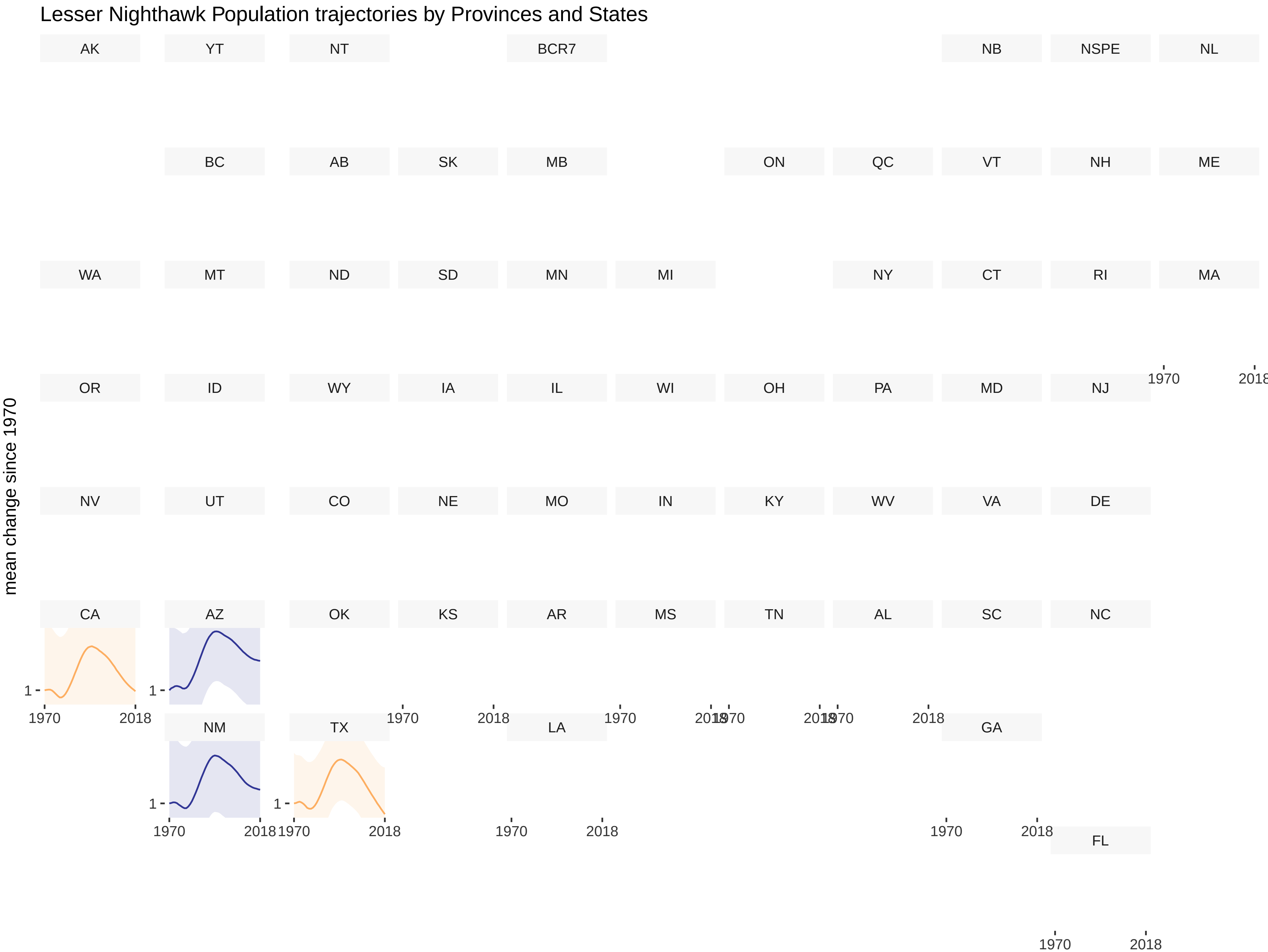


Eastern Whip−poor−will Population trajectories by Provinces and States



Common Poorwill Population trajectories by Provinces and States





Lesser Nighthawk Population trajectories by Provinces and States
AK
YT
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BCR7
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KY
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VA
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CA
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AR
MS
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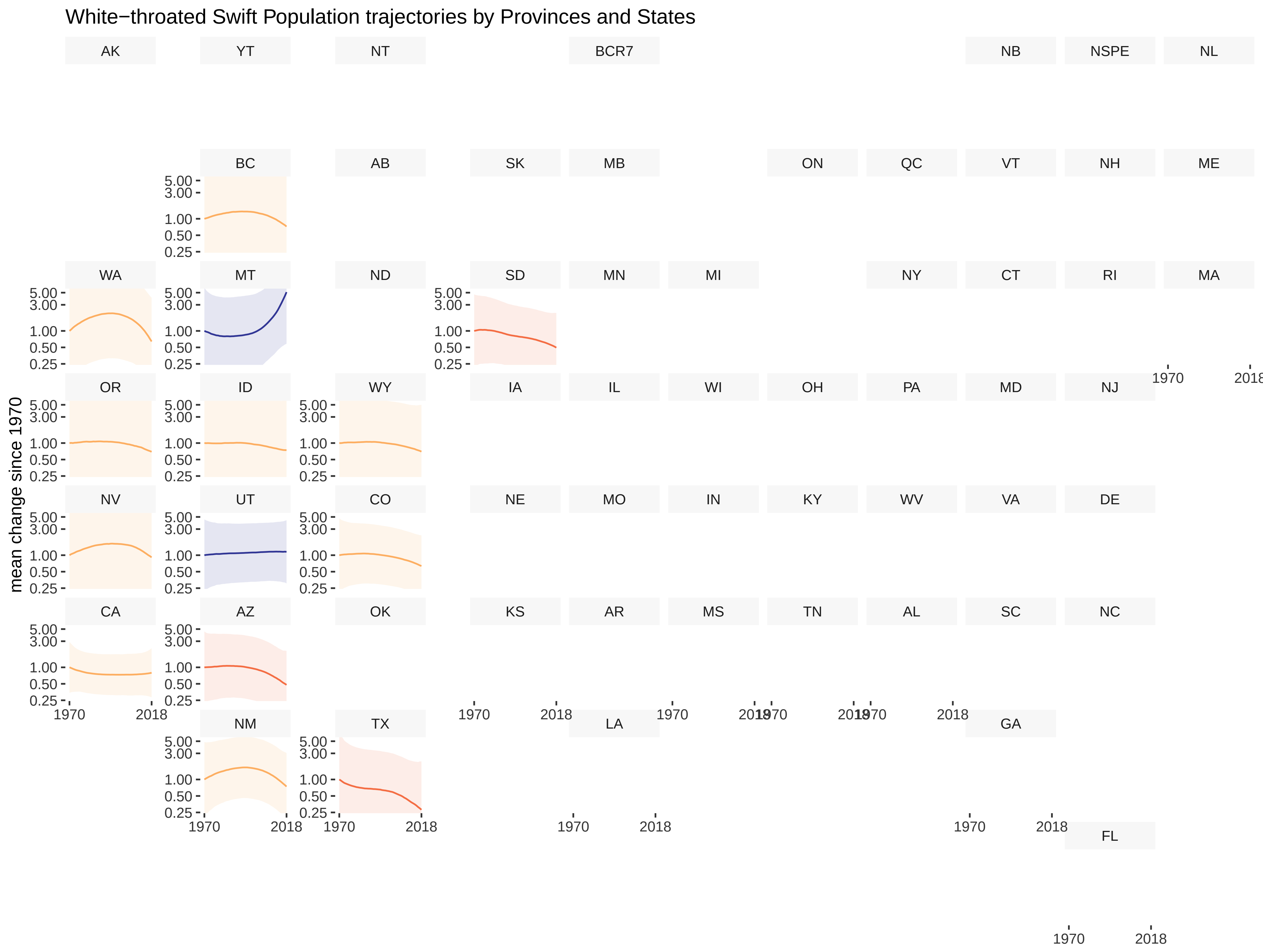
AL
SC
NC
NM
TX
LA
GA
FL
mean change since 1970
1
1970
2018



White−throated Swift Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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ON
QC
VT
NH
ME
WA
MT
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LA
GA
FL
5.00
3.00
1.00
0.50
0.25
1970
2018

Black Swift Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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NSPE
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ME
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ND
SD
MN
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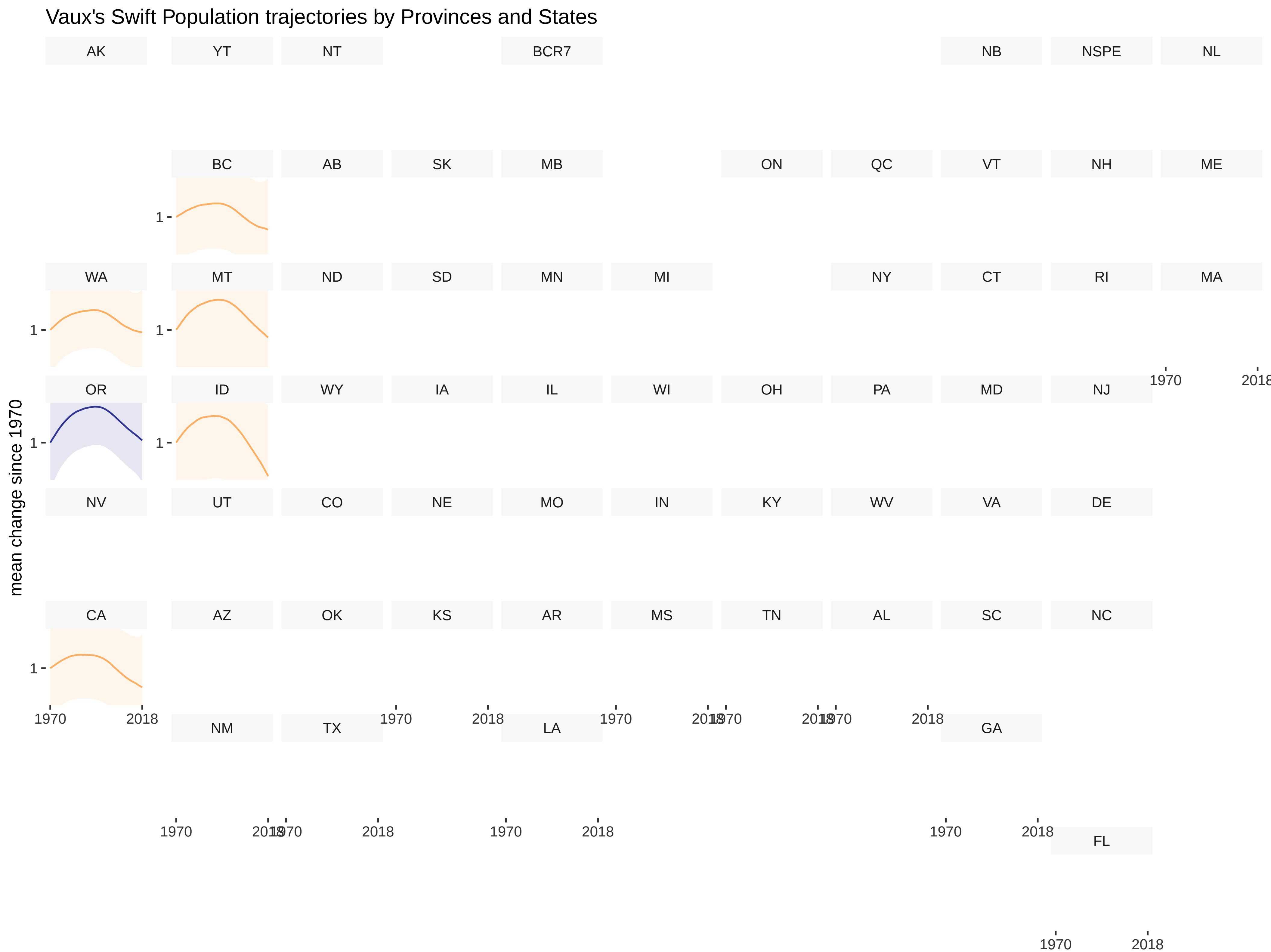
GA
FL
1.00
0.50
0.25
0.10
1970
2018


Vaux's Swift Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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NSPE
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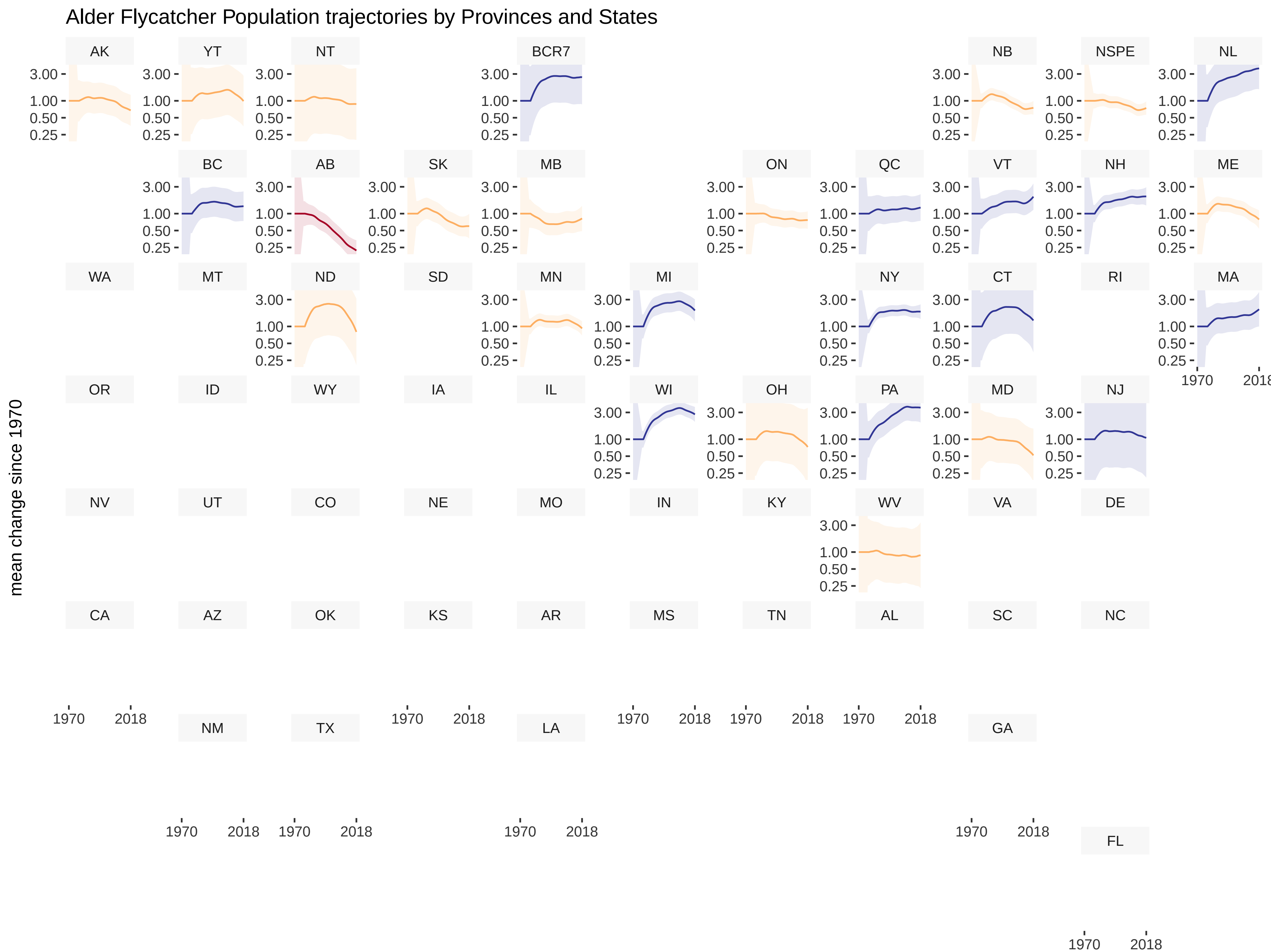
LA
GA
FL
1
1970
2018


Alder Flycatcher Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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NSPE
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ON
QC
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VA
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CA
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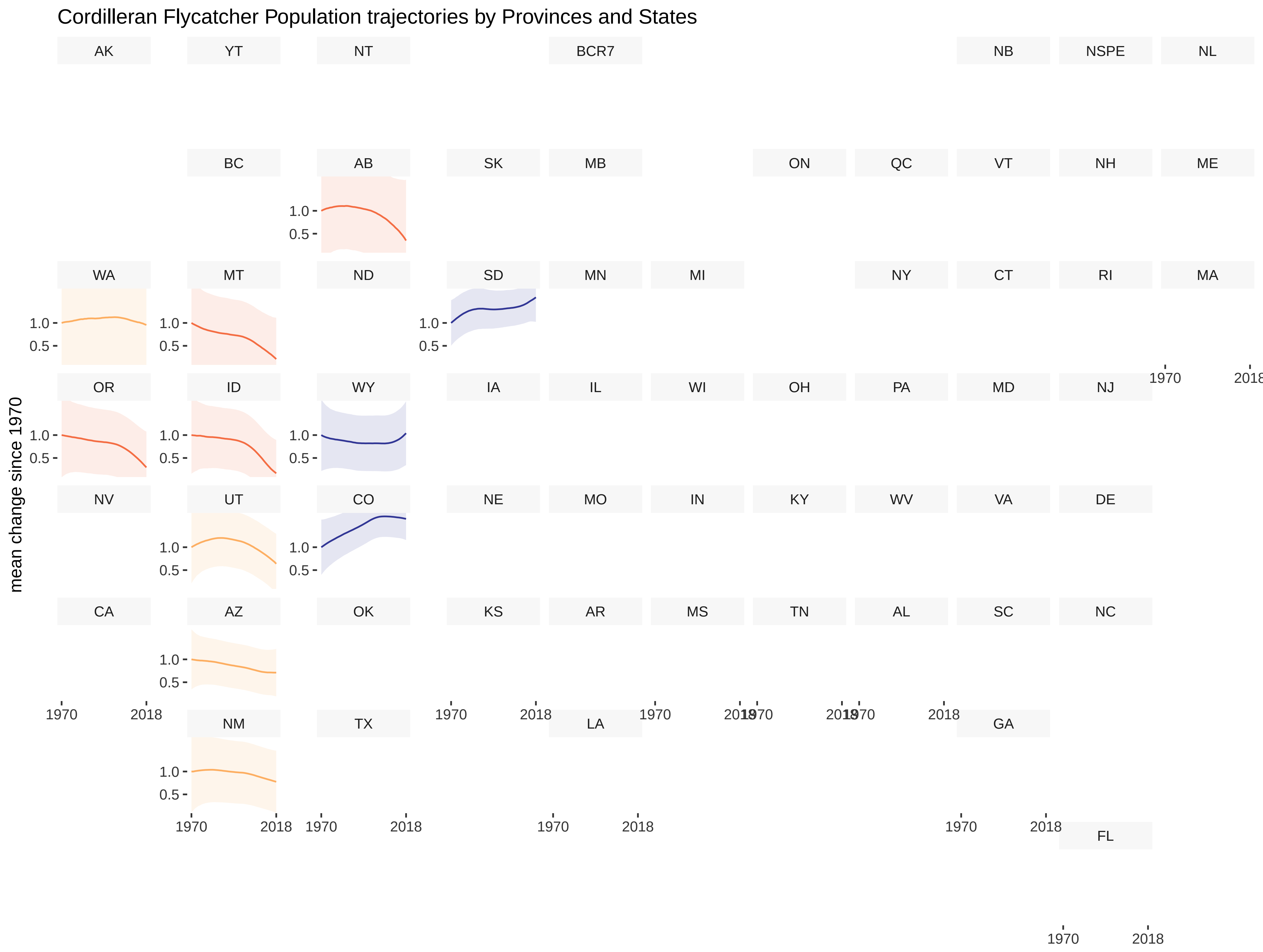
SC
NC
NM
TX
LA
GA
FL
3.00
1.00
0.50
0.25
1970
2018


Cordilleran Flycatcher Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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NSPE
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MO
IN
KY
WV
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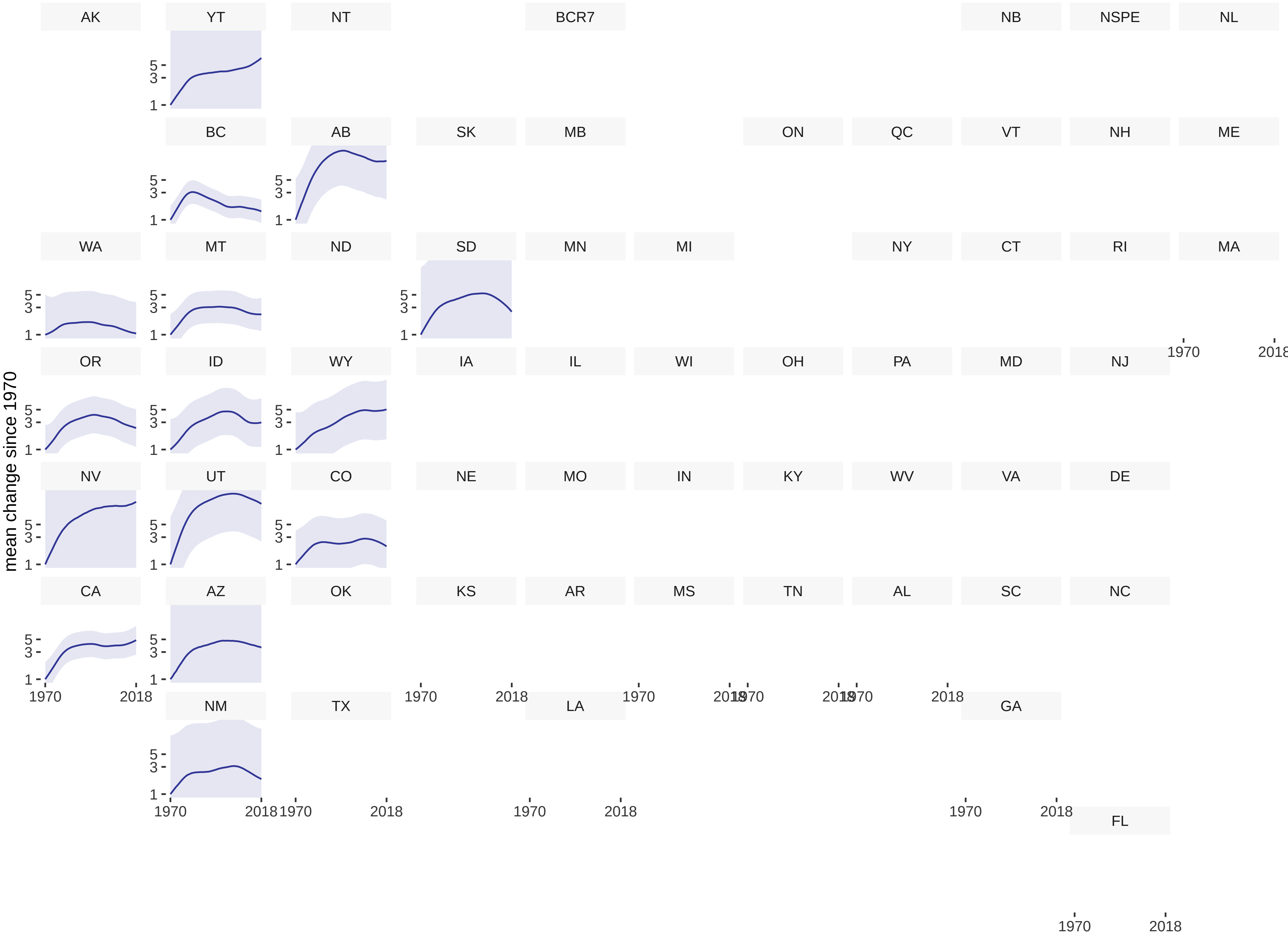
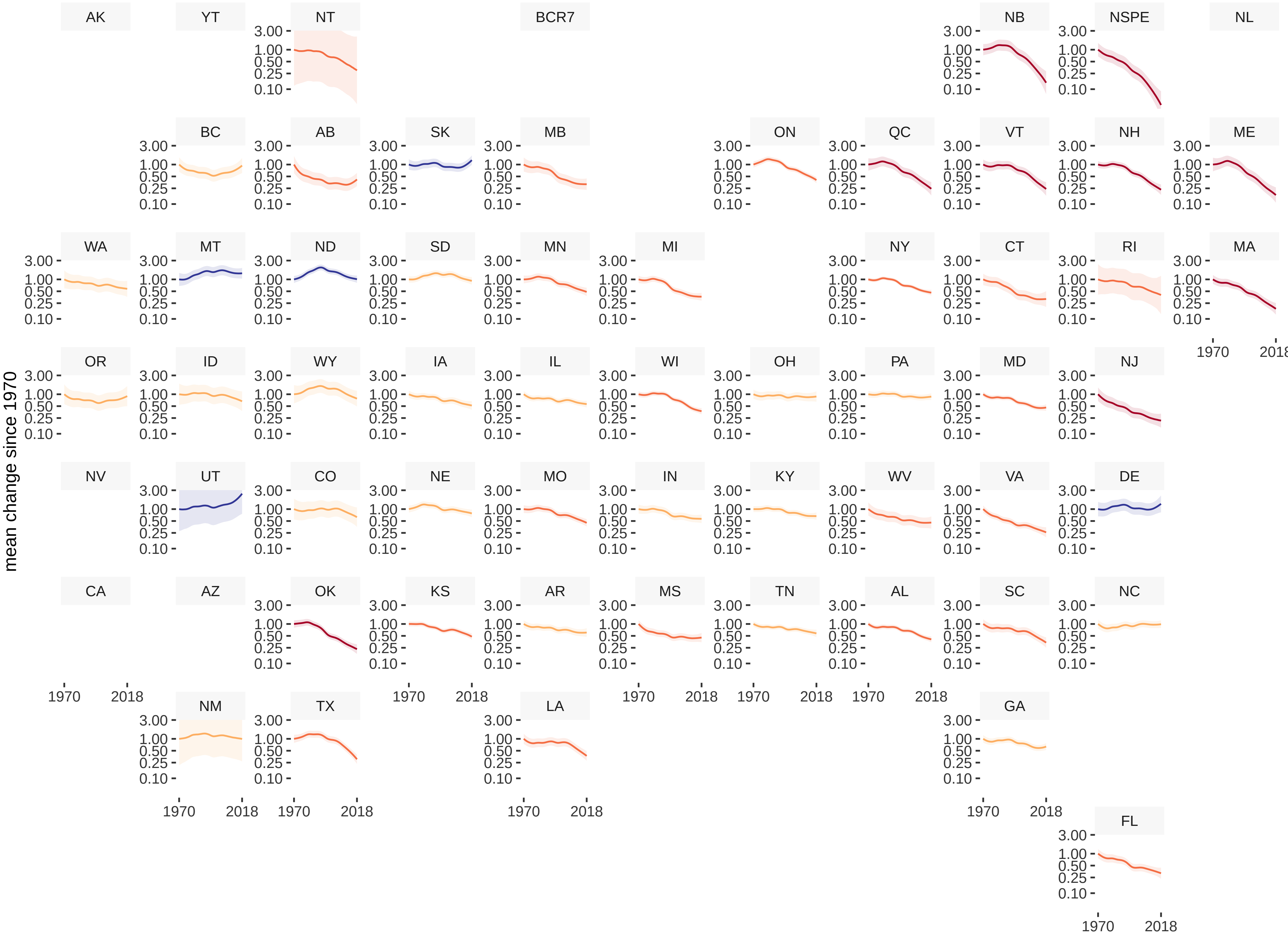
NC
NM
TX
LA
GA
FL
1.0
0.5
1970
2018

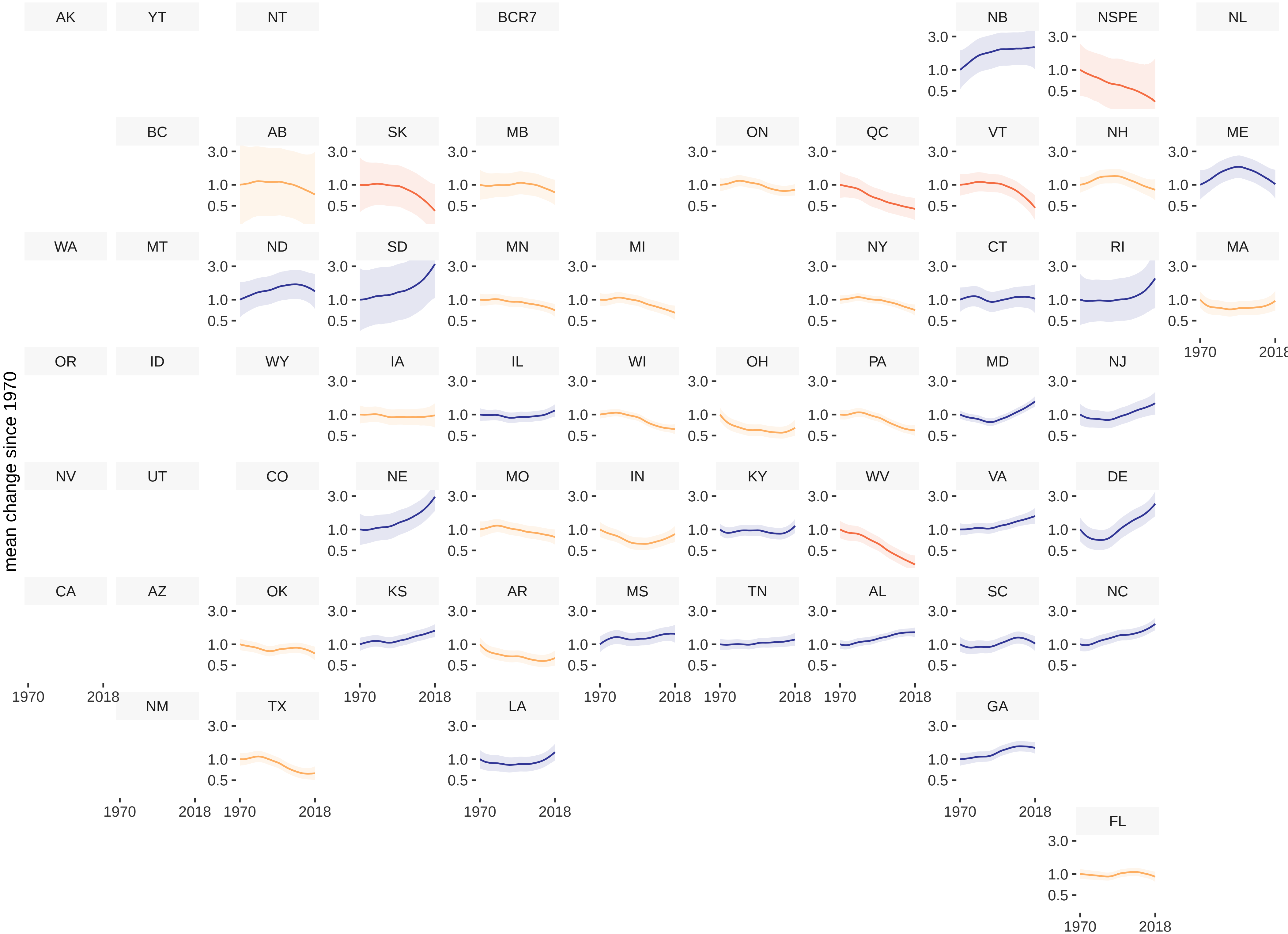
Dusky Flycatcher Population trajectories by Provinces and States



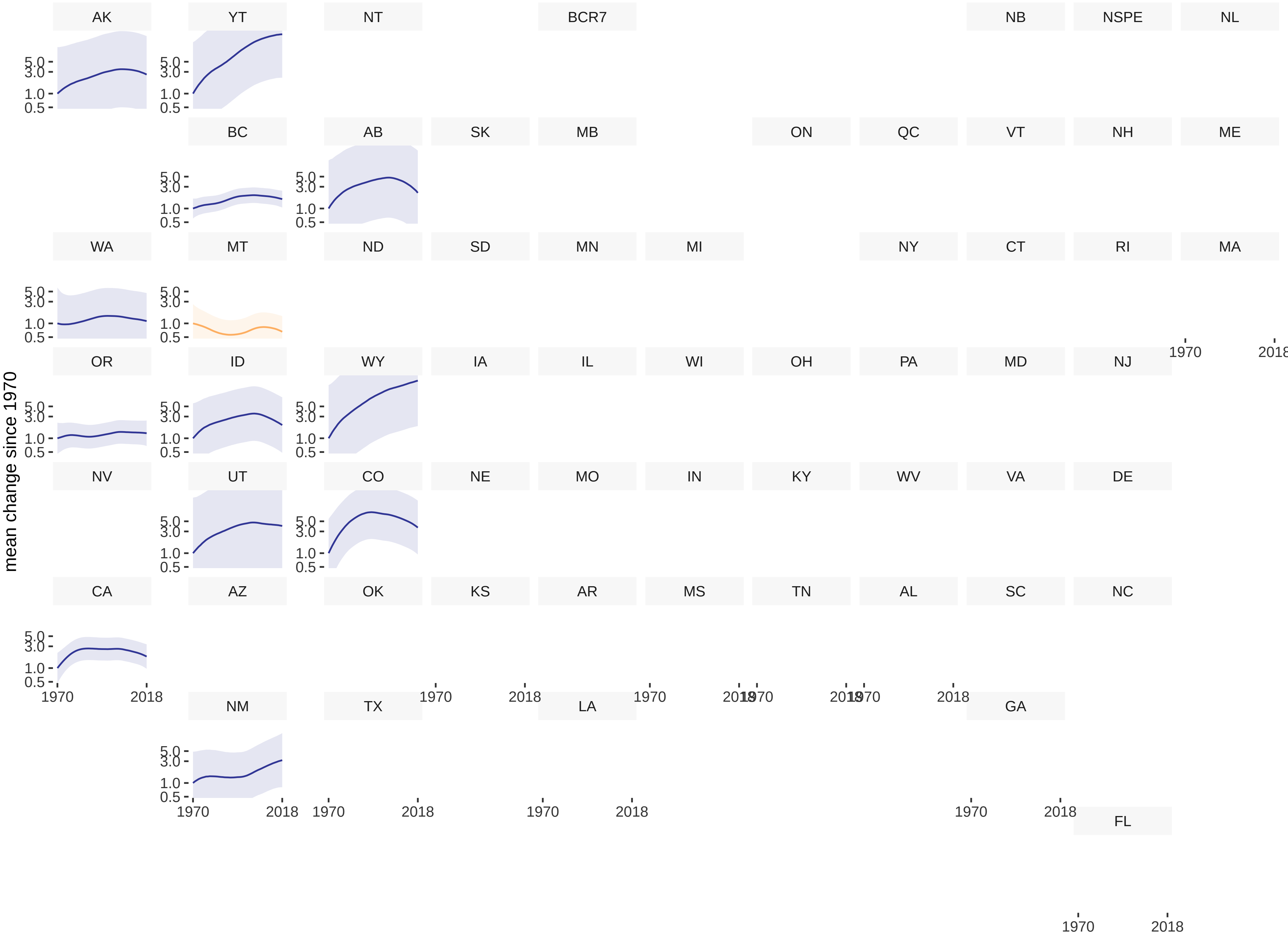
Eastern Kingbird Population trajectories by Provinces and States



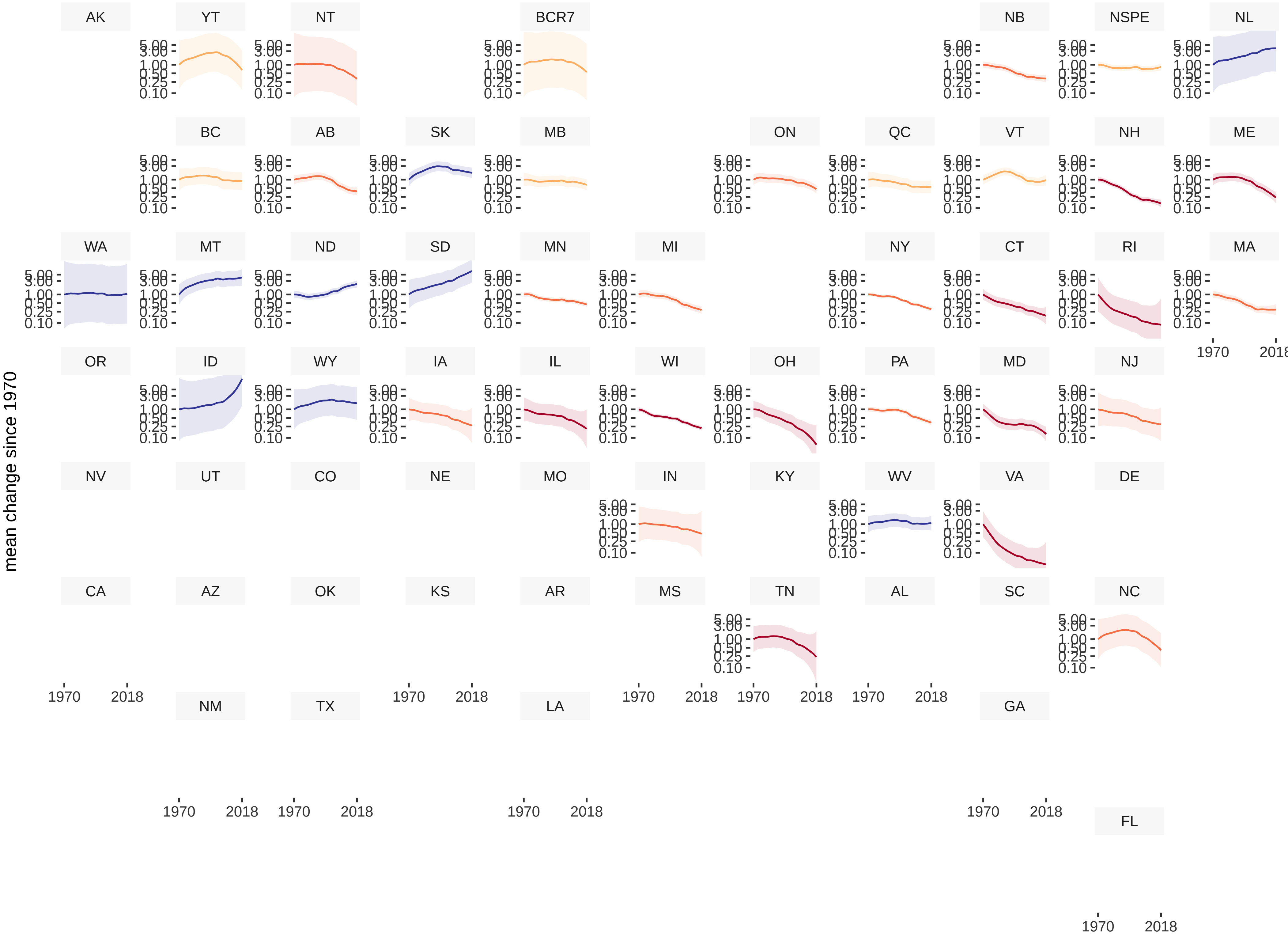
Great Crested Flycatcher Population trajectories by Provinces and States

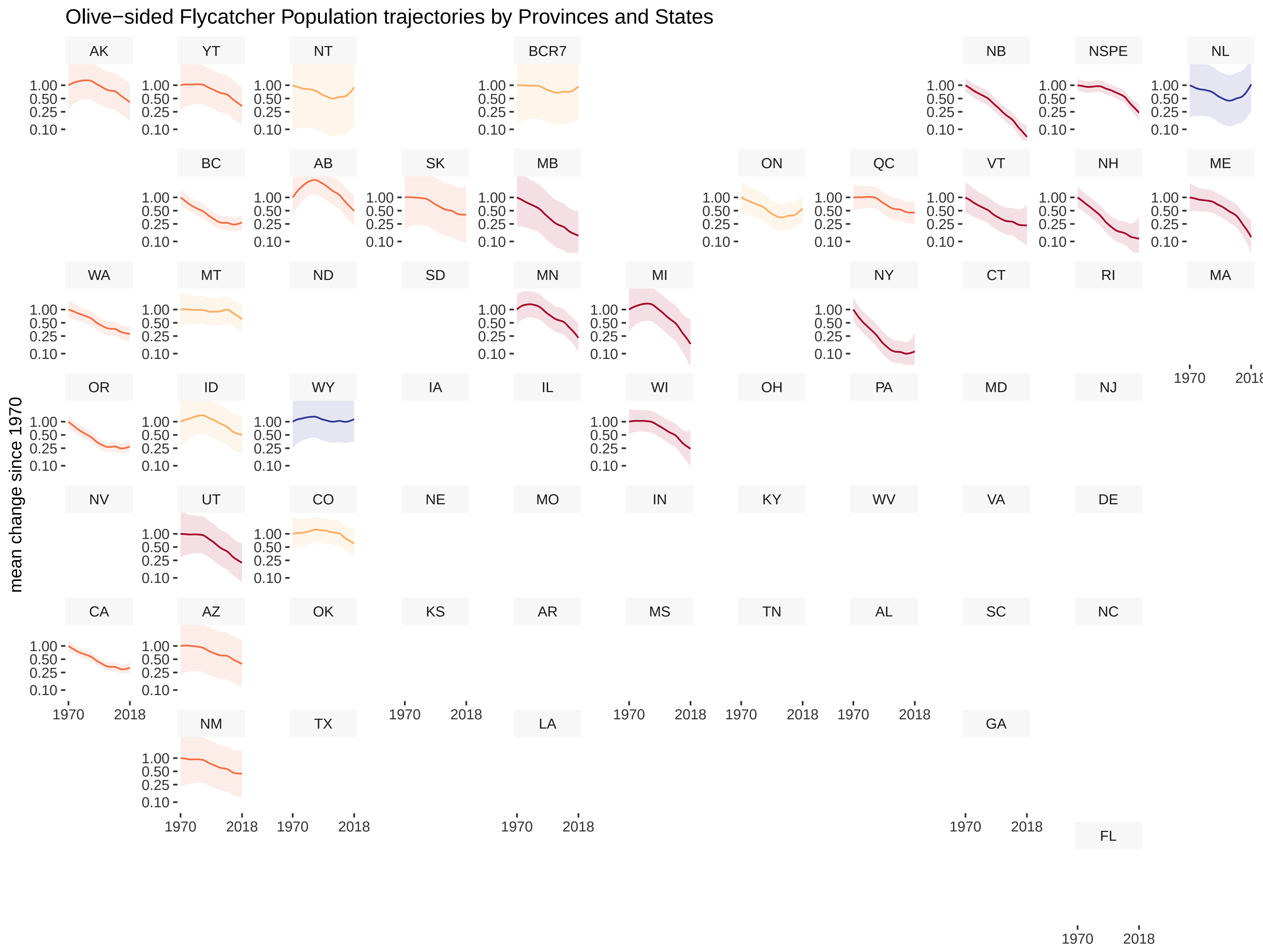


Hammond's Flycatcher Population trajectories by Provinces and States



Least Flycatcher Population trajectories by Provinces and States




Olive−sided Flycatcher Population trajectories by Provinces and States
mean change since 1970
1.00
0.50
0.25
0.10
1970
2018
AK
YT
NT
BCR7
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NSPE
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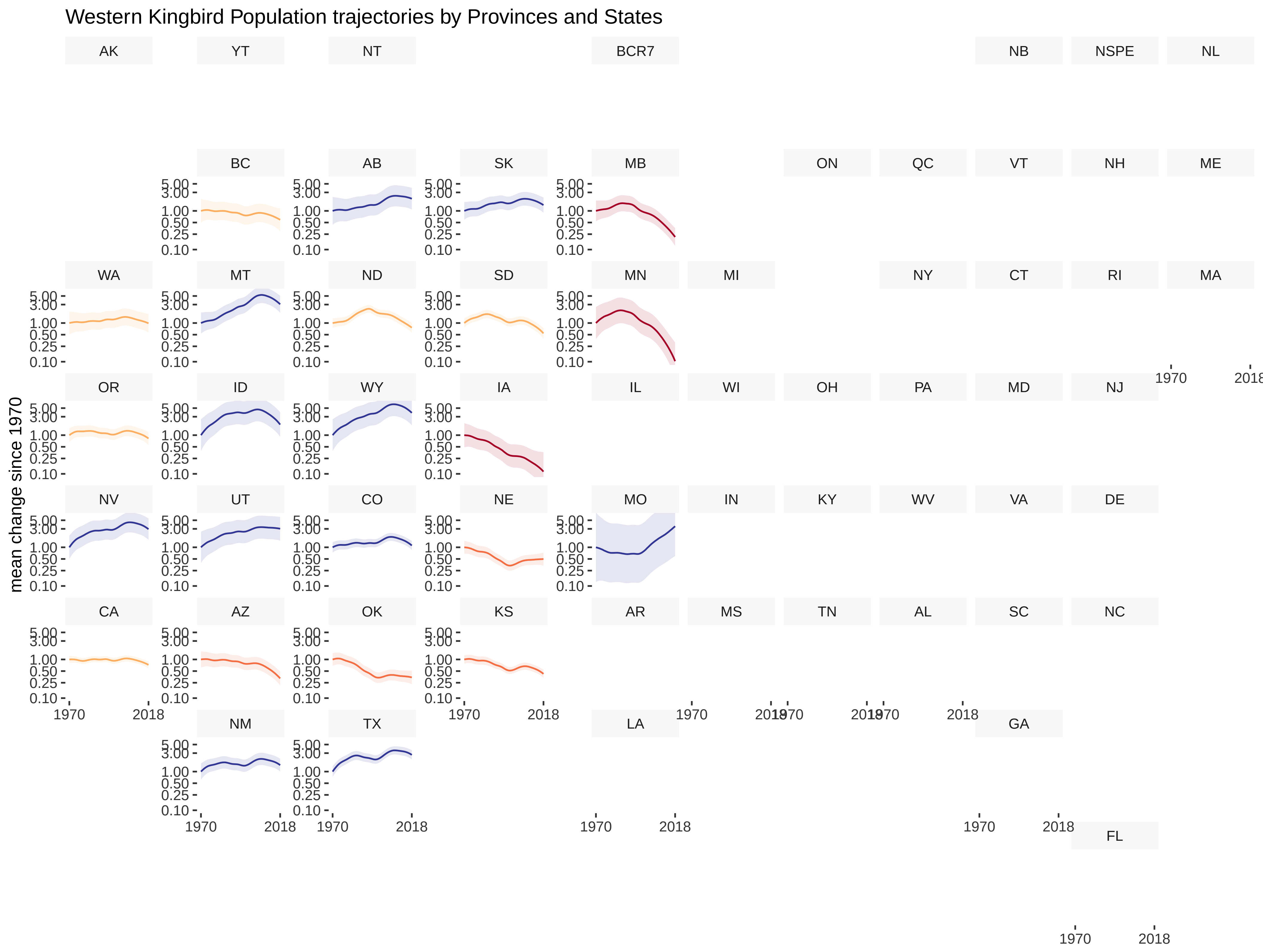

Western Kingbird Population trajectories by Provinces and States
mean change since 1970
AK
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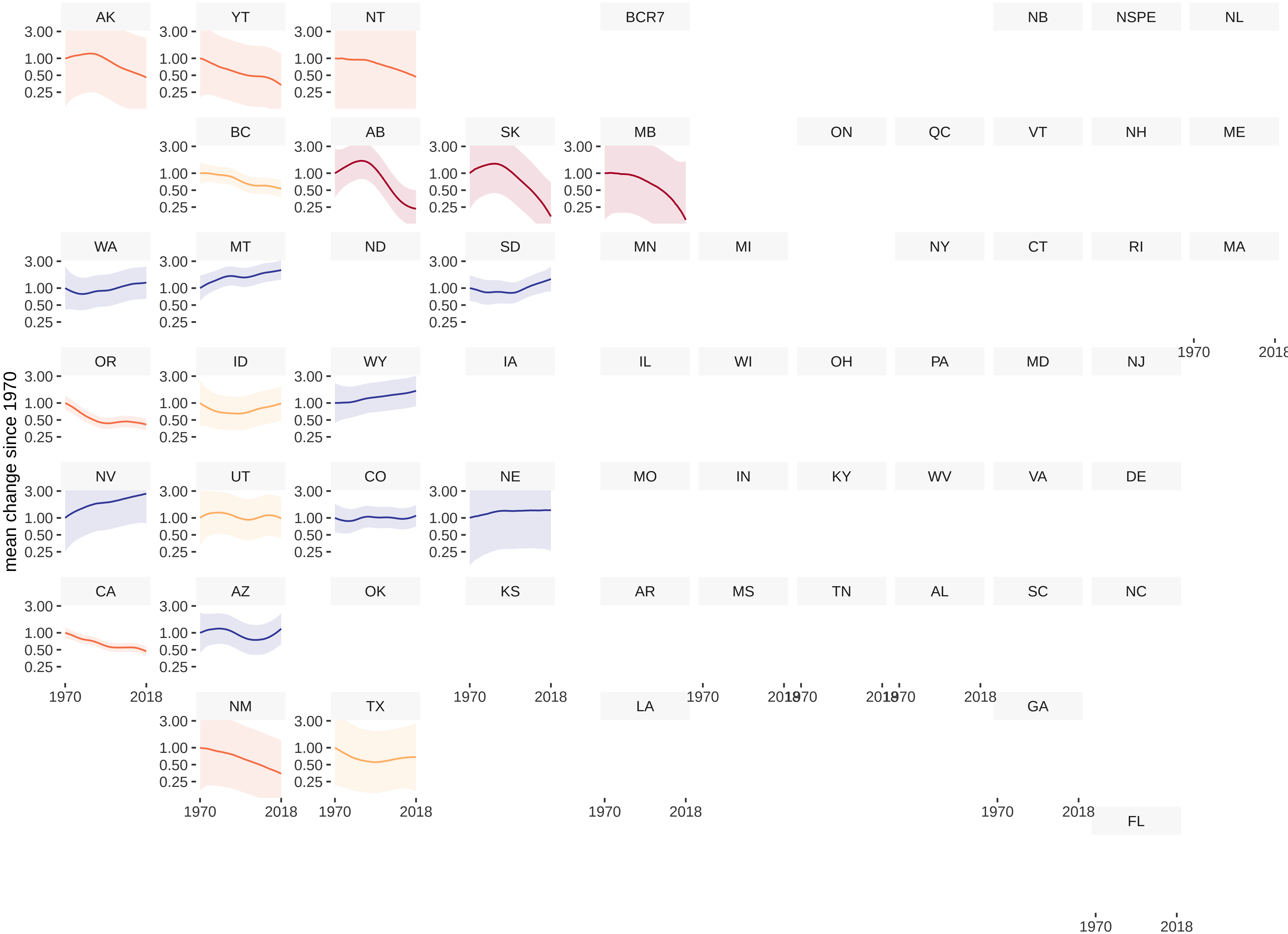
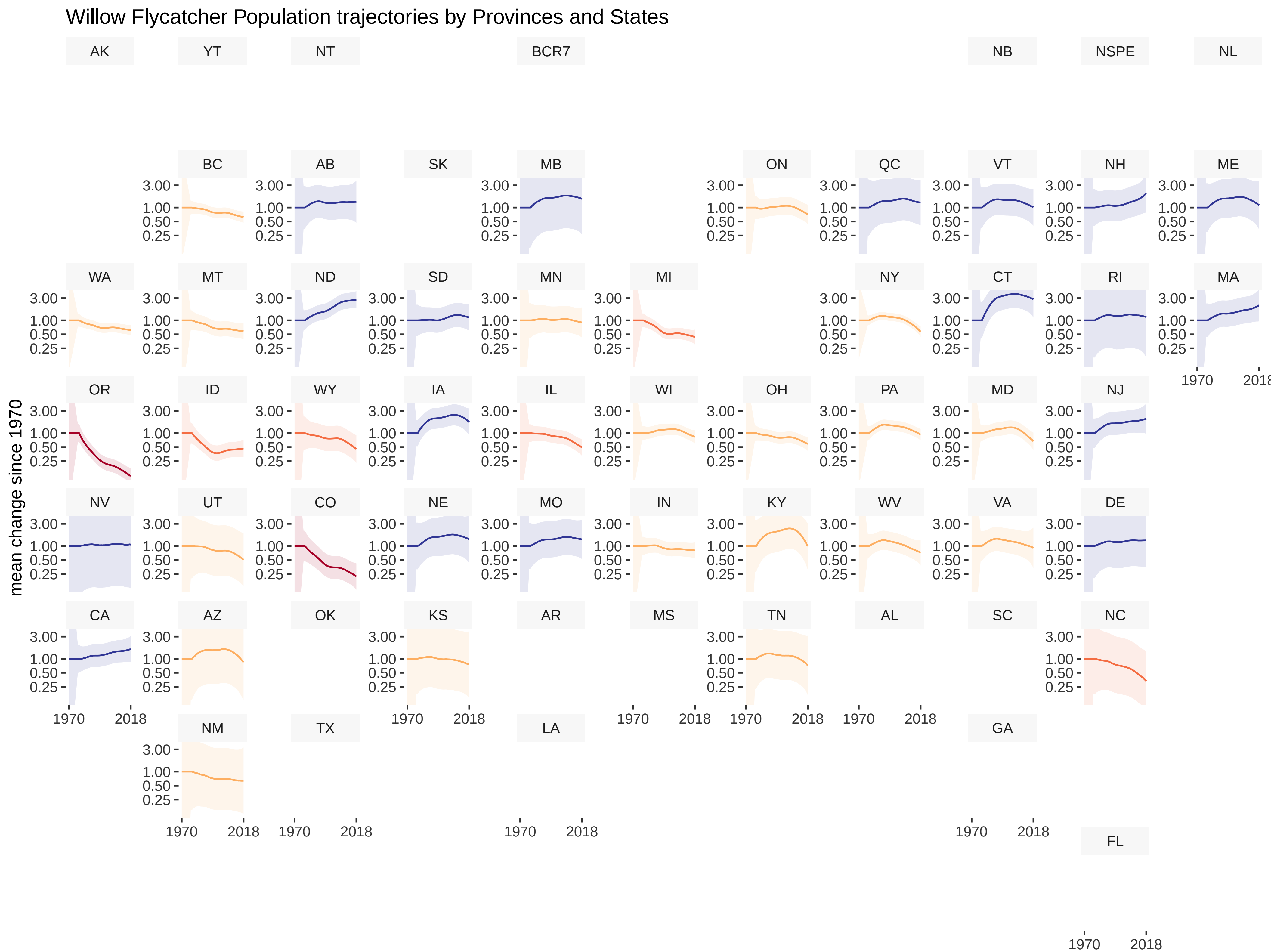
TX
LA
GA
FL
5.00
3.00
1.00
0.50
0.25
0.10
1970
2018

Western Wood−Pewee Population trajectories by Provinces and States





Willow Flycatcher Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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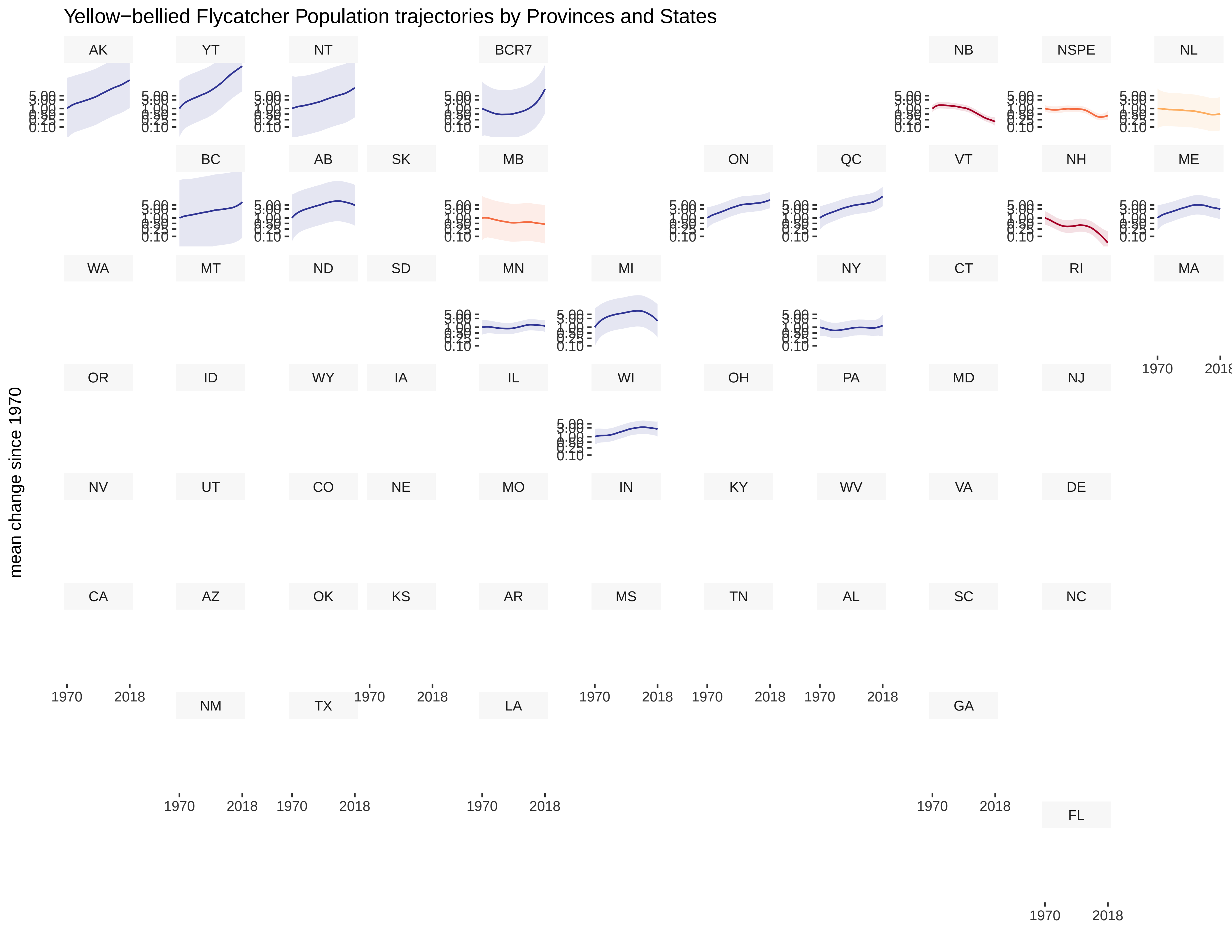
GA
FL
3.00
1.00
0.50
0.25
1970
2018



Yellow−bellied Flycatcher Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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NSPE
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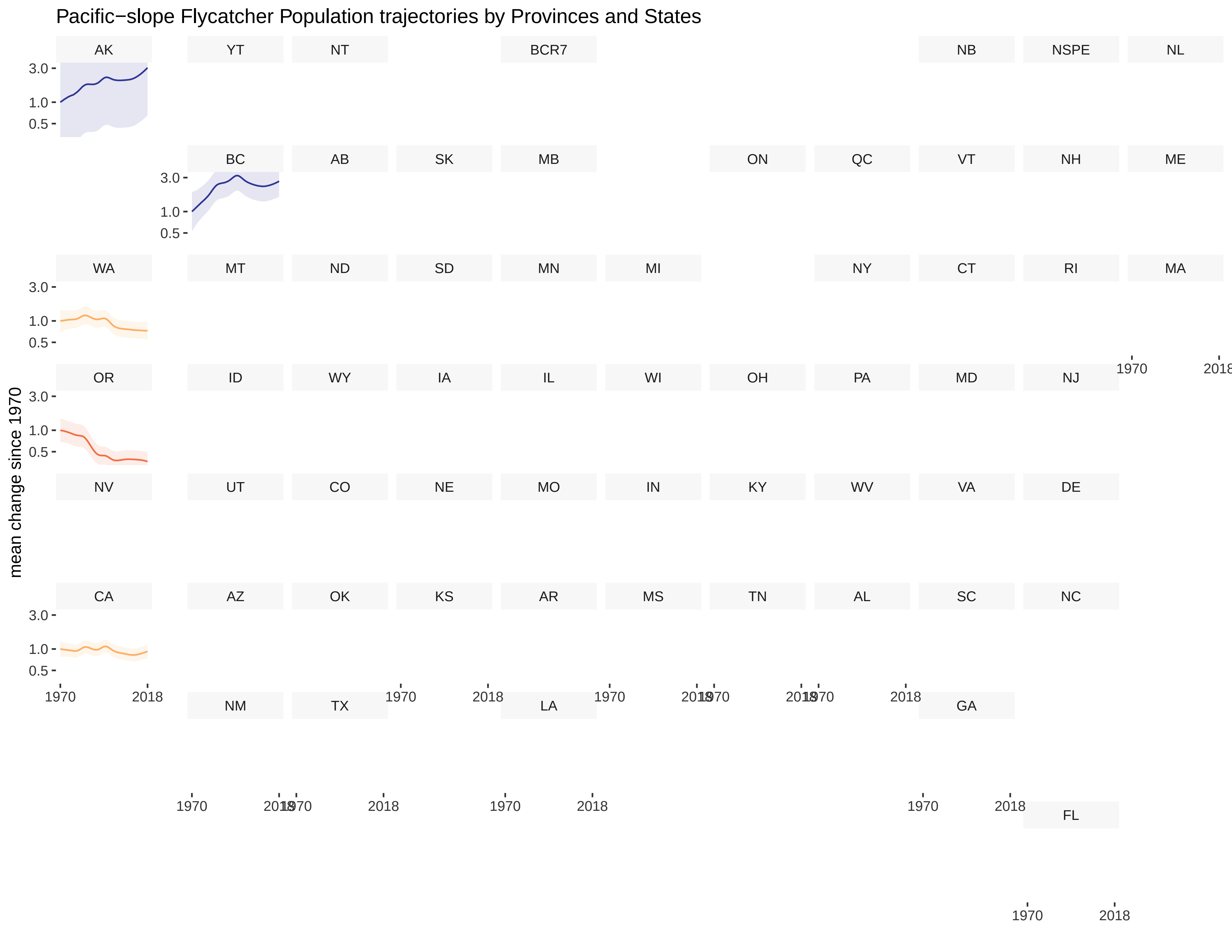
LA
GA
FL
5.00
3.00
1.00
0.50
0.25
0.10
1970
2018


Pacific−slope Flycatcher Population trajectories by Provinces and States
AK
YT
NT
BCR7
NB
NSPE
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BC
AB
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QC
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KY
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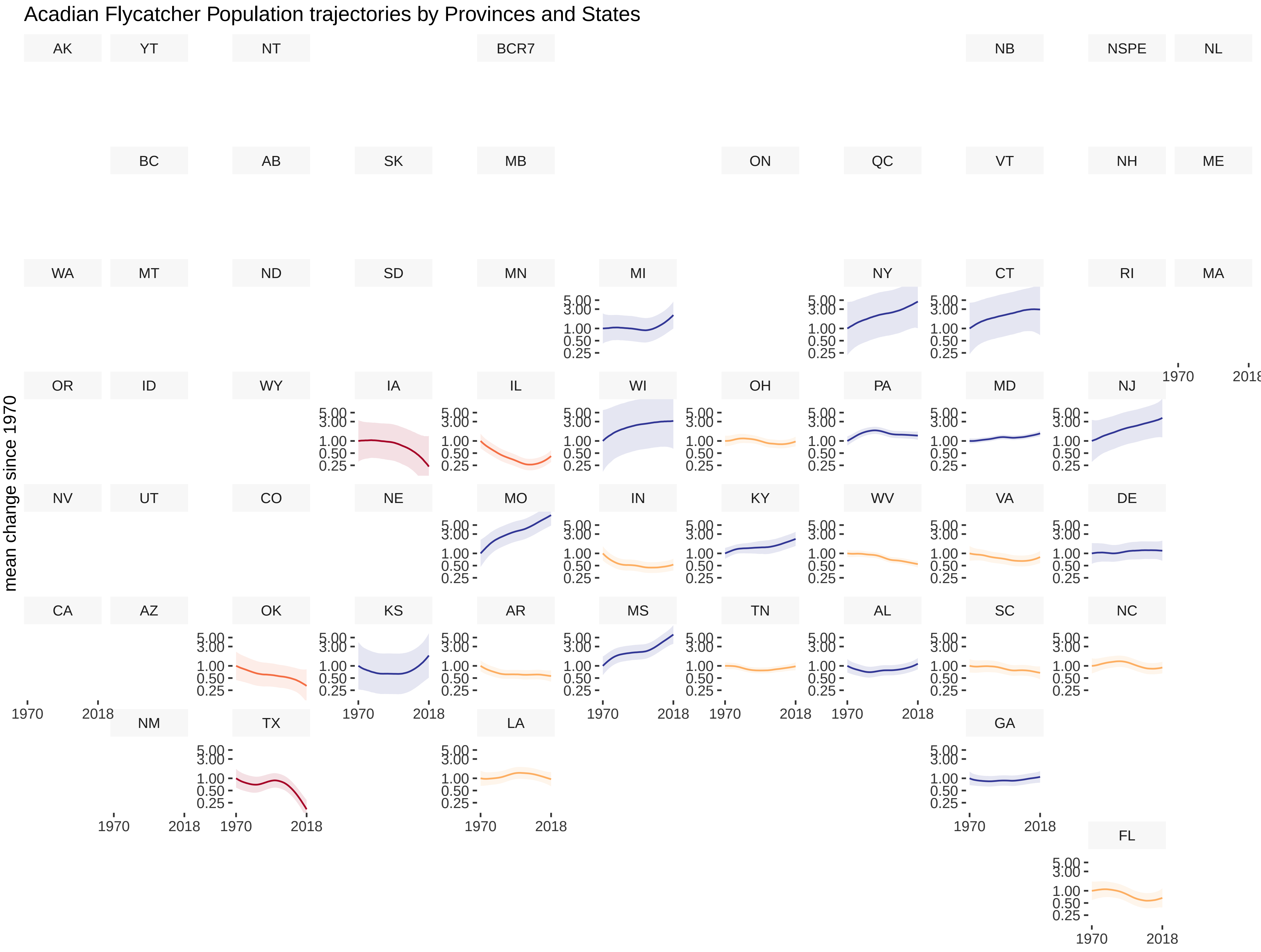
TX
LA
GA
FL
mean change since 1970
3.0
1.0
0.5
1970
2018



Acadian Flycatcher Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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NSPE
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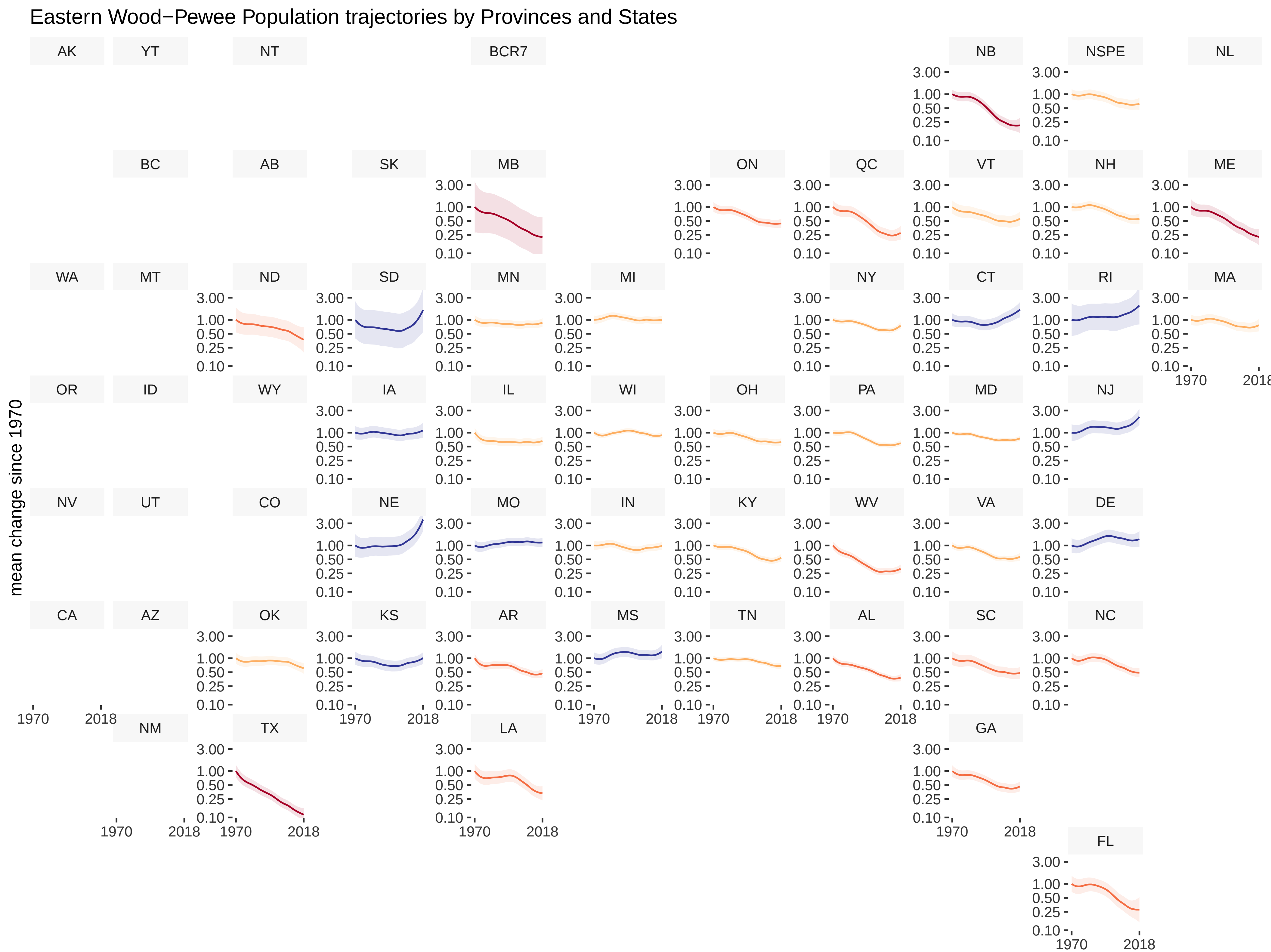
FL
5.00
3.00
1.00
0.50
0.25
1970
2018


Eastern Wood−Pewee Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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NSPE
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MB
ON
QC
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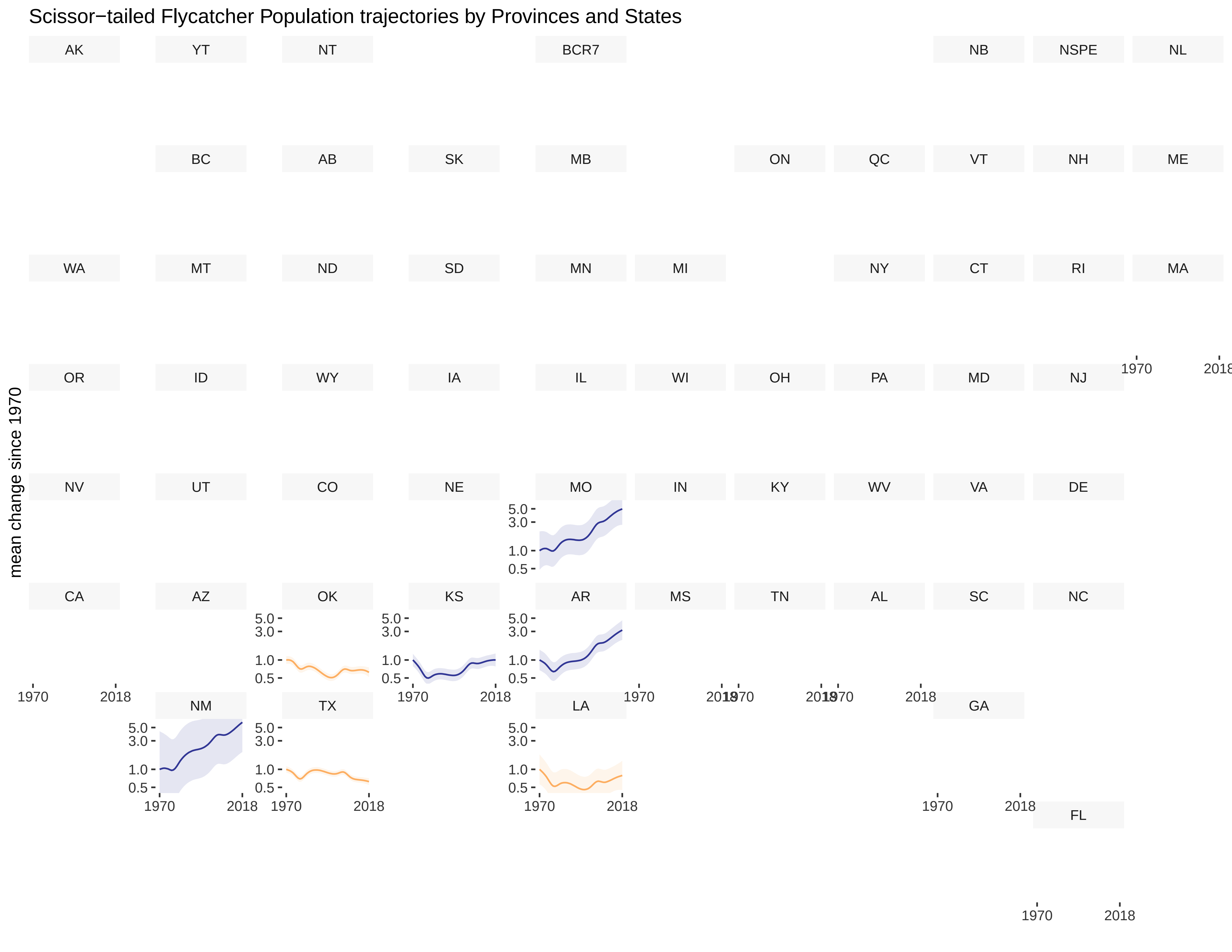
GA
FL
3.00
1.00
0.50
0.25
0.10
1970
2018

Gray Kingbird Population trajectories by Provinces and States


Scissor−tailed Flycatcher Population trajectories by Provinces and States
AK
YT
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NSPE
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KY
WV
VA
DE
CA
AZ
OK
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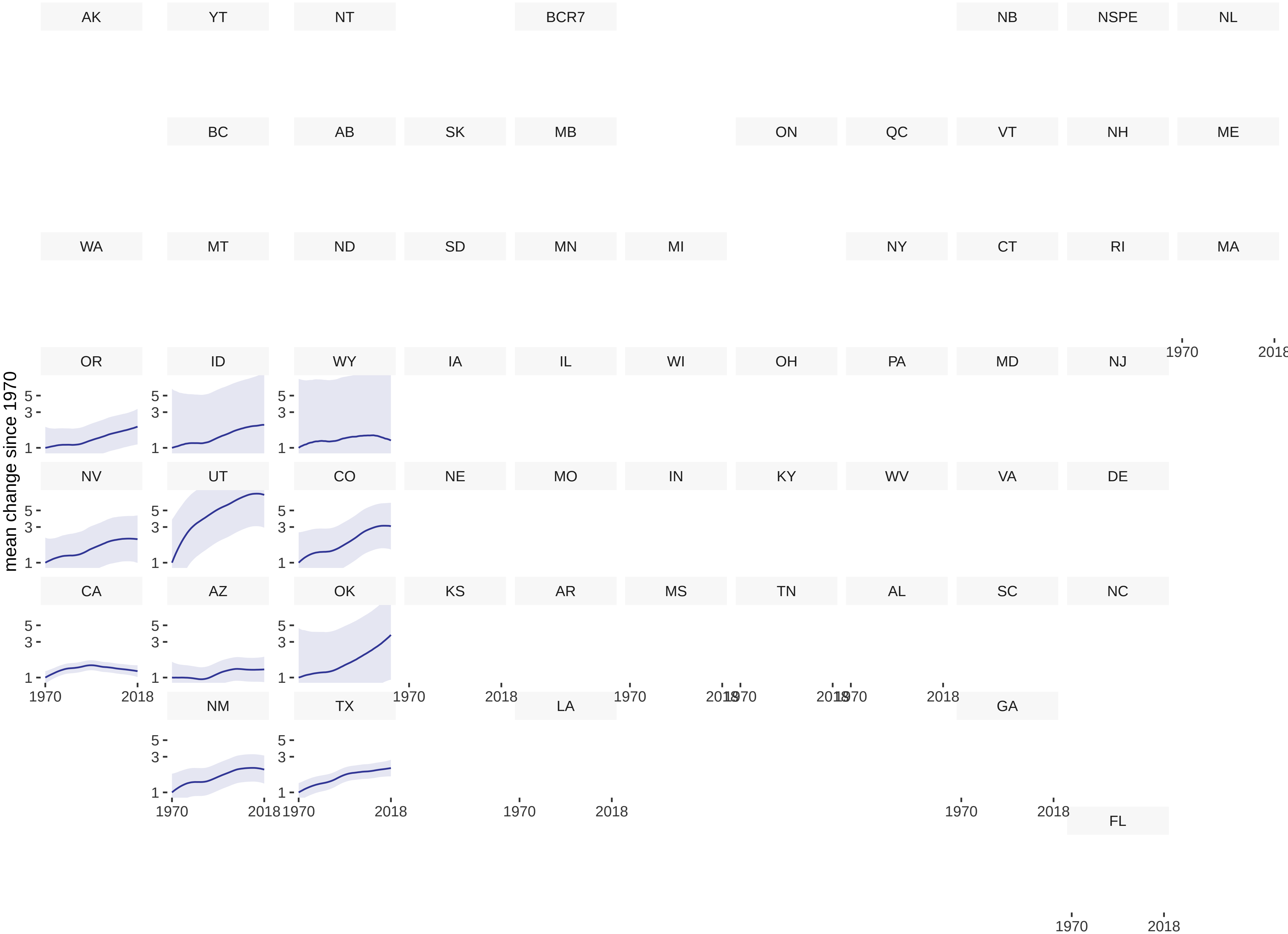
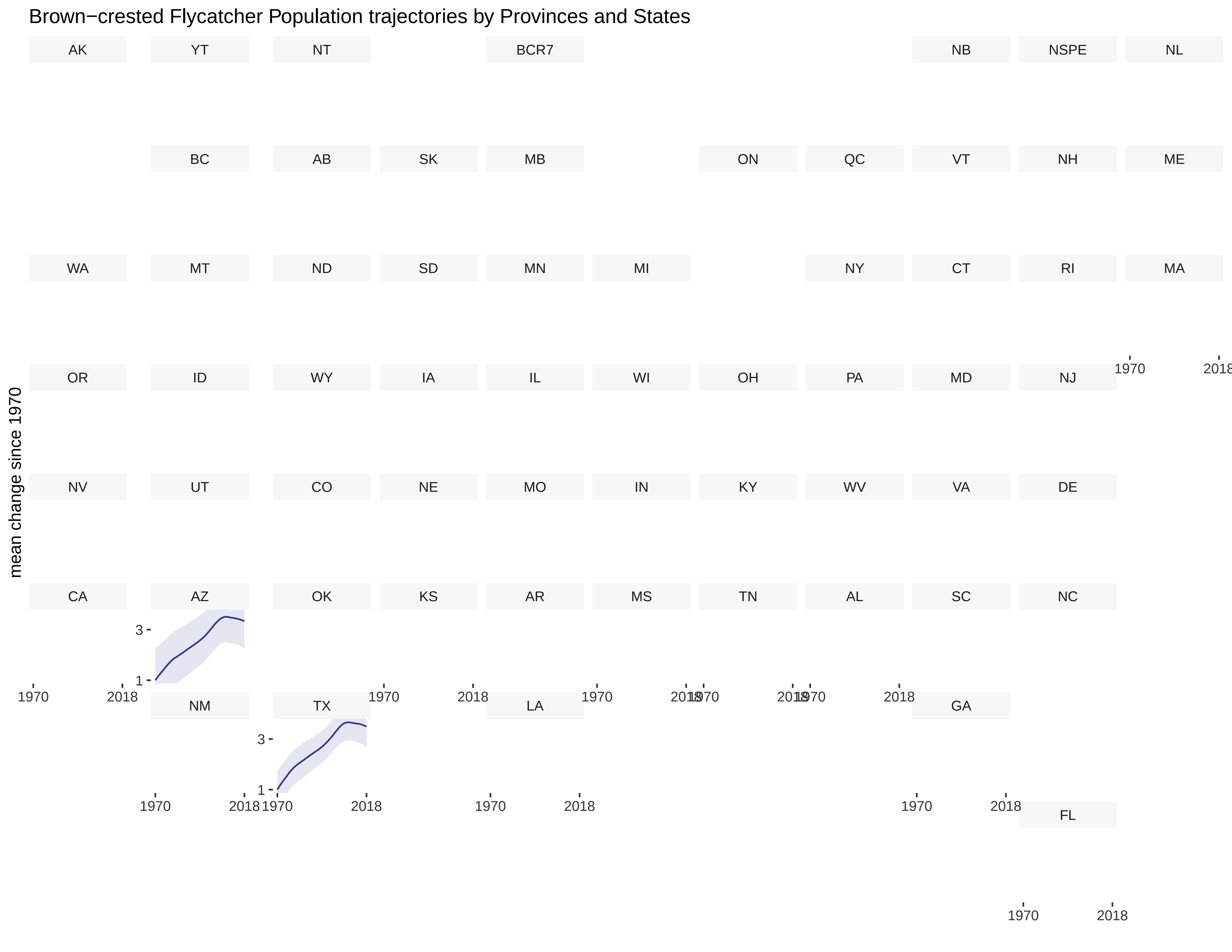
AL
SC
NC
NM
TX
LA
GA
FL
mean change since 1970
5.0
3.0
1.0
0.5
1970
2018

Ash−throated Flycatcher Population trajectories by Provinces and States




Brown−crested Flycatcher Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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NSPE
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KY
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NC
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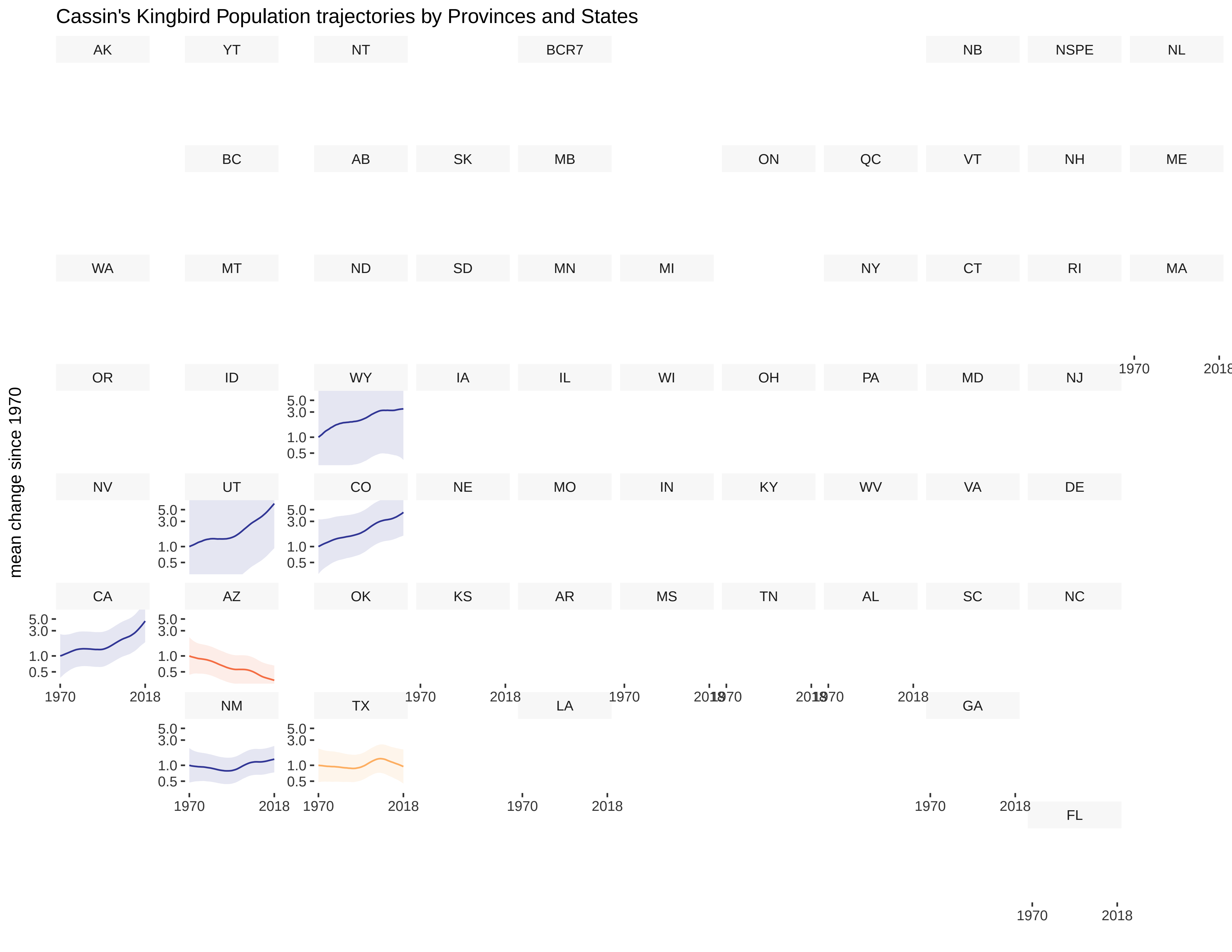
TX
LA
GA
FL
1
3
1970
2018


Cassin's Kingbird Population trajectories by Provinces and States
mean change since 1970
AK
YT
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BCR7
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NSPE
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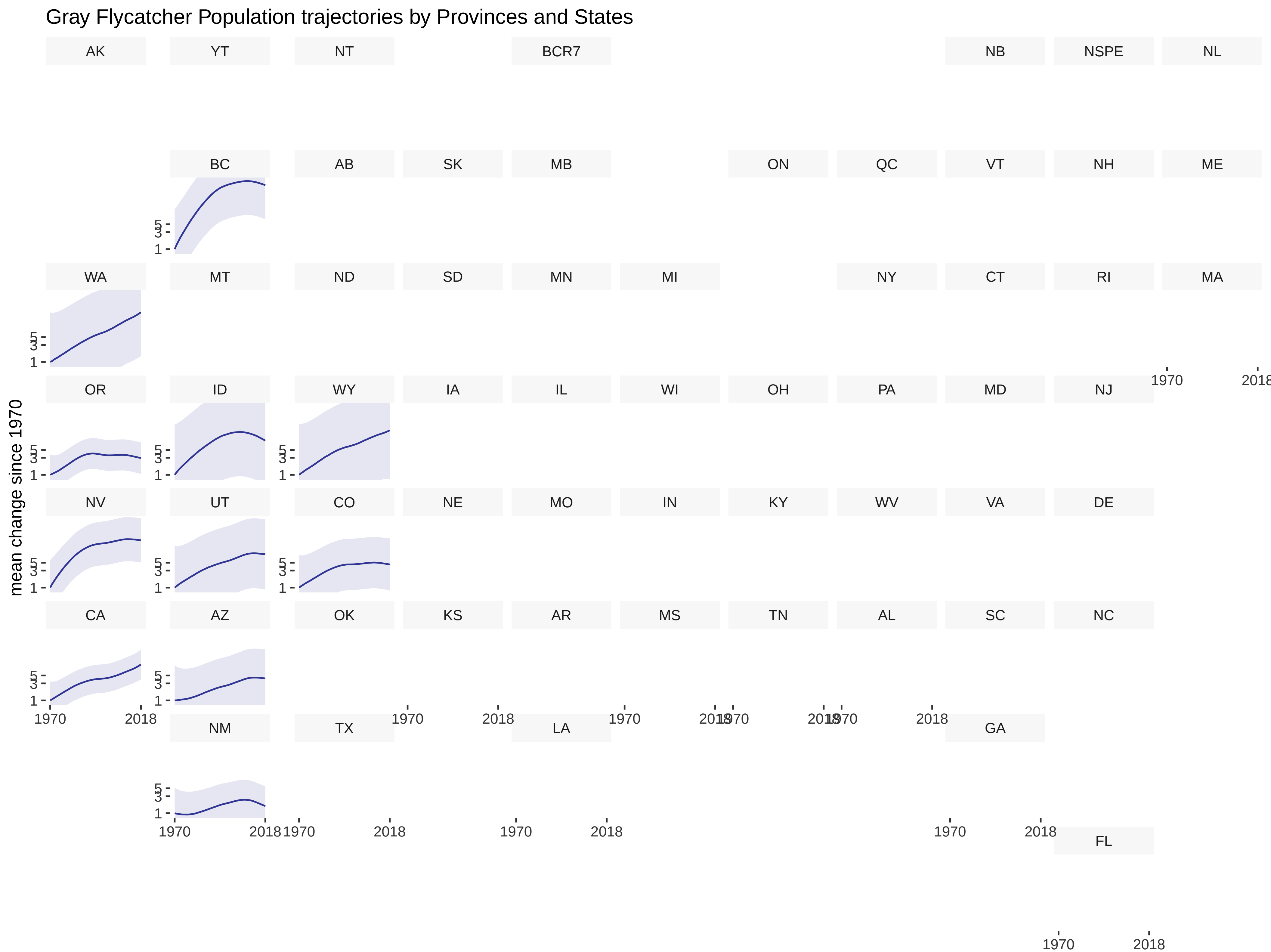
TX
LA
GA
FL
5.0
3.0
1.0
0.5
1970
2018


Gray Flycatcher Population trajectories by Provinces and States
mean change since 1970
AK
YT
NT
BCR7
NB
NSPE
NL
BC
AB
SK
MB
ON
QC
VT
NH
ME
WA
MT
ND
SD
MN
MI
NY
CT
RI
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OR
ID
WY
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WI
OH
PA
MD
NJ
NV
UT
CO
NE
MO
IN
KY
WV
VA
DE
CA
AZ
OK
KS
AR
MS
TN
AL
SC
NC
NM
TX
LA
GA
FL
1
3
5
1970
2018

Vermilion Flycatcher Population trajectories by Provinces and States

Couch's Kingbird Population trajectories by Provinces and States