ESA (Ecological Society of America). 2011. Annual report to the governing council. *Bull Ecol Soc Am* **92**: S1–S96.

Gorman EH. 2005. Gender stereotypes, same-gender preferences, and organizational variation in the hiring of women: evidence from law firms. *Am Sociol Rev* **70**: 702–28.

Granovetter M. 1973. The strength of weak ties. *Am J Sociol* **78**: 1360–80.

Greenwald AG, McGhee D, and Schwartz JLK. 1998. Measuring individual differences in implicit cognition: the Implicit Association Test. *J Pers Soc Psychol* **74**: 1464–80.

Khurana R. 2002. Searching for a corporate savior: the irrational quest for charismatic CEOs. Princeton, NJ: Princeton University Press.

Lawrence D and Holland M. 1993. Profiles of ecologists: results of a survey of the membership of the Ecological Society of America. Part I. A snapshot of survey respondents. *Bull Ecol Soc Am* **74**: 21–35.

Lincoln AE, Pincus S, Koster JB, and Leboy PS. 2012. The Matilda Effect in science: awards and prizes in the US, 1990s and 2000s. *Soc Stud Sci* **42**: 307–20.

Lockwood JA, Reiners DS, and Reiners WA. 2013. The future of ecology: a collision of expectations and desires? *Front Ecol Environ* **11**: 188–93.

Martin LJ. 2012. Where are the women in ecology? *Front Ecol Environ* **10**: 177–78.

Moss-Racusin CA, Dovidio JF, Brescoll VL, *et al.* 2012. Science faculty's subtle gender biases favor male students. *P Natl Acad Sci USA* **109**: 16474–79.

Ortega SA, Flecker K, Hoffman L, *et al.* 2006. Women and minorities in ecology II. Washington, DC: ESA.

Rudman LA, Ashmore RD, and Gary ML. 2001. "Unlearning" automatic biases: the malleability of implicit prejudice and stereotypes. *J Pers Soc Psychol* **81**: 856–68.

Torres L and Bingham B. 2008. Fixing the leaky pipe: increasing recruitment of underrepresented groups in ecology. *Front Ecol Environ* **6**: 554–55.

US Census Bureau. 2010. 2010 US Census. www.census.gov/2010census. Viewed 21 Aug 2014.

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Are natural history collections coming to an end as time-series?

Peer-reviewed letter

Much has been written about the value of natural history collections and their deteriorating state (WebReferences). Natural history collections are critically important to our understanding of the natural world, especially natural selection and evolution, because they preserve samples of Earth's biota extending back several centuries (Lister and Climate Change Research Group 2011). Less well appreciated is the serendipitous record they provide of anthropogenic effects on biodiversity: inherent in collections are valuable time-series with crucial baseline data beginning before accelerated rates of anthropogenic habitat modification (Tingley and Beissinger 2009; Johnson *et al.* 2011; Lister and Climate Change Research Group 2011). Innovative studies that provide insights into the long-term consequences of environmental change are made possible through the temporal record provided by natural history collections (for a list of selected studies, see WebTable 1).

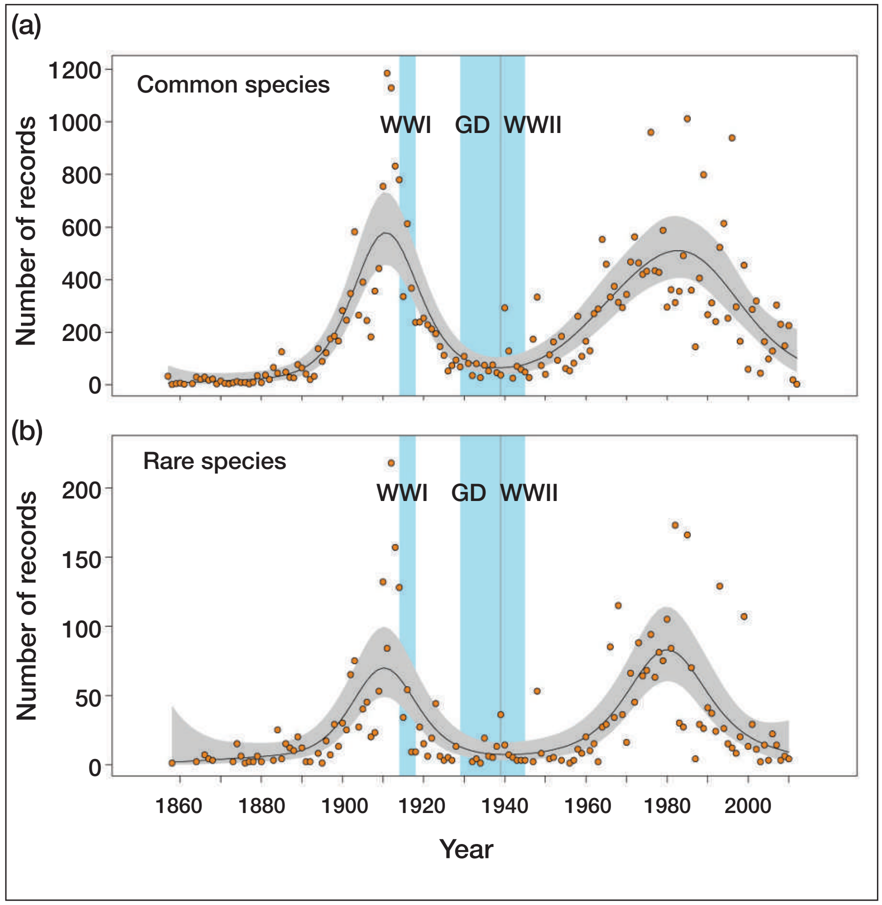

Figure 1. Changes in the number of records of Meliphagoidea for (a) common and (b) rare species. Species status is based on estimates of range size (Symonds and Johnson 2006), calculated as the number of one-degree grid squares occupied (range = 2–652, mean = 123); rare species ≤ 20. The blue areas depict the periods of World War I (WWI, 1914–18), the Great Depression (GD, 1929–39), and World War II (WWII, 1939–45). The line represents the fitted Generalized Additive Model with a AR(1) term controlling for temporal autocorrelation in the model residual. The gray area is a 95% confidence interval. Data comprise 40 246 records from all major natural history collections in Australia (seven institutions) as well as two in the US (American Museum of Natural History, Smithsonian National Museum of Natural History: 17 098 specimens), either via the online resources of OZCAM (http://ozcam.org.au) and ORNIS (http://ornis2.ornisnet.org) or directly from institutions where records are not available online. These represent the vast majority of all collections worldwide, including the extensive HL White, Rothschild, and Matthews Collections. We included only dried skins in our analysis and excluded records for which no year of collection was recorded.

Although many studies lament the declining status of natural history collections worldwide, few report specifically on trends in collection effort over time. An important exception is Winker (1996), who documented collection patterns for 174 285 birds housed in the National Museum of Natural History (NMNH; Washington, DC). Winker reported relatively sustained levels of collecting from the late 1880s to 1960, after which a rapid decline occurred. An upsurge in collecting since 1980, however, was reported by Joseph (2011), a trend he attributed in part to institutional surveys of less well-explored avifauna, particularly in South America. Thus, rather than sustained collecting of the better-represented North American bird fauna, the NMNH appears to have diverted its effort elsewhere at the (probably unintended) expense of maintaining time-series.

Here we document collection patterns over approximately 150 years (1860–2010) for 145 species belonging to the Meliphagoidea, a large and diverse superfamily containing about one-third of Australia's passerines (Gardner *et al.* 2010). Collection of Meliphagoidea species, both common and rare, peaked around 1910, declined rapidly thereafter, and remained low through the periods of the World Wars and Great Depression (Figure 1). Resurgence in collecting effort began during the late 1940s and continued until the mid-1980s, after which a gradual and sustained decline began, continuing to the present day. Current collecting is consequently at an all-time low, at levels equivalent to those of the early 1800s before collecting began in earnest in Australia.

This decline in collection effort likely has multiple causes (WebReferences), but key factors relate to dwindling funding for the research component of museums (Dalton 2003; Joseph 2011) and a reduction in available taxonomic and curatorial training (Middendorf and Pohlad 2014). In developed nations, such a downturn is undoubtedly influenced by negative community perceptions of the ethics of collecting, as well as perceptions that sampling of the fauna is complete (Remsen 1995). The extent to which these factors influence collection practice, however, varies geographically and depends in part on cultural attitudes and history of collection practice. For example, countries with a prominent wildlife hunting culture (eg the US) have not seen the level of downturn apparent in much of Europe (Roselaar 2003). In Australia, where the fauna is less well-known, current collection levels also appear higher than levels in Europe (Roselaar 2003; Joseph 2011). Thus, community perceptions that ultimately influence policy are complex and heterogeneous, and the extent and nature of future collection practice will necessarily be made on a case-by-case basis by the countries involved. For instance, the NMNH has resumed collection of some North American birds, resampling localities for which they have important historical collections (H James and B Schmidt pers comm), and Moritz *et al.* (2008) highlighted the value of such an approach.

Whether the overall reduction in ongoing collection effort is driven by reductions in funding, by negative community perceptions, or by both, its importance is profound: time-series are ending. We cannot rely on current levels of collecting to maintain them. Museum time-series have proved incidentally useful for a variety of purposes and have been integral in identifying temporal responses to environmental change: for instance, vertebrate specimens have been used to demonstrate (1) genetic bottlenecks due to insecticides, (2) climate-driven changes in genetic diversity, (3) alterations to plumage coloration, and (4) shifts in latitudinal clines in body size (WebTable 1). In plant taxa, museum time-series have isolated climate-driven reductions in stomatal density and earlier flowering (WebTable 1). Just as the use of stable isotopes and DNA were once unforeseen, there are likely to be a range of new techniques that can usefully be applied to time-series in the future. The loss of time-series now will limit our ability to track responses to environmental change, at a time of major climate shifts with broad-reaching consequences for biodiversity (Mora *et al.* 2013).

At the same time as public attitudes in many developed countries have hardened against collecting, there has been a growth of interest in natural history and a willingness to contribute to its understanding and conservation. One relatively untapped source of material that may promote ongoing collection of some specimens is represented by the casualties of accidents: roadkill, collisions with windows or other structures, and victims of domestic pets and extreme weather events (eg www.birdmonitors.net/Salvage.php). Of course this source will be biased toward conspicuous species associated with habitation in urbanized environments. Nevertheless, the volume and diversity of "salvaged" specimens can be considerable: Loss *et al.* (2014) estimated that 365–988 million birds are killed annually in the US from collisions with buildings, a source of mortality second only to predation by free-ranging domestic cats, estimated at 1.3–4.0 billion annually (Loss *et al.* 2013, 2014). Specimens derived from salvage are currently available, their numbers show little sign of abating, and there is a potentially large, voluntary labor source to assist in their collection. Informed debate on the future of collections is needed to highlight these issues and find geographically suitable solutions as existing time-series end.

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Dalton R. 2003. Natural history collections in crisis as funding is slashed. *Nature* **423**: 575.

Gardner JL, Trueman JWH, Ebert D, *et al.* 2010. Phylogeny and evolution of the Meliphagoidea, the largest radiation of Australian songbirds. *Mol Phylogenet Evol* **55**: 1087–102.

Johnson KG, Brooks JT, Fenberg PB, *et al.* 2011. Climate change and biosphere response: unlocking the collections vault. *BioScience* **61**: 147–53.

Joseph L. 2011. Museum collections in ornithology: today's record of avian biodiversity for tomorrow's world. *Emu* **111**: i–xii.

Lister AM and Climate Change Research Group. 2011. Natural history collections as sources of long-term datasets. *Trends Ecol Evol* **26**: 153–54.

Loss SR, Will T, and Marra PP. 2013. The impact of free-ranging domestic cats on wildlife of the United States. *Nat Commun* **4**: 1396.

Loss SR, Will T, and Marra PP. 2014. Bird–building collisions in the United States: estimate of annual mortality and species vulnerability. *Condor* **116**: 8–23.

Middendorf G and Pohlad BR. 2014. Ecoliteracy for ecology and ecologists: eroded underpinnings. *Front Ecol Environ* **12**: 194–95.

Mora C, Frazier AG, Longman RJ, *et al.* 2013. The projected timing of climate departure from recent variability. *Nature* **502**: 183–87.

Moritz C, Patton JL, Conroy CJ, *et al.* 2008. Impact of a century of climate change on small-mammal communities in Yosemite National Park, USA. *Science* **322**: 261–64.

Remsen JV. 1995. The importance of continued collecting of bird specimens to ornithology and bird conservation. *Bird Conserv Int* **5**: 145–80.

Roselaar CS. 2003. An inventory of major European bird collections. *Bull British Ornithol Club* **123**: 253–337.

Symonds MRE and Johnson CN. 2006. Range size–abundance relationship in Australian passerines. *Global Ecol Biogeogr* **15**: 143–52.

Tingley MW and Beissinger SR. 2009. Detecting range shifts from historical species occurrences: new perspectives on old data. *Trends Ecol Evol* **24**: 625–33.

Winker K. 1996. The crumbling infrastructure of biodiversity: the avian example. *Conserv Biol* **10**: 703–07.

doi:10.1890/14.WB.012