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Investigating the implications of shifting baseline syndrome on conservation

Lizzie P. Jones[1,2] | Samuel T. Turvey[2] | Dario Massimino[3] | Sarah K. Papworth[1]

[1]School of Biological Sciences, Royal Holloway, University of London, Egham, UK

[2]Institute of Zoology, Zoological Society of London, London, UK

[3]British Trust for Ornithology, Thetford, UK

Correspondence
Lizzie P. Jones
Email: lizzie.jones42@gmail.com

Sarah K. Papworth
Email: sarah.papworth@rhul.ac.uk

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Abstract

1. Shifting baseline syndrome (SBS) describes a persistent downgrading of perceived 'normal' environmental conditions with every sequential generation, leading to under-estimation of the true magnitude of long-term environmental change on a global scale. The presence of SBS should be considered when local ecological knowledge and participatory techniques are involved in conservation target-setting. However, despite increasing recognition of the phenomenon, there is little empirical evidence for SBS. Here we provide evidence of SBS, and the first empirical investigation of the impacts of SBS on public perceptions of conservation need.
2. Large-scale online questionnaires were used to collect public perceptions of long-term biological change regarding 10 UK bird species, as well as demographic information and measures of knowledge and experience of the local environment (n = 330). A paired data approach compared social perceptions to a large-scale longitudinal biological dataset. Using information theoretic and model selection techniques, we estimate the relative importance of multiple demographic, social and psychological predictors of SBS. We provide a framework for investigating evidence of SBS and its impacts on perceptions of conservation need for species in decline.
3. Evidence of generational amnesia was found as an age-related difference in perceptions of past ecological conditions. The perceptions of older participants had significantly higher agreement with biological data than the perceptions of younger participants. Our results therefore support the expectation that younger, less experienced people are less aware of historical ecological conditions and show greater evidence of SBS. We also present evidence of a negative impact of SBS on future conservation, as older people were more likely than younger people to perceive a greater need for conservation action for three declining species.
4. Our research supports the need to encourage greater intergenerational communication and increase experience of local nature. Discovering evidence of SBS in public perceptions of species experienced within everyday life demonstrates SBS as a pervasive social issue with the potential to impact public perceptions of local nature.

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KEYWORDS
change blindness, conservation, generational amnesia, local ecological knowledge, participatory, perceptions, personal amnesia, shifting baseline syndrome

1 | INTRODUCTION

Knowledge of past environments is critical to evaluate current conditions, comprehend change and set effective conservation targets for the future (Soga & Gaston, 2018). There is a wealth of empirical evidence recording our long-term impacts on the natural environment, from species extinctions and habitat loss (Dirzo et al., 2014) to climate change (Steffen et al., 2015). Despite this, conservation baselines are often formed using only recent information (Rodrigues et al., 2018). By focusing on more recent timescales, we may lose perspective on the true magnitude of long-term environmental change (Rost, 2018). This is known as shifting baseline syndrome (hereafter SBS), a socio-psychological phenomenon in which historical environmental information is lost over time and people do not notice changes in biological systems. Without intergenerational communication, it is thought that people tend to compare current ecological conditions to reference points set within their own autobiographical experience, forgetting or ignoring valuable historical information (Papworth, Rist, Coad, & Milner-Gulland, 2009; Pauly, 1995). However, relatively few studies provide empirical evidence for SBS (Papworth et al., 2009; Turvey et al., 2010), often due to a lack of access to longitudinal biological datasets against which to compare perceptions of biological change (Guerrero-Gatica, Aliste, & Simonett, 2019).

According to Papworth et al. (2009), two criteria must be met in order to demonstrate SBS empirically:

1. There must be biological change in the system and,
2. Any perceived change must be consistent with biological data.

The interpretation of these criteria depends on the mechanism by which SBS is occurring: either generational or personal amnesia. Generational amnesia, so called for the unperceived loss of knowledge between generations, occurs when the baseline for 'normal' ecological conditions shifts with each successive generation due to a lack of intergenerational communication, preventing accurate perception of long-term change (Kahn & Friedman, 1995). Therefore, under generational amnesia, individuals must have an accurate perception of current conditions, and there must be age- or experience-related differences in perceptions of change (see Figure 1 for theoretical example). Papworth et al. (2009) also described a second mechanism, personal amnesia, in which age- or experience-related differences are not found; instead, people have an accurate perception of current conditions but believe past conditions to be the same as current conditions. This second mechanism is comparable to the cognitive bias named the 'recency effect' in which people tend to recall more recent information most effectively (Baddeley & Hitch, 1993). By comparison, 'change blindness' or 'anchoring' describes a tendency to remember the past better than recent conditions (Simons & Rensink, 2005).

Numerous studies have envisaged significant negative implications of SBS for conservation (e.g. Papworth et al., 2009; Pauly, 1995; Sheppard, 1995). A recent review by Soga and Gaston (2018) highlighted three potential impacts of SBS on conservation worldwide, at both the public and management level. First, SBS may have significant impacts on stakeholder interest, engagement and support for conservation due to an increased tolerance for degraded environmental conditions (Hayhow et al., 2019; Papworth et al., 2009). For example, in the field of restoration ecology, Wu, Petriello, and Kim (2011) suggested that stakeholders tend to only support environmental restoration efforts if they recognize the difference between past and current conditions, and hence can visualize the potential effectiveness of restorative action. Soga and Gaston (2018) similarly highlighted an ongoing 'extinction of experience' as both a direct driver and impact of SBS. This term was originally coined by

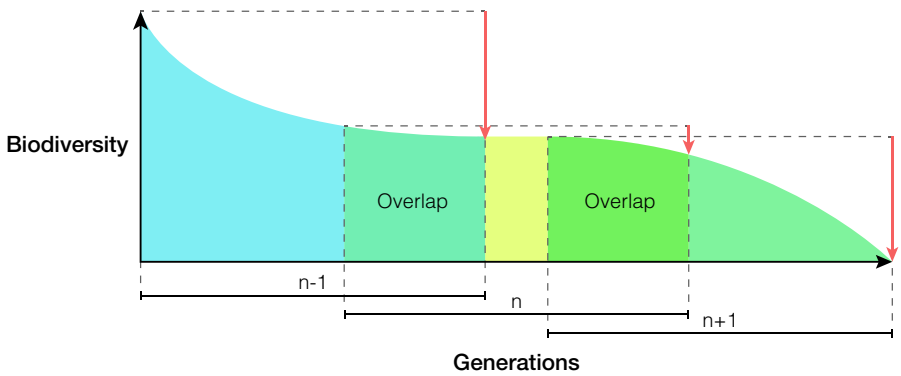

FIGURE 1 Theoretical depiction of generational amnesia occurring over three generations. Each generation (n) inhabits a window of time, which will overlap with previous and successive generations ($n - 1$ and $n + 1$) to provide the potential for intergenerational communication about biological condition, although this communication might not occur

Pyle (1993) to describe a lost connection to nature due to reduced daily contact with the natural environment (see also Miller, 2005). Many studies have reviewed the effects of culture and the media on the extinction of experience (Kesebir & Kesebir, 2017; Legagneux et al., 2018), while Soga, Gaston, Yamaura, Kurisu, and Hanaki (2016) evidenced the impacts on willingness to conserve, finding a positive association between children's passive and direct experience of nature and their support for biodiversity conservation in Japan.

Second, degraded expectations of desirable conditions may lead to less ambitious conservation and restoration targets within conservation management. Multiple demographic, cultural and personal traits are known to shape the lens through which change is observed (Bennett, 2016; Turvey et al., 2010). Managers might tend to compare current conditions to baselines set early in their careers, and thus underestimate long-term trends and limit personal perspectives of change to only recent reference points (Pauly, 1995; Vera, 2010).

Finally, the use of inappropriate baselines and unambitious targets alongside diminishing public motivation may lead to an ongoing complacency effect for conservation (Bilney, 2014), as both management and public stakeholders are more easily satisfied with current conditions and see little need for further conservation attention (Soga & Gaston, 2018). The potential effects of SBS should be taken into account when including local ecological knowledge (LEK, experience-based knowledge resulting from interactions with the local environment) in global research and policy (Turvey et al., 2014) due to its possible impact on tolerance for degraded conditions. LEK is increasingly recognized as a window through which to observe local-scale effects of global issues, from climate change (Herman-Mercer et al., 2016; Petheram, Zander, Campbell, High, & Stacey, 2010) to biodiversity loss (Rosa, Carvalho, & Angelini, 2014), and plays a significant role in global environmental assessments (IPBES, 2019; Tengö et al., 2017). There is, however, potential for the introduction of bias and uncertainty in the collection and interpretation of LEK, as poor recollection, reticence and psychological biases such as SBS may influence knowledge or recall of past conditions, highlighting the need to quantify the potential impacts of SBS on questionnaire-based data (Lozano-Montes, Pitcher, & Haggan, 2008; Turvey et al., 2010).

To demonstrate the existence of SBS empirically, scientific data on biological change must also be available and on an equivalent scale to individual perceptions of biological change (Papworth et al., 2009). This requirement necessitates the use of paired data techniques which can statistically compare the level of agreement between biological and social datasets at similar spatial and temporal scales (Gilchrist & Mallory, 2007; Huntington et al., 2004). A significant barrier to diagnosing SBS using this method is a lack of reliable ecological evidence of historical conditions or consistent long-term empirical data documenting change over multiple generations for many biological systems (Bonebrake, Christensen, Boggs, & Ehrlich, 2010; Campbell, Gray, Hazen, & Shackeroff, 2009; Guerrero-Gatica et al., 2019; Pinnegar & Engelhard, 2008). A recent meta-analysis by Guerrero-Gatica et al. (2019) noted that while many studies suggest the existence of SBS, many do not provide adequate empirical evidence of SBS to be conclusive, often because this was not the primary objective of the study (e.g. Ainsworth, Pitcher, & Rotinsulu, 2008; Kai et al., 2014; Lozano-Montes et al., 2008; Thurstan, Buckley, Ortiz, & Pandolfi, 2016). Therefore, often only age-related differences in participants' perceptions of local baselines are reported (Papworth et al., 2009), with little reference to equivalent biological data (Daw, 2010). For example, Saenz-Arroyo, Roberts, Torre, Cariño-Olvera, and Enríquez-Andrade (2005) conducted interviews across three generations of fishermen in the Gulf of California, and demonstrated that the oldest generation knew five times more species and could identify significant declines in four times the number of fishing sites than the youngest generation; these findings are indicative of generational amnesia, but in the absence of statistical comparison between paired biological and social data, they chiefly demonstrate that fisher experience (rather than perceptions) differed with age. On the other hand, Papworth et al. (2009) were first to consider SBS as a social phenomenon and provided the only empirical study to investigate the importance of multiple social and demographic factors influencing the existence of SBS, such as age, experience and birding interest. However, this study was conducted over a small geographical range and was limited by a short-term biological dataset, reducing overall power of the study and the number of explanatory variables used. Fernández-Llamazares et al. (2015) followed Papworth et al.'s (2009) definition framework using a larger sample size over a wider geographical range and provided the first empirical evidence that a lack of intergenerational communication can serve as a driving force behind SBS in local knowledge systems. However, limited availability of local biological data prevented direct geographical and chronological matching with interview-based perceptions of local change (Fernández-Llamazares et al., 2015).

We expand upon these studies using paired data techniques to statistically compare public perceptions of population abundance and long-term trends for 10 UK bird species against an independent long-term biological dataset. Our goal is to build upon previous studies and explore evidence for SBS using a large public sample. Furthermore, while previous studies have maintained a focus on finding evidence of SBS, we additionally aim to investigate the effects of both generational and personal amnesia on perceptions of the need for conservation attention for declining species. Online sampling techniques enabled access to a large sample of people in the United Kingdom, encompassing a wide range of socio-economic and demographic characteristics (Newing, 2010; Szolnoki & Hoffmann, 2013). Access to high-resolution longitudinal biological data spanning multiple generations (1966–2017) allowed focused geographical and chronological matching of individual perceptions and data on biological change. While our focus on birds was primarily driven by access to biological data, birds are a strong proxy for experience of nature in general, as birds and birdwatching are a culturally important and frequently experienced part of nature in the United Kingdom (Cox & Gaston, 2016).

Based on the criteria defined by Papworth et al. (2009), our aims are to:

1. Demonstrate the existence of biological change in a system, and that all participants have experience of this change.

2. Investigate evidence of generational amnesia as age- or experience-related differences in perception of change, and determine the key factors influencing level of agreement between participant perceptions and biological data.
3. Investigate evidence of personal amnesia through static perceptions of the biological system over time and higher agreement with recent biological data.
4. Investigate the effect of participant age and perception of population trend on individual perceptions of species of conservation concern and determine whether experience and personal perceptions of biological change influence conservation choices.

2 | METHODOLOGY

2.1 | Region selection

The combined BTO-JNCC Common Bird Census (CBC) and Breeding Bird Surveys (BBS) constitute a long-term census dataset from 1966 to 2017 (Harris et al., 2018). However, species abundance estimates for the combined census are not uniformly accurate as data collection methods changed after 1994 (transfer from CBC to BBS methodology) and survey effort varies both spatially and temporally according to surveyor availability (see Figure S1). Southeast England was selected as the area of highest density of BTO data (quantified using the number of BBS survey squares) and most reliable species population estimates in the United Kingdom (Gillings, Pearce-Higgins, Baillie, & Fuller, 2012). The study area consisted of 11 contiguous counties in Southeast England: Berkshire, Buckinghamshire, Cambridgeshire, Essex, Greater London, Kent, Hampshire and Isle of Wight, Hertfordshire, East and West Sussex and Surrey. These counties have similar land use and climate (Dessai & Sims, 2010), and most of the species included in this study are present throughout the region.

2.2 | Species selection

Eight regionally widespread bird species found in gardens and urban environments (sparrowhawk *Accipiter nisus*, goldfinch *Carduelis carduelis*, blue tit *Cyanistes caeruleus*, Eurasian jay *Garrulus glandarius*, barn swallow *Hirundo rustica*, house sparrow *Passer domesticus*, collared dove *Streptopelia decaocto*, Eurasian wren *Troglodytes troglodytes*) and two additional bird species present in non-urban environments across much of the study region (tree pipit *Anthus trivialis*, common cuckoo *Cuculus canorus*), were selected. The focus on the UK bird species seen regularly in garden and urban areas ensured that participants would be likely to have personal experience of the species. Species were selected because they are generally distinctive and easily recognizable even to non-trained observers, and

TABLE 1 Biological long-term population data extracted from the Woodward et al. (2018) dataset used to inform selection of the 10 bird species included in this study. Species listed in order of long-term species percentage population change, from most decreasing to most increasing. Data gathered from BTO BirdTrends (Woodward et al., 2018) and BTO BirdFacts (Robinson, 2005) representing all counties in England

UK common name	Scientific name	UK abundance (pairs in 2009)	Long-term change		Short-term change %	UK conservation status (2009)
			Time period	%	(2011–2016)	
Tree pipit	*Anthus trivialis*	88,000	1967–2016 (49 years)	−86	−4	Red
Common cuckoo	*Cuculus canorus*	15,000	1967–2016 (49 years)	−77	−11	Red
House sparrow	*Passer domesticus*	5.1 million	1977–2016 (39 years)	−70	−6	Red
Eurasian jay	*Garrulus glandarius*	170,000 (territories)	1967–2016 (49 years)	6	−5	Green
Swallow	*Hirundo rustica*	860,000 (territories)	1967–2016 (49 years)	4	−21	Green
Blue tit	*Cyanistes caeruleus*	3.6 million (territories)	1967–2016 (49 years)	24	−10	Green
Sparrowhawk	*Accipiter nisus*	33,000	1975–2016 (41 years)	98	−17	Green
Goldfinch	*Carduelis carduelis*	1.2 million	1967–2016 (49 years)	120	16	Green
Eurasian wren	*Troglodytes troglodytes*	7.7 million (territories)	1967–2016 (49 years)	128	47	Green
Collared dove	*Streptopelia decaocto*	980,000	1972–2016 (44 years)	306	−13	Green

because this species set varies in both abundance (as number of pairs or territories in 2014) and population trend (% annual change from 1970–2014), ranging from abundant and increasing to rare and declining (Woodward et al., 2018; Table 1).

2.3 | Questionnaire design and dispersion

A large-scale online questionnaire was conducted using the Qualtrics platform (version XM 2018), piloted with 12 participants from 11 to 13 July 2018 and live from 16 July to 9 September 2018. Ethical approval was granted by the Zoological Society of London (ZPD code: IOZ5) and Royal Holloway, University of London prior to piloting and data collection. All participants were asked to read a Participant Information Sheet before starting the online questionnaire and gave informed consent to participate in the study by choosing to begin the online questionnaire. Participants were acquired with non-random sampling methods, using emails and newsletters, blog posts and social media focused at academics, conservation charities and ornithological groups. Non-random sampling was used as the aim of the study was not to estimate population parameters but investigate relative differences in perceptions of bird populations, requiring a large participant sample size. The questionnaire was not incentivized and was advertised as a nature-orientated conservation study lasting up to 20 min, and so we assume that all participants had a prior vested interest in nature, environmental issues, ornithology or environmental research in general. As the geographical range of the biological dataset was limited to Southeast England, only participants from the same 10 counties were used in subsequent analyses. These participants were further subset based on residency (Table 4): those living in the region at the time of the survey (current), those living in the region at age 18 (past), and those living in the region in both periods. Results from all other participants (non-Southeast sample) and an additional Offline Southeast sample ($n = 79$) are available in Supporting Information.

Online questionnaires were used to collect data on personal perceptions of species abundance (as a rank order from most to least abundant across all species recognized) and trends (each species categorized as increasing, static or declining) between the past and present. Participation restrictions, instructions and a definition of 'local area' were included in the first page of the survey. Questions regarding 'the past' asked participants to remember environmental conditions when they were 18 years old. This age serves as a 'memory anchor', enabling easier recall of experience-based episodic memory (Havari & Mazzonna, 2015). Multiple explanatory variables were also collected (Table 2) including participant demographics (age and gender) and county (converted from postcode) of current and past residence (Office of National Statistics, 2018). Length of residency in past and current home county was collected to estimate consistency of experience and exposure to the same local bird population. Postcodes were also used to estimate current urbanity per county using the 2011 Rural-Urban Classification for Output Areas in England (Office of National Statistics, 2011). Bird species knowledge was estimated by testing participant ability to recognize all 10 species using photographs, and origin of knowledge was collected as a self-reported score from 0 to 100 across eight categories (personal experience, intergenerational communication, friends/other birders, education, books, TV, internet and other). Passive experience of nature was estimated using Likert-scale questions regarding the frequency of nature-based activities, and active birding experience was calculated as proportion of lifetime since year of first birding experience. Connectedness to nature was measured using a combination of two verified Nature Relatedness (NR) sub-scales, the NR-6 and NR-experience (Nisbet & Zelenski, 2013; Nisbet, Zelenski, & Murphy, 2009; Shanahan et al., 2017). Limiting the CTN section to 10 Likert-style questions minimized survey length but ensured valid measurement of nature connectedness. To assess participant perceptions of conservation concern for each species that was recognized by the participant, participants were asked to give a conservation attention score for each species between 0 and 5 for each species, in which species considered to be of highest priority gained a score of 5 (Jucker et al., 2018).

2.4 | Data analysis

Analyses were conducted using R software version 3.5.1 (R Core Team, 2019). Annual abundance and population trend per species per county were calculated from 1966 to 2017 using the rTRIM package (Pannekoek & van Strien, 2005; see Supporting Information for further details). For each participant, biological data were subset to include only the local county and year range from the year the participant was 18 years old to 2017, in order to create a paired biological and social dataset. Only species that were recognized by the individual participant were included.

To calculate agreement between individual perceptions and biological data for species abundance ranks, the perceived species abundance rank and ranked biological abundance were correlated using the Spearman Rank coefficient (Table 3). A scoring system was created to measure the degree of agreement between biological trends and perceived trends, with scores summed across all species to produce an overall score per participant (Table 3).

An information theoretic model selection and averaging approach was used to compare the significance of multiple predictors in explaining the incidence of SBS, explained by the response variables in Table 3. Predictors are: age, gender, connectedness to nature, proportion of life in current and past postcode, urbanity of current postcode, proportion of life as a birder now and at age 18, number of species recognized and correctly named, and frequency of walking in local area (see Table 2 for list of predictors in each model). Predictor variables were selected a priori for each model to represent original expectations from the literature and to prevent overparameterization. Predictor collinearity was evaluated using variance-inflation factor (vif) values (Zuur, Ieno, & Elphick, 2010). Where one or more terms in the unweighted global model had more than 1 *df*, the correlated predictor variables were identified using the generalized variance inflation factor ($\text{gvif}^{(½\ df)}$). In all cases, all variables had a vif or $\text{gvif}^{(½\ df)}$ value smaller than 2, indicating a very low

TABLE 2 Participant-specific predictor variables used to create candidate global models to determine participant ability to perceive current and past bird species abundance and long-term species trends

Predictor category	Predictors	Response variable			Data format	Trait measured	Literature support/example(s)
		Current	Past	Trend			
Demographic/ personal	Age	✓	✓	✓	Continuous (years)	Cumulative exposure/ experience throughout lifetime	Saenz-Arroyo et al. (2005) and Thurstan et al. (2016)
	Gender	✓	✓	✓	Categorical—Male/Female/NA	N/A	Stern, Dietz, and Kalof (1993) and Aswani, Lemahieu, and Sauer (2018)
	Connectedness to nature	✓		✓	Combined NR-6 and NR-Experience (score range: 0–50)	Current connectedness to nature using NR scales	Nisbet et al. (2009) and Shanahan et al. (2017)
Location	Proportion of life in current postcode	✓		✓	Proportion of total age (0–1)	Measure of exposure to current local bird populations	Papworth et al. (2009) and Thurstan et al. (2016)
	Proportion of life in past postcode		✓		Proportion of age before 18 years old (0–1)	Measure of exposure to past local bird populations	
	Urbanity of current postcode	✓		✓	Score adapted from ONS 2011 Rural Urban Classifications (1 = mostly rural, 5 = urban city)	Experience of local bird populations Access to nature	Papworth et al., (2009) and Soga and Gaston (2016)
Active experience/ knowledge	Proportion of life as a birder	✓		✓	Proportion of total age (0–1) Non-birders = 0	Measure of cumulative active experience of birds and interest in birding	Thurstan et al. (2016)
	Proportion of life as a birder by age 18		✓		Proportion of age by 18 years old (0–1) Non-birders at 18 = 0	Measure of interest in birding and birding experience by the age of 18	
	Number of species recognized	✓	✓	✓	Number of species recognized from photographs (score range: 0–10)	Measure of current interest in birds and a proxy for cumulative learned experience	Tulving (1989a, 1989b)
	Number of species correctly named	✓	✓	✓	Number of species named by matching name to photo (score range: 0–10)	Measure of current knowledge of bird species and proxy for level of interest	
Passive experience/ exposure	Frequency of walking in local area	✓		✓	Likert scale (0 = never, 5 = everyday)	Measure of recent exposure to local birds as passive experience	Braun and Dierkes (2016)

TABLE 3 Methods used to match and analyse biological and social data for the three response variables (current abundance rank, past abundance rank and trend score)

Response variable	Biological data	Questionnaire data	Comparison method
1. Current abundance rank agreement	Ranked current abundance of all recognized species	Perceived current ranked abundance of all recognized species from questionnaire	Spearman's rho
2. Abundance rank agreement at age 18	Ranked abundance of all recognized species in year participant was 18 years old	Perceived ranked abundance at age 18 of all recognized species from questionnaire	Spearman's rho
3. Trend agreement score (past to current)	Each species classified as increasing (positive trend, *SE* not including 0), decreasing (negative trend, *SE* not including 0) or static trend (falling between positive and negative *SE*) per county	Species classified as increasing Species classified as static Species classified as declining	Scoring system: 2, biological trend in county matches participant reported trend; 1, reported trend is incorrect by one level (e.g. increasing vs. static); 0, opposite trend reported

level of collinearity, so all variables were retained (Zuur et al., 2010). Correlation matrices were also performed to assess the multicollinearity for each sample, specifically for age and multiple measures of experience (see Supporting Information for full results).

Linear models were executed for the current and past rank abundance response variables, and a generalized linear model (GLM) with a Poisson transformation and log-link was selected for the trend accuracy response (St-Pierre, Shikon, & Schneider, 2018; Zeileis, Kleiber, & Jackman, 2008). Unstandardized predictors were used in all cases to directly examine the relationships between each predictor and the response variable (see Supporting Information for full model selection and averaging methods). Results were compared to the non-Southeast England sample to ensure that the main sample was representative of the UK in general, and to the Offline sample to ensure that online questionnaire methods gained the same result as traditional methods (see Tables S8–S18). The effect of SBS on perceptions of conservation need was investigated for the three most declining species included in the study (house sparrow, common cuckoo and tree pipit). Ordinal logistic regression was used to investigate the effect of age and perceived trend on perceived need for conservation attention (Agresti, 2018). To check the proportional odds ratio assumption, a Chi-square test was used to test for a significant difference in the AIC value for a multinomial logit model and the ordinal logistic regression model for each species (Fox & Monette, 2002).

3 | RESULTS

A full overview of the size and demographic and geographic distribution of participants is given in Table 4. A heat map showing the distribution of participants within the study region is given in Figure S2.

3.1 | Section 1: Demonstrating environmental change in the system

For each participant, the correlation coefficient (rho) across all species was calculated between the relative rank abundance from BTO data when they were 18 and the relative rank abundance from current BTO data (Figure 2). Two participants, both aged 18–30, did not experience biological change (Rho = 1), and were therefore excluded from all subsequent analyses. For the remaining participant sample, a correlation of participant age against biological change shows that older people experienced more biological change than younger people (Spearman rank, rho = −0.75, $p < 0.001$; Figure 2).

3.2 | Section 2: Evidence for generational amnesia

In order to demonstrate generational amnesia, individuals must have a similar, accurate perception of current conditions and show an age- or experience-related difference in perceptions of change in the system. We found no evidence of an age-related difference in current abundance rank agreement (−0.002 ± 0.002, $p = 0.288$; Figure 3a), as all age groups were found to have similar perceptions of current ecological conditions. Participants with a greater personal knowledge of bird species, measured as an ability to recognize a greater number of species, showed higher current rank agreement (0.085 ± 0.02, $p < 0.001$).

However, perceptions of past conditions (at age 18) did vary significantly with age. Our results indicate that older respondents have greater abundance rank agreement at age 18 than younger participants (0.007 ± 0.002, $p = 0.002$; Figure 3b), despite older participants experiencing greater levels of biological change during their lifetimes (Figure 2). We can therefore infer that, even though older participants had a longer time over which to remember, they recall past conditions that are more consistent with the biological dataset than those recalled by younger people.

Trend agreement scores did not vary significantly with age (−0.001 ± 0.002, $p = 0.62$). Higher trend agreement scores were only significantly explained by a greater number of species recognized (0.106 ± 0.022, $p < 0.001$), as trend scores were limited by the number of species each participant recognized. However, linear regression analysis found a significant positive interaction between number of species recognized and amount of knowledge gained

TABLE 4 Sample size, demographics and location information for participants residing in the study region, which is further subset into participants living in the region at the time of the survey (current), at age 18 (past) and in both time periods. For these participants the upper age limit is limited to 70 years old, in line with the available biological data

		Age distribution		Gender ratio (%)			Years in postcode ($M \pm SD$)	
Sample	*n*	Range	$M \pm SD$	Male	Female	N/A	Current	At age 18
Main sample—Southeast England								
All ages	330	19–81	49.3 ± 15.2	39.1	60.9	0	16.0 ± 13.5	14.8 ± 8.6
Current	308	19–70	48.2 ± 13.8	37.7	62.3	0	14.8 ± 12.4	–
Past (age 18)	282	20–70	48.8 ± 14.0	40.8	59.3	0	–	14.8 ± 8.5
Both current and past	201	19–70	46.8 ± 14.6	37.8	62.2	0	16.1 ± 13.2	14.8 ± 8.9

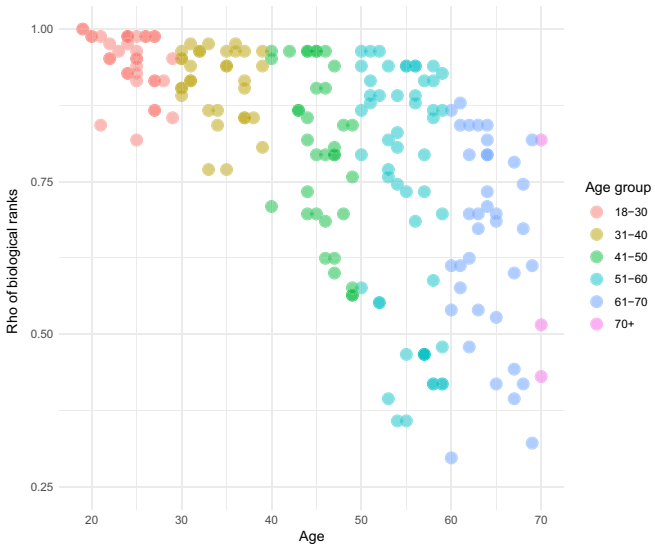

FIGURE 2 Participant age against the correlation of biological abundance rank at time of survey and at age 18 per participant across all species. Only participants living in the study region at age 18 and at the time of the survey are included ($n = 201$)

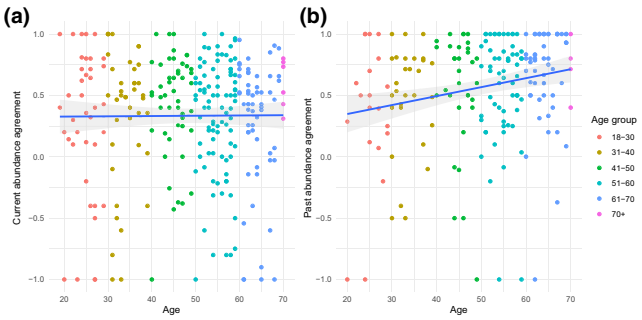

FIGURE 3 Agreement between species relative rank in participant perceptions and biological datasets: (a) in the present; (b) at age 18

from personal experience (5.68 ± 1.40, $p < 0.001$) and from books (3.77 ± 1.40, $p < 0.001$).

3.3 | Section 3: Evidence for personal amnesia

Personal amnesia was investigated for participants who experienced biological change and lived in the study region both at age 18 and at the time of the survey ($n = 199$). Of this subset, 37 participants (18.6%) had a static perception of species abundance ranks, ranking species in the same order of relative abundance at both age 18 and in the present (Spearman's rho = 1; Figure 4). The mean age of these participants was 45.1 years, and 73% had some experience of birdwatching. These participants were separated into two categories representing two contrasting cognitive biases: anchoring and recency effect. Four participants (aged 18–40) showed signs of personal amnesia (a form of recency effect) as they reported a static perception of species abundance in both time periods, and their perceptions of current conditions showed complete agreement with the current biological data (rho = 1).

3.4 | Section 4: Effect of SBS on perceptions of conservation attention

Analyses included only participants living in the study region both at age 18 and at the time of the survey, and that had experience of biological change ($n = 199$). Participants were only asked about species selected as recognized earlier in the questionnaire. The effect of SBS on perceived need for conservation (measured as conservation attention) was investigated for the three most declining species in the study (house sparrow, common cuckoo and tree pipit), which vary in relative abundance (see Table 1: house sparrow > tree pipit > common cuckoo). In all cases, the proportional odds assumption was met. Results for all species can be found in Table S20.

The house sparrow was awarded a mean conservation attention score of 3.71 out of 5. Higher scores were significantly predicted by increasing age, with the predicted odds of awarding a higher score increasing by 3.6% for each year of increasing participant age, independent of perceived trend (odds ratio = 1.036, $p = 0.031$, $n = 170$; Figure 5). However, despite an age effect appearing more evident for participants perceiving a declining or increasing trend (Figure 5), no significant interaction effects of age and trend were found. The

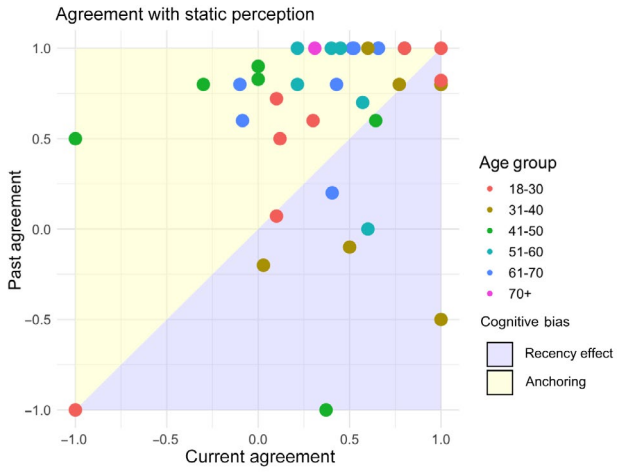

FIGURE 4 Participants with a static perception of species abundance ranks from age 18 to the present ($n = 37$). Participants within the blue area demonstrate the recency effect, reporting higher agreement with current biological conditions and which they also believe to have been the same in the past. Participants within the yellow area show signs of anchoring, in which people show higher agreement with past biological conditions and which they believe are still the same in the present

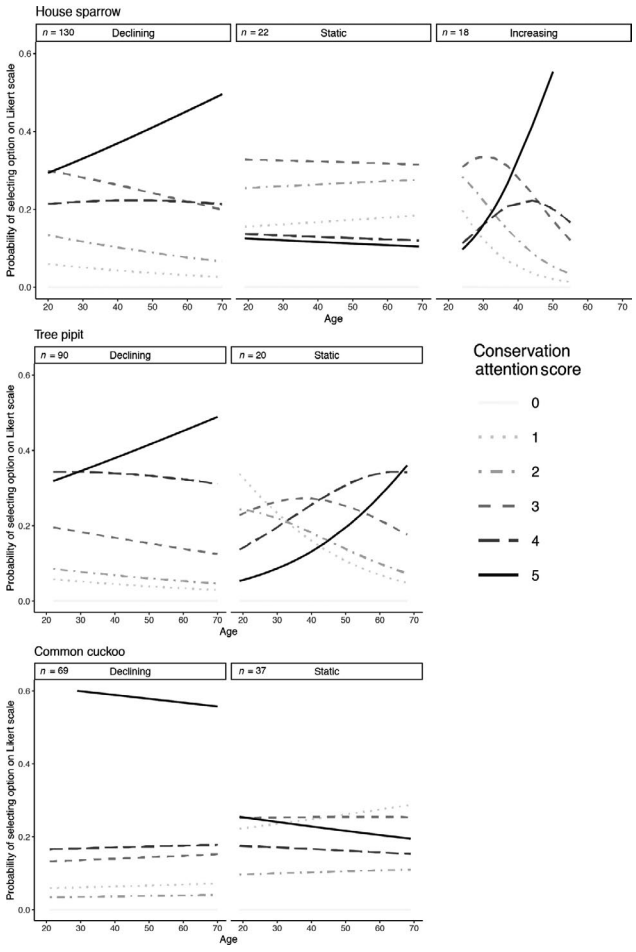

FIGURE 5 Interaction effects of perceived species trends and participant age on perceptions of conservation need, represented by conservation attention score

tree pipit was awarded a mean score of 3.62. The odds of awarding a higher score increased by 3.1% for each year of increasing participant age, independent of perceived trend (odds ratio = 1.031, $p = 0.028$, $n = 110$). Perceived trend also had a significant effect (Figure 5), as participants who perceived a declining population trend were 85.0% more likely to award a higher score than those who perceived a static population trend (odds ratio = 0.150, $p = 0.048$, $n = 110$). However, no significant interaction effects of age and trend were found. For the common cuckoo, mean score was highest at 3.83, but there were no significant effects of age or perceived trend.

4 | DISCUSSION

According to the conceptual framework defined by Papworth et al. (2009), two criteria are essential to find evidence of SBS: biological change must be present in a system, and differences in perceptions of change must be in line with biological data (Papworth et al., 2009). In this study, we substantiate both of these criteria, and provide empirical evidence for generational amnesia and limited evidence for personal amnesia in the study sample. Generational amnesia was identified as we found an age-related difference in perceptions of past ecological conditions, as older participants recall past conditions which are more consistent with the biological dataset than younger people. Therefore, the baseline against which participants perceive bird species abundance appears to be shifting with each successive generation. Evidence of personal amnesia was found in some younger participants, characterized as an accurate perception of current conditions which are believed to have been the same in the past. Our results therefore support the expectation that younger, less experienced people are less aware of historical ecological conditions and show greater evidence of SBS. Most importantly, we find evidence of SBS in relation to perceptions of conservation need, demonstrating a negative impact of generational amnesia on conservation support for species in decline. Older people were found to give significantly higher conservation attention scores than younger people for two out of three declining bird species included in this study, representing potential negative impacts on future conservation support for these species.

The first criterion required for SBS is to ensure that every participant is exposed to, and has experience of, biological change in the system (Papworth et al., 2009). We restricted analyses to the 99% of participants who had experienced change in local bird populations since they were 18 years old, and found that older people had experienced more biological change than younger people in the study region (Figure 2). The second criterion for SBS is to provide evidence that any perceived change is consistent with these biological data. Furthermore, in order to demonstrate the existence of generational amnesia, perceptions of change must be related to age or experience. First, we confirmed that all age groups reported similar current rank abundance agreement, representing no significant age-related difference in perceptions of current conditions

(Figure 3a). However, with regard to perceptions of past ecological conditions, older people reported significantly higher abundance rank agreement at age 18 than younger people (Figure 3b), despite having to recall information from further in the past. This finding provides empirical evidence of generational amnesia, as the perceptions of younger, less experienced participants had significantly lower agreement with biological data than did perceptions of older participants. This is especially significant, as it would generally be expected that a person's ability to remember the past accurately should diminish with age, a process known as cognitive ageing (Salthouse, 2004; Tulving, 1989a).

One explanation for our findings may be generational differences in cultural backgrounds during childhood, including varying levels of contact with nature. These differences may have caused different awareness of the natural world, although at the time of the study we found no age-related difference in frequency of experience of nature or connectedness to nature scores (see Supporting Information). However, we also found that across all age groups, participant perceptions generally had higher agreement with biological data in the past than the present, contrary to what might be expected given the relative clarity of recent episodic memories (Murre & Dros, 2015). While the acute mechanisms of human memory are still intensely debated, evidence suggests that long-term memory has higher capacity and can be more resilient to decay as it is contextualized and reinforced by cumulative experience and understanding (Cowan, 2008). Increased past agreement may also be the result of so-called 'reminiscence bumps' which are thought to enable the recall of older memories with greater accuracy (Jansari & Parkin, 1996). Building upon the review by Rost (2018), further research into the psychological mechanisms driving SBS are needed with focus on differences in the storage, decay and contamination of long- and short-term memory.

Following the original definition and investigation of personal amnesia by Papworth et al. (2009), we are the only subsequent study to suggest evidence of the phenomenon. However, personal amnesia is very rare across our study system, occurring in only four participants, or 2% of those living in the study region at both survey time points who experienced biological change, suggesting that it may constitute an individual rather than a wider-scale collective phenomenon (cf. Papworth et al., 2009). If subsequent studies suggest that personal amnesia is a greater problem than indicated here, it could be combatted using increased communication and education within the community, as well as with historical records and photographs (Papworth et al., 2009; Thurstan et al., 2016).

While the definition of SBS describes an age- or experience-related degradation of 'normal' expected conditions, arguably the most discussed aspect of SBS is the consequential threat posed for conservation support, uptake and long-term success (Pauly, 1995; Soga & Gaston, 2018; Soga et al., 2016). In other words, if people do not realize the extent of ecological decline due to SBS, does this negatively influence their conservation choices in the present? Our study is the first to explore this theory empirically, identifying a species-specific difference in the impacts of SBS on perceived need for conservation for two declining species, the house sparrow and tree pipit (see Figure 5). The potential for a negative impact of generational amnesia was identified as we found an age-related difference in the perception of a need for conservation action for both of these species, with older people significantly more likely to perceive a greater need for conservation attention than younger people. This result seems logical in the context of an ongoing extinction of experience, in which younger people are increasingly disconnected from nature (Soga & Gaston, 2016; Soga et al., 2016); however, this is contrary to the increasingly common media portrayal of younger people as pro-environmental advocates around the world (Gardner, Struebig, & Davies, 2020; Sullivan & Syvertsen, 2019). Bickford, Posa, Qie, Campos-Arceiz, and Kudavidanage (2012) emphasized that while environmental literacy may be improving, a lack of formal environmental education in school curricula may continue to widen the gap between people and nature, and prevent the development of long-term pro-environmental behaviour. However, no age-related effect was found for the common cuckoo, despite this species earning the highest mean conservation attention score of the three declining species. Furthermore, looking across all species included in this study, a similar age-related trend was found for the blue tit and goldfinch, indicating that perceptions of conservation need vary by age irrespective of species' population trend (see Table S20). This result may indicate that the impacts of SBS on conservation attention are species-specific, an area to be explored in further research.

Our results also indicate a possible conservation impact of species-specific personal amnesia, as participants who perceived a static population trend for the tree pipit awarded lower conservation scores, even though all three species show continuous population decline throughout the study period. In this case, an effect of personal amnesia on perceptions of conservation need was only identified for the tree pipit, as participants who perceived a static trend were significantly less likely to award higher conservation attention scores than participants who perceived a declining trend. Further study is also needed to elucidate whether biological factors such as charisma, distinctiveness and residency influence the incidence and impacts of SBS at the species-level (Courchamp et al., 2018).

Evidence of the presence and impacts of SBS within a large public sample highlights the potential magnitude of SBS as a widespread concern, holding the power to impact conservation understanding, uptake and support on a global scale (Bonebrake et al., 2010; Guerrero-Gatica et al., 2019; Humphries & Winemiller, 2009). In terms of conservation management, our study emphasizes the potential impacts of SBS on the strength of conclusions for conservation decision-making, especially when informed by anecdotal perceptions of long-term biological change (Anadón, GimÉnez, Ballestar, & Pérez, 2009; McClenachan, 2009; Thurstan et al., 2016). SBS has been cited among biases impacting LEK, which must be considered when LEK is utilized as a source of data for conservation research and management (Fernández-Llamazares et al., 2015; Kai et al., 2014). For example, Turvey et al. (2010) emphasized the

potentially rapid loss of cultural and linguistic knowledge across an entire community due to SBS, even for charismatic megafaunal species such as the Yangtze River dolphin *Lipotes vexillifer*.

However, as recommended by Soga and Gaston (2018), identification of the cause(s) of SBS enables the development of strategies to combat its negative impacts. Although neither current rank agreement nor trend agreement score was explained by age, results of model selection highlighted the role of species knowledge (measured as the ability to recognize a greater number of species from photographs) as the most important variable for predicting both current abundance agreement and ability to perceive long-term trends. As a measure of retained visual knowledge, higher species recognition is likely to originate from personal experience or intergenerational communication. However, we found a significant positive relationship between number of species recognized and knowledge gained from personal experience and from books. Our evidence of generational amnesia across an entire ecological community highlights a need for a shift of focus towards the promotion of intergenerational communication and knowledge-sharing about the UK bird species declines (Fernández-Llamazares et al., 2015; Kai et al., 2014). The importance of knowledge for accurate perception of long-term trends indicates the potential role of active involvement of LEK in combating SBS, through opportunities such as citizen science (Schuttler et al., 2018) or wildlife-based tourism (Ballantyne, Packer, & Hughes, 2009; Powell, Brownlee, Kellert, & Ham, 2012). Public involvement not only aids in preventing the extinction of experience (Louv, 2005; Soga & Gaston, 2016), another proposed cause of SBS, but also provides the dual-benefit of gathering extra data and increasing public knowledge to continually improve the quantity and quality of available biological datasets for further SBS research (Soga & Gaston, 2018).

There are three key limitations in this study that could be addressed in future research. First, although we present a case study of SBS, this is constrained to the United Kingdom and focuses only on birds; this is primarily due to the limited availability of long-term longitudinal biological datasets required to assess perceptions of change spanning multiple generations, a limitation highlighted by previous studies (e.g. Fernández-Llamazares et al., 2015; Thurstan et al., 2016). Wider availability of high-resolution biological datasets on an international scale could provide broader evidence for SBS, providing scope for more paired studies comparing cultural and ecological data. Further studies should look towards large-scale, broad-topic investigations of SBS spanning multiple aspects of environmental concern (e.g. perceptions of climate change; urbanization) in order to gain a full picture of the effects of SBS on environmental concern. Second, our study design used non-random sampling methods. However, the aim of this study was to investigate the processes and relationships between individuals, rather than attempting to estimate population-level parameters, and our methodology ensured the geographical and chronological matching of a large social sample against a consistent long-term biological dataset. Finally, while many previous SBS studies used face-to-face interview techniques, which can provide lower non-response rates (Heerwegh & Loosveldt, 2008) and more representative results than online surveys (Szolnoki & Hoffmann, 2013), the use of online questionnaires is increasingly recognized as a fast, cheap and convenient method to collect data (Wright, 2005). In the case of this study, we found the results of the online survey were in agreement with a smaller face-to-face sample (see Tables S2–S19 for results of model selection and averaging for all samples). However, the face-to-face sample in this study had a small sample size ($n = 79$), and further studies should aim to use a large interview sample to ensure data quality.

As several previous studies have recommended (Papworth et al., 2009; Thurstan et al., 2016; Turvey et al., 2010), caution must be taken when using retrospective accounts of change to investigate evidence of long-term change. We provide evidence to suggest that SBS can impact personal and generational perceptions of past, present and future biological conditions, and confirm previous concerns that SBS can negatively impact perceptions of conservation need for species in decline (Soga & Gaston, 2018). In the current era of rapid ecological degradation, the potential implications of SBS are momentous for many disciplines interested in perceptions of change over time, from conservation (Papworth et al., 2009) to climate change (Moore, Obradovich, Lehner, & Baylis, 2019). Looking toward environmental restoration, we must also recognize the issue of 'lifting baselines', which equally threatens our ability to recognize positive change and learn from the past, as previously degraded conditions are forgotten and improved conditions are considered normal (Roman, Dunphy-Daly, Johnston, & Read, 2015). Empirical evidence of the prevalence and impacts of SBS within the general public highlights the scope of the issue and the urgent need to promote greater awareness throughout conservation science. Future efforts to explore and unearth new, reliable data sources are needed to enable a better understanding of long-term change and allow the setting of more appropriate restoration targets. Meanwhile, further research into species-related and cultural variation in evidence for SBS is critical to improve and shape the work of conservationists, educators and policy- and decision-makers alike to improve frameworks for combatting the continuation of the phenomenon (Soga & Gaston, 2018). As a generational phenomenon, SBS is likely to continue as a pervasive issue in conservation. However, by understanding the extent, pattern and rate at which our own actions are degrading the natural environment, and by communicating this knowledge, we might hope to tackle SBS in the future.

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CONFLICT OF INTEREST

The authors declare no conflict of interests.

AUTHORS' CONTRIBUTIONS

L.P.J., S.K.P. and S.T.T. conceived the project idea, developed methods and discussed results; D.M. provided biological data and analytical advice; L.P.J. collected questionnaire data and performed analyses. All authors contributed to and authorized the final manuscript.

DATA AVAILABILITY STATEMENT

All biological data (provided by the British Trust for Ornithology) and anonymized social data collected using online questionnaires are available from Royal Holloway Digital Repository (https://doi.org/10.17637/rh.12640244.v1; Jones & Papworth, 2020). Please contact corresponding authors for more information.

ORCID

Lizzie P. Jones https://orcid.org/0000-0001-5881-2181
Sarah K. Papworth https://orcid.org/0000-0002-8746-1912

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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