

Shifting baseline syndrome: causes, consequences, and implications

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With ongoing environmental degradation at local, regional, and global scales, people's accepted thresholds for environmental conditions are continually being lowered. In the absence of past information or experience with historical conditions, members of each new generation accept the situation in which they were raised as being normal. This psychological and sociological phenomenon is termed shifting baseline syndrome (SBS), which is increasingly recognized as one of the fundamental obstacles to addressing a wide range of today's global environmental issues. Yet our understanding of this phenomenon remains incomplete. We provide an overview of the nature and extent of SBS and propose a conceptual framework for understanding its causes, consequences, and implications. We suggest that there are several self-reinforcing feedback loops that allow the consequences of SBS to further accelerate SBS through progressive environmental degradation. Such negative implications highlight the urgent need to dedicate considerable effort to preventing and ultimately reversing SBS.

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The magnitude, rate, and extent of the changes that humans have made to the Earth's natural environment are hard to grasp. Quantitative estimates abound. For instance, over the past several decades, almost one-quarter of all primary production has been appropriated for human consumption (Haberl *et al.* 2007), one-half of the planet's wildlands have been lost (Ellis *et al.* 2010), and wildlife populations worldwide have fallen by one-half (Dirzo *et al.* 2014). However, these estimates are quite abstract for many people, and discussion on these topics often references personal – usually local-scale – anecdotes and examples of environmental change (Al-Abdullrazzak *et al.* 2012; Ziembicki *et al.* 2013; Jabado *et al.* 2015). Unfortunately, there are reasons to believe that such contextualizing can serve to understate the changes that have taken place.

In a nutshell:

- Shifting baseline syndrome (SBS) describes a gradual change in the accepted norms for the condition of the natural environment due to lack of past information or lack of experience of past conditions
- Consequences of SBS include an increased tolerance for progressive environmental degradation, changes in people's expectations as to what is a desirable state of the natural environment (ie one that is worth protecting), and the establishment and use of inappropriate baselines for nature conservation, restoration, and management
- Researchers and policy makers must focus more attention and effort on understanding and planning how best to limit and reduce SBS

Daniel Pauly elucidated the concept of “shifting baseline syndrome” (SBS) in a seminal essay that placed it in a fisheries context (Pauly 1995). He pointed out that fishers and marine scientists tend to perceive faunal composition and stock sizes at the beginning of their careers as the unaffected baseline condition against which catch size is subsequently judged, and that this is likely to result in a gradual acceptance of the loss of fish species (Pauly 1995). Thus, a species that was widespread and abundant centuries ago may have experienced a large population decline over the intervening period, but most current researchers incorrectly presume that the population status in recent decades is the appropriate baseline (Bonebrake *et al.* 2010). By way of a terrestrial example, consider Japan, one of the world's most heavily forested countries, with more than 70% of its land area covered by forest. For those who were born five or ten generations ago, old-growth (primary) forests were the most predominant component of the landscape (Figure 1), but modified forests (eg timber forests) gradually expanded across the landscape with each passing generation, and by the year 2000, most old-growth forests had been transformed into human-modified ones (Figure 1), establishing a new norm. In the field of psychology, SBS is also referred to as “environmental generational amnesia” (Kahn 2002), whereby each generation grows up being accustomed to the way their environment looks and feels, and so, in a system experiencing progressive impoverishment, they do not recognize how degraded it has become over the course of previous generations.

Simply put, SBS involves a gradual change in the accepted norms for the condition of the natural environment due to a lack of experience, memory, and/or knowledge of its past condition. This implies that with ongoing global and regional deterioration in the natural environment, our baseline standards for environmental

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health will continue to decline, which represents an enormous challenge for the conservation, restoration, and management of that environment. Despite this prognosis, however, environmental scientists have to date paid markedly little attention to SBS, and although evidence of the occurrence of this phenomenon is rapidly accumulating, its nature (especially causes and consequences) and extent are still poorly understood. Whereas SBS is likely to be associated with a wide range of current global environmental issues, such as defaunation (Lotze and Worm 2009; Corlett *et al.* 2013), loss of natural habitats and processes (Humphries and Winemiller 2009), and increased levels of pollution (Lyytimäki 2013), debate on this topic has thus far largely centered on fisheries (Sáenz-Arroyo *et al.* 2005; Ainsworth *et al.* 2008; Lozano-Montes *et al.* 2008). Moreover, little discussion has focused on how SBS is best prevented or limited. In this review, we present evidence of SBS; describe a conceptual framework for understanding its causes, consequences, and implications; and make several strategic recommendations required to reduce and ultimately reverse SBS. We also outline several key areas of future research that could improve understanding of SBS. For this overview, we did not perform a formal systematic literature search because research on this topic is too fragmented and transdisciplinary (appearing in multiple guises) for such an approach to be feasible. The material we draw on was identified through a purposefully broad search (using a combination of Web of Science, Google Scholar, and Google) of both peer-reviewed literature and other sources to minimize publication bias.

Evidence

There is an increasing body of empirical evidence that indicates the occurrence of SBS, the majority of which comes from fisheries science (Figure 2). For example, in the Raja Ampat archipelago of Eastern Indonesia, which has experienced a precipitous decline in biodiversity over the past 30 years, Ainsworth *et al.* (2008) observed that younger fishers were able to recall less past abundance of wildlife than older fishers and therefore perceived a lower degree of population decline (Figure 2, a–d). In the upper Gulf of California, Mexico, where a marked depletion of fish stocks has occurred due to intense fishing and habitat degradation, Sáenz-Arroyo *et al.* (2005) reported that the number of fishing sites and fish species that younger fishers said were depleted was approximately one-quarter of that reported by older fishers (Figure 2, e and f). Likewise in Tanga, Tanzania, Katikiro (2014) showed that, compared to older fishermen, younger fishers were less likely to perceive that the current size of the fish catch has declined and that fish stocks are being overexploited.

Evidence of SBS has also been documented in other contexts (Figure 3). In a rural village in Yorkshire, UK, Papworth *et al.* (2009) found that younger residents were

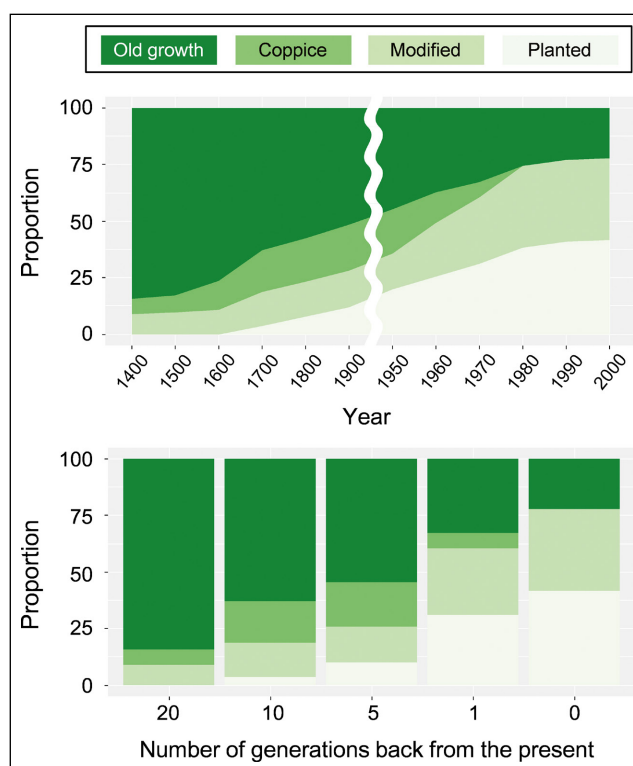


Figure 1. Six hundred years of change in the forest environment of Japan. (a) The compositional change in the types of forests (old-growth, coppice, modified, and planted forests). A modified natural forest is a natural forest with clearly visible human activities, such as saw-timber natural forest and abandoned coppice. (b) The composition of the forest environment at five different time points, consisting of 0, 1, 5, 10, and 20 generations back from the present; the period of one generation was defined as 30 years. Reproduced with permission from Yamaura *et al.* (2012).

less aware of changes in the abundance of common bird species over the past 20 years than were older residents (Figure 3a). In the Beni, Bolivia, where rapid defaunation has occurred due to deforestation, habitat degradation, and hunting, Fernández-Llamazares *et al.* (2015) observed that the perceived number of locally extinct tree and fish species, along with the magnitude of changes in composition of local wildlife (birds and game vertebrates), were lower for younger respondents than for older ones (Figure 3, b–e). In the Seward Peninsula, Alaska, where rapid environmental change in a hydrological system is occurring (eg groundwater re-charge and river run-off), Alessa *et al.* (2008) found that younger people were less aware of changes in the availability of the local water resource and in water quality (Figure 3, f and g). Finally, Herman-Mercer *et al.* (2016), who conducted interviews among indigenous communities in subarctic Alaska, reported that the levels of respondents' perceptions of climate change vary between generations, with older generations identifying more overall change (eg increased temperatures, decreased snow cover) than younger ones (Figure 3h).

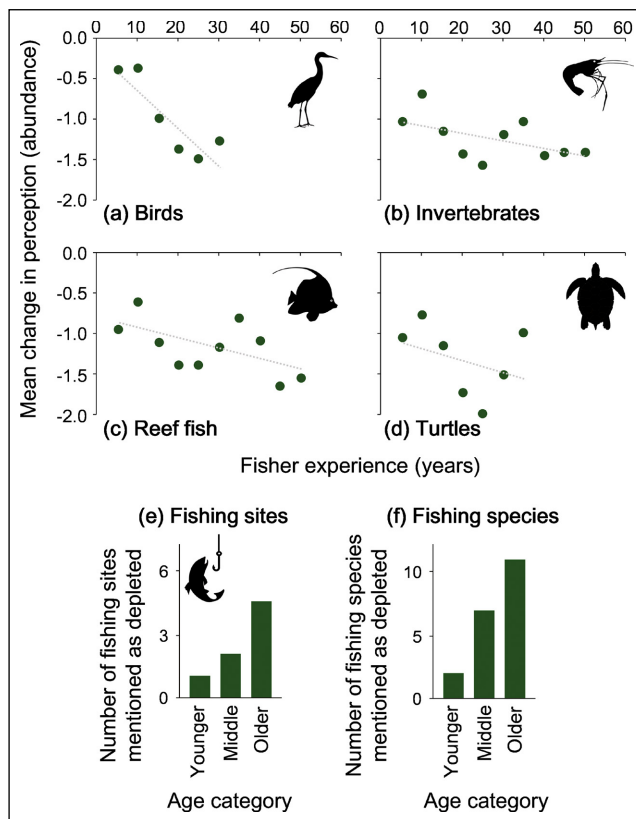


Figure 2. Empirical evidence suggesting the occurrence of SBS as reported in fisheries science. As compared to older ones, younger fishers (a–d) perceived a lesser degree of population decline of wildlife species (birds, invertebrates, reef fish, and turtles) and (e and f) mentioned a lower number of fishing sites and fish species as depleted. Data from (a–d) Indonesia (Ainsworth *et al.* 2008) and (e and f) Mexico (Sáenz-Arroyo *et al.* 2005).

Causes

Essentially, SBS occurs when conditions of the natural environment gradually degrade over time, yet people (eg local citizens, natural resource users, policy makers) falsely perceive less change because they are not aware of, or fail to recall accurately, what the natural environment was like in the past. SBS may therefore have three major causes: (1) lack of data on the natural environment, (2) loss of interaction with the natural environment, and (3) lack of familiarity with the natural environment (Figure 4). We do not regard environmental degradation per se as a cause of SBS, although it is obviously a key factor (Papworth *et al.* 2009).

Lack of data on the natural environment

Arguably, the fundamental driver of SBS is the lack, or paucity, of relevant historical data on the natural environment. Most time-series data are relatively recent, and this is often particularly true for those regions

with the highest levels of biodiversity and abundance of life (Bonebrake *et al.* 2010). A recent analysis revealed that the majority of biodiversity monitoring schemes in Europe were initiated late in the 20th century, well after anthropogenic impacts had already reached more than half of their current magnitude (Figure 5a; Mihoub *et al.* 2017). Without reliable historical environmental data, people cannot infer whether long-term environmental changes have occurred, nor to what extent, and so they have little choice but to define baselines according to their own knowledge and experiences; clearly, from a both scientific and a practical standpoint, there is no single “correct” or “desirable” baseline (ie the state of the natural environment that we should target for conservation and restoration), and identifying appropriate baselines is a substantial challenge (Campbell *et al.* 2009; Lotze and Worm 2009).

One might of course counter that the availability of (even very good) empirical evidence has not always been sufficient to convince people of historical trends in environmental conditions. Recent examples of belief- rather than evidence-based environmental policy making raise the possibility that SBS could even accelerate in an age of increasing data availability (compare with Sutherland and Wordley 2017).

Loss of interaction with the natural environment

Across much of the world, people, especially children, currently spend considerably less time interacting with the natural environment than did previous generations (Soga and Gaston 2016; Soga *et al.* 2018) (Figure 5b). Louv (2005) coined the term “nature-deficit disorder” to describe the increasingly common tendency for children to have little contact with nature and to spend more time indoors with television, computers, and video games. This progressive loss of human–nature interactions – the “extinction of experience” (Pyle 1993; Miller 2005) – is another key driver of SBS. Direct interaction with natural environments is important, and perhaps essential, for people to recognize (ie store an appropriate memory of) the current condition of these environments. In a system experiencing progressive impoverishment, therefore, extinction of experience is likely to accelerate the loss of their memories of earlier (more intact) environmental states.

There are two major factors that lead to extinction of experience (Soga and Gaston 2016). The first is the loss of opportunity to interact with nature, which is driven by the loss of natural environments and by the higher proportion of the global human population living in urban areas, where opportunities for interacting with nature are limited (Miller 2005). The second factor is the reduced inclination to engage with nature (Lin *et al.* 2014), which is associated with the rise in alternative leisure-time activities (eg social media, television,

the internet), and the possibility of vicarious interactions with nature (eg through books, television; although this type of nature experience can also foster people's emotional connection to nature; Soga *et al.* 2016).

Loss of familiarity with the natural environment

As well as direct engagement with the natural environment, familiarity with it is also crucial for people to accurately assess its condition. One of the key measures of people's familiarity with the natural environment is their level of natural history knowledge (eg identification skills for plants and animals in the surrounding environment; Bebbington 2005; Leather and Quicke 2010), yet this type of knowledge is increasingly disappearing from the populace, especially in developed countries (Pilgrim *et al.* 2008; Tewksbury *et al.* 2014). Indeed, exposure to natural history in the educational sector has also declined considerably in many parts of the developed world over the past several decades (Figure 5c; Leather and Quicke 2010; Tewksbury *et al.* 2014). This rapid decline in people's natural history knowledge can also accelerate the occurrence and progress of SBS, since those who have a poor understanding of natural history are less likely to recognize changes in the condition of the natural world (Dallimer *et al.* 2012; Schwartz *et al.* 2014), and may have lower perceived environmental baselines.

Of course, there are still groups of people in society who are exceptionally familiar with the natural environment, including ecologists, nature reserve managers, nature guides, and amateur naturalists. Such people have great potential for fostering natural history knowledge through educational, recreational, and cultural programs (eg environmental education in schools, tour guides in natural history museums and national parks), and could therefore play an important role in preventing SBS (see the section "Preventing SBS" below).

Consequences

SBS has three key consequences (Figure 4). The first, and most immediate, is an increased societal tolerance for progressive environmental degradation, including declining wildlife populations, loss of natural habitats, and increasing pollution. People generally base their evaluation of environmental degradation on how different current environmental conditions are from their own "cognitive baselines" (Lozano-Montes *et al.* 2008); therefore, as they become more accustomed to a degraded environment, they will perceive future environmental degradation as less important.

Second, SBS is also likely to alter people's expectations as to what is a desirable (ie worth protecting) state of the natural environment. This is not surprising as most people's beliefs about what is a "good" or "healthy" condition

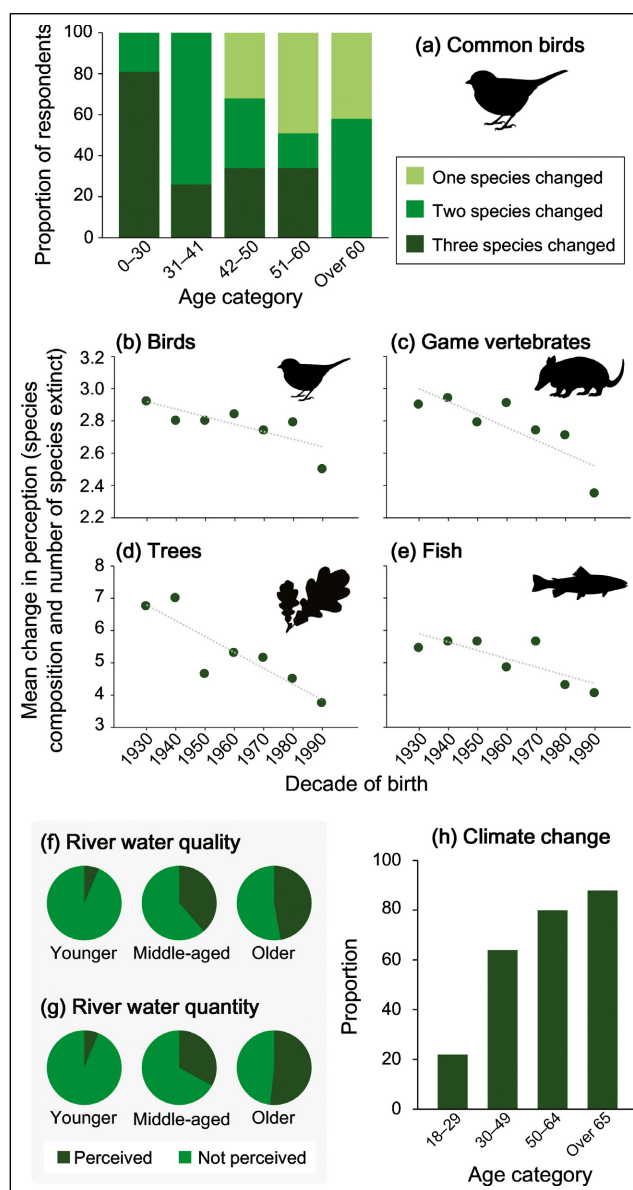


Figure 3. Empirical evidence suggesting the occurrence of SBS reported in studies other than fisheries science. Younger residents, compared to older ones, perceived (a) a lesser degree of population changes among common bird species; (b–e) a smaller number of locally extinct tree and fish species and magnitude of changes in composition of local wildlife (birds and game vertebrates); (f and g) a lesser degree of change in the availability of the local water resource and water quality; and (h) a smaller degree of climate change (eg increased temperatures, decreased snow cover). Data from (a) the UK (Papworth *et al.* 2009), (b–e) Bolivia (Fernández-Llamazares *et al.* 2015), (f and g) the US (Alessa *et al.* 2008), and (h) the US (Herman-Mercer *et al.* 2016).

for the natural environment will be shaped by their personal experience, particularly during childhood, and earlier states cannot be recalled (Kahn 2002). In north-central Arizona, there has been considerable change in the structure of ponderosa pine (*Pinus ponderosa*) forests (increasing tree density and mature trees) over the past

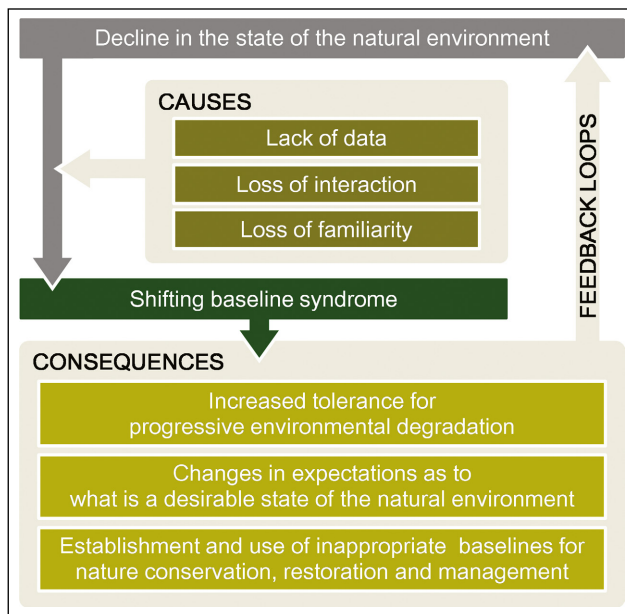


Figure 4. The causes and consequences of SBS, which can result in a feedback loop in which the consequences accelerate further SBS. Note that environmental degradation itself does not automatically result in SBS.

century due to fire exclusion. Ostergren *et al.* (2008) determined local residents' attitudes toward forest restoration programs aimed at decreasing forest tree density, such as mechanical thinning and prescribed burning. Their results showed that rural residents (ie those living near forests) were less likely to agree to restoration actions, from which the researchers inferred that rural residents "are accustomed to relatively dense forest stands and may therefore have difficulty perceiving a heavily thinned forest as a 'healthy' forest".

Third, if policy makers and resource managers have false perceptions of past environmental conditions, they may set inappropriate targets for environmental conservation, restoration, and management programs (Humphries and Winemiller 2009; Bonebrake *et al.* 2010; Bilney 2014). The Dogger Bank in the North Sea, a candidate Special Area of Conservation under the European Union Habitats Directive, represents a good example of this issue. Although historical records indicate that the Dogger Bank has been subject to anthropogenic activities since before the 16th century and that there have been prolonged declines in fish abundance, conservation targets for marine protected area management in this region have been developed using only present-day environmental data (within the last decade) (Plummeridge and Roberts 2017), which may hinder the establishment of suitable (ie more ambitious) conservation/restoration targets. Unfortunately, given the long history of anthropogenic impacts on the Earth's ecosystems and the paucity of relevant historical data, this problem may be common in many parts of the world (Lotze and Worm 2009; Bilney 2014; Mihoub *et al.* 2017).

Feedback loops

There are several feedback loops which allow the consequences of SBS to further accelerate SBS through progressive environmental degradation (Figure 4). First, increased tolerance for incremental environmental degradation is likely to diminish people's motivation to support, and participate in, conservation programs aimed at preventing further degradation of the natural environment. To quote Papworth *et al.* (2009), "if you are unaware of the change around you then how can you be expected to engage with the conservation of that environment?" Second, changes in public expectations for what constitutes a healthy original state of the natural environment may affect people's decision-making processes regarding its conservation and restoration (Ostergren *et al.* 2008), which may in turn affect the future environmental state (note that this feedback loop can occur even if people have high levels of motivation to conserve the natural environment). Third, and similar to the second point, if policy makers and resource managers use improper baselines as a target for nature conservation, restoration, and management, desirable conservation outcomes will not be achieved because they are more likely to be satisfied with, and complacent about, their current conservation efforts. Consequently, they may be less motivated to undertake further actions to improve the condition of that environment ("conservation complacency"; Bilney 2014).

Preventing SBS

We propose four – not mutually exclusive – key strategic recommendations to prevent and ultimately reverse SBS.

Restore the natural environment

Because degradation of the natural environment is a primary reason for SBS, environmental restoration is critically important in its prevention (albeit, in principle, SBS can occur not only when the natural environment is progressively degrading but also when it is improving ("lifting baselines"; Roman *et al.* 2015). One of the most obvious approaches is rewilding (ie restoring wild and nearly wild environments), which provides something resembling historical baselines for those whose perceptions are potentially affected by SBS. The notion of rewilding is becoming increasingly popular and is being implemented as a major conservation approach, especially in Europe and North America (Lorimer *et al.* 2015). For instance, the Rewilding Europe initiative aims to restore one million hectares of land, as well as populations of large, native herbivores, across 10 different locations in Europe by 2022 (www.rewildingeurope.com). Rewilding efforts are also going on in urban areas; one of the most advanced of these projects is Zealandia, a 225-ha ecosanctuary in the city of Wellington, New Zealand

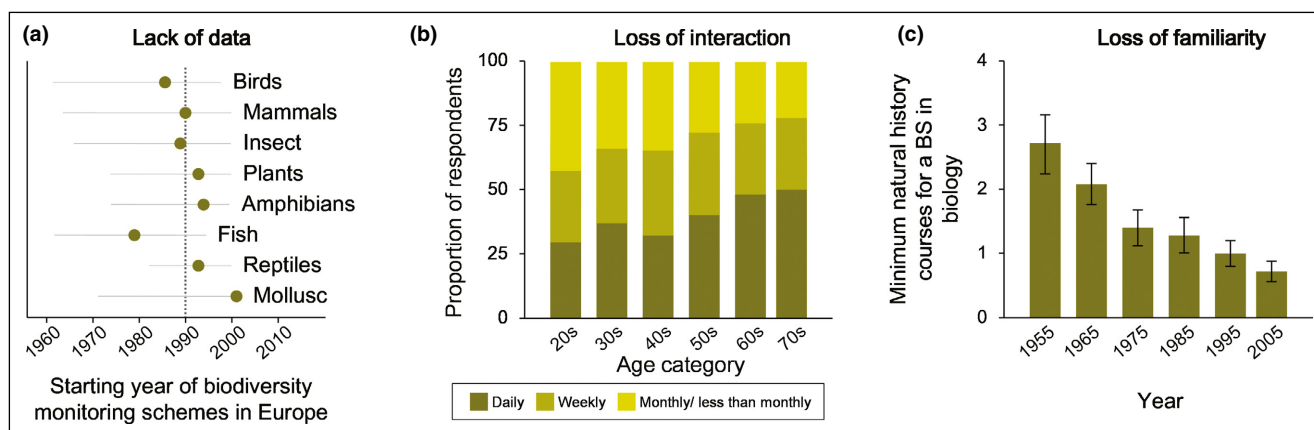


Figure 5. Evidence demonstrating (a) the lack of data on the natural environment, (b) the loss of interaction with the natural environment, and (c) a loss of familiarity with the natural environment. Panels show (a) the starting year of biodiversity monitoring schemes in Europe (solid circles: median values; horizontal bars: 1st and 3rd quartiles; vertical dashed line: the overall median value across eight taxonomic groups); (b) the age-related decline in people's direct experience of nature during childhood (visiting neighborhood natural environments) in Japan ($n = 1147$); and (c) a 50-year change in the minimum number of natural history-related courses required for a BS degree in biology in US institutions (median values with standard deviation). Data from (a) Mihoub *et al.* (2017), (b) Soga *et al.* (2018), and (c) Tewksbury *et al.* (2014).

(www.visitzealandia.com), where the intention is to restore the land as much as possible to its pre-human state.

Monitor and collect data

Further progression of SBS may be mitigated through the accumulation of data about the natural environment (Lister and Climate Change Research Group 2011; Mihoub *et al.* 2017). One powerful approach for collecting large-scale and long-term environmental data is citizen science, which encourages public participation and collaboration in scientific research (Amano *et al.* 2016; McKinley *et al.* 2017). There are currently several large-scale citizen-science projects of this kind; for instance, eBird, which is one of the largest, has collected more than 300 million bird observations across the world, allowing scientists to develop predictive models of bird distribution and abundance (www.ebird.org/content/ebird). It is notable that these projects contribute not only to accumulating environmental data but also to reducing the extinction of experience and strengthening people's connection with nature.

In addition to monitoring the current environment, reconstructing historical conditions using existing data is also valuable for preventing SBS (Lotze and Worm 2009; Bonebrake *et al.* 2010; Gatti *et al.* 2015). Recent progress in molecular and isotope techniques, combined with statistical modeling, has increasingly allowed accurate and detailed reconstruction of past environmental conditions (Christensen *et al.* 2014; Matsuzaki and Kadoya 2015). For example, Christensen *et al.* (2014) developed a statistical model that predicts changes in global fish biomass, analysis of which indicated that the biomass of predatory fish (ie the large-bodied fishes that humans tend to eat) has declined by two-thirds over the past 100 years.

Collecting large quantities of high-quality, reliable data about the natural environment is not going to be enough to prevent SBS. Recent scholarship in conservation science has argued that many practitioners and decision makers are reluctant to use such scientific evidence for the implementation of conservation and management policies, the so-called "research–implementation gap" (Sutherland and Wordley 2017; Toomey *et al.* 2017). Therefore, the key challenge in preventing SBS is how to address the gap between research and practice, and how to encourage policy makers to participate in evidence-based decision making – as opposed to acting on assumptions – about environmental issues.

Reduce the extinction of experience

Promoting positive interactions with natural environments helps to limit SBS, as studies have shown that firsthand experiences with nature (eg visiting urban greenspaces and observing local fauna and flora) improves people's level of understanding of the condition of the natural environment (Lindemann-Matthies 2002; Schwartz *et al.* 2014).

There are two main approaches to increasing people's direct experiences with nature (see Soga and Gaston 2016). The first is to expand their opportunities to interact with nature by providing more natural environments in the vicinity of local neighborhoods, since there is a positive relationship between the amount of nearby natural environments and the frequency of their use (Soga *et al.* 2015). The second is to increase people's inclination and desire to interact with natural environments (ie increasing nature orientation), which may possibly be achieved through environmental education and social marketing programs. Although the role of nature orienta-

tion on people's use of natural environments is still poorly understood, recent studies suggest that its contribution is comparable to, and sometimes stronger than, that of opportunity (Lin *et al.* 2014). Therefore, to limit the extinction of experience, both the opportunity and the orientation components need to be enhanced simultaneously (Soga and Gaston 2016).

Educate the public

Education has two important roles in limiting or preventing SBS: first, it can increase and reinforce people's familiarity with the natural environment (ie increasing their natural history knowledge), and second, it can provide them with accurate knowledge about its past and current condition.

Although much attention is focused on classroom education, these activities can be promoted and actively practiced by various individuals and organizations (eg natural history researchers, museums, ecotourism tour guides, botanical gardens, and zoological parks). Shwartz *et al.* (2012) reported that participating in a 1-day educational program in urban gardens increased adults' knowledge and awareness of the local fauna and flora. As such, future education policies should target adults as well as children, which could in turn create a positive "spillover" effect to children.

Future research directions

There are several key areas in which research efforts could be focused to improve understanding of SBS. First, it is crucial to determine under what conditions, and over what spatial scales, SBS is likely to occur and to progress more rapidly. Indeed, while evidence for SBS is accumulating, there is currently a clear bias toward studies reporting fishers' perceptions of changes in fishery resources (Sáenz-Arroyo *et al.* 2005; Ainsworth *et al.* 2008; Lozano-Montes *et al.* 2008). Given that the presence and magnitude of SBS might depend on the contexts, settings, and cultures in which it is examined, future studies should investigate SBS across a variety of environmental conditions, ecosystems, stakeholders, and populations, as well as over different spatial scales (from local to regional to national levels). Second, from a conservation viewpoint, there is an urgent need to amass more detailed information on how and to what extent SBS actually affects the implementation process, and eventual outcomes, of conservation and environmental management policies. Although it has long been thought that SBS deters policy makers and resource managers from attempting ambitious conservation goals (Humphries and Winemiller 2009; Bilney 2014; Plummeridge and Roberts 2017), there is currently no quantitative analysis on this issue. Third, very little is known about the nature and strength of the feedback loops of SBS (Figure 4). In this review we identified

three key feedback pathways by which the consequences of SBS could accelerate further SBS through progressive environmental degradation, but it is still unclear how they operate, interact with each other. More empirical research, particularly from long-term studies is required to fill this knowledge gap. Finally, the abovementioned research directions will require a multidisciplinary approach that integrates social science, psychology, politics, and environmental science.

Conclusions

At a time when the Earth's ecosystems are being degraded and lost at an accelerated pace, the existence of SBS poses clear challenges for environmental conservation and management; it could be one of the fundamental reasons that our society tolerates the continuing destruction and degradation of the natural environment and does not always understand and support the need for conservation and restoration efforts to protect our ecosystems. SBS is potentially widespread and is associated with various major environmental issues, including defaunation, loss of natural habitats and processes, natural resource depletion, and increased levels of pollution. These implications highlight an urgent need to focus more attention and efforts on planning how best to prevent SBS, as well as to communicate to a broad audience – including policy makers, resource managers, conservationists, and educators – the importance of this phenomenon. Understanding and successfully addressing SBS will contribute greatly to the long-term conservation and sustainable management of the Earth's natural systems on which we all depend.

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References

- Ainsworth CH, Pitcher TJ, and Rotinsulu C. 2008. Evidence of fishery depletions and shifting cognitive baselines in Eastern Indonesia. *Biol Conserv* 141: 848–59.
- Al-Abdulrazzak D, Naidoo R, Palomares MLD, and Pauly D. 2012. Gaining perspective on what we've lost: the reliability of encoded anecdotes in historical ecology. *PLoS ONE* 7: e43386.
- Alessa L, Kliskey A, Lammers R, *et al.* 2008. The Arctic Water Resource Vulnerability Index: an integrated assessment tool for community resilience and vulnerability with respect to freshwater. *Environ Manage* 42: 523.

- Amano T, Lamming JD, and Sutherland WJ. 2016. Spatial gaps in global biodiversity information and the role of citizen science. *BioScience* 66: 393–400.
- Bebbington A. 2005. The ability of A-level students to name plants. *J Biol Educ* 39: 63–67.
- Bilney RJ. 2014. Poor historical data drive conservation complacency: the case of mammal decline in south-eastern Australian forests. *Austral Ecol* 39: 875–86.
- Bonebrake TC, Christensen J, Boggs CL, and Ehrlich PR. 2010. Population decline assessment, historical baselines, and conservation. *Conserv Lett* 3: 371–78.
- Campbell L, Gray N, Hazen E, and Shackeroff J. 2009. Beyond baselines: rethinking priorities for ocean conservation. *Ecol Soc* 14: art14.
- Christensen V, Coll M, Piroddi C, et al. 2014. A century of fish biomass decline in the ocean. *Mar Ecol-Prog Ser* 512: 155–66.
- Corlett RT. 2013. The shifted baseline: prehistoric defaunation in the tropics and its consequences for biodiversity conservation. *Biol Conserv* 163: 13–21.
- Dallimer M, Irvine KN, Skinner AM, et al. 2012. Biodiversity and the feel-good factor: understanding associations between self-reported human well-being and species richness. *BioScience* 62: 47–55.
- Dirzo R, Young HS, Galetti M, et al. 2014. Defaunation in the Anthropocene. *Science* 345: 401–06.
- Ellis EC, Klein Goldewijk K, Siebert S, et al. 2010. Anthropogenic transformation of the biomes, 1700 to 2000. *Global Ecol Biogeogr* 19: 589–606.
- Fernández-Llamazares Á, Díaz-Reviriego I, Luz AC, et al. 2015. Rapid ecosystem change challenges the adaptive capacity of local environmental knowledge. *Global Environ Chang* 31: 272–84.
- Gatti G, Bianchi CN, Parravicini V, et al. 2015. Ecological change, sliding baselines and the importance of historical data: lessons from combining observational and quantitative data on a temperate reef over 70 years. *PLoS ONE* 10: e0118581.
- Haberl H, Erb KH, Krausmann F, et al. 2007. Quantifying and mapping the human appropriation of net primary production in Earth's terrestrial ecosystems. *P Natl Acad Sci USA* 104: 12942–47.
- Herman-Mercer N, Matkin E, Laituri M, et al. 2016. Changing times, changing stories: generational differences in climate change perspectives from four remote indigenous communities in Subarctic Alaska. *Ecol Soc* 21: art28.
- Humphries P and Winemiller KO. 2009. Historical impacts on river fauna, shifting baselines, and challenges for restoration. *BioScience* 59: 673–84.
- Jabado RW, Al Ghais SM, Hamza W, and Henderson AC. 2015. The shark fishery in the United Arab Emirates: an interview based approach to assess the status of sharks. *Aquat Conserv* 25: 800–16.
- Kahn Jr PH. 2002. Children's affiliations with nature: structure, development, and the problem of environmental generational amnesia. In: Kahn Jr PH and Kellert SR (Eds). *Children and nature: psychological, sociocultural, and evolutionary investigations*. Cambridge, MA: MIT Press.
- Katikiro RE. 2014. Perceptions on the shifting baseline among coastal fishers of Tanga, northeast Tanzania. *Ocean Coast Manage* 91: 23–31.
- Leather SR and Quicke DJ. 2010. Do shifting baselines in natural history knowledge threaten the environment? *Environmentalist* 30: 1–2.
- Lin BB, Fuller RA, Bush R, et al. 2014. Opportunity or orientation? Who uses urban parks and why. *PLoS ONE* 9: e87422.
- Lindemann-Matthies P. 2002. The influence of an educational program on children's perception of biodiversity. *J Environ Educ* 33: 22–31.
- Lister AM and Climate Change Research Group. 2011. Natural history collections as sources of long-term datasets. *Trends Ecol Evol* 26: 153–54.
- Lorimer J, Sandom C, Jepson P, et al. 2015. Rewilding: science, practice, and politics. *Annu Rev Env Resour* 40: 39–62.
- Lotze HK and Worm B. 2009. Historical baselines for large marine animals. *Trends Ecol Evol* 24: 254–62.
- Louv R. 2005. *Last child in the woods*. Chapel Hill, NC: Algonquin Books.
- Lozano-Montes HM, Pitcher TJ, and Haggan N. 2008. Shifting environmental and cognitive baselines in the upper Gulf of California. *Front Ecol Environ* 6: 75–80.
- Lyytimäki J. 2013. Nature's nocturnal services: light pollution as a non-recognised challenge for ecosystem services research and management. *Ecosyst Serv* 3: e44–48.
- Matsuzaki SIS and Kadoya T. 2015. Trends and stability of inland fishery resources in Japanese lakes: introduction of exotic piscivores as a driver. *Ecol Appl* 25: 1420–32.
- McKinley DC, Miller-Rushing AJ, Ballard HL, et al. 2017. Citizen science can improve conservation science, natural resource management, and environmental protection. *Biol Conserv* 208: 15–28.
- Mihoub JB, Henle K, Titeux N, et al. 2017. Setting temporal baselines for biodiversity: the limits of available monitoring data for capturing the full impact of anthropogenic pressures. *Sci Rep-UK* 7: 41591.
- Miller JR. 2005. Biodiversity conservation and the extinction of experience. *Trends Ecol Evol* 20: 430–34.
- Ostergren DM, Abrams JB, and Lowe KA. 2008. Fire in the forest: public perceptions of ecological restoration in north-central Arizona. *Ecol Restor* 26: 51–60.
- Papworth SK, Rist J, Coad L, and Milner-Gulland EJ. 2009. Evidence for shifting baseline syndrome in conservation. *Conserv Lett* 2: 93–100.
- Pauly D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. *Trends Ecol Evol* 10: 430.
- Pilgrim SE, Cullen LC, Smith DJ, and Pretty J. 2008. Ecological knowledge is lost in wealthier communities and countries. *Environ Sci Technol* 42: 1004–09.
- Plummeridge AA and Roberts CM. 2017. Conservation targets in marine protected area management suffer from shifting baseline syndrome: a case study on the Dogger Bank. *Mar Pollut Bull* 116: 395–404.
- Pyle RM. 1993. *The thunder tree: lessons from an urban wildland*. Boston, MA: Houghton Mifflin.
- Roman J, Dunphy-Daly MM, Johnston DW, and Read AJ. 2015. Lifting baselines to address the consequences of conservation success. *Trends Ecol Evol* 30: 299–302.
- Saenz-Arroyo A, Roberts C, Torre J, et al. 2005. Rapidly shifting environmental baselines among fishers of the Gulf of California. *P Roy Soc B* 272: 1957–62.
- Shwartz A, Cosquer A, Jaillon A, et al. 2012. Urban biodiversity, city-dwellers and conservation: how does an outdoor activity day affect the human–nature relationship? *PLoS ONE* 7: e38642.
- Shwartz A, Turbé A, Simon L, and Julliard R. 2014. Enhancing urban biodiversity and its influence on city-dwellers: an experiment. *Biol Conserv* 171: 82–90.
- Soga M and Gaston KJ. 2016. Extinction of experience: the loss of human–nature interactions. *Front Ecol Environ* 14: 94–101.
- Soga M, Gaston KJ, and Kubo T. 2018. Cross-generational decline in childhood experiences of neighborhood flowering plants in Japan. *Landscape Urban Plan* 174: 55–62.
- Soga M, Gaston KJ, Yamaura Y, et al. 2016. Both direct and vicarious experiences of nature affect children's willingness to conserve biodiversity. *Int J Environ Res Public Health* 13: 529.
- Soga M, Yamaura Y, Aikoh T, et al. 2015. Reducing the extinction of experience: association between urban form and recreational use of public greenspace. *Landscape Urban Plan* 143: 69–75.

- Sutherland WJ and Wordley CF. 2017. Evidence complacency hampers conservation. *Nature Ecol Evol* 1: 1215–16.
- Tewksbury JJ, Anderson JG, Bakker JD, *et al.* 2014. Natural history's place in science and society. *BioScience* 64: 300–10.
- Toomey AH, Knight AT, and Barlow J. 2017. Navigating the space between research and implementation in conservation. *Conserv Lett* 10: 619–25.

- Yamaura Y, Oka H, Taki H, *et al.* 2012. Sustainable management of planted landscapes: lessons from Japan. *Biodivers Conserv* 21: 3107–29.
- Ziembicki MR, Woinarski JCZ, and Mackey B. 2013. Evaluating the status of species using Indigenous knowledge: novel evidence for major native mammal declines in northern Australia. *Biol Conserv* 157: 78–92.



FrontiersEcoPics

Oases for insects

Under the parched soil of the hyper-arid central Namib Desert lies a water source waiting to be exploited by thirsty insects. Desert fauna must be resourceful when seeking out water, which in this case has been unearthed by termites. The harvester termite *Hodotermes mossambicus*, whose range extends throughout the semi-arid regions of southern Africa, forms colonies that continually expand their vast subterranean nests. During the excavation process, they often dump piles of damp soil on the ground surface, the dampness probably arising from underground water associated with the nearby ephemeral Kuiseb River. Wet soil dumps were never observed farther than about 200 meters from the dry river channel.

Various insects, including several dipterans, the tenebrionid beetle *Zophosis moralesi*, and the dune ant *Camponotus detritus*, were all seen exploiting the moisture from these soil dumps (see <https://bit.ly/2pOb0nR> for a video of this previously undocumented behavior). Indeed, *C detritus*, which are usually very aggressive, may become transfixed on the damp soil, ignoring both human presence and any nearby termites, including *H mossambicus* soldiers which, in turn, ignore the ants and let them drink unhindered.



Insects drinking from damp soil dumps were observed near the Gobabeb Research Centre during daylight hours from February to October 2017, when average soil temperatures ranged between 21.9° and 35.3°C (71.4° and 95.5°F). As long as the termite mounds remained active (ie soil and other material being discharged from the nest), then fresh damp soil would often appear aboveground, serving as a valuable resource for a wide variety of other desert-dwelling insects.

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