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Topical Review

Non-material contributions of wildlife to human well-being: a systematic review

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Abstract

Wildlife has important effects on human well-being, ranging from beneficial contributions to life threatening interactions. Here, we systematically reviewed publications of both positive and negative non-material contributions of wildlife to people (WCP) for different taxonomic groups (birds, mammals, reptiles and amphibians) and dimensions of human well-being such as health, social well-being, identity and spirituality. Overall, the majority of studies reported negative WCP, such as feelings of insecurity or injuries. However, over the last decade the number of publications on positive WCP such as good mental health, positive emotions or learning increased, mainly in the Global North. These spatial and temporal patterns may hint towards normative influences that drive the relative proportion of reported WCP. However, these normative influences are not yet well understood and future research should examine potential biases by conducting policy assessments or surveys among researchers to understand drivers and motivations behind their research questions. We found almost no joint assessments of positive and negative WCP for any wildlife species. Studies also showed taxon-specific differences in WCP outcomes, with predominantly positive WCP reported for birds and predominantly negative WCP published for mammals or reptiles. Physical health was the most dominant aspect of well-being studied and affected by WCP while other well-being dimensions such as social well-being, learning or identity were less frequently covered in the literature. Future studies should jointly evaluate positive and negative effects of wildlife on human well-being and implement multi-taxon approaches to obtain a more balanced and comprehensive understanding of WCP. These assessments of WCP will provide actionable science outcomes that will shape human-wildlife coexistence and promote human health and well-being.

1. Introduction

Wildlife is important for human well-being (Díaz et al. 2006, Mace et al. 2012) and plays a major role in many people’s lives (Mackerron and Mourato 2013, Cox and Gaston 2016, Chang et al. 2017). Wildlife’s influence on human well-being can be described through ‘Nature’s Contributions to People (NCP)’, which are categorized as non-material, material and regulating NCP (Díaz et al. 2018). All three types of NCP affect multiple aspects of human well-being such as access to food, water, shelter, health, education, social relationships, security or freedom of choice (Díaz et al. 2015, 2018). Several studies have
summarized the material and regulating NCP of wildlife to human well-being (Inskip and Zimmerman 2009, Alves 2012, Harrison et al 2014, Sandifer et al 2015, Marchini and Crawshaw 2015). This review focuses on non-material NCP of wildlife, with a focus on vertebrate species in terrestrial and aquatic environments (i.e. mammals, birds, reptiles and amphibians).

Non-material NCP cover the non-material dimensions of people's quality of life and affect, among others, subjective physical or psychological experiences, learning and inspiration or people's identities (Díaz et al 2018). They directly relate to cultural ecosystem services as defined in the ecosystem service framework (e.g. Milcu et al 2013, Haines-Young and Potschin 2018). In this study, we therefore refer to both cultural ecosystem services and non-material NCP of wildlife and also include studies published under the umbrella of cultural ecosystem services or outside of both frameworks. In the following, we use the term 'Wildlife's Contributions to People (WCP)' throughout the remainder of the manuscript. Examples for WCP are experiences of wildlife which can, among other things, improve health, foster spiritual and inspirational experiences or support social relationships (Ramstad et al 2007, Dallimer et al 2012, Bryce et al 2016, Penteriani et al 2016, Forrester et al 2018).

While both the ecosystem service literature and the NCP framework have acknowledged the existence of positive and negative impacts of nature on human well-being (Pascual et al 2017, Díaz et al 2018), past research within these frameworks has mostly emphasized on positive effects (Shackleton et al 2016, Vaz et al 2017). For wildlife, however, many studies do not refer to the NCP or ecosystem service frameworks and reports of negative effects are actually frequent. As an example, studies on human-wildlife coexistence usually report negative outcomes where people come to harm economically, physically or mentally (e.g. Inskip and Zimmerman 2009, Barua et al 2013, Marchini and Crawshaw 2015). Studies that report positive effects of wildlife show that, for instance, experiencing wildlife can improve psychological and mental health, and has a recreational value (Farber and Hall 2007, Dallimer et al 2012, Arbieu et al 2017, Cox et al 2017b). Most importantly, with regard to non-material NCP, only few reviews have examined both, the positive and negative WCP in combination, and those that exist usually cover only few aspects of WCP (Harrison et al 2014, Pascual-Rico et al 2020) or just focus on a specific group of wildlife species such as scavengers or carnivores (Moleón et al 2014, Expósito-Granados et al 2019, Lozano et al 2019).

Several conceptual frameworks exist that describe the mechanisms or channels of how nature and ecosystems can influence human well-being (e.g. Russell et al 2013, Markeych et al 2017). These concepts can also be used to disentangle the different types of wildlife experiences which lead to the positive and negative WCP that influence human well-being. Here we adopted the framework of (Russell et al 2013), which is particularly suited to characterize non-material linkages between humans and nature, and adapted the four proposed channels Interaction, Living Within, Perceiving and Knowing to describe how people experience wildlife (Box 1).

**Box 1. Channels describing the non-material linkages between humans and wildlife (Wildlife's Contributions to People, WCP) that contribute to human well-being. We adopted the framework from (Russell et al 2013) and adjusted the definitions in order to describe how people specifically experience wildlife:**

- **Interaction** describes multisensory experiences where people physically interact with wildlife. Examples are catching fish, hunting or feeding wild animals.
- **Living Within** defines the everyday, conscious or subconscious, voluntary and involuntary contact with wildlife in areas in which a person lives. This entails living in a forested area, close to the seashore and near urban parks and sharing these same habitats with wild animals.
- **Perceiving** is the remote sensory interaction with wildlife, often associated with a single sensory ability such as the visual processing of information (e.g. watching birds or watching a nature documentary). However, it could also include a person's ability to hear, feel and smell things that are associated with wildlife (e.g. listening to bird sounds).
- **Knowing** describes the cognitive/metaphysical connection between humans and wildlife that arises through thinking, contemplating or remembering experiences from wildlife encounters.

Overall, this review synthesizes how the positive and negative WCP emerge through the different channels by which people experience wildlife and how they have been studied in the scientific literature (figure 1). Specifically, we were interested in (a) the spatio-temporal pattern of different types of reported human-wildlife experiences and WCP; (b) the distribution of positive and negative WCP reported for vertebrate species in terrestrial and aquatic environments (i.e. mammals, birds, reptiles and amphibians), (c) differences in the number of studied WCP effects with regards to human well-being dimensions and (d) highlighting the dominant channels that shape human-wildlife experiences and their effect on human well-being as well as how well studied they are in the scientific literature.

For this purpose, we examined different wildlife taxa and multiple human well-being dimensions. Recent WCP overviews focused on particular aspects
of human well-being such as recreation, health, psychological well-being or religion (e.g. Alves 2012, Barua et al 2013, Harrison et al 2014, Lovell et al 2014, Marselle et al 2019). Here, we built on these efforts and broadened the set of human well-being dimensions (e.g. Russell et al 2013) including aspects such as emotions, learning experience and social well-being to develop our synthesis (see table 2). In addition, we assigned studies to world regions depending on which local areas, regions or countries were studied.

2. Review methods

We conducted a systematic literature search using Web of Science (21.11.17–25.03.2020) and following the PRISMA guidelines (Moher et al 2009). To select relevant scientific articles, we used specific search strings by combining search terms covering wildlife, the human well-being dimensions of interest and different types of wildlife experiences (table 1). Each search string consisted of a wildlife search term and either a keyword for a human well-being dimension or a channel combined by using ‘AND’. For instance, we used search queries such as ‘mammals AND inspiration’, ‘reptiles AND human health’ or ‘birds AND mental health’ (for a full list of search strings see supplementary material I, table A1 (available online at stacks.iop.org/ERL/15/093005/mmedia)).

Our initial search query produced a total of more than 20 000 search hits of research articles. We then screened through the search hits looking at titles and abstracts in detail. This screening process was based on the following criteria: (1) articles were published in a peer-reviewed journal before 2020 (reviews in peer-reviewed journals were allowed, book chapters and other forms of publication were excluded); (2) articles were published in relevant scientific disciplines such as ecology, wildlife management, environmental psychology, medicine or ethnobiology; and (3) articles contained information on whether or not wildlife (e.g. individual animals, species richness) and human well-being played a major role in the study. During the screening process we only selected relevant articles for the review and, after additionally removing duplicate studies, obtained a list of 513 research articles for a detailed full text assessment (supplementary material I, figure A1).

During the full text assessment, we selected articles that met the following conditions: (a) studies examined human adults, (b) studies examined wildlife species and human well-being dimensions according to our definition (see next section), (c)
Table 1. Search terms used for the literature review in web of science. The asterisk symbol (*) enables wildcards in the Web of Science searches and represents a character, group of characters, or no character.

| Wildlife       | Search term                                      |
|----------------|--------------------------------------------------|
| Wildlife       | 'wildlife'                                       |
| Birds          | 'birds', 'bird*'                                 |
| Mammals        | 'mammals', 'mammal*', 'carnivore'                |
| Reptiles       | 'reptiles', 'reptile*', 'alligator', 'snake'     |
| Amphibians     | 'amphibians', 'amphibian*'                      |

Human well-being

Subjective well-being  'subjective well-being', 'well-being', 'life-satisfaction', 'happiness'
Social well-being      'social relationships'
Physical health         'human health', 'human injury', 'human physiological health', 'attack', 'bite injury',
Psychological health    'mental health', 'psychological well-being', 'phobia'
Emotions                'human emotions'
Security                'security'
Connection to wildlife   'connection to nature'
Personal identity        'identity'
Sense of place           'sense of place'
Spirituality            'spirituality'
Inspiration             'inspiration', 'folklore', 'tales', 'cultur* significance'
Learning                'human learning experience'

Channels

Interaction             'human interaction', 'hunting', 'feeding', 'conflict', 'diving'
Living Within          'human coexistence'
Perceiving              'sound', 'bird watching'
Knowing                 'knowing AND education', 'thinking', 'memory AND thinking'

Table 2. Categorization of human well-being dimensions and human emotions used in this study (e.g. Russell et al 2013).

| Human well-being dimension | Description                                                                 |
|----------------------------|-----------------------------------------------------------------------------|
| Subjective well-being      | life satisfaction, composite measures of well-being (specific indicators used in psychology or other disciplines), multiple aspects of well-being (e.g. personal growth) |
| Social well-being          | relationship with family and friends, contact with other people             |
| Physical health            | subjective health, injuries and deaths                                      |
| Psychological well-being   | mental and psychological well-being indicators, e.g. stress, depression, phobia |
| Emotions                   | 6 basic emotions: interest (e.g. awe), joy, sadness, disgust, anger and fear |
| Security                   | social and personal insecurity, fear of safety, worry, concern, sense of freedom, less control, perception of risk |
| Connection to wildlife     | connection to nature fostered by wildlife experience, or actual measures of connection to wildlife or animals (e.g. scale of connectedness to nature) |
| Identity                   | kinship between human and animals or wildlife, sense of self, identity measures |
| Sense of place             | special value of certain places, people's attachment or identification with places, dependence on places, place identity |
| Spirituality               | spiritual meaning of animals, beliefs (signs of bad luck etc), magic and taboos |
| Inspiration                | literature (stories and folklore), language (metaphors, proverbs etc), music and art |
| Learning                   | Learning experiences, opportunity for education                            |

studies clearly reported or observed an ‘effect’ of wildlife on a human well-being dimension (see section below on human well-being and on data collection, further details are provided in supplementary material I, table A2). These effects could either be based on reported significant statistical relationships, based on quantitative records such as descriptive statistics (e.g. number of attacks and injuries).
or it could be based on specific statements, observations and qualitative assessments derived from interviews, surveys, field work or literature analysis (e.g. reported personal statement about faith beliefs). Finally, we did not include research with a focus on medical practices or surgical techniques and also excluded vector-borne diseases, because we consider the effects of such diseases on human health to be caused by pathogens and microbes (e.g. bacteria or viruses) and not the vectors (e.g. wildlife and other animals). However, we did include medical studies if they specifically referred to incidents between wildlife and humans, for example epidemiological studies. We also considered articles where the effect of wildlife on human well-being had been examined through questionnaires, the use of media, such as pictures and movies, or where wildlife sounds were displayed through audio files. Reviews were also considered when they summarized non-peer reviewed literature (e.g. poems, books, ethnological studies).

In order to identify relevant studies that where potentially missed by our systematic search and screening process, we also adopted a snowball-approach and additionally looked for literature referenced in the reviewed papers (e.g. Hansen and Pauleit 2014). These articles were added to the full text assessment right away. In the end, the full text assessment yielded 277 articles that were included in this review.

2.1. Definition of wildlife
In this study we refer to wildlife as wild, non-domestic living animal species in their terrestrial and aquatic environment that belong to the following vertebrate species group: mammals (including terrestrial, aquatic and marine), birds, reptiles and amphibians (Fryxell et al 2014). We excluded animals in captivity (e.g. zoo and farm animals) and pets, because they have been extensively reviewed elsewhere (Wells 2009, Herzog 2011) and are not covered by our definition of wildlife. As there has been an increase in studies showing how species richness or abundance of birds positively effect human mental health and well-being (Dallimer et al 2012, Cox et al 2017b), we included studies that used a variety of measures for wildlife. We considered articles that used biodiversity indicators (e.g. species richness, diversity, total abundance), perceived species richness, single species and animals, several species or broadly defined species groups (e.g. carnivores, songbirds).

2.2. Human well-being dimensions
We focused on multiple aspects of human well-being and their dimensions which can be affected by WCP. We chose to focus on 10 constituents of human well-being (e.g. subjective well-being, physical and psychological health or connection to nature) used in a previous study (Russell et al 2013). We further included social well-being (social relationships), because the Millennium Ecosystem Assessment (MA 2005) recognizes social relationships as an important component of human well-being.

There is increasing recognition that emotions may influence or determine other human well-being dimensions such as subjective well-being or physical health (e.g. Diener and Suh 1997, Kemeny and Shemytuk 2008). Emotions are also acknowledged as potential drivers of human well-being constituents in Russel et al’s framework (2013) and the Millennium Ecosystem Assessment (MA 2005) (e.g. fear is affecting ‘sense of control’ and emotional states can affect ‘health’ in each framework, respectively), but have not been considered as a separate dimension of human well-being. However, we believe that emotions should be considered as a separate aspect of human well-being in this review, since the human well-being dimensions described in (Russell et al 2013) and the Millennium Ecosystem Assessment (MA 2005) might rather describe the results of cognitive processes (e.g. thinking, contemplation) than the affective reactions (e.g. instinctive emotional reaction before a cognitive process) and emotional dispositions towards life events and circumstances (e.g. Gläser-Zikuda 2012).

We therefore included human emotions as a separate dimension of human well-being to provide a more complete perspective on human emotional responses and dispositions in the context of human-wildlife relationships (e.g. Jacobs 2012, Jacobs and Vaske 2019). Specifically, we look at the 6 basic emotions described by Izard (2007) because this set of emotions captures the variety of emotional dispositions and states toward wildlife: interest (e.g. awe), joy, sadness, disgust, anger and fear. As emotions have been increasingly studied over the past years (Jacobs and Vaske 2019), we consider the addition of emotions as an opportunity to reflect the current trend in human-wildlife research.

These final 12 well-being dimensions all cover positive and negative effects of wildlife on human well-being. We identified these positive and negative WCP according to a predefined identification strategy (see supplementary material I, table A2). According to these criteria, positive WCP outcomes include better mental health, positive emotions (e.g. joy, happiness, positive affect) or better social relationships (e.g. Curtin 2009, Lee and Davey 2015, Cox et al 2017b). Negative effects include detrimental experiences with wildlife where humans, for instance, come to harm (e.g. Gunther et al 2004, Debata et al 2016, Pentetian et al 2016) or cases where people suffer from feelings of insecurity because of wildlife living in the same area (Jadhav and Barua 2012, Mayberry et al 2017). Learning, connection to wildlife or inspiration triggered by wildlife experiences were generally defined as positive WCP.

Here, it should also be noted that positive and negative WCP might also influence those
dimensions of human well-being that relate to material contributions of wildlife (Díaz et al 2018). For instance, hunting wildlife may provide food for people, but also recreational benefits.

2.3. Channels
Because most studies describe multiple ways how WCP are experienced, we chose the framework of (Russell et al 2013) to categorize people's experience with wildlife according to four different channels: Interaction, Living Within, Perceiving and Knowing (box 1). These channels are well-suited for understanding WCP because they are able to describe the non-material links between humans and wildlife (figure 1). We note that in our review, Knowing does not only describe how people think about and remember their own personal wildlife experiences, but also their knowledge about wildlife, as well as expressed statements or opinions that reflect people’s emotions towards wildlife (e.g. if someone had no prior experience with wildlife but still feels positive attachment, insecurity or fear). We also assumed that wildlife-induced inspiration or spirituality is based on and influenced by Knowing. In addition, it should be mentioned that single studies could also cover multiple channels as, for instance, Living Within and Interaction or Living Within and Knowing were often connected.

2.4. Data collection process
For each selected article we recorded information on title, authors, publishing year and study origin (e.g. country and continent). If a study covered multiple continents, we categorized them as ‘multiple continents’ and global studies were categorized as ‘global’. Each studied wildlife taxa (mammals, birds, reptiles or amphibians) was also recorded as well as the wildlife measure (e.g. single species, species groups or species richness indicator, supplementary material I, table A3). In addition, we coded studies according to whether or not they examined either positive or negative WCP or both (see supplementary material I, table A2), which human well-being dimension they studied and what channel (type of wildlife experiences) was involved in linking wildlife to human well-being.

When a study reported a clear connection or relationship between wildlife and a human well-being dimension this was counted as one ‘effect’. Some studies examined several human well-being dimensions in relation to different wildlife taxa. Similarly, several channels could be involved in how wildlife affected the same human well-being dimension. A single study in the review could thus report several effects per wildlife taxon for different human well-being dimensions and for different channels. As mentioned earlier, reported ‘effects’ could be based on both quantitative and qualitative methodology, i.e. they were not only based on statistically significant relationships.

All data processing was conducted in R (R Development Core Team 2020). We calculated descriptive statistic for the number of studies examining positive and negative WCP (or both) and also counted the identified effects on human well-being. We estimated the total number of positive or negative effects for each human well-being dimension per wildlife taxon and per channel. We additionally created network plots to visualize the links (e.g. number of effects) between wildlife and human well-being via the four channels of wildlife experience (Interaction, Living Within, Perceiving and Knowing). To produce the network plots (figure 3) we created a data sheet with the sum of all effects (positive and negative) for each possible combination between wildlife taxon, human well-being dimension and channel. The final figure was created with the R package ‘bipartite’ and the function ‘plotweb’ (Dormann et al 2020).

3. Results and discussion
The 277 studies included in our review were published between 1940 and 2019 (figure 2(a)). The number of studies reporting only negative WCP (n = 203) affecting human well-being was 3.8 times higher than the number of studies reporting positive WCP (n = 53; figure 2(a)). 21 studies reported both types of outcomes. Likewise, the total number of positive effects per human well-being dimension identified within studies (33.3%, n = 120 out of 360) was also smaller than the number of negative effects (66.6%, n = 240). Mammals comprised the taxonomic group where WCP were most often studied in the reviewed literature (n = 127), followed by reptiles (n = 119) and birds (n = 68). Compared to the other wildlife groups, amphibians were rarely studied (n = 7) (figure 2(b)).

3.1. Taxon-dependency of positive and negative WCP
We found differences among taxonomic groups with regard to the frequency of identified positive and negative WCP and their effects on the different human well-being dimensions. In all groups except birds (i.e. mammals, reptiles and amphibians) the number of studies reporting negative WCP outnumbered positive ones (figure 2(b)). Among the studies on birds, 64.1% (n = 50 out of 78) reported positive WCP. In comparison, positive WCP were reported in much fewer studies for mammals (24.5%, n = 34 out of 139), amphibians (14.3%, n = 1 out of 7) and reptiles (8.8%, n = 11 out of 125) (figure 2(b)).

The positive WCP of birds are most likely due to the fact that birds are usually not harmful to humans. Birds can also be visually and acoustically attractive to humans because of their physical appearance (e.g. colourfulness, behaviour) and their songs (Belaire...
et al 2015, Hedblom et al 2017). Since they are mostly active during daytime and thus easier to observe compared to mammals, birds are more likely to positively affect human lives and their well-being (Cox et al 2017b). In fact, many positive WCP of birds are reported in psychological studies (see supplementary material I, figure A3) (e.g. Fuller et al 2007, Dallimer et al 2012). Birds and other taxon groups also appear in cultural and ethnographic publications where they are described as sources of inspiration for myths and legends or play an important role in religious beliefs (e.g. Berndt 1940, Altaf et al 2017). For example, in Aboriginal myths from the Lower Murray (Australia) birds have prominent roles as clan ancestors and are credited with powers to transform land and to establish customs and laws (Clarke 2016).

In other cases, amphibians and reptiles were involved with inspirational or spiritual aspects of human well-being, because they were part of folklore, traditional beliefs or positive superstitions (e.g. Alves 2012). For instance, the Nage people in Indonesia believe that the call of the tiny house-lizard guarantees success for decisions made or confirms the truth of an expressed statement (Forth 2013). Well-being benefits obtained from other taxonomic groups (e.g. mammals and reptiles) were also most often reported in reference to inspiration, spirituality or connection to wildlife. In some cases, for instance, when tourists watched specific wildlife species, mammals (e.g. whales, wolf) also triggered positive emotions such as surprise and joy (e.g. Farber and Hall 2007, Curtin 2009).
We found, in regard to the overall number of studies reporting negative WCP, that the majority of studies examined reptiles (45.1%, \( n = 114 \)) and mammals (41.5%, \( n = 105 \)). These numbers are not surprising, considering that many potentially harmful carnivores or other large mammals (e.g. elephants) that pose problems for human-wildlife coexistence as well as poisonous species are found within these two taxonomic groups. Consequently, most of the negative effects on human well-being dimensions identified for these species groups were either injuries (e.g. Gunther et al 2004, Behdarvand and Kaboli 2015) or bites and poisoning (e.g. Pugh et al 1979, Sarkhel et al 2017). A few studies reported attacks on humans by birds (Warne and Jones 2003, Lees et al 2013) and we also found studies where birds and amphibians were the main target of superstitions and negative folklore (Ceríaco 2011, Hull and Fergus 2017).

### 3.2. Geographical patterns of WCP

We identified studies from 74 different countries (excluding studies of entire continents and reviews) with research on WCP. Most of the studies (excluding reviews, global studies and studies on multiple continents, \( n = 27 \)) originated from the Global North (49.6%, \( n = 124 \) out of 250), i.e. from Europe, North America, and Oceania (Australia and New Zealand) (figure 2(c)). However, we also found a substantial number of studies conducted in Asian (27.6%, \( n = 69 \)) and African countries (15.2%, \( n = 38 \)).

Our results may indicate different research interests across global regions and a focus on positive effects, maybe even a reporting bias, in the Global North. For instance, the proportion of studies publishing positive WCP in comparison to negative WCP was relatively high in Europe with 37.3% (\( n = 22 \) out of 59), in Oceania (Australia and New Zealand) with 36.7% (\( n = 11 \) out of 30), while less so in North America with 22.2% (\( n = 10 \) out of 45). In comparison, there were fewer studies on positive WCP in regions of the Global South, including Asia (16.2%, \( n = 12 \) out of 74), Latin America (23.8%, \( n = 5 \) out of 21) and Africa (22.0%, \( n = 9 \) out of 40). This geographic pattern corresponds to findings from another literature review that identified similar publication biases in ES research and linked them to the influence of large funding agencies such as the European Commission or US government organizations (Mcdonough et al 2017). Overall, negative WCP dominated the global literature which was particularly the case in the Global South.

One explanation for the larger number of studies reporting negative WCP in the Global South could be that in some of these regions, especially in rural areas, people still live in direct vicinity of mammals and reptiles that can cause real danger (e.g. poisonous snakes, large carnivores), while in the Global North people usually are more removed from direct contact with wildlife in their daily lives (Cox et al 2017a). The reporting bias of more positive WCP reported in the Global North might be related to the recent increase in awareness of positive contributions of nature (MA 2005, Diaz et al 2018). This increased research interest may be linked to an observed disconnection of people to nature in the Global North (Soga and Gaston 2016, Cox et al 2017a). Future research should examine how the prevalence of harmful wildlife and the disconnection of people to nature shape both negative and positive WCP.

### 3.3. Temporal patterns of WCP

Over the past decades, we saw an increase in the number of studies addressing issues of wildlife and human well-being. Interestingly, before the 21st century almost all studies were concerned with negative WCP. One notable exception was an ethnographic paper on bird legends from the Narunga Tribe in South Australia published in 1940 (Berndt 1940) (figure 2(a)). Before the year 2000, 86.5% of the studies published negative WCP, 9.6% positive WCP and 1.9% both outcomes (\( n = 52 \)). From 2000, the number of publications increased steeply, including higher numbers of published positive WCP (figure 2(a)). The percentage of studies (published between 2001 and 2019) reporting positive WCP increased to 21.3% (\( n = 48 \) out of 225) and 8.9% reported both positive and negative WCP.

This shift in the focus of wildlife-human well-being studies may be related to a general change in the perspective on nature at the turn of the century (e.g. Mace 2014). Several publications addressed the importance of nature for human well-being and had a strong impact on both policy and society. For instance, the Millennium Ecosystem Assessment published in 2005 (MA 2005) did not only emphasize the importance of nature and biodiversity for human well-being but also re-established the formerly introduced concept of ecosystem services (Ehrlich and Mooney 1983, Daily 1997) and made this knowledge available to a wider public. Around the same time, researchers started focusing more on the benefits humans can obtain from nature and the multi-layered relationship between people and the environment (Mace 2014, Balvanera et al 2017), leading also to the establishment of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in 2012. Funding programs were started that supported research on the relationship between ecosystems and human society (e.g. Carpenter et al 2012) and fostered increasing research emphasis on topics such as ecosystem services (Mcdonough et al 2017), indicating that science policies and funding might have had a tacit effect on ecosystem services research (Vihervaara et al 2010). Besides the ecosystem services framework, the more recently introduced Nature’s Contributions to People (NCP) concept (Díaz et al 2018) also strongly incorporated the idea that humans benefit...
from nature and that nature and people are intensely interconnected. Through these concepts, the role of species, and thus also wildlife, has been brought to the forefront as is also evident in the increase of research on biodiversity’s and wildlife’s effects on human well-being (figure 2(a)).

3.4. Patterns related to human well-being dimensions

We were able to identify all human well-being categories in relation to WCP (figures 3(a), (b)). Researchers often examined only a single human well-being dimension, while some also analysed multiple aspects of well-being in a single study. Overall, we found that some human well-being dimensions were more frequently studied than others. Physical health was the well-being dimensions that was most often studied within the reviewed literature (45.4%, n = 154 out of 277 studies), followed by emotions (11.5%, n = 39), spirituality (11.2%, n = 38), inspiration (10.0%, n = 34), security (6.5%, n = 22) and psychological well-being (5.9%, n = 20). Those human well-being dimensions which appeared less frequently in the literature were subjective well-being, social well-being, sense of place, connection to wildlife, learning and personal identity (all <3%, figures 3(a), (b)).

Most of the studies examining physical health reported negative effects (98.1%, n = 152 out of 155) such as injuries caused by wildlife. Only three studies (1.9%) reported positive physical health outcomes after experiencing wildlife (figure 3(a)). One study found a positive relationship between bird species richness, a proxy indicator for environmental quality, and good human health (Wheeler et al 2015), the second examined the longevity of people in areas where Cuckoos co-occur (Møller et al 2017) and the third mentioned the health benefits of hunting (Delisle et al 2018). Similarly, negative effects of wildlife on security (96.2%, n = 25 out of 26), emotions (63.3%, n = 31 out of 49) or spirituality (55.0%, n = 28 out of 51) prevailed, for example feelings of insecurity, fear or negative beliefs (e.g. superstitions, dark omens). The number of positive and negative effects of wildlife affecting psychological well-being were mostly equal in number (50.0%, n = 11 out of 22); study results for inspiration, learning and connection to wildlife were all considered positive WCP.

Our results indicate that well-being dimensions such as sense of place, learning, personal identity, subjective well-being and social well-being were less often studied compared to others (e.g. human physical health or emotions). One possible reason for the low publication numbers might be that these topics have only recently emerged as research topics in the context of wildlife and human well-being (Hausmann et al 2016, Chan et al 2018). In fact, none of the articles addressing these human well-being dimensions were published before the year 2000. Even the dimensions for connection or psychological well-being were only found after the year 2000 (e.g. Sandifer et al 2015). The use of vague terminology might additionally explain why certain well-being dimensions were underrepresented. For instance, there are multiple uses and definitions for the term ‘identity’, covering personal identity, cultural identity or place identity (O’Brien 2006, Tengberg et al 2012, Rall et al 2017).

Finally, researchers with interest in these topics may have mainly studied nature in the broader sense (e.g. vegetation cover or urban green spaces) rather than wildlife, for instance, because ecological and spatial data are more readily available.

The high proportion of physical health-related studies and results may be explained by the large number of research from the medical sciences, where attention may have focused on wildlife issues more than in other scientific disciplines (e.g. psychology), and by the generally higher publication numbers in the medical field compared to other disciplines. We also noticed that much research and knowledge about the culturally influenced WCP, i.e. inspirational and spiritual value, were often not published in peer-reviewed journals or in other languages than English and, as a consequence, are often lost to the broader scientific community (e.g. Alves 2012, Arroyo-Quiroz et al 2017). In addition, we want to emphasize that non-material WCP that are not directly health-related are almost always subject to the cultural background of people and that this cultural dependency of the role of wildlife for human societies is currently not well understood and deserves more attention in future research.

3.5. Channels

We found examples for all four types of wildlife experiences (Interaction, Living Within, Perceiving and Knowing), albeit at varying frequencies. For instance, 53.2% of the studies (n = 167 out of 277) investigated the channel Interaction, but only 8.9% of the reviewed studies investigated the channel Perceiving (n = 28 out of 277).

We found that people interact with wildlife in multiple ways during their daily lives, outdoor activities or as tourists. Only a few studies reported positive WCP of human-wildlife interactions on different human well-being dimensions and consequently, identified effects were low (11.4%, n = 21 out of 184) (figure 3). For instance, people experienced positive emotions when feeding birds (Galbraith et al 2014, Cox and Gaston 2016) or obtained new knowledge and insights about wildlife through learning experiences (e.g. Haywood et al 2016, Hanisch et al 2019). Interactions with wildlife also fostered social relationships, for instance when human-macaque interactions nurtured family and social ties of park visitors (Lee and Davey 2015) and people’s connection to wildlife (Cox and Gaston 2016). However, studies
Figure 3. Identified positive (a) and negative (b) effects of non-material contributions provided by wildlife (WCP) affecting different human well-being dimensions. The effects on human well-being are linked to each wildlife taxon through the four channels of human-wildlife experiences: Interaction, Living Within, Perceiving and Knowing (see box 1 and table 2 for categorization; WB = well-being).

on Interaction mainly reported negative effects (figure 3) on human well-being (88.6%, n = 163), with the majority of these effects being related to physical health (93.3%). Other negative effects of wildlife interactions were emotions such as fear and anger (Arroyo-Quiroz et al 2017), concern for safety (Ogra 2008) or bad mental health after conflicts or injuries (Jadhav and Barua 2012), outcomes indirectly linked to physical health (supplementary material I, table A2).

Living Within describes how people, either consciously or subconsciously, experience wildlife during their daily lives. Many investigations were conducted on human populations that lived near or within the natural habitat of certain wildlife species (n = 34). Thus, the likelihood of the studied populations being aware of or encountering wildlife during daily life was high. We found that living in areas with wildlife had both positive (17.1%, n = 7 out of 41) and negative (82.9%, n = 34) effects on different human well-being dimensions (figure 3). For instance, living in areas with high bird abundance and species richness was found to increase mental health, personal and neighbourhood well-being as well as connection to nature (Luck et al 2011, Cox et al 2017b). On the other hand, living in areas with large carnivores or other dangerous animals could often produce insecurity and negative emotions (e.g. Mormile and Hill 2016, Mayberry et al 2017). In fact, the majority of reported negative effects triggered via Living Within were associated with feelings of insecurity due to unsafe conditions, exposure to danger or risk (Security, 58.8%, n = 20) or fear (Emotions, 32.4%, n = 11).
In several studies (n = 28) the importance of *Perceiving* wildlife for human well-being was investigated (figure 3), and most frequently through visual perception during outdoor activities (e.g., urban parks) or while watching wildlife (e.g., safari, whale watching). Several laboratory studies using audio recordings to test the importance of other sensory perceptions also showed that listening to nature sounds mixed with bird songs reduced stress or facilitated recovery after psychological stress (Alvarsson et al 2010, Medvedev et al 2015). In addition, bird songs were attributed with restorative and stress reducing effects (Ratcliffe et al 2013), made people feel calm while being outdoors (Hedblom et al 2017) and reduced health anxiety among elderly people (Dzhambov and Dimitrova 2014). We found 41 positive (82.7%) and 6 negative (12.8%) effects on various human well-being dimensions caused by *Perceiving* wildlife. Among all the positive effects, four human well-being dimensions were prominently associated with *Perceiving* wildlife, i.e., psychological well-being (24.4%, n = 10), connection to wildlife (22.0%, n = 9), human emotions (19.5%, n = 8), and learning (12.2%, n = 5). Negative effects of *Perceiving* wildlife were usually found for emotions (83.3%, n = 5).

The channel *Knowing* was the second most often studied channel among the reviewed articles (27.1%, n = 87 out of 277). *Knowing* often occurred when people reflected on past wildlife experiences gained during time spent outdoors (e.g., vacation, gardening, hunting) or when they owned or acquired specific knowledge and opinions about wildlife species. This means that in many cases the human well-being dimension learning was affected by *Knowing*. Education also played an important role, as was shown in studies which tested if education programs and information meetings influenced how people felt towards wildlife (Johansson et al 2017).

Again, we found reports of both positive (57.2%, n = 83 out of 145) and negative (42.8%, n = 62) effects of wildlife on human well-being elicited through *Knowing* (figure 3). Contrary to *Interaction* (associated with mostly negative effects) and similar to *Perceiving*, the number of reported positive effects were higher than the associated negative effects on human well-being. Typically, *Knowing* affected spirituality, human emotions and inspiration (figure 3). In these cases, wildlife’s influence on spirituality was both positive (44.9%, n = 22 out of 49) and negative (55.1%, n = 27). For instance, beliefs and superstitions can address wildlife as carriers of bad luck and negative omens but also signs of good fortune (Ceriaco 2012, Ohemeng et al 2017, Wyndham and Park 2018). Similarly, positive emotions such as joy, interest or surprise (26.7%, n = 8 out of 30) were fostered via *Knowing*, i.e. through remembering or reflecting on past wildlife experiences (e.g. Jacobs et al 2014, McIntosh and Wright 2017). *Knowing* additionally affected emotions in negative ways (73.3%, n = 22) by provoking feelings of fear and disgust (Tucker and Bond 1997, Davey et al 1998, Johansson and Karlsson 2011). All identified cases where *Knowing* wildlife influenced human inspiration (n = 34) reported positive effects. These studies reported that wildlife inspired people to create legends, folklore and tales, where different species play the main characters or occur as important symbols (e.g. Berndt 1940, Clarke 2016).

4. Conclusion

Our synthesis shows that WCP have received a strong increase in attention over the past decades. While overall, globally, negative reports of WCP are more common, the proportion of positive studies was greater in the Global North compared to the Global South, and positive effects were increasingly reported in recent decades. These temporal and spatial patterns and the lack of systematic assessments of positive and negative WCP may indicate possible normative influences that drive research and the relative proportion of reported positive or negative WCP. These normative influences are not well understood yet, but there might be an indication that at least some larger international processes such as the Millennium Ecosystem Assessment in 2005 (MA 2005), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services in 2012 (IPBES), and even the UN Sustainable Development Goals in 2015 (SDGs) may have influenced research objectives through greater public awareness as well as policy and funding incentives. Future research could better examine these potential biases by conducting policy assessments or surveys among researchers to understand drivers and motivations behind their research questions.

Most positive WCP were reported for birds while studies on mammals and reptiles mostly reported negative WCP. Surprisingly, we found almost no systematic, joint assessments of positive and negative contributions for any wildlife species (but see Harrison et al 2014 or Pascual-Rico et al 2020). Future studies should therefore explore multi-taxon approaches considering both positive and negative WCP and should consider the culture- and context-dependencies of human experiences with wildlife. Such systematic assessments of both positive and negative WCP will be critical for evaluating the costs and benefits of wildlife, which has become increasingly important to managing wildlife in close proximity to humans and wildlife conflicts (Lozano et al 2019).

Physical health was the most dominant aspect of human well-being that was negatively affected by WCP and there were almost no medical studies that focus on the potential positive effects of WCP on health. Studies examining positive effects of WCP on psychological health are still relatively rare, but publication numbers are increasing. In this
context, future wildlife studies should contribute to the expanding field of biodiversity and mental health studies (e.g. Marselle et al 2019) or even the hidden mental health impacts of human-wildlife conflicts (Barua et al 2013). Mental health problems in the Global North are increasing (e.g. OECD/European Union 2018) and promoting wildlife experiences, for instance by resource provisioning to increase wildlife populations (Cox and Gaston 2018) as well as increasing opportunities for wildlife contact, e.g. through nature education or creating wildlife viewing opportunities, might lead to more positive WCP which could in turn increase people’s well-being and provide a nature-based solution to public health.

We identified many positive and negative effects of wildlife on human emotions in the reviewed literature. In general, the human emotional responses to wildlife have been increasingly studied over the past years (Jacobs 2012), but efforts still need to be made to better understand positive and negative emotions towards wildlife and how these emotions influence how people coexist with wildlife or experience wildlife (Gaston et al 2018).

Building on recent efforts, future research on wildlife now needs to broaden the range of human well-being dimensions considered and should also include aspects of well-being, such as subjective and social well-being, sense of place, learning or identity, that to date are rarely studied. This will help to deepen our understanding of how wildlife influences human well-being.

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Author contributions

J M, K B-G and T M designed the study. J M carried out the literature review and analysis. J M wrote the initial draft of the manuscript. All authors contributed substantially to the writing of the manuscript.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon request.

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References

Altma F, Jadid A, Umar M, Iqbal K J, Rashid Z and Abbasi A M 2017 Ethnomedicinal and cultural practices of mammals and birds in the vicinity of river Chenab, Punjab-Pakistan J. Ethnobiol. Ethnomed. 13 41
Alvarsson J J, Wiens S and Nilsson M E 2010 Stress recovery during exposure to nature sound and environmental noise Int. J. Environ. Res. Public Health 7 1036–46
Alves R 2012 Relationships between fauna and people and the role of ethnozoology in animal conservation Ethnobiol. Conserv. 1 1–9
Arbieu U, Grünwald C, Schleuning M and Böhning-Gaese K 2017 The importance of vegetation density for tourists’ wildlife viewing experience and satisfaction in African savannah ecosystems PloS One 12 e0185793
Arroyo-Quiroz A I, García-Barrios R, Argüeta-Villamar A, Smith R J and Salcido P R G 2017 Local perspectives on conflicts with wildlife and their management in the Sierra Gorda Biosphere Reserve, Mexico J. Ethnobiol. 37 719–42
Balvanera P et al 2017 Interconnected place-based social-ecological research can inform global sustainability Curr. Opin. Environ. Sustain. 29 1–7
Barua M, Bhagwat S A and Jadhav S 2013 The hidden dimensions of human-wildlife conflict: health impacts, opportunity and transaction costs Biol. Conserv. 157 309–16
Behdarvand N and Kaboli M 2015 Characteristics of grey wolf attacks on humans in an altered landscape in the West of Iran Hum. Dimens. Wildl. 20 112–22
Belarte J A, Westphal L M, Whelan C J and Minor E S 2015 Urban residents’ perceptions of birds in the neighborhood: biodiversity, cultural ecosystem services, and disservices Condor 117 192–202
Berndt R M 1940 A curlew and owl legend from the Narunga Tribe, South Australia Oceania 10 456–62
Bryce R, Irvine K N, Church A, Fish R, Ranger S and Kenter J O 2016 Subjective well-being indicators for large-scale assessment of cultural ecosystem services Ecosyst. Serv. 21 258–69
Carpenter S R et al 2012 Program on ecosystem change and society: an international research strategy for integrated social-ecological systems Curr. Opin. Environ. Sustain. 4 134–8
Ceriaci L M P 2011 Folklore and traditional ecological knowledge of geckos in Southern Portugal: implications for conservation and science J. Ethnobiol. Ethnomed. 7 26
Ceriaci L M P 2012 Human attitudes towards herpetofauna: the influence of folklore and negative values on the conservation of amphibians and reptiles in Portugal J. Ethnobiol. Ethnomed. 8 8
Chan K M A, Gould R K and Pascual U 2018 Editorial overview: relational values: what are they, and what’s the fuss about? Curr. Opin. Environ. Sustain. 35 A1–7
Chang C H, Barnes M L, Frye M, Zhang M, Quan R, Reismann I M G, Levin S A and Wilcove D S 2017 The pleasure of pursuit: recreational hunters in rural Southwest China exhibit low exit rates in response to declining catch Enol. Soc. 22 43
Clarke P A 2016 Birds as totemic beings and creators in the Lower Murray, South Australia J. Ethnobiol. Ethnomed. 36 277–93
Cox D T C and Gaston K J 2016 Urban bird feeding: connecting people with nature PloS One 11 1–13

12
Cox D T C and Gaston K J 2018 Human–nature interactions and the consequences and drivers of provisioning wildife Philose. Trans. R. Soc. B. Biol. Sci. 373 20170092
Cox D T C, Hudson H L, Shanahan D F, Fuller R A and Gaston K J 2017a The rarity of direct experiences of nature in an urban population Landsc. Urban Plan. 160 79–84
Cox D T C, Shanahan D F, Hudson H L, Plummer K E, Siriwudena G M, Fuller R A, Anderson K, Hancock S and Gaston K J 2017b Doses of neighborhood nature: the benefits for mental health of living with nature Bioscience 67 147–55
Curtin S 2009 Wildlife tourism: the intangible, psychological benefits of human-wildlife encounters Curr. Issues Tour. 12 451–74
Daily G C 1997 Introduction: what are ecosystem services? Nature’s Services: Societal Dependence On Natural Ecosystems, ed G C Daily (Washington, DC: Island Press) pp 1–10
Dallimer M, Irvine K N, Skinner A J M, Davies Z G, Rouget J R, Malbry L L, Warren P H, Armworth P R and Gaston K J 2012 Biodiversity and the feel-good factor: understanding associations between self-reported human well-being and species richness Bioscience 62 47–55
Davey G C, Mcdonald A S, Srivastava D K, Slack S M, Reimann B C 1998 A cross-cultural study of animal fears Behav. Res. Ther. 36 735–50
Debata S, Swain K K, Sahu H K and Shekhar H 2016 Human–sloth bear conflict in a human-dominated landscape of northern Odisha, India Ursus 27 90–98
Delisle A, Kiatkoski Kim M, Stoeckl N, Watkin Lui F and Marsh H 2013 The socio-cultural benefits and costs of the traditional hunting of dugongs Dugong dugon and green turtles Chelonia mydas in Torres Strait, Australia Oryx 52 230–61
Diaz B S et al 2018 Assessing nature’s contributions to people Science 359 270–2
Diaz S et al 2015 The IPBES conceptual framework—connecting nature and people Curr. Opin. Environ. Sustain. 14 1–16
Diaz S, Fargione J, Chapin F S and Tilman D 2006 Biodiversity loss threatens human well-being PLoS Biol. 4 3000–5
Diener E and Suh E 1997 Measuring quality of life: economic, social, and subjective indicators Soc. Indic. Res. 40 189–216
Dormann C F, Friedl J and Gruber B 2020 Package ’bipartite’ Version 2.15 (available at: https://github.com/biometry/bipartiteDescription)
Dzhambov A M and Dimitrova D D 2014 Elderly visitors of an urban park, health anxiety and individual awareness of nature experiences Urban For. Urban Green. 13 806–13
Ehrlich P R and Mooney H A 1983 Extinction, substitution, ecosystem services Bioscience 33 248–54
Exposito-Granados M et al 2019 Human–carnivore relations: conflicts, tolerance and coexistence in the American West Environ. Res. Lett. 14 123005
Farber M and Hall T E 2007 Emotion and environment: visitors’ extraordinary experiences along the Dalton highway in Alaska J. Leis. Res. 39 248–70
Forrester J A, Weiser T G and Forrester J D 2018 An update on fatalities due to venomous and nonvenomous animals in the United States (2008–2015) Wilderness Environ. Med. 29 36–44
Forth G 2013 Symbolic lizards: forms of special purpose classification of animals among the Nage of Eastern Indonesia Anthrozoos 26 357–72
Fryxell J M, Graeme C and Sinclair A R E 2014 Wildlife Ecology, Conservation and Management, ed J M Fryxell, C Graeme and A R E Sinclair (Chichester: Wiley)
Fuller R A, Irvine K N, Devine-Wright P, Warren P H and Gaston K J 2007 Psychological benefits of greenspace increase with biodiversity Biol. Lett. 3 390–4
Galbraith J A, Beggs J R, Jones D N, McNaughton E J, Krull C R and Stanley M C 2014 Risks and drivers of wild bird feeding in urban areas of New Zealand Biol. Conserv. 180 64–74
Gaston K J, Soga M, Duffy J P, Garrett J K, Gaston S and Cox D T C 2018 Personalised ecology Trends Ecol. Evol. 33 916–25
Gläsner-Zikuda M 2012 Affective and emotional dispositions of/for learning Encyclopedia of the Sciences of Learning, ed N M Seel (Boston, MA: Springer) pp 165–9
Gunther K A, Haroldson M A, Frey K, Cain S L, Copeland J and Schwartz C C 2004 Grizzly bear—human conflicts in the Greatest Yellowstone ecosystem, 1992–2000 Ursus 15 10–22
Haines-Young R and Potschin M 2018 Common International Classification of Ecosystem Services (CICES): V5.1 And Guidance on the Application of the Revised Structure (available at: www.cices.eu)
Hanisch E, Johnston R and Longnecker N 2019 Cameras for conservation: wildlife photography and emotional engagement with biodiversity and nature Hum. Dimens. Wildl. 24 267–84
Hansen R and Pauliet S 2014 From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas Ambio 43 516–29
Harrison P A et al 2014 Linkages between biodiversity attributes and ecosystem services: a systematic review Ecosystem Serv. 9 191–203
Hausmann A, Slotow R, Burns J K and Di Minin E 2016 The ecosystem service of sense of place: benefits for human well-being and biodiversity conservation Environ. Conserv. 43 117–27
Haywood B K, Parrish J K and Dooliver J 2016 Place-based and data-rich citizen science as a precursor for conservation action Conserv. Biol. 30 476–86
Heblom M, Knez I, Ode Sang Å and Gunnarsson B 2017 Evaluation of natural sounds in urban greenery: potential impact for urban nature preservation R. Soc. Open Sci. 4 202017
Herzog H 2011 The impact of pets on human health and psychological well-being: fact, fiction, or hypothesis? Carr. Dir. Psychol. Sci. 20 236–9
Hull K and Fergus R 2017 Birds as seers: an ethno-ornithological approach to omens and prognostication among the Ch’orti’ Maya of Guatemala J. Ethnobiol. 37 604–20
Inskeep C and Zimmermann A 2009 Human–feline conflict: a review of patterns and priorities worldwide Oryx 43 18–34
Izard C E 2007 Basic emotions, natural kinds, emotion schemas, and a new paradigm Perspect. Psychol. Sci. 2 260–80
Jacobs M and Vaske J J 2019 Understanding emotions as opportunities for and barriers to coexistence with wildlife Human–Wildlife Interactions, ed B Frank, J A Gilchrist and S Marchini (Cambridge: Cambridge University Press) pp 65–84
Jacobs M H 2012 Human emotions toward wildife Hum. Dimens. Wildl. 17 1–3
Jacobs M H, Vaske J J, Dubois S and Fehres P 2014 More than fear: role of emotions in acceptability of lethal control of wolves Eur. J. Wildl. Res. 60 589–98
JadHAV S and Barua M 2012 The elephant vanishes: impact of human—elephant conflict on people’s wellbeing Health Place 18 1356–65
Johansson M, Frank J, Sten O G and Flykt A 2017 An evaluation of information meetings as a tool for addressing fear of large carnivores Soc. Nat. Resour. 30 281–98
Johansson M and Karlsson J 2011 An subjective experience of fear and the cognitive interpretation of large carnivores Hum. Dimens. Wildl. 16 15–29
Kemeny M E and Shestuyk A 2008 Emotions, the neuroendocrine and immune systems, and health Handbook of Emotions, ed M Lewinsohn, M Haviland-Jones and L Feldman Barrett (New York: The Guilford Press) pp 661–75
Lee W N and Davey G 2015 Chinese visitors’ experiences of nature and wild macaques: inspiration and personal growth for living in Hong Kong Hum. Dimens. Wildl. 20 206–19
Lees D, Sherman G D H, Maguire G S, Dann P, Cardilini A P A and Weston M A 2013 Swooping in the suburbs; parental
defence of an abundant aggressive urban bird against humans Animals 3 754–66
Lovell R, Wheeler B W, Higgins S L, Irvine K N and Depledge M H 2014 A systematic review of the health and well-being benefits of diverse environments J. Toxicol. Environ. Health B: Crit. Rev. 17 1–20
Lozano J et al 2019 Human-carnivore relations: a systematic review Biol. Conserv. 237 880–92
Lucz G W, Davidson P, Boxall D and Smallbone L 2011 Relations between urban bird and plant communities and human well-being and connection to nature Conserv. Biol. 25 816–26
MA—Millennium Ecosystem Assessment 2005 Ecosystems and Human Well-being: Synthesis (Washington, DC: Island Press)
Mace G M 2014 Whose conservation? Science 343 1558–60
Mace G M, Norris K and Fitter A H 2012 Biodiversity and ecosystem services: a multilayered relationship Trends Ecol. Evol. 27 19–25
Mackerron G and Mourato S 2013 Happiness is greater in natural environments Glob. Environ. Change 23 992–1000
Marchini S and Crawshaw P G 2015 Human–wildlife conflicts in Brazil: a fast-growing issue Hum. Dimens. Wildl. 20 323–8
Markeyes I et al 2017 Exploring pathways linking greenspace to health: theoretical and methodological guidance Environ. Res. 158 301–17
Marselle M R, Martens D, Dallimer M and Irvine K N 2019 Review of the mental health and wellbeing benefits of biodiversity Biodiversity and Health in the Face of Climate Change, ed M R Marselle, J Stadler, H Korn, K Irvine and A Bonn (Berlin: Springer) pp 75–211
Mayberry A L, Hovorka A J and Evans K E 2017 Well-being impacts of human-elephant conflict in Khumaga, Botswana: exploring visible and hidden dimensions Conserv. Soc. 15 280–91
Mcdonough K, Hutchinson S, Moore T and Hutchinson J M S 2017 Analysis of publication trends in ecosystem services research Ecosyst. Serv. 25 82–88
Mcintosh D and Wright P A 2017 Emotional processing as an important part of the wildlife viewing experience J. Outdoor Recreat. Tour. 18 1–9
Medvedev O, Shepherd D and Hautus M J 2015 The restorative potential of soundscapes: a physiological investigation Appl. Acoust. 96 20–26
Milcu A I, Hanspach J, Abson D and Fischer J 2013 Cultural ecosystem services: a literature review and prospects for future research Ecol. Soc. 18 44
Moher D et al 2009 Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement PLoS Med. 6 e1000097
Moleón M, Sánchez-Zapata J A, Margalida A, Carrete M, Owen-Smith N and Donáz J A 2014 Humans and scavengers: the evolution of interactions and ecosystem services Bioscience 64 394–403
Møller A P, Morelli F and Tryjanowski P 2016 Living with urban baboons: exploring attitudes and their implications for local baboon farmers live Encol. Ind. 72 768–9
Mormile J E and Hill C M 2016 Living with urban baboons: exploring attitudes and their implications for local baboon conservation and management in Knyasa, South Africa Hum. Dimens. Wildl. 22 99–109
O’Brien F A 2006 A question of value: what do trees and forests mean to people in Vermont? Landsc. Res. 31 257–75
OECD/European Union 2018 Health at a Glance: Europe 2018 (Paris: OECD Publishing)
Ogra M V 2008 Human-wildlife conflict and gender in protected area boundaries: A case study of costs, perceptions, and vulnerabilities from Uttarakhand (Uttaranchal), India Geoforum 39 1408–22
Ohemeng F, Lawson E T, Ayivor J, Leach M, Waldman L and Ntimao-Baidu Y 2017 Socio-cultural determinants of human–bat interactions in Rural Ghana Anthrozoots 30 181–94
Pascual U et al 2017 Valuing nature’s contributions to people: the IPBES approach Curr. Opin. Environ. Sustain. 26–27 7–16
Pascual-Rico R, Martín-López B, Sánchez-Zapata J A and Morales-Reyes Z 2020 Scientific priorities and shepherds’ perceptions of ungulate’s contributions to people in rewilding landscapes Sci. Total Environ. 705 135876
Penteriani V et al 2016 Human behaviour can trigger large carnivore attacks in developed countries Sci. Rep. 6 1–8
Pugh R H N, Bourdillon C C M, Theakston R D G and Reid H A 1979 Bites of the carpet viper in the Niger Valley Lancet 314 625–7
R Development Core Team R 2020 R: A language and environment for statistical computing (available at: www.r-project.org)
Rall E, Bieling C, Zytynska S and Haase D 2017 Exploring city-wide patterns of cultural ecosystem service perceptions and use Ecol. Indic. 77 80–95
Ramstad K M, Nelson N J, Paine G, Beech D, Paul A, Paul P, Allendorf F W and Daugherty C H 2007 Species and cultural conservation in New Zealand: maori traditional ecological knowledge of Tuatara Conserv. Biol. 21 455–64
Ratcliffe E, Gatersteißen B and Sowden P T 2013 Bird sounds and their contributions to perceived attention restoration and stress recovery J. Environ. Psychol. 36 221–8
Russell R, Guerry A D, Balvanera P, Gould R K, Basurto X, Chan K M A, Klain S, Levine J and Tam J 2013 Humans and nature: how knowing and experiencing nature affect well-being Amma. Res. Environ. Resour. 38 473–502
Sandifer P A, Sutton-Grier A E and Ward B P 2015 Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: opportunities to enhance health and biodiversity conservation Ecosystem Serv. 12 1–15
Sarkhel S, Ghosh R, Mana K and Gantait K 2017 A hospital based epidemiological study of snakebite in Paschim Medinipur Toxicol. Rep. 4 115–9
Shackleton C M, Ruwanza S, Sinasson Sanni G K, Bennett S, De Lacy P, Modipa R, Mmati N, Sachikonye M and Thondhlana G 2016 Unpacking pandora’s box: understanding and categorising ecosystem disservices for environmental management and human wellbeing Ecosystems 19 587–600
Soga M and Gaston K J 2016 Extinction of experience: the loss of human-nature interactions Front. Ecol. Environ. 14 94–101
Tengberg A, Fredholm S, Eliasson I, Knez I, Saltzman K and Wetterberg O 2012 Cultural ecosystem services provided by landscapes: assessment of heritage values and identity Ecosystem Serv. 2 14–28
Tucker M and Bond N W 1997 The roles of gender, sex role, and disgust in fear of animals Pers. Individ. Differ. 22 135–8
Vaz A S, Kueffer C, Kull C A, Richardson D M, Vicente J R, Kühn I, Schröter M, Hauck J, Bonn A and Honrado P J 2017 Integrating ecosystem services and disservices: insights from plant invasions Ecosystem Serv. 23 94–107
Vihervaara P, Ronkä M and Walls M 2010 Trends in ecosystem services research: Early steps and current drivers Ambio 39 314–24
Warne R M and Jones D N 2003 Evidence of target specificity in attacks by Australian magpies on humans Wildl. Res. 30 265–7
Wells D L 2009 The effects of animals on human health and well-being J. Soc. Issues 65 233–43
Wheeler B W, Lovell R, Higgins S L, White M P, Akcock I, Osborne N J, Hufn K, Sahel C E and Depledge M H 2015 Beyond greenspace: an ecological study of population general health and indicators of natural environment type and quality Int. J. Health Geogr. 14 1–17
Wyndham F S and Park E K 2018 ‘Listen carefully to the voices of the birds’: a comparative review of birds as signs J. Ethnobiol. 38 533
