Affective reactions to losses and gains in biodiversity: Testing a prospect theory approach

Mathew P. White [a,b,*], Gregory N. Bratman [c], Sabine Pahl [b,d], Gerald Young [e], Deborah Cracknell [a], Lewis R. Elliott [a]

[a] European Centre for Environment & Human Health, University of Exeter, UK
[b] Cognitive Science HUB, University of Vienna, Austria
[c] School of Environmental and Forest Sciences, University of Washington, USA
[d] Department of Psychology, University of Plymouth, UK
[e] Department of Psychology, University of California, Berkeley, USA

ARTICLE INFO

ABSTRACT

Recent reports have presented evidence of dramatic biodiversity declines. Despite the threat posed by such losses we know little about people's reactions to such information, or rarer 'bright spot' stories of localised recovery. We explored these issues through the lens of prospect theory, testing three aspects: a) reference dependence, b) loss aversion, and c) diminishing sensitivity. Study 1 (n = 393) presented US participants with a hypothetical ecological survey reporting changes in bird species at a key site between 1996 and 2016 using a 2 (Baseline species richness: Low/high) x 2 (Change direction: Loss/gain) x 4 (Change magnitude: 5/10/15/20 species) between-participants design. Study 2 (n = 570) used the same design but focused on marine species richness among a UK sample. Responses were measured using a version of the Scale of Positive and Negative Experience. Both studies found evidence of reference dependence, but not loss aversion. In fact both studies found that reactions to biodiversity gains were stronger than equivalent losses; gains 'loomed larger' than losses. There was little evidence of diminishing sensitivity; scope insensitivity was the predominant pattern for losses and gains across both studies. Although those high in nature relatedness reacted more strongly to losses and gains, relatedness did not moderate any effects. Results suggest that communicators should not be surprised if reports of biodiversity declines do not have the impact they hoped, and that weaving in 'bright spot' stories may help people engage with the broader issues.

1. Introduction

"The astonishing decline in wildlife populations shown by the latest Living Planet Index – a 60% fall in just over 40 years..." (Lambertini, Director General World Wildlife Fund (WWF) International, 2018)

"Over time, connected patches became more species rich, containing 20% more plant species than unconnected patches by the end of the study" (Damschen et al., 2006)

Biodiversity is critical for both planetary and human health (Bernstein, 2014; Cardinale et al., 2012; Diaz et al., 2019). The dramatic loss of biodiversity globally (Mace et al., 2008; McCalllum, 2015), despite global efforts to curb the trend, is of concern to scientists and policy makers world-wide (Pereira et al., 2012). What is less understood is how

the public responds to these types of reports, especially when they refer to specific numerical/statistical changes over a given period of time (e.g. the headline above from the WWF's Living Planet Index, 2018). Understanding public reactions is important because communicators are presumably hoping that presenting evidence of environmental degradation will raise awareness, change beliefs and attitudes, and will ultimately influence both individual and policy behaviour (Sawe & Knutson, 2015). Having a clearer understanding of what kinds of messages have the most impact, and of the psychological processes underpinning these responses, could lead to better communications and outcomes (Davis, 1995). For instance, does informing people that biodiversity levels have dropped by 60% (WWF, 2018) result in negative emotions twice as strong as being informed that levels have dropped by

30%; and what impact might 'good news' or 'bright spot' (Cvitanovic & Hobday, 2018) stories about examples of biodiversity rehabilitation, such as the second opening quote from Damschen et al. (2006), have on people's responses? The current research investigated these issues.

1.1. Prospect theory and biodiversity

The current attempt to improve our understanding of people's immediate affective responses to receiving information about biodiversity losses and gains drew inspiration from Prospect Theory (Barberis, 2013; Kahneman & Tversky, 1979; Tversky & Kahneman, 1981). Prospect theory was originally developed to better explain and understand why people make, for example, financial decisions under uncertainty that appear inconsistent with classical economic theory. Three key aspects of prospect theory are reference dependence, loss aversion and diminishing sensitivity.

Reference dependence emphasises the importance of reference points, or baselines. What someone has already, expects to have in the future, or sees someone else having, tends to influence their reactions to new outcomes (Thaler, 1980). For instance, a person may feel dissatisfied with a pay rise of 3%, even if it makes them materially better off, if their previous pay rise was 5%. Our aim was to test whether such relativities also applied to changes in biodiversity by exploring identical losses/gains with respect to higher or lower baseline levels of biodiversity. Pauly (1995) explicitly recognises the importance of reference points in the 'shifting baseline' hypothesis with respect to scientific attitudes towards declines in fish species richness: "*each generation of fisheries scientists accepts as a baseline the stock size and species composition that occurred at the beginning of their careers, and uses this to evaluate changes… The result obviously is a gradual shift of the baseline…, and inappropriate reference points for evaluating economic losses resulting from overfishing, or for identifying targets for rehabilitation measures*" (p. 430). Kahn (2002, pp. 93–116) referred to this as 'environmental generational amnesia' whereby the degraded habitat and reduction in species for one generation becomes the norm for the next. While these perspectives refer to adaptation over much longer periods of time than is feasible to test in an experimental study, they illustrate the importance of baseline familiarity and relativity of earlier knowledge.

Loss aversion describes how people respond differently to losses versus gains of the same magnitude. For instance, under rational choice theory, an actor 'should' experience just as much pain on losing $10 as they experience joy from gaining $10. However, people are consistently found to experience about twice the level of discomfort from losses as comfort from equivalent gains (i.e. 'losses loom larger than gains', Tversky & Kahneman, 1991). This is in part because people have stronger psychological attachments to things which they already have than to things which they do not. This is in line with the 'endowment effect', the finding that people are typically willing to pay for new things, such as a mug, less than the amount they are willing to accept for someone to buy things from them (e.g. an old mug) that they already have (Morewedge & Giblin, 2015). Although people do not 'have' species, in the same way they have mugs, we reasoned that knowledge about the existing presence of a species might create an implicit endowment effect such that people are more upset by knowledge of its loss, than they are excited by knowledge of the introduction of a new species that was not there previously. If true this would effectively result in a greater aversion to biodiversity losses than a welcoming of biodiversity gains. Although previous papers have discussed the potential role of loss aversion with respect to biodiversity (Bull et al., 2017; Hummel et al., 2009), we know of no prior work which has tested this possibility by comparing equivalent biodiversity gains and losses.

Finally, *diminishing sensitivity* describes how psychological reactions to increases/decreases of an outcome may be non-linear, instead exhibiting a quadratic relationship of diminishing marginal effects. For instance, a gift of $10 may increase happiness by 3 points, but $20 only increase it by an additional 2 points to 5 points (instead of $2 \times 3 = 6$),

and $30 may only increase it by an additional 1 point to 6 points (instead of $3 \times 3 = 9$). Each additional $10 is associated with ever decreasing increases in affective responses. A similar diminishing sensitivity is theorised to exist for losses, although the shape of the curves is thought to be asymmetric such that initial losses tend to have larger effects than initial gains due to loss aversion (see above). In the case of biodiversity, diminishing sensitivity is directly related to the notion of scope insensitivity in environmental economics which has been used to explain people's decreasing marginal willingness to pay to protect wildlife and/or endangered species (Desvousges et al., 1993, pp. 91–164; Veisten et al., 2004).

The three elements of prospect theory, as applied to news about biodiversity, can be seen in Fig. 1. The x-axis reflects changes from a given reference point, which in terms of biodiversity might be the levels of biodiversity at a previous census. Broadly speaking, changes may be positive (increases) or negative (decreases) with respect to this reference point. Psychological reactions to these changes (e.g. affective responses to new information about changes in biodiversity) are represented on the y-axis and can also be positive (above the horizontal) or negative (below the horizontal), and take into account the original reference point (i.e. *reference dependence*). *Loss aversion* is represented on the figure by the steeper drop in affective responses (y^1) for a small loss (x), than the rise in affective responses (y) from a similar gain (x). *Diminishing sensitivity* is represented by the slopes of both the gain and loss curves which reflect smaller and smaller changes in affective responses, the farther the changes are from the reference point.

1.2. Related literature

Although little previous research has explored public reactions to information about biodiversity levels, a growing body of work has looked at the affective states of people in settings with different levels of biodiversity. Broadly speaking, greater biodiversity is generally found to be good for psychological well-being; people experience more positive and fewer negative emotions in more biodiverse settings (e.g. Cox et al., 2017; Fairchild, Fowler, Pahl, & Griffin, 2018; Fuller et al., 2007; Wolf et al., 2017), or at least those they *perceive* as more biodiverse (Dallimer et al., 2012). Moreover, several studies (e.g. Fuller et al., 2007) have assumed in their analyses that the relationship is essentially linear with constant marginal effects (e.g. going from a setting with 5 species to 10 species will be associated with the same increase in well-being as going from one with 10–15 species). To the extent that this pattern is true, and people are aware of it, then it is possible that they will react to news of biodiversity gains and losses in a proportionate manner; they should be twice as happy to hear of 10 species being reintroduced as 5, twice as sad to hear of the loss of 10 species compared to 5.

There are several reasons why we feel this is unlikely. First, there is evidence that people are relatively unaware of: a) actual biodiversity levels (Dallimer et al., 2012), b) their own affective reactions to the natural world (Nisbet & Zelenski, 2011), and c) the implications of biodiversity loss (Hunter & Brehm, 2003). This raises doubt that their reactions to news about changes in biodiversity levels should be proportionate to their actual experiences even if these were linear. Second, the linearity of the relationship between biodiversity and people's emotional experiences is also uncertain. Results from both large population-representative surveys (White et al., 2019) and controlled experimental studies (Cracknell et al., 2016) suggest diminishing marginal affective returns from greater exposure to nature and/or biodiversity levels. Small increases in nature exposure and biodiversity are good, large increases are not necessarily proportionately better. Although this is more consistent with current predictions of diminishing sensitivity we are not suggesting that people are therefore drawing on their experiences of biodiversity to inform their reactions to news of biodiversity changes, for the reasons given in the first point above. Rather, we see both processes as reflecting people's underlying tendency to be disproportionately sensitive to small versus large changes.
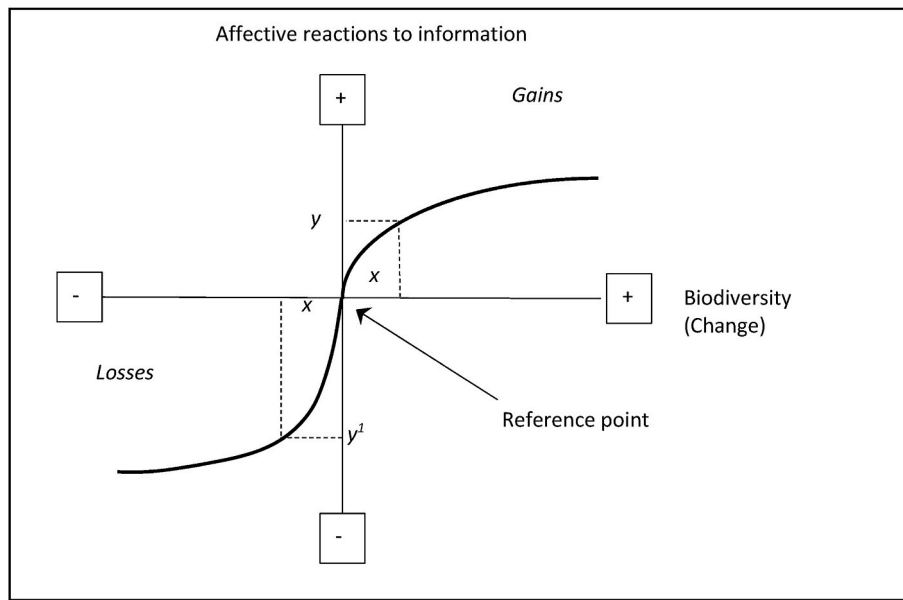
Fig. 1. Prospect theory predictions applied to reports of biodiversity change in the current studies.

1.3. The current research

The current study tested whether people's reactions to information about changes in biodiversity follow the three core predictions of prospect theory outlined above. We did this by presenting two samples, one in the US and one in the UK, with fictitious but realistic biodiversity reports. The two reports were conceptually identical except that the first focused on bird species richness, and the second focused on fish species richness (to explore generalisability across biodiversity contexts). Both reports outlined how ecologists had monitored bird/fish biodiversity levels (focusing on the number of species they found, i.e. *species richness*) at a specific site at two time points 1996/2016. The reports made it clear whether species richness had increased or decreased over the 20-year period (i.e. direction of change) and by how much (i.e. change magnitude). In order to test the predictions of prospect theory we developed 16 different conditions in each context which allowed us to: a) present either (relatively) high or low baseline levels of species richness in 1996 to act as reference points; b) report direction of change, either species losses or gains since 1996; and c) present parallel change magnitudes for both gains and losses. These baseline numbers and relative changes in species richness were based on an informal review of actual ecological reports, as well as discussions with members of the Biology Department at Stanford University, and were designed to be as believable and realistic as possible. Specific hypotheses were as follows:

Hypothesis 1 (H1). People will have greater affective reactions to *changes* in species richness (compared to 1996 baseline) than to the absolute number of species present at follow-up in 2016 (i.e. reference dependence).

Hypothesis 2 (H2). Where change over time is of the same magnitude, direction of change is important such that losses will have a larger (negative) impact on affective responses than the (positive) impact of gains (i.e. loss aversion).

Hypothesis 3 (H3). Linear changes in change magnitude (i.e. species richness, 5, 10, 15, 20) will be non-linearly associated with affective states (i.e. diminishing sensitivity). This was tested for gains and losses separately using quadratic polynomial contrasts.

In addition to our core hypotheses we also explored the role of nature relatedness (or connectedness) in these judgements, i.e. the degree to which an individual feels a cognitive and/or affective affiliation with the natural world (Schulz, 2002; Nisbet et al., 2009). We reasoned that people high on this trait might have more pronounced positive/negative reactions to news of biodiversity gains/losses respectively than those lower on relatedness, since they say they care more about the natural world. However, we had no firm predictions on how this trait might interact with our core hypotheses so this analysis was exploratory. For instance, although people high in nature relatedness might have stronger reactions to gains and losses in absolute terms, we saw no clear *a priori* reason why the relative size of the reactions to losses and gains would be different among those high versus low in nature relatedness.

2. Study 1

2.1. Participants

The study was conducted online in spring 2017. Study 1 participants ($n = 497$) were recruited in the US via student participant pools. There were 343 females (67.6%), mean age was 24yrs (*SD* 7.69; range 18–64). Supporting the success of the randomisation procedure, there were no significant differences in age or gender as a function of condition. We did however find evidence of "straight-lining" ($n = 16$) where participants selected exactly the same response option for all affective responses suggesting they did not take the exercise seriously. Furthermore, a further 88 participants failed to correctly identify the direction of change in a manipulation check question (see below) suggesting they failed to notice the primary piece of information. Exclusion of both groups resulted in a final analytical sample of $n = 393$ (79%). Inclusion of all participants had only one substantive effect on results (see discussion below).

2.2. Design

The study presented participants with two key pieces of information, the number of species present in: a) the baseline year (1996); and b) the follow-up year (2016). Specifically there were: a) two levels of baseline species richness in 1996 (Baseline: Low n = 24 *vs.* High n = 44); b) two levels of direction of change between 1996 and 2016 (Direction = Gain/increase *vs.* Loss/decrease); and c) four levels of change magnitude (ns = 5, 10, 15 or 20 species), resulting in a 16 condition between-participants design.

2.3. Procedure

2.3.1. Ethics, consent, and study overview

Ethical approval was granted by the Stanford University Human Subjects Committee. A short overview of the study for participants was provided online followed by an online consent form. We do not have a record of how many participants declined to take part after accessing the study. No formal power calculation was conducted, as we found no comparable studies upon which to base one.

2.3.2. The scenarios

The full introductory and scenario texts can be seen in Supplementary Materials A-C. Participants were introduced to the (real) Michelin Flatlands in Central Texas, an important refuge for migratory birds on the North American Central Flyway. They were informed that biodiversity levels at the site were collected in 1996 and 2016 by local experts and volunteers. Scenario realism was ensured by ecologist authors on this paper familiar with techniques in biodiversity measurement (e.g. 'bio-blitzes', Robinson et al., 2013). Descriptions of data collection were accompanied by photographs showing birders counting species and habitat suitability maps.

To further aid credibility, participants were told they would be provided with information about the total number of bird species broken down into three broad groups depending on migratory season (early/mid/late). Common, rather than scientific, names were used for these non-expert samples. Finally, biodiversity loss/gain was not uniform across the three species groups, such that even though the total number of species may fall, some new species may appear to take advantage of the ecological niche vacated by previously established ones. Although this complexity was added to make the scenarios more realistic, we recognise that it also makes the message more nuanced.

Following the general introduction, participants were provided with a summary of results including a clear headline statement, e.g. for the 'high baseline, 10 species loss' condition: "*The results showed an important DECREASE in the total number of species across the two periods in 1996 and 2016, from 44 to 34 species*". This single sentence contained all three elements of the design, the original *baseline* in 1996 (here the High baseline of 44 species), the *direction* of change (here a loss/decrease) and the *change magnitude* (here a loss of 10 species).

Text was accompanied by a simple bar chart to aid comprehension (Fig. 2) and touched on some of the potential causes for the change. For losses, the conclusion was: "*The drop in bird biodiversity was attributed to many factors including increased urbanization (and associated habitat loss), invasive species, tree disease, seasonal variability shifts associated with*

climate change, and increase in pesticide use from nearby agricultural lands". For gains it was: "*The increase in bird biodiversity was attributed to many factors including decreased urbanization (and associated habitat conservation), fewer invasive species, and a decrease in pesticide use from nearby agricultural lands*". The messages and layout were based on previous, authentic reports.

2.4. Outcome measure

Affective responses to the report were measured using an adapted version of the Scale of Positive And Negative Experience (SPANE, Diener et al., 2010) which asked participants how the information they had read made them feel in terms of a range of positive (e.g. happy, contented) and negative emotions (e.g. angry, sad). The SPANE was preferred to the Positive And Negative Affect Scale (PANAS, Watson et al., 1988) because of a more balanced range of emotions in terms of arousal (Diener et al., 2010). The original SPANE asks people about the frequency with which they experience these emotions over the last four weeks (from 'Never/very rarely' to 'Very often/always'). However, as we were only interested in participants' immediate reactions to new biodiversity information our version asked about the extent to which participants experienced each emotion after reading the report: "*Thinking about the information you have just read, in terms of biodiversity change in the Michelin Flats from 1996-2016, please rate the degree to which you experienced each of the following feelings from 0 (not at all) to 6 (very strongly)*". Here we focus on the total Affect-balance scores which combine both positive (Cronbach's alpha Study 1 = 0.96; Study 2 = 0.97) and negative (Cronbach's alpha Study 1 = 0.95; Study 2 = 0.94) emotions as follows: Affect-balance = Total Positive – Total Negative (Diener et al., 2010). Affect-balance (which runs from −6 to +6) was chosen as the main outcome, rather than positive and negative affect separately, as it better reflects Prospect Theory's bi-polar distribution of utility (i.e. affective reactions) from very negative to very positive negative (i.e. vertical axis in Fig. 1).

2.5. Additional measures

After participants had completed the SPANE they were asked the 6-item short version of the Nature Relatedness Scale (NRS-6, Nisbet & Zelenski, 2013) with items such as '*My ideal vacation spot would be a remote, wilderness area*' with response options from '*Strongly Disagree*' (1) to '*Strongly Agree*' (5) (Cronbach's alpha Study 1 = 0.83; Study 2 = 0.82) so items were collapsed to form a single scale. This was followed by: a) a manipulation check question: '*Overall, did species richness INCREASE or DECREASE in the example you looked at earlier?*' with response options: '*Increase*', '*Decrease*', '*Don't know*'; and b) a credibility question "*How believable was the information presented in this biodiversity report?*" from '*not at all believable*' (1) to '*completely believable*' (7). All items, including demographics not used in the current analyses, were asked in the final section are presented in Supplementary Materials D.

2.6. Analyses

Hypotheses were explored using three between-participant Analyses of Variance (ANOVAs) with affect-balance as the dependent variable, and in respect to H3 by using additional planned quadratic contrasts. The first hypothesis testing reference dependence focused only on those levels of biodiversity (2016 species number: 29/34/39) common across both baseline conditions (Baseline: High/low). If absolute levels of biodiversity are the only thing that mattered, people should have the same reaction to news of 34 species being present in 2016 regardless of whether the level in 1996 was 24 (low baseline) or 44 (high baseline). By contrast if baselines matter (reference dependency) we would expect news of 34 species being present to result in a positive reaction if the baseline was below this number (i.e. 24 and indicative of an increase) but a negative reaction if the baseline was above this number (i.e. 44

Bird Species Richness in Michelin Flatlands
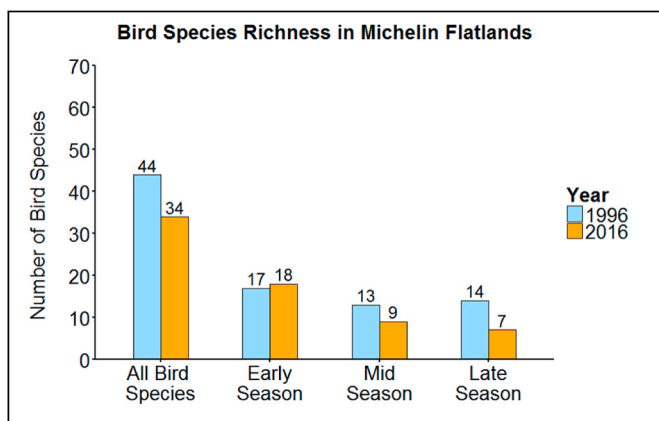
Note. Results for the high baseline, decrease in 10 species condition.

Fig. 2. A bar chart presented to Study 1 participants to help summarise changes in bird species in Michelin Flatlands (1996–2016).
Note. Results for the high baseline, decrease in 10 species condition.

indicative of a decrease).

The second hypothesis focused on effect magnitude rather than direction in order to be able to compare the relative impact of gains/losses directly. For instance, we predicted that news of a 10 species loss would have a larger effect in a negative direction than a 10 species gain would have in a positive direction. However, due to the different directions of the effect, to explore their relative magnitude we squared the affect-balance scores to ensure that both scores were positive and could be compared directly (much as regressions derive Sums of Squares to explore deviation around a central tendency irrespective of direction). Then, to aid interpretability we took the square root of these scores so that the absolute numbers were comparable to the original scale scores used. As preliminary analysis found no effect of specific baseline this was dropped from these analyses for clarity.

The third analysis ran quadratic contrasts to test for non-linear relationships (specifically diminishing marginal returns) between change magnitude and affective reactions. These were run for gains and losses separately because according to prospect theory the curves either side of the reference point are asymmetric due to predicted loss aversion i.e. a stronger reaction to small losses versus small gains (Fig. 1). For completeness, linear terms were also tested in case they better reflected the relationship than the quadratic ones.

Finally, exploratory analyses re-ran the first two analyses with nature relatedness as a covariate with interaction terms between nature relatedness and all factors, to explore whether relatedness moderated any effects. As it is not possible to explore non-linear fixed effects interactions in ANOVA within SPSS, to explore the third hypothesis a quadratic term was created for change magnitude (change magnitude squared), which was then interacted with nature relatedness and entered into a linear regression that also included the linear and quadratic terms. Two regressions were conducted, one for gains and one for losses.

2.7. Results

2.7.1. Preliminary analyses

Credibility of the scenarios was perceived as relatively high on the 1–7 scale, $M = 5.48$ ($SD = 1.26$). To explore whether some scenarios were more credible than others we ran a 2 (Baseline: High/low) x 2 (Direction: Gain/loss) x 4 (Change magnitude: 5/10/15/20) between participants ANOVA; the only significant effect was a main effect of direction, $F(1,392) = 20.85$, $p < 0.001$, $eta^2 = 05$. Respondents thought the loss scenarios ($M = 5.76$; $SD = 1.12$) were somewhat more credible than the gain scenarios ($M = 5.20$; $SD = 1.33$), though the latter still received relatively high ratings. Our efforts to make even the biodiversity gain scenarios realistic and believable appear to have been successful. Means and 95% Confidence Intervals (CIs) for affect-balance for all conditions can be seen in Table 1 and Fig. 3, and results of the affect-balance ANOVAs used to test our hypotheses in Table 2. Means and standard deviations for all conditions, as well as full analyses are presented in Supplementary Table E1 where for completeness results for positive and negative sub-scales are also presented separately.

2.7.2. Hypothesis testing

2.7.2.1. Reference dependence (H1).
Reference dependence was investigated using a 2 (Baseline: High/low) x 3 (Species number 2016: 29/34/39) between-subjects ANOVA. Results showed strong support for H1 with a significant main effect of baseline but no significant main effect of species number or interaction (Table 2). Whereas affect-balance was significantly higher if the baseline was low ($M = 3.38$; $SD = 1.69$) versus high ($M = -2.69$; $SD = 1.73$), there was no significant difference as a function of the actual number of species in 2016: 29 ($M = 0.26$; $SD = 3.71$), 34 ($M = 0.05$; $SD = 3.43$), 39 ($M = 0.63$; $SD = 3.36$). Participants were more positive about a given number of species present in 2016, if this reflected an increase from 1996 levels rather than a decrease.

2.7.2.2. Loss aversion (H2).
To explore whether, irrespective of reference point, decreases in biodiversity had a larger impact on affective responses than increases of the same magnitude, we ran a 2 (Direction: Gain/loss) x 4 (Change magnitude: 5/10/15/20) between-participants ANOVA. Contrary to H2, gains ($M = 3.12$, $SD = 1.63$) had a significantly larger effect on the transformed affect-balance scores (to account for direction) than losses ($M = 2.73$, $SD = 1.64$). Change magnitude and the interaction were not significant. In this context, gains seemed to have a greater impact (loomed larger) than similar sized losses.

2.7.2.3. Diminishing sensitivity (H3).
The two one-way ANOVAs, one for

Table 1

Participant numbers (N), means (M) and 95% confidence intervals (CIs) for affect-balance by condition for studies 1 and 2.

Condition (Number of Species)				Study 1				Study 2		
Species			Species	Affect-balance				Affect-balance		
1996	Change		2016	N	M	(95% CIs)		N	M	(95% CIs)
Low										
24	Increase	+20	44	24	2.51	(1.80,	3.23)	37	3.66	(3.06, 4.27)
24	*Increase*	*+15*	*39*	*22*	*3.58*	*(2.83,*	*4.33)*	*35*	*3.07*	*(2.45, 3.69)*
24	*Increase*	*+10*	*34*	*24*	*2.94*	*(2.23,*	*3.66)*	*37*	*3.18*	*(2.58, 3.79)*
24	*Increase*	*+5*	*29*	*23*	*3.64*	*(2.91,*	*4.38)*	*32*	*3.34*	*(2.70, 3.99)*
24	Decrease	−5	19	24	−2.35	(-3.07,	−1.64)	36	−1.25	(-1.86, −0.64)
24	Decrease	−10	14	27	−2.69	(-3.36,	−2.01)	38	−2.45	(-3.04, −1.85)
24	Decrease	−15	9	24	−2.35	(-3.07,	−1.64)	37	−3.11	(-3.71, −2.51)
24	Decrease	−20	4	28	−2.74	(-3.40,	−2.07)	33	−2.61	(-3.25, −1.97)
High										
44	Increase	+20	64	27	3.30	(2.62,	3.97)	33	3.14	(2.50, 3.78)
44	Increase	+15	59	25	2.81	(2.11,	3.52)	42	3.58	(3.02, 4.15)
44	Increase	+10	54	22	3.01	(2.26,	3.76)	35	3.01	(2.39, 3.63)
44	Increase	+5	49	27	2.86	(2.18,	3.54)	35	2.93	(2.32, 3.55)
44	*Decrease*	*−5*	*39*	*23*	*−2.20*	*(-2.93,*	*−1.46)*	*36*	*−2.29*	*(-2.90, −1.68)*
44	*Decrease*	*−10*	*34*	*24*	*−2.85*	*(-3.57,*	*−2.14)*	*36*	*−2.43*	*(-3.04, −1.81)*
44	*Decrease*	*−15*	*29*	*24*	*−2.99*	*(-3.71,*	*−2.28)*	*29*	*−1.96*	*(-2.64, −1.28)*
44	Decrease	−20	24	25	−2.50	(-3.20,	−1.80)	39	−3.00	(-3.59, −2.42)

Note: Follow-up 2016 Ns = 29, 34 & 39 in italic were deliberately duplicated in the High and Low baseline scenarios to enable us to test Hypothesis 1. Affect-balance scores ranged from −6 to +6.
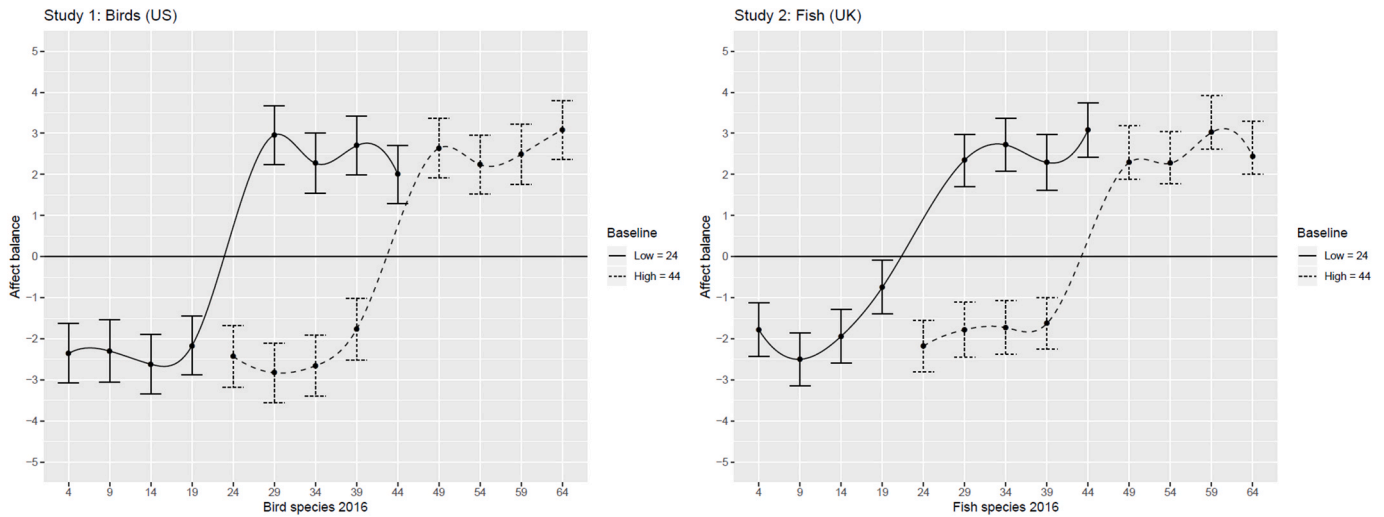
Fig. 3. Participant means (M) and 95% confidence intervals (CIs) for affect-balance by condition for studies 1 and 2.
Note. The number of species in 1996 was 24 number in the low baseline conditions and 44 in the high baseline conditions. Species numbers 29, 34 and 39 have data for both High and Low baseline conditions. The solid (low baseline) and dashed (high baseline) lines are not formal trend lines, they have been added merely to aid identification of which baseline conditions each species richness data point pertain to.

Table 2
Tests of hypotheses on affect-balance in studies 1 and 2.

			Study 1					Study 2		
	df	F	Contrast estimate	p	eta²	df	F	Contrast estimate	p	eta²
			(95% CIs)					(95% CIs)		
H1: Reference dependence										
Baseline (relativities)	1	443.97	–	<.001	.77	1	399.97	–	<.001	.67
Species number (absolutes)	2	1.67	–	.192	.02	2	0.55	–	.581	<.01
Baseline x species number	2	0.98	–	.379	.01	2	0.12	–	.883	<.01
H2: Loss aversion										
Direction (Loss/gain)	1	5.89	–	.016	.02	1	32.70	–	<.001	.06
Change magnitude	3	0.23	–	.879	<.01	3	3.15	–	.025	.02
Direction x magnitude	3	0.88	–	.453	<.01	3	0.41	–	.747	<.01
H3: Diminishing sensitivity										
Losses										
Linear	–	–	-.21 (−.73, .30)	.416	–	–	–	-.74 (−1.18, −.30)	.001	–
Quadratic	–	–	.27 (−.25, .79)	.309	–	–	–	.22 (- .22, .67)	.321	–
Gains										
Linear	–	–	-.15 (−.64, .33)	.535	–	–	–	.25 (- .20, .69)	.274	–
Quadratic	–	–	.00 (−.49, .49)	.995	–	–	–	.05 (- .39, .48)	.829	–

gains and one for losses, had 4 levels (Change magnitude: 5/10/15/20). There was no evidence of diminishing sensitivity (i.e. a significant quadratic term) for either losses (Ms 5/10/15/20 = −2.28, −2.76, −2.67, −2.63 respectively) or gains (Ms 5/10/15/20 = 3.13, 3.10, 3.35, 3.41 respectively). There were also no significant linear effects suggesting that people's reactions to any level of loss, or any level of gain, were similar.

2.7.3. Nature relatedness

The potentially moderating role of nature relatedness on **reference dependence (H1)** was investigated using a 2 (Baseline: High/low) x 3 (Species number 2016: 29/34/39) between-subjects Analysis of Covariance (ANCOVA) with nature relatedness as covariate. There was no main effect of nature relatedness $F(1,128) = 0.74$, $p = .390$, $eta^2 = 0.01$, but there was a significant interaction between baseline and relatedness $F(1,128) = 9.07$, $p = .003$, $eta^2 = 0.07$. Those high in nature relatedness reacted more strongly as a function of changes from baseline than those low in nature relatedness. None of the other interactions with nature relatedness were significant (all $Fs < 1.59$, all $ps > .21$, see Supplementary Table H1).

The potentially moderating role of nature relatedness on **loss aversion (H2)** was investigated using a 2 (Direction: Gain/loss) x 4 (Change magnitude: 5/10/15/20) between-subjects ANCOVA with nature relatedness as covariate. This time there was a significant main effect of nature relatedness $F(1,377) = 21.98$, $p < .001$, $eta^2 = 0.06$, such that (as with H1) transformed affect-balance scores were higher for those with higher nature relatedness. However, none of the other interactions with relatedness were significant (all $Fs < 3.60$, all $ps > .06$, see Supplementary Table H1).

Finally, the potentially moderating role of nature relatedness on **diminishing sensitivity (H3)** was explored with two, univariate regressions one for gains and one for losses. Crucially, the interaction term between nature relatedness and change magnitude squared was non-significant for both losses (β = 0.00; 95% Confidence Intervals (CIs) [-.00, .01]; $p = .569$) and gains (β = -.00, 95% CIs [-.01, .00], $p = .522$). Of note, the interaction terms between nature relatedness and change magnitude (i.e. as a linear term) were also non-significant for both losses and gains (βs <.06; $ps > .198$).

In short, although people with higher nature relatedness did react more strongly to both positive and negative changes in biodiversity than

those with lower nature relatedness, the patterns with respect to our key hypotheses were similar: a) reference dependence was present at all levels of nature relatedness, b) reactions to gains were stronger than to losses for all levels of nature relatedness, and c) nature relatedness did not affect the slope of the loss and gain curves.

3. Study 2

The design and outcome measures of Study 2 were identical to Study 1; it was conducted at the same time (spring 2017); and it was covered by the same ethical approval. The major differences were that the biodiversity scenario focused on fish species richness in a fictional marine setting and it was conducted in the UK.

3.1. Participants

Participants (n = 817) were UK members of an online platform run by an international market research company (Cint). The mean age was 51yrs (*SD* = 17.5; range 18–87) and there were 378 (51%) females. Again there were no significant differences in age or gender as a function of condition. There was also evidence of "straight-lining" (*n* = 68), and incorrect responses to the manipulation check (n = 179). Exclusion of both groups resulted in a final analytical sample of *n* = 570 (70%). Again analyses including all respondents found similar results with one exception (Supplementary Table G1, and discussion below).

3.2. Scenarios

Participants were presented with the fictional St Martin's Bay, based on Swanage Bay in Dorset. Whereas study 1 used a real location, a fictional location was used here to reduce the potential influence of any prior knowledge or beliefs. The same basic story was recounted of species monitoring in 1996 and 2016 by local experts and volunteers but a fictional location was used to reduce any potential familiarity effects. In an attempt to bolster credibility fish species were broken down into three broad groups depending on where they tended to be found in the water column (top, middle, or bottom). Again, biodiversity loss/gain was not uniform across the three species groups. Figures similar to those in Study 1 (e.g. Fig. 2) were presented although the summary text was changed as follows. For losses: "*The drop in biodiversity was attributed to many factors including increased scallop dredging, warmer waters associated with climate change, and increased pollution from the nearby city*"; for gains it was: "*The increase in biodiversity was attributed to many factors including decreased scallop dredging and decreased pollution from the nearby city*".

3.3. Results

3.3.1. Preliminary analyses

Credibility of the scenarios was again high *M* = 5.95 (*SD* = 0.97). Running a 2 (Baseline: High/low) x 2 (Direction: Gain/loss) x 4 (Change magnitude: 5/10/15/20) between participants ANOVA again revealed only a significant main effect of direction, *F* (1,568) = 11.00, *p* < 0.001, *eta²* = 02. Respondents thought the loss scenarios (*M* = 6.08; *SD* = 0.92) were somewhat more credible than the gain scenarios (*M* = 5.82; *SD* = 1.00).

Means and 95% Confidence Intervals (CIs) for affect-balance for all conditions can be seen in Table 1 and Fig. 3. Results of the affect-balance ANOVAs used to test our Hypotheses are presented in Table 2. Means and standard deviations for all conditions, as well as full analyses are presented in Supplementary Table D where again for completeness results for positive and negative sub-scales are also presented separately.

3.3.2. Hypothesis testing

3.3.2.1. Reference dependence (H1). Reference dependence was again

investigated using a 2 (Baseline: High/low) x 3 (Species number 2016: 29/34/39) between-subjects ANOVA. Results showed strong support for H1 with a significant main effect of baseline but no significant main effect of species number or interaction (Table 2). Whereas affect-balance was significantly higher if the baseline was low (*M* = 3.19; SD = 1.96) versus high (*M* = −2.24; SD = 1.88), there was no significant difference as a function of the actual number of species in 2016: 29 (*M* = 0.82; *SD* = 3.28), 34 (*M* = 0.42; *SD* = 3.36), 39 (*M* = 0.35; *SD* = 3.38). Findings replicated Study 1, participants rated a given level of species in 2016 more favourably if it reflected an increase rather than a decrease in 1996 levels.

3.3.2.2. Loss aversion (H2). Loss aversion was again investigated using a 2 (Direction: Gain/loss) x 4 (Change magnitude: 5/10/15/20) between-participants ANOVA. Contrary to H2, and replicating Study 1, gains (*M* = 3.41, *SD* = 1.55) had a significantly larger effect on the transformed affect-balance scores (to account for direction) than losses (*M* = 2.66, *SD* = 1.55). There was also a significant main effect of change magnitude with some evidence that larger changes had slightly larger effects than smaller ones: 5 (*M* = 2.82; *SD* = 1.63), 10 (*M* = 2.84; *SD* = 1.67), 15 (*M* = 3.21; *SD* = 1.52), 20 (*M* = 3.28; *SD* = 1.60). Replicating Study 1, gains had a greater impact (loomed larger) than losses.

3.3.2.3. Diminishing sensitivity (H3). The two one-way ANOVAs, one for gains and one for losses, had 4 levels (Change magnitude: 5/10/15/20). There was again no clear support for diminishing sensitivity, with non-significant quadratic terms for both losses (*Ms* 5/10/15/20 = −1.77, −2.44, −2.60, −2.82 respectively) and gains (*Ms* 5/10/15/20 = 3.13, 3.10, 3.35, 3.41 respectively). There was, however, a significant linear term for losses (contrast estimate = -.74, 95% CIs −1.18, -.30; *p* < .001) with greater losses associated with stronger negative reactions (see *M*s above). Contrary to Study 1 there was evidence that people were more affected by greater losses, but also contrary to the prediction this followed a linear rather than quadratic pattern.

3.3.3. Nature relatedness

As with Study 1, the potentially moderating role of nature relatedness on **reference dependence (H1)** was investigated using a 2 (Baseline: High/low) x 3 (Species number 2016: 29/34/39) between-subjects ANCOVA with nature relatedness as covariate. Again, there was no main effect of nature relatedness *F*(1,193) = 2.57, *p* = .111, *eta²* = 0.01, though this time the interaction between baseline and relatedness was not significant *F*(1,193) = 3.27, *p* = .072, *eta²* = 0.02. None of the other interactions were significant (all *F*s < 0.60, all *p*s > .55, see Supplementary Table H1).

The potentially moderating role of nature relatedness on **loss aversion (H2)** was investigated using a 2 (Direction: Gain/loss) x 4 (Change magnitude: 5/10/15/20) between-subjects ANCOVA with nature relatedness as covariate. Again there was a main effect of nature relatedness *F* (1,554) = 38.93, *p* < .001, *eta²* = 0.07, transformed affect-balance scores were higher for those with higher nature relatedness. There were, again no significant interactions with nature relatedness (all *F*s < 0.87, all *p*s > .46).

Finally, as with Study 1, the potentially moderating role of nature relatedness on **diminishing sensitivity (H3)** was explored with two univariate regressions one for gains and one for losses including linear and quadratic terms for change magnitude and their interaction with nature relatedness. Again, the interaction term between nature relatedness and change magnitude squared was non-significant for either losses (β = -.00; 95% Confidence Intervals (CIs) [-.01, .00]; *p* = .820) or gains (β = -.00, 95% CIs [-.01, .00], *p* = .358), nor were the interaction terms between nature relatedness and the linear change magnitude terms significant (*β*s <.06; *p*s > .187).

As with Study 1, although people with higher nature relatedness did react more strongly to both positive and negative changes in biodiversity

than those with lower nature connectedness, the patterns in relation to our key hypotheses were similar: a) people showed reference dependence across levels of nature relatedness, b) there was no evidence of loss aversion, and c) nature relatedness did not influence the slope of the loss and gain curves.

4. Discussion

The current studies aimed at improving our understanding of how people respond to reports about losses in biodiversity such as those highlighted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, Diaz et al., 2019), and rarer so called 'bright spot' messages of biodiversity rehabilitation (Cvitanovic & Hobday, 2018). Apart from the varied ways in which humans benefit from biodiversity (e.g. food, pollination of crops, waste processing, e.g. Diaz et al., 2006), there is growing evidence that people derive direct psychological benefit from being in more biodiverse settings (Cox & Gaston, 2018; Cracknell et al., 2016). However, knowing this does not necessarily inform us as to how people will respond to news about changes in biodiversity. People may underestimate the extent to which their emotional states are influenced by the natural world (Nisbet & Zelenski, 2011), so their affective reactions to news of change need not be in accordance with their experiences of it *in situ*. Given that messages about biodiversity loss (in particular) partly aim to motivate behaviour to reverse the trend (Miller, 2005), understanding people's responses to such news is thus important in its own right.

To help structure our investigation into these issues, we applied prospect theory, originally designed to explore decisions under uncertainty in economic contexts, to biodiversity. Future levels of biodiversity are uncertain, especially at the local scale. Though there has been an overall downward trend for some time (Johnson et al., 2017), in some contexts examples exist where species have been reintroduced, or degraded environments have improved, and thus there may also be gains (Cvitanovic & Hobday, 2018; Johnson et al., 2017). While a body of research exists exploring public attitudes towards such changes, it tends to focus on attitudes towards a single species and on characteristic mega-fauna such as carnivores (e.g. wolves/bears, Hermann & Menzel, 2013). Far less is known about how people respond to more generic news about species levels or about changes in the diversity of less charismatic species of the kind presented in many major reports on biodiversity change.

4.1. Summary of results and relation to previous literature

Supporting reference dependence (H1), relative change was more important for affective reactions than the absolute number of species in both studies. Participants felt more positive about a relative increase in species over time than a relative decrease regardless of the actual number of species in 2016. This suggests, not surprisingly, that our participants did not have a clear threshold for what constituted a 'good' or 'bad' level of biodiversity in these sites and were, as predicted, using a previous reference point to guide them. This is consistent with the 'evaluability hypothesis' proposed by Hsee (1996) who argued that in many contexts it is hard for non-experts to know *a priori* whether a piece of information is good or bad because it is hard to evaluate out of context. Whether or not we would have found similar effects among expert ecologists would be a subject for further research, but our findings support the suggestion that when individuals are uncertain as to whether an outcome is good or bad in some absolute sense, they rely on reference points in order to form a judgment. Greater awareness of this information may be important for communicators because it suggests that in areas of domain uncertainty (e.g. biodiversity levels) presenting data on change is likely to have a bigger impact than absolute information, and it will be helpful to explain the context of change carefully.

There was no support for loss aversion (H2) when comparing loss and gain scenarios in either study. In fact we found the exact opposite, with

stronger affective reactions to gains than losses in both Study 1 and 2. Psychological research has long demonstrated a 'negativity bias' such that negative information tends to have a larger impact on affective states than positive information (Vaish et al., 2008). However, in some situations, positive information, or the adoption of gain versus loss frames for the same objective situation, can have a stronger impact than negative information, or loss versus gain frames (e.g. Lee & Aaker, 2004; Morton et al., 2011; Nabi et al., 2018; Rothman et al., 2006)[1]. In particular, negative information can be demotivating and may encourage people to deny (Floyd et al., 2000), avoid thinking about (Boomsma et al., 2016), or attenuate their reactions to, the issues at hand. In part this may be to avoid feelings of discomfort, guilt and dissonance (Bissing-Olson et al., 2016), especially when they can do little to personally change the situation (Peters et al., 2018).

Since respondents in the current situation could not personally improve the biodiversity levels at our two locations, this lack of personal efficacy may partly explain why affective reactions to losses were not as strong as they were to gains. Moreover, gains were also offering messages of hope, i.e. good things can happen, and positive change can occur if we take the right steps (so called 'hope appeals', e.g. Chadwick, 2015). The closing sentence of the executive summary explicitly accounted for biodiversity gains in terms of deliberate human actions including (Study 2) "*decreased scallop dredging and decreased pollution from the nearby city*", highlighting that positive things could and were being done (i.e. 'response efficacy', Maddux & Rogers, 1983), which may have induced feelings of hope (Corral Corall Verdugo, 2012). Although we cannot explore this possibility directly here, as hope was not itself one of the items in the SPANE, future work could extend the current work to look at more specific emotions.

An alternative possibility might relate to a violation of expectancies. Evidence suggests that unexpected outcomes can arouse stronger emotions than expected ones (Scherer, 2009) and since news of biodiversity gains might be more unexpected than losses, given the general trajectory (Diaz et al., 2019), we might expect more marked positive emotions from gains and more muted responses to more familiar loss messages. Supporting this possibility, gains were seen as slightly less "credible" (i. e. suggesting they were less expected) and reactions to them were stronger than to equivalent losses. Further research that directly measures expectations prior to receiving the information would help unpack this possibility (White et al., 2003).

There was also no support for the hypothesis of diminishing sensitivity. Instead participants tended to demonstrate 'scope insensitivity' (Veisten et al., 2004) reacting to any gain/loss, no matter how large, in a similar positive/negative fashion. Although there was some evidence of stronger negative reactions to greater losses in Study 2, the pattern was linear, and not quadratic as hypothesised. As this was not found in Study 1 we remain cautious about over-interpreting this isolated finding, especially given the multiple tests being run.

Finally, there was no evidence that trait-level nature relatedness moderated any of these effects. As might be expected, people higher in relatedness tend to react more strongly to both gains and losses than those lower in relatedness, reflecting greater concern with these issues (Nisbett et al., 2009). However this generally higher level of concern was not the cause of the unexpected finding of gains looming larger than losses because there was no interaction between direction and nature-relatedness in either study. That is, the tendency to react more strongly to gains than losses was true of those at all levels of relatedness even if those higher in relatedness reacted more strongly overall to both scenarios.

4.2. Limitations and future studies

The findings need to be considered within the context of several limitations. First, in order to create a strong experimental design, the scenarios were necessarily hypothetical and people may respond differently to genuine stories. For instance, the sites and levels of

biodiversity change were relatively small compared to the global levels examined in the IPBES report. Thus although both positive and negative scenarios were rated as highly credible by participants, suggesting they were effective, further work is needed to investigate reactions to information at a variety of spatial scales.

Second, although our samples were heterogeneous, they were collected online and were not representative of either the US or UK populations. A more representative study would be able to shed light on how specific demographic groups, especially those in different countries or cultural contexts, respond to different messages. Although we were tempted to investigate potential differences according to demographic groups, we were reluctant to do this because it would involve substantial reductions in cell sizes (due to the large number of conditions).

Third, we had relatively large numbers of straight-liners and people who failed the manipulation check, suggesting that people either: a) did not take the online experiment seriously; b) found the long introductory material tiresome and/or confusing; and/or c) found the manipulation check itself confusing because it did not ask about the magnitude of any change and people may have selected the middle option because they correctly noticed that some groups of species went in the opposite direction of the overall trend. Including all straight-liners and those who failed the manipulations check produced largely similar results, with two exceptions (Supplementary Table G1). The first, was that in Study 1 there was no significant difference in the effect of losses and gains for H2 (and thus still no support for loss aversion), and in Study 2 the main effect of species number was also non-significant. In short, although effects were largely robust to inclusion or exclusion of participants who may not have fully read/understood the materials, the large number suggests that similar materials may need to be shorter and designed even more carefully in future.

Fourth, although we used different samples (in different countries) and different fauna (birds *vs.* fish) in order to improve confidence in any effects, this also made direct comparison between the two studies problematic because differences between them (e.g. H2) could have been due to either sample, context or both. For instance, we recognise that particularly positive reactions to gains in fish species in Study 2 might have been due to the fact that several of the species mentioned were commercially harvested and thus it is possible that some participants (especially male respondents in the UK context, Jefferson et al., 2014) reacted to this increase in terms of commercial opportunities. We originally selected different contexts because we felt that people would relate more to a context within their own country; the shift from birds to fish was an attempt to not restrict any findings to only one biological class. However, it is important to appreciate the implications of these differences and future work is needed to systematically explore how people respond to different classes of animal and plant biodiversity in different cultural contexts.

Fifth, we also note that climate change was potentially made more salient in the species loss than species gain scenarios while all other factors were kept constant. It is unclear what effect this small detail within the whole experimental materials might have had (since the effect of losses were never greater than gains) but we recognise in hindsight that it would have been easy to have included a climate change related statement in the scenarios and thus reduced this potential confound in explaining biodiversity changes. More generally, future work may want to explore the effect of different attributions for any changes (e.g. anthropogenic *vs.* 'natural', Brun, 1992; Ferguson & Branscombe, 2010) on affective reactions alongside the size of the changes *per se.*

Sixth, we said nothing about the 'appropriateness' of the species being recorded in the bio-blitzes. Some short-terms gains in biodiversity can be highly detrimental to overall eco-systems in the long-run if these species are 'invasive', or 'alien', i.e. inadvertently or deliberately introduced to eco-systems where they were never present before, and can out compete native species (Pimentel et al., 2005). The problem is particularly acute in marine ecosystems due to a lack of natural barriers

(Molnar et al., 2008), with invasive species such as the lionfish having devastating effects on coral reef species in the Caribbean, for example (Green et al., 2012). Although we decided to omit this kind of complexity from the current study, further research could explore the extent to which members of the general public understand and are sensitive to these kinds of subtleties.

Seventh, we recognise that our studies focused on a very limited set of people's reactions (using the SPANE) and additional outcome measures e.g. feelings of hope, preferences for nature protection programmes, or behavioural outcomes (e.g. donations to environmental organisations trying to protect biodiversity levels) could be included in future studies to know whether information about changes in biodiversity might stimulate meaningful actions. Studies using information about real biodiversity changes might be better placed to do this.

Finally, we recognise that people's reactions to information about biodiversity change (whether hypothetical or real) says little about people's emotional and behavioural reactions to different levels of biodiversity *in situ* (Fuller et al., 2007). We believe our findings are nonetheless valuable in themselves to help understand reactions to reports such as the IPBES one (Diaz et al., 2019), though we recognise that the two processes may be very different.

4.3. Implications

These limitations notwithstanding, perhaps the biggest implication of the current research is the recognition of the need for greater theorising with respect to how the public reacts to news about changes in biodiversity, and an improvement in the research designs used to test them. We appreciate that our attempt to develop a study design which tested prospect theory's predictions had limitations, but the research's strength was that it was clearly based on a theory that had been discussed in the biodiversity literature as potentially important but, to our knowledge, not previously tested (Bull et al., 2017; Hummel et al., 2009). Apart from the clear impact of reference points, as already recognised in a slightly different way by Pauly (1995) however, the current research offers relatively little support for prospect theory's predictions, especially the notion of loss aversion. Moreover the lack of any diminishing sensitivity also questions the intuitive notion that people will be more shocked by a 60% decline (WWF, 2018) than a 30% decline in species, or more pleased about a 40% versus 20% increase (Damschen et al., 2006) in species. If these patterns hold in other, more applied, contexts this is a sobering thought for communicators trying to stress the urgency of the situation and suggests other paradigms are needed.

Although there was some support for the intuitive notion that people with greater nature relatedness (a concept with links to biospheric values, Nisbet & Zelenski, 2013) would react more strongly to news of both gains and losses in biodiversity, this did not moderate our findings. Nevertheless considering this distinction in communications and designing messages that take into account different levels of nature relatedness may be important. If the end goal of such messages is not to just to arouse emotions, but ultimately encourage action and change behaviour, then we also need to consider how messages tie into existing theoretical models of behaviour change in the environmental field such as the comprehensive action determination model (Klöckner, 2013), the stage model of self-regulated behaviour (Bamberg, 2013), and the integrated framework of pro-environmental behaviour (Steg et al., 2014). Applying this thinking, communicators such as IPBES, the WWF, and others are likely to increase the impact of their messaging by: a) making people more aware of the consequences of human actions which in turn are thought to b) influence current emotions (as tested in the current research), and c) norms, especially moral norms, which are then thought to influence both d) attitudes and e) goal intentions (see Chng et al., 2018 for such a mapping).

More tentatively, communicators may consider promoting, albeit rarer, 'bright spot' stories (Cvitanovic & Hobday, 2018), even if the biodiversity gains are small in absolute terms. Following the hope

appeals and positive framing literature in health and climate change communication research (Chadwick, 2015; Morton et al., 2011), participants in both studies, seemed particularly responsive to good news messages; ecologists do not need to demonstrate large improvements, even a few examples may be enough in alleviating potential negative story fatigue (Moeller, 2002). Whether or not positive messages about biodiversity change leads to positive action (Cvitanovic & Hobday, 2018), or 'social loafing' along the lines of "oh well I don't need to do anything then" (Karau & Williams, 1993) would require further research.

4.4. Concluding comments

To our knowledge this is the first study that has tested hypotheses derived from prospect theory in the novel context of biodiversity change. Results question at least two fundamentals of prospect theory as applied to news of changes in biodiversity, assumptions we suspect may have been implicit in communicators' minds. Two different samples, in two different countries, considering two different biodiversity contexts, showed no evidence of loss aversion; in fact news of biodiversity gains appeared to 'loom larger' than equivalent losses, at least in terms of their immediate affective reactions. News of greater losses (and gains) also failed to result in stronger emotional reactions; presenting people with ever larger numbers of biodiversity loss and expecting them to be proportionately worried may be unrealistic. To have the desired consequences, communicators may therefore need to integrate their messages within the framework of more sophisticated models of how behaviour change occurs as a result of information about biodiversity loss. They also need to consider creative ways in which news of biodiversity gains may inspire hope and how building nature relatedness more broadly may make people more receptive to key messages. Given the manifold challenges and urgency of addressing biodiversity loss, our results suggest current practices of providing the public with ever greater numbers/percentages of species loss are failing to have the intended consequences and a significant re-think about more sophisticated messaging based on extensive research in other fields (e.g. climate change) may be required.

Notes

1. Traditionally the terms loss and gain frame refer to the same objective situation expressed in different ways (e.g. a treatment for 100 people may 'save 10 lives' or 'fail to save 90 lives'). Here, by contrast, we are comparing the same objective situation (e.g. 29 species) expressed in reference to different baselines (i.e. 24 vs. 34), so gains and losses are actually relative to a baseline and not just a matter of framing.

Author Statement

Mathew White: Conceptualization, Methodology, Analysis, Writing-Original Draft Preparation; Greg Bratman: Conceptualization, Writing-Reviewing and Editing. Sabine Pahl: Data Collection, Writing- Reviewing and Editing. Gerald Young: Material Preparation; Data Collection; Writing- Reviewing and Editing: Deborah Cracknell: Material Preparation; Writing- Reviewing: Lewis Elliott: Analysis Checking; Visualization.

Declaration of competing interest

This manuscript has been approved by all authors and is not under consideration for publication elsewhere. If accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder.

Acknowledgments

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2020.101502.

References

Bamberg, S. (2013). Changing environmentally harmful behaviors: A stage model of self-regulated behavioral change. Journal of Environmental Psychology, 34, 151–159.

Barberis, N. C. (2013). Thirty years of prospect theory in economics: A review and assessment. The Journal of Economic Perspectives, 21, 173–196.

Bernstein, A. (2014). Biological diversity and public health. Annual Review of Public Health, 35, 153–167.

Bissing-Olson, M. J., Fielding, K. S., & Iyer, A. (2016). Experiences of pride, not guilt, predict pro-environmental behavior when pro-environmental descriptive norms are more positive. Journal of Environmental Psychology, 45, 145–153.

Boomsma, C., Pahl, S., & Andrade, J. (2016). Imagining change: An integrative approach toward explaining the motivational role of mental imagery in pro-environmental behavior. Frontiers in Psychology, 7, 1780.

Brun, W. (1992). Cognitive components in risk perception: Natural versus manmade risks. Journal of Behavioral Decision Making, 5, 117–132.

Bull, J. W., Lloyd, S. P., & Strange, N. (2017). Implementation gap between the theory and practice of biodiversity offset multipliers. Conservation Letters, 10, 656–669.

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., Narawani, A., Mace, G. M., Tilman, D., Wardle, D. A., Kinzig, A. P., Daily, G. C., Loreau, M., Grace, J. B., Larigauderie, A., Srivastava, D. S., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. Nature, 486, 59–67.

Chadwick, A. E. (2015). Toward a theory of persuasive hope: Effects of cognitive appraisals, hope appeals, and hope in the context of climate change. Health Communication, 30, 598–611.

Chng, S., Abraham, C., White, M. P., Hoffmann, C., & Skippon, S. (2018). Psychological theories of car use: An integrative review and conceptual framework. Journal of Environmental Psychology, 55, 23–33.

Corall Verdugo, V. (2012). The positive psychology of sustainability. Environment, Development and Sustainability, 14, 651–666.

Cox, D. T. C., & Gaston, K. J. (2018). Human–nature interactions and the consequences and drivers of provisioning wildlife. Philosophical Transactions of the Royal Society B: Biological Sciences, 373, 20170092.

Cox, D. T. C., Shanahan, D. F., Hudson, H. L., Fuller, R. A., Anderson, K., Hancock, S., & Gaston, K. J. (2017). Doses of nearby nature simultaneously associated with multiple health benefits. International Journal of Environmental Research and Public Health, (14), 172.

Cracknell, D., White, M. P., Pahl, S., Nichols, W. J., & Depledge, M. H. (2016). Sub-aquatic biodiversity and psychological well-being: A preliminary examination of dose-response effects in an aquarium setting. Environment and Behavior, 48, 1242–1269.

Cvitanovic, C., & Hobday, A. (2018). Building optimism at the environmental science-policy-practice interface through the study of bright spots. Nature Communications, 9, 3466.

Dallimer, M., Irvine, K. N., Skinner, A. M., Davies, Z. G., Rouquette, J. R., Maltby, L. L., Warren, P. H., Armsworth, P. R., & 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.

Damschen, E. I., Haddad, N. M., Orrock, J. L., Tewksbury, J. J., & Levey, D. J. (2006). Corridors increase plant species richness at large scales. Science, 313, 1284–1286.

Davis, J. J. (1995). The effects of message framing on response to environmental communications. Journalism & Mass Communication Quarterly, 72, 285–299.

Desvousges, W. H., Johnson, F., Dunford, R., Hudson, S., Wilson, K., & Boyle, K. (1993). Measuring resource damages with contingent valuation: Tests of validity and reliability. In J. Hausman (Ed.), Contingent valuation: A critical assessment. Amsterdam: NorthHolland.

Díaz, S., Fargione, J., Chapin, F. S., III, & Tilman, D. (2006). Biodiversity loss threatens human well-being. PLoS Biology, 4(e277), 1300–1305.

Díaz, S., Settele, J., Brondízio, E., Ngo, H., Guèze, M., Agard, J., Arneth, A., Balvanera, P., Brauman, K., Butchart, S., Chan, K., Garibaldi, L., Ichii, K., Liu, J., Submranian, S., Midgley, G., Miloslavich, P., Molnár, Z., Obura, D., Zayas, C., et al. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the intergovernmental science-policy platform on biodiversity and ecosystem Services. Intergovernmental science-policy platform on biodiversity and ecosystem Services. https://www.ipbes.net/news/ipbes-global-assessment-summary-policymakers-pdf.

Diener, E., Wirtz, D., Tov, W., Kim-Prieto, C., Choi, D. W., Oishi, S., & Biswas-Diener, R. (2010). New well-being measures: Short scales to assess flourishing and positive and negative feelings. *Social Indicators Research, 97*, 143–156.

Fairchild, T. P., Fowler, M. S., Pahl, S., & Griffin, J. N. (2018). Multiple dimensions of biodiversity drive human interest in tide pool communities. *Scientific Reports, 8*(1), 1–11, 15234.

Ferguson, M. A., & Branscombe, N. R. (2010). Collective guilt mediates the effect of beliefs about global warming on willingness to engage in mitigation behavior. *Journal of Environmental Psychology, 30*, 135–142.

Floyd, D. L., Prentice-Dunn, S., & Rogers, R. W. (2000). A meta-analysis of research on protection motivation theory. *Journal of Applied Social Psychology, 30*, 407–429.

Fuller, R. A., Irvine, K. N., Devine-Wright, P., Warren, P. H., & Gaston, K. J. (2007). Psychological benefits of greenspace increase with biodiversity. *Biology Letters, 3*, 390–394.

Green, S. J., Akins, J. L., Aleksandra Maljković, A., Isabelle, M., & Côté, I. M. (2012). Invasive lionfish drive Atlantic coral reef fish declines. *PloS One, 7*. e32596.

Hermann, N., & Menzel, S. (2013). Predicting the intention to support the return of wolves: A quantitative study with teenagers. *Journal of Environmental Psychology, 36*, 153–161.

Hsee, C. K. (1996). The evaluability hypothesis: An explanation for preference reversals between joint and separate evaluations of alternatives. *Organizational Behavior and Human Decision Processes, 67*, 247–257.

Hummel, S., Donovan, G. H., Spies, T. A., & Hemstrom, M. A. (2009). Conserving biodiversity using risk management: Hoax or hope. *Frontiers in Ecology and the Environment, 7*, 103–109.

Hunter, L. M., & Brehm, J. (2003). Qualitative insight into public knowledge of, and concern with, biodiversity. *Human Ecology, 31*, 309–320.

Jefferson, R. L., Bailey, I., Richards, J. P., & Attrill, M. J. (2014). Public perceptions of the UK marine environment. *Marine Policy, 43*, 327–337.

Johnson, C. N., Balmford, A., Brook, B. W., Buettel, J. C., Galetti, M., Guangchun, L., & Wilmshurst, J. M. (2017). Biodiversity losses and conservation responses in the Anthropocene. *Science, 356*, 270–275.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decisions under risk. *Econometrica, 47*, 263–292.

Kahn, P. H., Jr. (2002). Children's affiliations with nature: Structure, development, and the problem of environmental generational amnesia. In P. H. Kahn, & S. R. Kellert (Eds.), *Children and nature: Psychological sociocultural, and evolutionary investigations.* MIT Press.

Karau, S. J., & Williams, K. D. (1993). Social loafing: A meta-analytic review and theoretical integration. *Journal of Personality and Social Psychology, 65*, 681–706.

Klöckner, C. A. (2013). A comprehensive model of the psychology of environmental behaviour—a meta-analysis. *Global Environmental Change, 23*, 1028–1038.

Lee, A. Y., & Aaker, J. L. (2004). Bringing the frame into focus: The influence of regulatory fit on processing fluency and persuasion. *Journal of Personality and Social Psychology, 86*, 205–218.

Maddux, J. E., & Rogers, R. W. (1983). Protection motivation and self-efficacy: A revised theory of fear appeals and attitude change. *Journal of Experimental Social Psychology, 19*, 469–479.

McCallum, M. L. (2015). Vertebrate biodiversity losses point to a sixth mass extinction. *Biodiversity & Conservation, 24*, 2497–2519.

Miller, J. R. (2005). Biodiversity conservation and the extinction of experience. *Trends in Ecology & Evolution, 20*, 430–434.

Moeller, S. D. (2002). *Compassion fatigue: How the media sell disease, famine, war and death.* London: Routledge.

Molnar, J. L., Gamboa, R. L., Revenga, C., & Spalding, M. D. (2008). Assessing the global threat of invasive species to marine biodiversity. *Frontiers in Ecology and the Environment, 6*, 485–492.

Morewedge, C. K., & Giblin, C. E. (2015). Explanations of the endowment effect: An integrative review. *Trends in Cognitive Sciences, 19*, 339–348.

Morton, T. A., Rabinovich, A., Marshall, D., & Bretschneider, P. (2011). The future that may (or may not) come: How framing changes responses to uncertainty in climate change communications. *Global Environmental Change, 21*, 103–109.

Nabi, R. L., Gustafson, A., & Jensen, R. (2018). Framing climate change: Exploring the role of emotion in generating advocacy behavior. *Science Communication, 40*, 442–468.

Nisbet, E. K., & Zelenski, J. M. (2011). Underestimating nearby nature: Affective forecasting errors obscure the happy path to sustainability. *Psychological Science, 22*, 1101–1106.

Nisbet, E. K., & Zelenski, J. M. (2013). The NR-6: A new brief measure of nature relatedness. *Frontiers in Psychology, 4*, 813.

Nisbet, E. K., Zelenski, J. M., & Murphy, S. A. (2009). The nature relatedness scale: Linking individuals' connection with nature to environmental concern and behavior. *Environment and Behavior, 41*, 715–740.

Pauly, D. (1995). Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology & Evolution, 10*, 430.

Pereira, H. M., Navarro, L. M., & Martins, I. S. (2012). Global biodiversity change: The bad, the good, and the unknown. *Annual Review of Environment and Resources, 37*, 25–50.

Peters, G. J. Y., Ruiter, R. A., Ten Hoor, G. A., Kessels, L. T., & Kok, G. (2018). Towards consensus on fear appeals: A rejoinder to the commentaries on kok, peters, kessels, ten hoor, and ruiter (2018). *Health Psychology Review, 12*, 151–156.

Pimentel, D., Zuniga, R., & Morrison, D. (2005). Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics, 52*, 273–288.

Robinson, L. D., Tweddle, J. C., Postles, M. C., West, S. E., & Sewell, J. (2013). *Guide to running a BioBlitz. Natural history museum, bristol natural history consortium.* Stockholm Environment Institute York, and Marine Biological Association.

Rothman, A. J., Bartels, R. D., Wlaschin, J., & Salovey, P. (2006). The strategic use of gain- and loss-framed messages to promote healthy behavior: How theory can inform practice. *Journal of Communication, 56*, 202–221.

Sawe, N., & Knutson, B. (2015). Neural valuation of environmental resources. *NeuroImage, 122*, 87–95.

Scherer, K. R. (2009). The dynamic architecture of emotion: Evidence for the component process model. *Cognition & Emotion, 23*, 1307–1351.

Steg, L., Bolderdijk, J. W., Keizer, K., & Perlaviciute, G. (2014). An integrated framework for encouraging pro-environmental behaviour: The role of values, situational factors and goals. *Journal of Environmental Psychology, 38*, 104–115.

Thaler, R. H. (1980). Toward a positive theory of consumer choice. *Journal of Economic Behavior & Organization, 1*, 39–60.

Tversky, A., & Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science, 211*, 453–458.

Tversky, A., & Kahneman, D. (1991). Loss aversion in riskless choice: A reference-dependent model. *Quarterly Journal of Economics, 106*, 1039–1061.

Vaish, A., Grossmann, T., & Woodward, A. (2008). Not all emotions are created equal: The negativity bias in social-emotional development. *Psychological Bulletin, 134*, 383–403.

Veisten, K., Hoen, H. F., Navrud, S., & Strand, J. (2004). Scope insensitivity in contingent valuation of complex environmental amenities. *Journal of Environmental Management, 73*, 317–331.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*, 1063–1070.

White, M. P., Alcock, I., Grellier, J., Wheeler, B. W., Hartig, T., Warber, S., Bone, A., Depledge, M. H., & Fleming, L. E. (2019). 120 minutes of nature contact per week is positively related to health and well-being. *Scientific Reports, 9*, 7730.

White, M. P., Pahl, S., Buehner, M. J., & Haye, A. (2003). Trust in risky messages: The role of prior attitudes. *Risk Analysis, 23*, 717–726.

Wolf, L. J., zu Ermgassen, S., Balmford, A., White, M. P., & Weinstein, N. (2017). Is variety the spice of life? An experimental investigation into the effects of species richness on self-reported mental well-being. *PLoS One, 12*. e0170225.

World Wildlife Fund, Aiming Higher, M., & Grooten, M. (2018). *Living Planet report - 2018:* Switzerland: Gland. R.E.A. Almond (Eds). WWF.