Check for updates

Received: 30 August 2022 | Accepted: 13 April 2023

DOI: 10.1002/pan3.10495

PEOPLE AND NATURE | BRITISH ECOLOGICAL SOCIETY

PERSPECTIVE

Climate-driven 'species-on-the-move' provide tangible anchors to engage the public on climate change

Gretta T. Pecl[1,2] | Rachel Kelly[1,2,3,4] | Chloe Lucas[1,5] | Ingrid van Putten[1,3] | Renuka Badhe[6] | Curtis Champion[7,8] | I-Ching Chen[9] | Omar Defeo[10] | Juan Diego Gaitan-Espitia[11] | Birgitta Evengård[12] | Damien A. Fordham[13,14] | Fengyi Guo[15] | Romina Henriques[16,17] | Sabine Henry[18] | Jonathan Lenoir[19] | Henry McGhie[20] | Tero Mustonen[21] | Stephen Oliver[22] | Nathalie Pettorelli[23] | Malin L. Pinsky[24,25] | Warren Potts[26] | Julia Santana-Garcon[1,27] | Warwick Sauer[26] | Anna-Sofie Stensgaard[14,28] | Morgan W. Tingley[25] | Adriana Verges[29]

[1]Centre for Marine Socioecology, University of Tasmania, Hobart, Tasmania, Australia; [2]Institute for Marine and Antarctic Studies, University of Tasmania, Hobart, Tasmania, Australia; [3]CSIRO Oceans and Atmosphere, Castray Esplanade, Battery Point, Tasmania, Australia; [4]Future Ocean and Coastal Infrastructure Consortium, Memorial University of Newfoundland, St. John's, Newfoundland and Labrador, Canada; [5]School of Geography, Planning and Spatial Sciences, University of Tasmania, Hobart, Tasmania, Australia; [6]European Polar Board, The Hague, The Netherlands; [7]Fisheries Research, NSW Department of Primary Industries, National Marine Science Centre, Coffs Harbour, New South Wales, Australia; [8]National Marine Science Centre, Southern Cross University, Coffs Harbour, New South Wales, Australia; [9]Department of Life Sciences, National Cheng Kung University, Tainan City, Taiwan; [10]UNDECIMAR. Faculty of Sciences, Montevideo, Uruguay; [11]The Swire Institute of Marine Science and School of Biological Sciences, The University of Hong Kong, Hong Kong SAR, China; [12]Department of Clinical Microbiology, Umeå University, Umeå, Sweden; [13]The Environment Institute and School of Biological Sciences, University of Adelaide, Adelaide, South Australia, Australia; [14]Center for Macroecology, Evolution & Climate, GLOBE Institute, University of Copenhagen, Copenhagen, Denmark; [15]Department of Ecology and Evolutionary Biology, Princeton University, Princeton, New Jersey, USA; [16]Technical University of Denmark, National Institute of Aquatic Resources, Silkeborg, Denmark; [17]Marine Genomics Group, Department of Biochemistry, Genetics and Microbiology, University of Pretoria, Hatfield, South Africa; [18]Department of Geography and Institute of Life, Earth and Environment (ILEE), University of Namur, Belgium; [19]UMR CNRS 7058« Ecologie et Dynamique des Systèmes Anthropisés » (EDYSAN), Université de Picardie Jules Verne, Amiens, France; [20]Curating Tomorrow, Liverpool, UK; [21]Snowchange Cooperative, Selkie, Finland; [22]Australian Broadcasting Corporation, Ultimo, New South Wales, Australia; [23]Zoological Society of London, Institute of Zoology, London, UK; [24]Department of Ecology, Evolution, and Natural Resources, Rutgers University, New Brunswick, New Jersey, USA; [25]Department of Ecology and Evolutionary Biology, University of California, Los Angeles, California, USA; [26]Department of Ichthyology and Fisheries Science, Rhodes University, Grahamstown, South Africa; [27]Flourishing Oceans Initiative, Minderoo Foundation, Perth, Australia; [28]Department of Veterinary and Animal Sciences, University of Copenhagen, Frederiksberg C, Denmark and [29]Centre for Marine Science & Innovation, School of Biological, Earth & Environmental Sciences, UNSW Sydney, Sydney, New South Wales, Australia

Correspondence
Gretta T. Pecl
Email: gretta.pecl@utas.edu.au

Funding information
Australian Research Council; Centre for Marine Socioecology; Commonwealth Scientific and Industrial Research Organisation; Institute for Marine and Antarctic Studies; National Research Foundation; NOAA Fisheries; Rhodes University; Snowchange; University of New South Wales

Handling Editor: Helen Roy

Abstract

1. Over recent decades, our understanding of climate change has accelerated greatly, but unfortunately, observable impacts have increased in tandem. Both mitigation and adaptation have not progressed at the level or scale warranted by our collective knowledge on climate change. More effective approaches to engage people on current and future anthropogenic climate change effects are urgently needed.
2. Here, we show how species whose distributions are shifting in response to climate change, that is, 'species-on-the-move', present an opportunity to engage people with climate change by linking to human values, and our deep connections with the places in which we live, in a locally relevant yet globally coherent narrative.

[Correction added on 22 July 2023, after first online publication: 'New South Wales' has been removed from Affiliation 17].

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2023 The Authors. *People and Nature* published by John Wiley & Sons Ltd on behalf of British Ecological Society.

3. Species-on-the-move can impact ecosystem structure and function, food security, human health, livelihoods, culture and even the climate itself through feedback to the climate system, presenting a wide variety of potential pathways for people to understand that climate change affects them personally as individuals.
4. Citizen science focussed on documenting changes in biodiversity is one approach to foster a deeper engagement on climate change. However, other possible avenues, which may offer potential to engage people currently unconnected with nature, include arts, games or collaborations with rural agriculture (e.g. new occurrences of pest species) or fisheries organisations (e.g. shifting stocks) or healthcare providers (e.g. changing distributions of disease vectors).
5. Through the importance we place on the aspects of life impacted by the redistribution of species around us, species-on-the-move offer emotional pathways to connect with people on the complex issue of climate change in profound ways that have the potential to engender interest and action on climate change.

KEYWORDS
biodiversity, climate change communication, climate change engagement, environmental communication, human values, message framing, place attachment, species redistribution

1 | INTRODUCTION

Climatic change in recent decades has affected the distributions of over 12,000 species across marine, freshwater and terrestrial systems (Lenoir et al., 2020), revealing that we are currently living through the largest redistribution of life on Earth for at least tens of thousands of years. Geographical range limits of species are dynamic, and as the climate alters, species shift locations (where they are able) to stay within preferred environmental conditions. Temperature is, therefore, a major driver of climate-driven changes in distribution; however, climate change may also alter species distributions indirectly, via extreme events for example. These changes in species distributions, or range shifts, affect human well-being directly, for example, through emerging diseases and changes in food supply, and indirectly, by degrading ecosystem health and enhancing climate warming through positive feedback loops (Pecl et al., 2017). The far-reaching implications of climate-driven species redistribution can predicate extensive biodiversity changes (Vergés et al., 2016), yet these alterations are not yet considered in global goals and targets for biodiversity. Moreover, at a global level, nature conservation is not making significant progress; targets to halt the loss of biodiversity are not being met (CBD, 2020; Díaz et al., 2020), and efforts to conserve biodiversity and ecosystem services which could help to address climate change are being undermined (Díaz et al., 2019; IPBES, 2019). Climate change is a key driver for species extinction and a threat multiplier for biodiversity, with extinction risk increasing with every degree of warming (IPBES, 2019).

Here, we highlight how pervasive climate-driven changes in species distributions offer the potential for locally relevant narratives on climate change that enable connections to a wide range of human emotions, through intersections with human values, trust networks, and place attachment. We start with an overview of current public understanding of climate change and delineate what effective communication and engagement on this complex issue entails. We then explore how 'species-on-the-move' can be a tangible anchor to engage individuals and communities in climate change dialogue, without the feeling of helplessness that can be associated with catastrophic events such as climatic extremes or species extinction. We conclude by outlining how we can build and expand on these efforts to effectively engender widespread understanding of the action needed on climate change.

Climate change poses one of the most serious risks to biodiversity (IPBES, 2019; Scheffers et al., 2016) and to human societies (Ripple et al., 2020). However, the dynamics, scale, and complexity of this threat render it difficult for people to perceive climate change directly (Weber & Stern, 2011). Consequently, climate change is a complex challenge in terms of communication, engagement, and participation. Four dimensions of 'psychological distance' make climate change particularly challenging to communicate: temporal distance (time); spatial distance (place); social distance (cultural difference) and hypothetical distance (certainty or uncertainty; Trope & Liberman, 2010). Together, these describe the 'perception of when [an event] occurs, where it occurs, to whom it occurs and whether it occurs' (Trope & Liberman, 2010). Collectively, psychological processes such as these explain why some of the most visibly dramatic

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

consequences of climate change (e.g. sea ice and glacier melting), often occurring in the least densely populated regions of the world, fail to engage many people (Manzo, 2010). In contrast, species-on-the-move, when presented in locally and contextually relevant ways, can provide the opportunity for people to connect more strongly to the reality of climate change in ways that are relevant to them.

Although a growing majority of people accept the science of anthropogenic climate change, translating this apparent concern into the necessary social and political action remains elusive (Rowson, 2013). Nevertheless, the impacts of climate change, including the melting of sea ice in the Arctic, the retreat of mountain glaciers, more frequent and intense extreme weather events and fires, sea level rise and species extinctions (Ripple, 2020), as well as emerging and re-emerging diseases (Altizer et al., 2013), are becoming increasingly evident, and global public concern has grown over the last 6 years. The 2018 Global Attitudes Survey, conducted by the Pew Research Center, found that across 91 countries, a median of 67% of people surveyed believed that climate change was a major threat to their country, up from 56% in 2013 (Fagan & Huang, 2019). However, the 2019 values varied across countries; as low as 38% in Israel, and as high as 90% in Greece. Moreover, the overall figures also hide significant and growing political polarisation on the topic of climate change in many countries (Capstick et al., 2015; Fagan & Huang, 2019).

An interdisciplinary body of climate communication literature, emerging from psychology, sociology, human geography and communication studies, provides evidence-based guidance on effective strategies for engaging society in both individual and collective action on climate change. This research shows that neither the provision of scientific information on climate change, nor attempts to appeal to the objective authority of science, are effective methods of public engagement (Corner & Groves, 2014; Wynne, 2006). Instead, advocates of social adaptation to climate change are looking to more conversational (Nettlefold & Pecl, 2020) and participatory modes of communication (Maeseele, 2015; Pearce et al., 2015; Whitmarsh et al., 2011). This large body of research highlights three fundamental features of social life that are pivotal to inclusive engagement across diverse segments of global society: human values, trust networks and place attachment (Box 1).

Climate change is already having direct and tangible personal impacts on humans. These impacts may be categorised into three main types: experience of gradual changes, including increases in temperature; experience of more frequent extreme events like fires or heatwaves and observations of changes affecting other species connected to us, including altered migration patterns of birds or changes in the time of flowering of plants. Although variations in the weather and gradual warming lead to greater concern about climate change (Zaval et al., 2014), the magnitude of this effect is small (Bergquist & Warshaw, 2019). Exposure to extreme events, including fires, heatwaves, floods or large storms, can provoke greater concern initially, but these experiences are often intertwined with extreme existential fear and trauma, which can disengage or psychologically paralyse people and cause them to despair (Cunsolo Willox et al., 2013; O'Neill & Nicholson-Cole, 2009). In contrast, observations of climate-mediated changes to the species around us (i.e. species-on-the-move) can incite a range of strong emotions that connect with our values and our sense of place in potentially constructive ways that prompt action. Likewise, evidence of biodiversity responses to past warming intervals and abrupt climatic shifts (some of similar rate and magnitude to what is being forecast for the future) in places and regions with high attachment values, provide important thinking tools for visualising the ecological and evolutionary consequences of future climate change on biodiversity and the services it provides to humanity (Fordham et al., 2020).

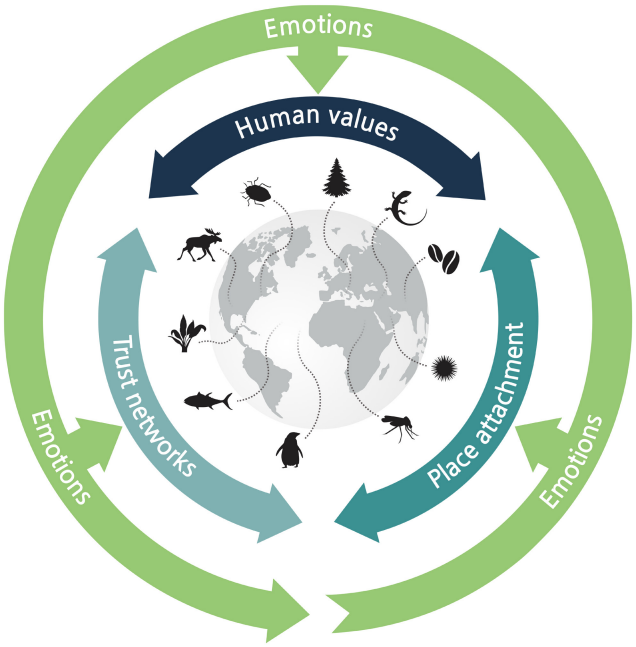
2 | SPECIES-ON-THE-MOVE: 'OBJECTS OF CARE' THAT CONNECT US WITH VALUES, PEOPLE AND PLACES

People are inherently aware of which species 'belong' in the environments they frequent and use, and which species do not. Many social groups have strong cultural connections based on species interactions, and our relationships with other species are often underpinned by dearly held values. However, although the climate-driven redistribution of species is one of the most pervasive effects of climate change (Fordham et al., 2020; Pecl et al., 2017), and these changes are tangible and visible at local scales, given the growing societal disconnect from nature (e.g. Larson et al., 2018), these changes may go unnoticed unless explicitly brought to people's attention. Species-on-the-move, when presented in locally and contextually relevant ways, can represent a meaningful anchor to communicate climate science, the implications of climate change, and the urgency of addressing the issue. This is because these changes in species distribution offer the potential to engage individuals intellectually, emotionally, behaviorally and sometimes even economically or from the perspective of human health. Species-on-the-move can be understood as 'objects of care' (sensu Wang et al., 2018) that link people directly and more immediately with climate change and centre it as a more personally relevant issue that may evoke strong emotions in ways that potentially prompt action (Figure 1).

A key benefit to anchoring climate change communication to species-on-the-move is that this lens can often avoid the potential for emotional overwhelm and fear that typically follows climate communication, focusing almost exclusively on large-scale impacts and extreme weather events. Emotions provoked by the local loss of a species or the local arrival of a new 'invader' may still produce worry. However, this is a much more productive emotion than existential fear prompted by extreme weather events or by a species going totally extinct because it does not hijack our cognitive abilities where we get so scared or angry that our ability to think clearly and access the executive function in the prefrontal cortex is diminished (Huntley, 2020). Even those for whom climate change is not an active concern may have enough interest in particular species-on-the-move (or their effects on human well-being) to

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

BOX 1 Human values, trust networks and place attachment are critical for effective and inclusive engagement on climate change



Human values are individually held yet culturally informed beliefs about what is important in life. They are the frames of reference, or guiding principles, through which individuals evaluate information and make decisions. Human values evoke strong emotions, and have both rational and affective dimensions (Leiserowitz, 2006). They remain relatively stable over the course of a person's life but can be influenced by shifting norms and transformational experiences, including socio-ecological change (Kendal & Raymond, 2019). People who demonstrate concern about climate change tend to place high importance on the value of caring for nature (Dietz et al., 2007; Howell, 2013; Lucas, 2018; Reser et al., 2012). While this suggests that encouraging connections with nature may have positive effects on generating concern about climate change (Schultz et al., 2005), it also reflects the fact that predominant narratives frame climate change as an environmental problem, rather than emphasising its impacts on human systems (Lucas & Davison, 2019).

On this basis, we propose two complementary directions for climate communication. First, that stories and experiences of other species impacted by climate change are likely to resonate with people who are already concerned about climate change, and could be leveraged to deepen existing concern, potentially promoting individual and collective action (Ives et al., 2018; Whitburn et al., 2019), or active participation in adaptation. Second, that stories and experiences highlighting *human* dimensions of climate change are needed for wider and more inclusive engagement, particularly with those who are not currently concerned (Corner et al., 2018; Goldberg et al., 2019). Narratives that appeal to socially conservative values, such as continuity, tradition and responsibility, as well as narratives that speak to the values of opportunity and freedom, may also be useful in engaging with people who are less likely to be concerned about climate change (Whitmarsh & Corner, 2017). Furthermore, engagement that explores the connections between the effects of climate change on other species and on humans is likely to be effective across a broad spectrum of values.

Trust networks are social groups connected through mutually trusted individuals or organisations (Lucas et al., 2015). These are the conduits for shared cultural narratives, experiences and resulting norms and values (Hornsey & Fielding, 2020). Humans are inherently social and have developed unconscious psychological mechanisms, including motivated reasoning, to enable in-group conformity and agreement (Druckman & McGrath, 2019; Kunda, 1990). Once an issue has been 'framed' or interpreted by influential members of a group, this framing acts as a lens for the whole group, enabling them to interpret any information on this issue in a way that confirms the strongly held views of the group (Kolandai-Matchett & Armoudian, 2020; Nelson & Kinder, 1996). In this way, certain narratives about climate change have created 'ruts' that polarise social groups and are hard to shift and change (Lucas & Warman, 2018). One strategy for disrupting polarised climate discourse is to develop alternative framings of climate change that instead focus on values that are shared across social groups (Blackmore et al., 2013; Lucas & Warman, 2018). Trusted messengers, particularly those who are respected by divergent social groups, are important conduits for these narratives (Kolandai-Matchett & Armoudian, 2020; Levin & Cross, 2004).

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Place attachment (or sense of place) is the emotional bond people form with a place (Bell et al., 2018). Positive emotions associated with a place contribute to human well-being (Stedman, 2002), and the strength of this emotional bond is an important predictor of climate change engagement (Scannell & Gifford, 2013). Place attachment is mediated by the quality and range of natural resources present in a place (van Putten et al., 2018) and, therefore, is influenced by any variation in these place-specific values (Larson et al., 2013). Taking guidance from the term salutogenesis (Pitt, 2018), which underscores the link between place attachment, environmental quality and well-being outcomes, it is reasonable to assume that changes to the environment will likely impact an individual's sense of place (Mittelmark et al., 2017). Place attachment is an important concept to understand in relation to change because people use it to not only develop and construct meanings but also form their identities through their experiences with places (Graham et al., 2009). Species present in the environments we form attachment to are often 'objects of care' (sensu Wang et al., 2018) and provide different bonding routes (van Putten et al., 2018) that mediate how changes in the distribution of species might affect place attachment. Thus, we infer that species range shifts—a clear manifestation of climate change—can impact upon our place attachment.

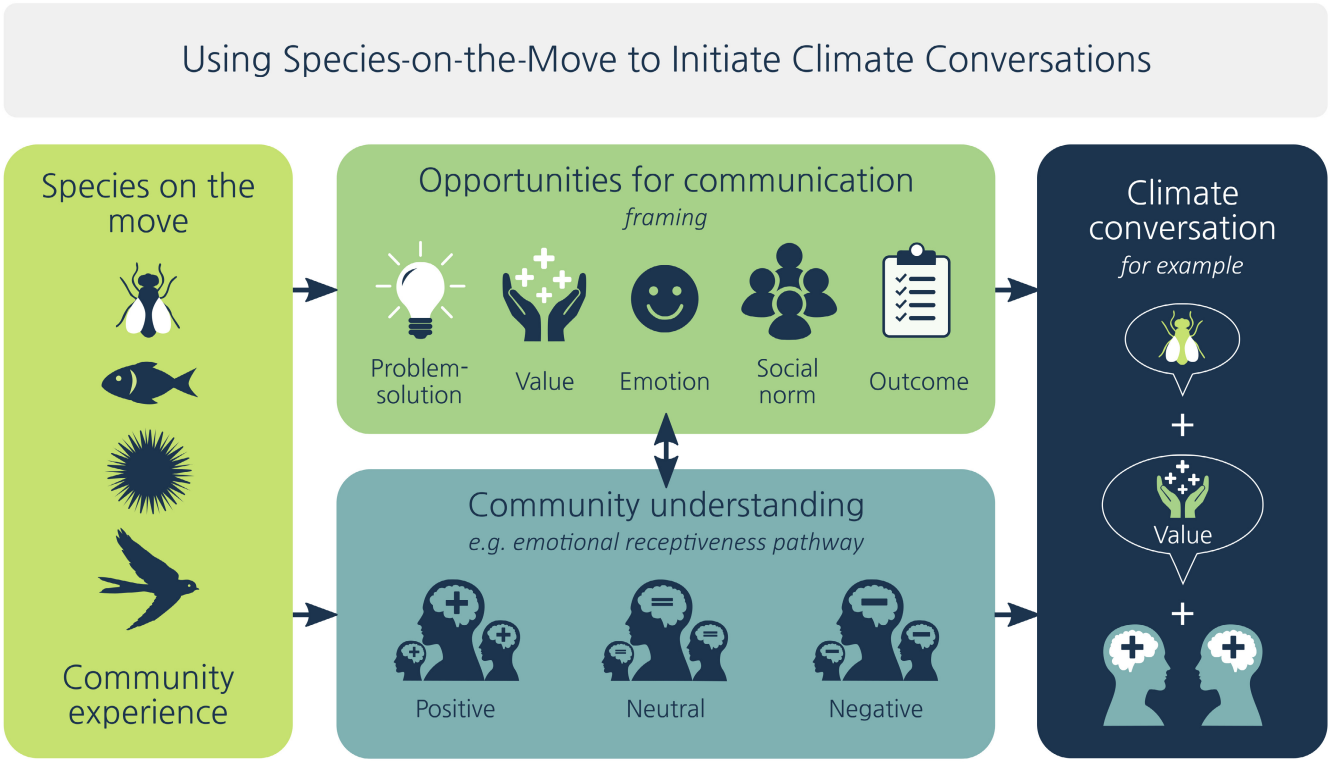


FIGURE 1 Climate-driven changes in species distributions represent opportunities for communication on climate change using frames that connect to a range of human values and emotions.

motivate action outside of a more political climate change framing (Lucas & Davison, 2019). In addition, species-on-the-move often occur at a scale likely to generate local interest—and at a scale where investment in adaptation is practical—without creating the sense of hopelessness and helplessness that comes with a focus on global-scale impacts. Moreover, climate communication is most effective for engendering individual agency and action when aimed at smaller audiences (i.e. 10,000 people or less), and so locally relevant species-on-the-move are ideally suited to this scale of engagement (Bhowmik et al., 2020).

3 | RETHINKING AND REFRAMING CLIMATE CHANGE CONVERSATIONS

Human communities are connected with other species through long-term ecological, cultural, spiritual and economic relationships. Climate-driven changes in species distributions—the local losses of plants and animals that we are familiar with, but also the gains of species that are new to us—provide an opportunity to rethink how we frame climate change communication (Figure 1). Frames are

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

interpretive storylines for communications—they define an issue and affect how information is evaluated (Nisbet, 2019). By defining a problem in a particular way, accepted frames circumscribe potential responses and solutions. Frames make direct connections to the emotional regions of the brain and are most effectively delivered via trusted messengers (Lakoff, 2010). Frames that can be used to communicate environmental issues include emotional, problem-solution, value-based, social-norm and outcome frames (Kolandai-Matchett & Armoudian, 2020). Each can evoke emotions that are negative (e.g. anger, worry, grief), positive (e.g. joy, hope, empathy) or perhaps neutral (e.g. surprise, anticipation). In Table 1, we show how different framings of species-on-the-move can provide emotional pathways for thinking about climate change in ways that connect with people's values, their attachment to place and trusted networks (see also Figure 1). The aim is not to provide a definitive list of possible framings, but to show the diverse opportunities for communication presented by species-on-the-move. We should also note that conservations regarding climate-driven species-on-the-move may need to be nuanced, acknowledging (where appropriate) other potential drivers of change, and including clear differentiation from incursions of introduced or alien species (ie those that occur beyond their accepted normal distribution as a result of human activity). Furthermore, not all climate-driven species-on-the-move will have negative impacts, although some certainly may have impacts equivalent to invasive species (ie introduced species, as a result of human activity, that significantly modify or disrupt the ecosystem).

Species-on-the-move provide opportunities for developing climate change conversations that recognise and associate climate-driven changes in species distributions with broader climate impacts. For example, people living along the east coast of Tasmania, where a range-shifting long-spined sea urchin has overgrazed kelp forests creating 'urchin barrens' that impact recreational and commercial fisheries (Ling et al., 2009), may feel sadness and grief at the loss of kelp ecosystems. Conversely, some people in these communities may also feel hope and gratitude for the new urchin fishery that developed specifically to reduce their impact on local reefs (Ling & Keane, 2018). The connection between this ecosystem, fishery changes and climate change (i.e. long-term warming of coastal waters) can, thus, be communicated using a 'problem-solution' frame (Kolandai-Matchett & Armoudian, 2020 and see Table 1).

4 | COMMUNICATING CLIMATE CHANGE USING SPECIES-ON-THE-MOVE

In several different contexts and places around the world, climate-driven shifts in species' distributions are already being used to effectively engage people and communities on the issues of climate change (Table 2, Box 2), although not necessarily with the explicit aim of connecting the shifts to particular human values or emotions, or consciously using specific framings. These initiatives span a range of approaches, including citizen science, eco-tourism, interactive report cards and web-based tools, formal educational activities for schools, investigative journalism articles, as well as TV documentaries (such as the recent *Australian Ocean Odyssey*), and books for the general public (Shah, 2020). Citizen science appears, not surprisingly, to be a particularly popular approach to engage the public on climate-driven species redistribution and offers the advantage of increasing data availability and extending our understanding of underlying biological processes at the same time (Kullenberg & Kasperowski, 2016; Martin et al., 2019).

In Taiwan, for example, citizen science projects have developed rapidly over the past decade owing to the well-established cyber infrastructure, popularity of social media, and open data culture (Chyn et al., 2019; Ko et al., 2019). Currently, more than 70% of the 4.5 million species occurrence data across wide taxonomic groups reported for the country was contributed by citizen scientists (Ko et al., 2019). Some citizen science projects are based on simple methods, such as uploading species photos to social media (much like *What's That Fish* in New Zealand, Middleton et al., 2021), where researchers readily provide taxonomic or biological information that can engage opportunistic observers. Such data accumulate rapidly, support the detection of range shifts, phenology change and even disease outbreaks, all of which can be crucial in communicating climate change in a locally relevant way to audiences. For example, the Taiwan Moth Information Center has used Facebook to collect more than 362,000 moth records since 2011, and citizen science data are an important contribution to the first national report of birds (i.e. State of Taiwan's Birds Partnership., 2020), revealing widespread shifts in distribution of birds.

Redmap Australia, the Range Extension Database and Mapping project www.redmap.org.au, is an Australia-wide citizen science project where fishers, divers, boaters and marine naturalists are invited to submit photos of species they opportunistically observe outside of their expected distributions, via the project website or its smartphone application (Pecl et al., 2019). Each sighting submitted is verified by one of a network of over 80 scientists, and the observer is then sent a personalised email confirming the species identification and the nature of the sighting (e.g. unusual and out-of-range, etc.). The Redmap Australia initiative was specifically established to provide an early indication of which species may be shifting as the coastal waters warm (e.g. Robinson et al., 2015), and, just as importantly, to use observations submitted to engage the public on marine climate change *using their own data*. The one-on-one dialogue between scientists and observers, via the emails received from the verification process, and the individual engagement achieved on Facebook, has helped build trust in the project (Nursey-Bray et al., 2018). As a point of difference to many citizen science projects, Redmap engages people who are typically often 'unengaged' with science, as it involves opportunistic observations verified after data submission in contrast to projects requiring training and formal signup procedures. The Redmap website has had >1,500,000 webpage downloads with visits from >180 countries, and the Facebook page has 10,000 followers reaching upwards of 50,000 people each month. Formal evaluation of participants demonstrated

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 1 Examples of documented climate-driven changes in species distributions (from Pecl et al., 2017) and suggestions of how these might be used to initiate locally relevant conversations about climate change with individuals and communities. We outline how message framing strategies can be designed to evoke emotional responses in order to improve public awareness and capacity to adapt to climate change. We describe opportunities for communication using different environmental communication frames (adapted from Kolandai-Matchett & Armoudian, 2020), including emotional (E), problem-solution (P/S), value-based (V), social-norm (S/N) and outcome (O) frames. Emotions highlighted in red, green and blue are negative, positive and neutral emotions, respectively.

Species	Description of climate-driven change in distribution	Emotional receptiveness—pathways	Opportunities for communication (framing)	Examples of using species-on-the-move as a central message for starting climate conversations
Bumblebees	A contraction in range at the warmer edge of the distribution, and shift upslope for some species in North America and Europe due to climate change but without a corresponding extension of range limits at the cooler range edge (Kerr et al., 2015). The health of plants and animals that people depend on may be affected by the change in distributions of these important pollinators, in turn affecting food production as well as biodiversity and ecosystem health	People are likely to have a changed experience of landscape without bumblebees and for some there will be a feeling of loss of the sound and presence of bees. The lack of bumblebees will result in decline of dependent plant species and may create worry about the economic and practical repercussions for horticultural activities that require bee pollination. The loss of bumblebees and their important ecosystem role might spark sympathy and care for the environment and the protection of other important pollinator species	**E:** Feelings of loss and highlighting the human-nature connection can influence broader behaviour and action on climate change. **P/S:** Public action to protect bumblebees and other pollinators can be encouraged as a solution to this climate impact problem. **V:** People's connection to place can be appealed to by using messages that describe the bees' role in people's connection to nature. **S/N:** Describing how members of the community are acting to protect pollinators can impel others to do the same. **O:** Highlighting the potential loss of flowers and plants can encourage communities to take action.	**Humble care** Emotional frame (human-nature relationship) combined with a problem-solution frame 'As a pollinator, the fluffy and familiar bumblebee provides a service that we may only notice when it's gone. Without bumblebees, we may also lose our ability to propagate much loved flowers, fruit and vegetables. While it may now be too hot for bumblebees to thrive here because our climate is changing, we can protect and encourage pollinators—including insects and birds—by providing habitat corridors, keeping existing habitat safe, and keeping our gardens biodiverse and healthy. We can also protect our pollinators through reducing greenhouse gas emissions that contribute to climate change'.
Tropical and temperate fish	A poleward shift of tropical fishes and range contractions of temperate fishes associated with ocean warming in southern Africa. These changes in species composition and abundance have negatively impacted Angolan artisanal and recreational fisheries, but positively impacted Namibian recreational and commercial fisheries (Potts et al., 2014). In South Africa, these changes have impacted the recreational spearfishing sector (Lloyd et al., 2012)	The worry of the loss of livelihoods is large because many of the communities dependent on these species are in economically impoverished areas. The potential disappearance of both traditional subsistence and recreation activities will likely be felt as a great loss to those who have practiced them, sometimes over generations New opportunities for those who are open to change. As fishes disappear there might be greater interest in learning about what is coming and new species arriving. The anticipation of potential opportunities can be a source of hope	**E:** Worry for potential loss of livelihoods and traditional subsistence can be a focal point from which to encourage community action to adapt to these changes in distributions. **P/S:** Emphasising the ability to adapt and develop solutions can create a sense of preparedness and empowerment for developing adaptive futures. **V:** Highlighting values such as economic security can be a means to communicate how changes in species distributions affect communities but also potentially creates opportunities. **S/N:** Highlighting that those who have learned about and targeted new species or new opportunities (e.g. tourism) are now reaping economic rewards can encourage others to do the same. **O:** Proposing positive outcomes is more effective to inspire action than negative ones. Highlighting the potential gains for fishers in harvesting new species can encourage them to learn to adapt their practices.	**Moving feast** Problem-solution combined with a values frame (adaptive values-based frame). 'Climate change is causing a southward movement of many of your target species. This is causing changes in the composition of your catch, with many of your traditional species disappearing. Fortunately, new species are arriving in your fishing area so please read the 'Moving species' fact-sheet and share it with you fellow fishers so that you can adapt your fishing methods to maximise your benefit from these new arrivals.'

(Contiunes)

25758314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 1 (Contiunes)

Species	Description of climate-driven change in distribution	Emotional receptiveness—pathways	Opportunities for communication (framing)	Examples of using species-on-the-move as a central message for starting climate conversations
Coffee	The regions of climate suitability for coffee cultivation are changing, with low elevation areas of Mexico, Guatemala, El Salvador, Nicaragua and Costa Rica becoming less suitable and new growing regions upslope becoming more suitable. Local producers, and in particular rural communities, will be greatly affected, with implications for livelihoods and regional economies. Additionally, the new upslope growing regions may be impacted ecologically (Baca et al., 2014). Changing distributions of globally important crops may require multi-jurisdictional strategic planning and cooperation	There is likely to be real worry and fear for the loss of livelihood. Not only the economic values associated with the crop are potentially lost, but also there is cultural and environmental concern for direct impacts associated with potentially moving to a new area. Anticipation about redistribution of this crop and the coordination needed to plan can provide an opportunity to reinvent both farming opportunities in existing communities, and the coffee industry as it moves into new areas – and thus create some enthusiasm and hope. The strategic planning approach may create overall interest, promoting openness to change and potential for triple-bottom line economic, environmental and cultural benefits	**E:** Reflecting the lived reality of the communities is likely to be effective in eliciting interest and generating cooperation to create effective adaptation solutions. **P/S:** Identifying the need to devise shared solutions to this problem can inspire community action to work together. **V:** Shifts to upslope regions must be sensitive to existing ecological values in these areas, as well as the security of workers. **S/N:** Communicating that those who act to adapt will be better prepared for climate change impacts can encourage others to do the same. **O:** Developing messages that communicate the likely losses resulting from inaction can encourage climate action in response to these impacts.	**Sensitive solutions** Value-based fame (focused on anthropocentric value) 'Changing climate means that our low elevation regions may no longer be suitable for growing coffee beans. This will affect all of us, as well as our children's economic opportunities and future. Before we commit to moving away from the places in which we have invested so much, we need to work together to plan and create opportunities for sustainable farming that can protect livelihoods within our existing communities
Mosquitoes (and see Box 2 for other medical examples)	Warming is changing the distribution of common disease vectors like mosquitoes. In both Ethiopia and western Colombia the distribution of malaria cases has shifted upslope, increasing in warmer years. Locations previously free of malaria are now climatically suitable and can result in epidemics due to lack of immunity among local residents (WHO, 2020). Changes in distribution of diseases can challenge health systems at national and international scales, draining public and private sector resources.	There is likely to be immediate concern for people's health, likely associated with stress and worry. For those not directly impacted there will likely be sympathy towards people impacted. If given appropriate funding, there is an existing capacity to deal with malaria and something can be done about protecting people, there is likely to be some hope If there is a capacity to drive effective health measures and protection, there is potentially an opportunity for self-efficacy and determination. Collective action appeals to the fundamental values of universalism and benevolence	**E:** The discussion and development of solutions to this threat can provide feelings of hope for this community. **P/S:** Solution frames affirm and motivate the potential for individual action, empowering the community to reduce the spread of malaria. **V:** Messages that convey a need for collective action appeal to the fundamental values of universalism and benevolence and increase community concern. **S/N:** Communicating community co-operation as the norm can strengthen this community's chance of avoiding an epidemic. **O:** Emphasising the losses that will be incurred in the face of inaction can engage community members to join an effort to reduce the spread of malaria.	**Community co-operation** Social-norm frame (focused on protecting families, noting that poverty may limit potential capacity to act). 'The threat of malaria in our community is real. Malaria is spreading into our region because of the changing climate. Young children and pregnant women are particularly at risk. We are working together to stay safe and stop the spread of this disease. There are some things that every one of us can do to help stop the spread of the mosquitoes that carry this disease'.

25758314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 1 (Contiunes)

Species	Description of climate-driven change in distribution	Emotional receptiveness—pathways	Opportunities for communication (framing)	Examples of using species-on-the-move as a central message for starting climate conversations
Atlantic salmon	Atlantic salmon has declined in Finland, while another fish, the northern pike (which feeds on juvenile salmon), has expanded its range in response to warmer water temperatures. In an effort to boost salmon reproduction, Indigenous Skolt Sámi co-management measures have increased harvests of pike and started ecological restoration of important salmon spawning sites (Conservation of Arctic Flora and Fauna (CAFF), 2013, Mustonen, 2015). Sustainable production can be harder to achieve as the distribution of species shifts, impacting culturally or economically important fisheries and challenging management.	The loss of traditional fisheries that have both cultural and economic value will likely create a feeling of worry for the future. There may even be anger at western civilisation for further threatening an already precarious cultural link. If people have an inherent connectedness to species the potential loss will translate into inherent sadness and grief There is likely to be a feeling of sympathy and empathy for the connection people have to the species. At the same time the attempt to maintain and co-manage these species will potentially create pride in actively preserving cultural connections. It will provide an opportunity for those open to change to actively engage	**E:** Evoking feelings of pride through the success of indigenous co-management initiatives can create hope in continuing to manage the impacts. **P/S:** Targeting pike can be a win-win solution for both the salmon stocks and Sámi community and create agency for action. **V:** Evoking cultural values can inspire connection to nature and a desire to protect it. **S/N:** Emphasising that more and more Sámi fishers are targeting pike instead of salmon can create a community-wide shift in fishing practices. **O:** Providing a vision for a positive outcome can reduce the feeling of being overwhelmed and focus people on developing opportunities for positive solutions.	**Capacity for action** Problem-solution combined with emotional frame (focused on pride in collective action) 'In Finland, as our waters are warming, our Atlantic salmon stocks are declining. We can no longer continue fishing as we used to. Our Skolt Sámi communities lead the way, showing us how to adapt to this situation by changing what we do to best protect and prepare our communities and environment for a changing future. We are proud of their actions to preserve the salmon that are so important to all of us'.
Mountain birds	Climate change is driving significant changes in the distribution and abundance of birds. Mountain birds in Italy, for example, have shifted upslope into areas projected to overlap with suitable areas for ski industry development, creating challenges for the future conservation of these species (Brambilla et al., 2016). As species of conservation concern change distribution, it may create conflicts with industries that are needed for work and economic security.	The movement of the birds may create concern about potential income loss due to conflicts (if the birds become a perceived limitation to industry development). If opposing interests arise this will likely create anger and frustration for some of the local communities For some in the community there might be some surprise and relief that birds are moving and that they have some available habitat that they can go to	**E:** Describe how conflict can be damaging for everyone. The ski-industryski industry and environmentalists can work together to develop a solution to this impact. **P/S:** Emphasising the timeliness and need for action that enable the co-development of a solution that benefits all. **V:** Messages that draw on both anthropocentric (i.e. economic) and ecocentric (i.e. conservation) values can engender community-wide concern and action. **S/N:** Communicating a norm that everyone is seeking to reduce conflict can discourage others from engaging in conflict around adaptation to changes. **O:** A message centred around an outcome of reduced conflict could encourage collective action to develop a shared solution.	**Let us find our common ground** Outcome framing (focus on shared gain) 'Changing climate in our region will affect our communities and the nature that surrounds us. Mountain birds are moving upslope—this will affect how we manage our ski industry and how we regulate bird conservation. We need to work together to develop management solutions that can benefit us all and reduce any potential conflict, whilst protecting these birds and their habitats for all to enjoy'.

(Contiunes)

25758314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 1 (Continues)

Species		Description of climate-driven change in distribution	Emotional receptiveness—pathways	Opportunities for communication (framing)	Examples of using species-on-the-move as a central message for starting climate conversations
Sea urchin		Many species that shift as a result of climate change may not have large ecosystem effects; however, some may function in large numbers as invasive species. The long-spined sea urchin has shifted into Tasmania, tracking the pattern of warming in this region. Urchins feed on kelps, converting kelp forests into urchin barrens, affecting the regional lobster and abalone fisheries (Ling et al., 2009). But a new industry can develop around urchin harvest	Some emotions that would be experienced by the affected community are the sadness and grief associated with the loss of environment/ecosystem integrity (system deterioration) and the visual impact this has. The fishers who are reliant on the system for their livelihoods will likely experience worry about income loss. But the fishing industry can also find some hope in being able to participate in a potentially new industry and act to help the environment through harvesting the urchins. This is likely to at least provide some gratification to the industry.	**E:** Loss of kelp forests is associated with sadness and grief. But there may also be hope in the fishing industry's ability to adapt and also protect the environment through harvesting of urchins. **P/S:** This impact can be framed with a solution by identifying the fishing industry as a champion and custodian of the local environment. Urgency to act is also emphasised under such framing. **V:** Appealing to environmental values (e.g. protecting kelp from urchin expansion) can encourage community support for the fishing industry's role in reducing these climate impacts. **S/N:** Highlighting that many fishers are already reaping the financial and ecological rewards of targeting urchins can impel others to do the same. **O:** Identifying the potential gains for industry and community can inspire creative solutions for action.	**Creative empowerment** Problem-solution frame (focused on win-win opportunities) 'The long-spined sea urchin is moving rapidly down our coastline, converting kelp forests to urchin barrens in its wake. We need to stop this spread before it more heavily affects our important fishing industries. A new urchin-harvesting industry will massively reduce the number of urchins in our local waters, whilst also providing jobs and employment for our community'

people had learnt about range extensions, species distributions and climate change and also gained insights into the importance of having accurate species information incorporated into policy decisions (Nursey-Bray et al., 2018). Redmap has been very effective in building awareness and understanding of marine climate change in the community, with 97% of people indicating they trusted the data and information emerging from Redmap, and 78% of people sharing information they learnt from the project with other people in their network (Nursey-Bray et al., 2018).

In some regions, standardised ecological surveys are available to reliably track species-on-the-move through time and across space. Visualisations and maps provide an accessible mechanism for communicating historical and ongoing shifts in species distributions and can be used to not only engage the public but also provide resources for educators and journalists and to directly inform decisions made by resource managers. The OceanAdapt project and website focuses on North America (US and Canada) to compile data annually from ecological surveys across the continental shelf. The data are processed into animated maps and graphs intentionally organised so users can explore and discover changes in spatial distribution over the last few decades for any of the 500+ species depicted. In addition, peer-reviewed habitat projections are also available to guide long-term adaptation efforts (Morley et al., 2018). These interactive visualisations have proven engaging for a wide audience, and the website—which has had 75,000 pageviews since 2014—has informed at least 20 original media articles, provided data for an investigative journalism project 'Ocean Shock' and supplied visualisations for a conservation biology textbook (Cardinale et al., 2019) and a documentary movie (Abel, 2018). More directly, however, the accessibility and high quality of the underlying data has helped inform fisheries management and marine conservation, including a national climate change indicator for the United States (https://www.epa.gov/climate-indicators/climate-change-indicators-marine-species-distribution), climate vulnerability assessments (Hare et al., 2016) and climate adaptation planning for at least four fisheries management organisations. Species-on-the-move are not traditionally considered in fisheries management or marine conservation, and accessible visualisations have helped to change this approach, particularly when the results help corroborate 'on-the-water' reports from fishers reporting similar changes.

Even before widespread citizen science projects were available to track range shifts in real time, scientists and communicators have used projections from species distribution models to communicate the reality of shifting species resulting from ongoing and future climate change. The boom of making predictive species distribution models—particularly correlative models of a species 'environmental niche'—reached a fever pitch in the late 2000s, coinciding with widely accessible modelling software and methodological validation (Elith et al., 2006; Phillips & Dudík, 2008), and support for the idea that predictive modelling was needed for conservation planning (Rodríguez et al., 2007). Despite strongly voiced warnings that range shift predictions were likely misleading and often wrong (Dormann, 2007), such predictions nonetheless proliferated in the

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

scientific literature (Beale & Lennon, 2012), generally defended as being useful first approximations for conservation planning (Wiens et al., 2009). In some cases, predictions with unquantified uncertainty were treated as predictive fact by the media, who asked the public to imagine a world where a certain species no longer exists in a certain place, such as the iconic Bald Eagle climatically shifting out of the Grand Canyon of the United States (Bowling, 2018). To this end, visualisations of potential range shifts have been instrumental in communicating to the public what a potential future with climate change might look like from the perspective of beloved animals (Lai et al., 2014). These broadly communicated exercises of the imagination perilously conflate prediction with prophecy, but as a prelude to more recent abilities of citizen science to track ongoing range shifts, the imagination of predicted future species' ranges may have been an effective method of introducing the tangible biotic impacts of climate change to a large segment of the public (Yusoff & Gabrys, 2011).

5 | LOCAL TO GLOBAL: SCALING UP AND EXPANDING COMMUNICATION OF SPECIES-ON-THE-MOVE

Climate-driven changes in species distribution have already been used to engage fishers, divers, naturalists, school children, government agencies and policy makers on the complex issues of climate change (Table 2). However, there is potential to substantially and strategically expand on these efforts in several key ways to broaden effective engagement, in terms of specific approaches to communicate species-on-the-move, connections made and audiences reached, as well as extending the scale and global reach (Table 3, Box 2). This potential can be enhanced by inclusion of different platforms (e.g. Twitter, Facebook, Instagram, YouTube), approaches (e.g. citizen science, art/science exhibition, books, games, radio/TV programs, workshops) and presenters (e.g. people from different age groups, genders, ethnicities, religions or socio-economic backgrounds) to engage audiences, as this has been shown to help reach a greater diversity of people (Vermeeren et al., 2016).

Strategic engagement initiatives using species-on-the-move at the local to regional level can collectively contribute to international goals and targets regarding climate change communication. The Convention on Biological Diversity and the Sustainable Development Goals (SDGs), for example, include a number of targets related to public education and participation regarding climate change (SDGs 4.7, 12.8, 13.3). The Aarhus Convention (adopted in 1998 and enforced in 2001) established three rights relating to the environment, clearly relevant to climate change: (i) the right of access to environmental information, both on the state of the environment and in relation to human health; (ii) the right to participate in environmental decision-making and (iii) the right of access to justice where these rights are not attained. Communication and engagement on climate-driven species-on-the-move can provide effective mechanisms to ensure that we are working towards these rights of the people in ways that resonate with them and connects with their values.

There are a number of big-picture initiatives and opportunities that can be localised to promote public awareness, education and participation, including the Decade of Ecosystem Restoration (2021–30), Decade of Ocean Science (2021–30) and the last decade of the SDGs (until 2030). The SDGs, in particular, offer a framework that is built around shared goals, and that already incorporates existing rights and international conventions. The post-2020 biodiversity framework will be shaped in terms of its contributions to Agenda 2030 and the SDGs. Targets within these will be highly relevant to species-on-the-move (Pecl et al., 2017), and further supporting a just, sustainable future where people and nature flourish in a stable climate.

The importance of engaging the whole of society to address climate change has been recognised many times. For example, the UN Framework Convention on Climate Change (Article 6) and the Paris Agreement (Article 12) acknowledge the importance of public education, training, awareness, access to information, participation and international co-operation. These six elements are of critical importance in addressing climate change and are referred to collectively as Action for Climate Empowerment (ACE). Since the adoption of the Paris Agreement, these were operationalised in the Work Programme for the Paris Agreement, in 2018, which acknowledged the importance of a wide range of sectors and actors in the achievement of ACE, including museums, cultural and educational institutions.

Globally, museums, zoos and aquariums present an unprecedented opportunity for climate change education and participation, with 95,000 museums and many zoos and aquariums worldwide (Gusset & Dick, 2010). Museums, zoos and aquariums can promote people's connections with biodiversity and with climate change by acknowledging the importance of different forms of knowledge and information, emotions and supporting people's skills and climate actions. Such an approach requires climate change to be presented in ways that have personal meaning, do not rely on science alone, promote participation in the topic and promote a multidisciplinary understanding of climate change and its impacts (see, e.g. McGhie, 2018a, 2018b). Museums, zoos and aquariums can also be used as a space promoting both a greater awareness and understanding of the current situation regarding climate change and its impacts, and opportunities to imagine, debate and create pathways to desired futures (McGhie et al., 2020). Large, stored collections in museums can also help people explore environmental change in a hands-on way and provide people with opportunities to participate in citizen science initiatives, bringing together education, training, access to information, public participation and international co-operation. These citizen science initiatives, along with other approaches outlined in Tables 2 and 3, build capacity for research that in turn helps build adaptive capacity to climate change and its impacts. Ultimately, different platforms and contexts will be applicable in different circumstances; collectively we need many different actors, connecting via different pathways to engage as many people as possible.

Given the goal of engendering positive and active engagement in addressing climate change, any initiatives designed

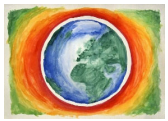
25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 2 Examples of existing initiatives that explicitly use species-on-the-move to communicate climate change.

Initiative	Summary	Geographic focus
Biodiversity and Climate Change Citizen Science Project http://www.humboldt.org.co/es/actualidad/itemlist/tag/Ciencia%20Participativa Soacha and Gómez (2016).	A national initiative that integrates the participation of citizen scientists to document changes in biodiversity and distribution of species in key ecosystems (e.g. birds from the High Andean plateau wetlands; Orchids from tropical dry forests). Offers an online platform (Colombia Naturalist) to document findings	Colombia
Redmap Australia http://www.redmap.org.au/ Pecl et al., 2019	Redmap (Range Extension Database & Mapping project) invites Australian fishers, divers and boaters to spot, log and map marine species that are potentially shifting distribution around the Australian coast. Each submitted photograph is verified by an expert for that species and a personalised email is sent back to the observer	Australia
What's That Fish New Zealand https://www.facebook.com/WhatsThatFishNZ/ Middleton et al., 2021	A Facebook-based project where the community is invited to submit photographs of species they suspect are unusual for a given location, with an aim of encouraging 'two-way conversations between scientists and the community on climate change & impacts on species'	New Zealand
Summit moth Taiwan http://twmoth.tesri.gov.tw/peo/FBMothQueryP	The summit moth project invites people hiking to high mountains (>3000 m.a.s.l.) in Taiwan to submit photos of moths to a dedicated Facebook page. Moths are a model species for citizen science monitoring as they are attracted by lights to cabins or camping sites along hiking routes. This project documents the diversity of mountain moths and those new to Taiwan's alpine ecosystem	Taiwan
Species on the Move UK https://twitter.com/SOTM_UK Pettorelli et al., 2019	A Twitter-based project where members of the UK public can tweet photos of any terrestrial, freshwater or marine species they observe and know or suspect is new to the UK or to specific regions within the UK. https://www.zsl.org/science/mitigating-the-impacts-of-climate-change-on-biodiversity/the-impact-of-climate-change-on	U.K.
Observadores del Mar https://www.observadoresdelmar.es/ Azzurro et al., 2016	An initiative providing citizen scientists with an online platform to log unusual sightings of marine species, with multiple projects targeting different species of interest	Spain/ Mediterranean Sea
Vigie Nature / Vigie Flore http://www.vigienature.fr/fr Martin et al., 2019	A French citizen science initiative that aims to document the distributions of terrestrial species for the purpose of understanding how these may be changing	France
FjordPhyto eco-tourism and citizen science https://scripps.ucsd.edu/programs/fjordphyto/ Cusick et al., 2020	A project that engages Antarctic tour operators and tourists to collect phytoplankton from Antarctic fjords in order to monitor climate-driven changes in these assemblages	Antarctica
Small-scale clam fishery community-based data collection project Gianelli et al., 2019	A community-based data collection project that engages extensively with artisanal fishers to monitor the abundance and changes in distribution of the cool-water yellow clam (*Mesodesma mactroides*) in Uruguay	Uruguay
What's the Catch, student educational activity https://pinsky.marine.rutgers.edu/resources/whats-the-catch-engaging-students-in-systems-thinking/	An undergraduate student activity that utilises the climate-driven redistribution of marine fishes, and associated implications for fishing communities, to teach systems thinking concepts	USA
Media e.g., National Geographic https://www.nationalgeographic.com/news/2017/04/climate-change-species-migration-disease/	In-depth journalism articles utilise species-on-the-move as a vehicle to communicate the impacts of climate change. Examples of language used in the titles of such articles include 'Half of All Species Are on the Move—And We're Feeling It' and 'As climate change displaces everything from moose to microbes, it's affecting human foods, businesses and diseases'	Global
Popular books	'The next great migration: the beauty and terror of life on the move' by Sonia Shah describes, in part, climate-driven redistribution of species over time as a 'lifesaving response to environmental change'	Global
Covering Climate Now	A journalism initiative, which includes hundreds of media outlets worldwide, committed to bringing more and better coverage of climate change, including species on the move, to a global audience	Global

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 3 Potential opportunities for building on existing engagement on climate change using climate-driven changes in species distribution. Many of these, especially 3, 4, 5, 6 and 7, could include or incorporate (but not be limited to) citizen science approaches.

1 Games	
Many different types of games could be created or adapted to include range-shifting species and other climate change impacts to engage large audiences of all ages in informal learning opportunities. Examples include the card-matching games associated with Redmap Australia (www.redmap.org.au) and web-based ecosystem simulation games like Ecobuilder. Apps, online and video games could be particularly successful engaging teenagers.	
2 Arts	Image ©Pixabay
Performance, storytelling, artworks, music, photo and film informed by research through collaborative works between climate change scientists and artists can reach audiences from diverse cultural or linguistic backgrounds. Examples include the Ocean Hub project by Empatheatre, and the Rainforest Music Festival that could be adapted to communicate messages about species-on-the-move and consequences of their movements. Potentially a powerful way of communicating sometimes complex messages to people typically unengaged or unexposed to science, but with strong oral traditions.	
3 Museums, zoos, aquaria and discovery centers	Image ©Jorge Royan
Established networks of museums interested in climate change (e.g. Museums and Climate Change Network) provide lifelong learning opportunities for the public through exhibits, collections and citizen science projects that include range shifts perspectives. These can attract attendance from a cross-section of society but also facilitate partnerships and interaction between different stakeholders including government authorities and planners, researchers and public audiences.	
4 Formal education	Image ©woodleywonderworks
Schools can make use of educational kits (e.g. Great Southern Reef educational resource) designed by scientists to incorporate climate-driven changes in species redistribution into their curriculum through formal class-teaching and field observations. Science outreach efforts like these provide easily accessible tools for schools and home learners to educate the young generation about climate change impacts.	
5 Rural agriculture and fisheries organisations	Image ©Walter Aristondo
Farmers, agriculture agencies, fishers, fisheries agencies, local monitoring groups, landcare and coastcare groups could be provided with support to help monitor new species shifting into their regions via apps or websites, or recorded locally, and in turn, use information gathered to communicate species-on-the-move in locally relevant ways. Such platforms can engage rural agricultural and fisheries stakeholders impacted by species range shifts, as well as the broader public that may be typically unengaged with science, by using their own observations.	
6 Ecotourism	Image ©Woodwalker
Ecotourism provides favourable learning opportunities for tourists in a relaxed and interactive manner. Tourism operator's organisations like the Polar Citizen Science Collective actively work to advocate and support science by engaging travellers in scientist-led citizen science research. The same approach could be applied to advocate and support species-on-the-move research by leveraging travellers globally on species redistribution in popular ecotourist sites.	
7 Medical associations and healthcare providers	
Physicians and doctors can become advocates for climate and health in their community by speaking to policymakers, press and community groups on public health impacts of climate change through changing distributions of disease vectors and novel disease risks. Examples include the Medical Society Consortium on Climate Change and Health and Climate for Health initiative. Platforms like the Global Mosquito Alert Consortium can contribute to mapping the changing distribution of mosquito vectors.	
8 International day of species-on-the-move	Image ©Pixabay
Similar to the concept of International Day for Biological Diversity (IDB), an International Day of Species On The Move (IDSOTM) could be devoted to communicating ongoing species redistribution and calling for actions in response to these range shifts. Climate change scientists could work with entities like the United Nations to raise worldwide awareness of tangible and observable climate change impacts.	

around using species-on-the-move as an engagement tool could consider several aspects of outcome evaluation. However, a reliable scientific framework to measure the performance, impact and outcome of behaviour change interventions is not readily available (Gatersleben, 2018; Sweeney, 2009). To accurately measure change, ideally the actual intended behaviour (e.g. positive participation), or the outcomes of the behaviour (e.g. more media posting and attention on shifting species), should be observed directly. Prohibitive costs of direct observational approaches may be supplemented with self-reported behaviour (i.e. being asked to answer questions like 'have I changed my outlook on climate change because of exposure to shifting species initiatives?'), even

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

BOX 2 Species-on-the-move and public health

In addition to species as components of biodiversity, climate change (along with human and animal movement) is altering the distribution of infectious diseases of both medical and veterinary importance (Bergquist et al., 2018). More than 70% of all emerging infections are zoonotic (i.e. coming to humans from animals; Jones et al., 2008). For instance, SARS-CoV-2 belongs to this class, as do the Nipah and hanta virus, ebola and *Fransicella tularensis* causing tularemia. The on-going global reshuffling of species is likely to produce novel species assemblages, increasing the opportunities for viral sharing between previously isolated species, for example. In some cases, this will inevitably facilitate spillover of new diseases to humans (Carlson et al., 2020). Already known vector-borne diseases, such as Zika, dengue, chikungunya and yellow fever are also expanding, in concert with global warming and changes in the ranges of their mosquito vector species, most notably *Aedes albopictus* (the Asian tiger mosquito) and *Aedes aegypti* (Kraemer et al., 2019; Ryan et al., 2019). In the battle against their global spread, various initiatives in academia or health organisations have actively sought to engage citizens or communities in the surveillance of disease-carrying mosquitoes. The Global Mosquito Alert Consortium, is a large UNEP-backed global platform bringing together citizen science initiatives for a coordinated approach to mosquito vector-monitoring by engaging with the public (Tyson et al., 2018). In addition, health professionals (alongside scientists) often rank among the most trusted of messengers, and a focus on public health often elicits strong emotional reactions consistent with support for climate change mitigation and adaptation (Myers et al., 2012). Health researchers, medical societies and clinicians could, therefore, form a powerful, united voice in framing the climate change crisis as a health imperative, presenting a unique opportunity to engage and empower society, including patients and policy makers (Koh, 2016). A (re-)framing of climate change as a public health issue may encourage people to consider the human health context of climate change, providing a new frame of reference that may broaden the personal significance and relevance of climate change to segments in society that may otherwise be disengaged or dismissive of the issue (Maibach et al., 2010).

though it is prone to potential inaccuracy. Combined quantitative and qualitative information, such as generated in formal evaluations of the citizen science range shift initiative Redmap Australia (Nursey-Bray et al., 2018; Pecl et al., 2019), will provide the most useful approach to demonstrate success in whether positive engagement and active engagement in range shift initiatives can change mental models about climate change.

6 | CONCLUSIONS AND NEXT STEPS

Species-on-the-move offer a powerful opportunity to develop narratives that evoke shared values between different social groups (Kelly et al., 2019,) in ways that generate locally relevant social understandings of climate change (Nursey-Bray et al., 2018). These narratives, based on tangible changes that can be observed by all, represent an effective and individually meaningful way to engage people. The establishment of new species in an environment is often permanent and cannot be dismissed as a one-off event; species are observable living entities, their detection does not (usually) require instruments or necessarily rely on experts, meaning that their presence cannot be easily denied. In addition, scientists and other groups (e.g. teachers, agriculture or fishery managers, medical practitioners) working on these species are often trusted messengers, with the potential to influence diverse social networks (e.g. Ipsos MORI, 2018; Rainie et al., 2019). The climate-driven redistribution of species presents both opportunities and challenges that will require adapting to (Bonebrake et al., 2017), and the changing presence of species can potentially raise interest in a dynamic nature and create opportunities for people to contribute to climate change science through their personal interests and activities (e.g. citizen science).

Participation in environmental monitoring via citizen science has been highlighted as enabling people to 'immerse themselves deeply in learning about global challenges' and potentially 'provide personally transformative experiences' (United Nations, 2019). The recent enormous rise in participatory citizen science projects, via platforms such as Zooniverse, iNaturalist and SciStarter, is further evidence that appetite for citizen science is increasing and pervasive. The post COVID-19 'anthropause' (Rutz et al., 2020) has meant that large national parks and reserve areas have closed to visitors, and people seem to now be looking to the environment accessible to them under these circumstances. The uptick is particularly high for citizen science projects that document the various animal or plant species around them, showing the inherent need of many people to connect with nature—projects like the 'Lockdown Garden Surveys' in South Africa have proven to be extremely successful. At a larger scale, Zooniverse reported that 200,000 participants contributed over 5 million classifications, the equivalent of approximately 48 years of research in 1 week alone. Moreover, although the challenges associated with climate-driven species redistribution are fundamentally different from those associated with the management of invasive alien species, there are natural synergies between the invasive species management and the species-on-the-move management agendas (Pettorelli et al., 2019) providing proven pathways and examples of how communication and engagement initiatives focused on species-on-the-move could be scaled up to support global coordination and effective action.

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Evidence suggests that people need to feel that they are part of nature in order to engage in actions that can potentially protect it (Moreton et al., 2019). There is substantial potential for people to connect more deeply with their local environment through engagement with species-on-the-move and climate change that offers:

1. Personal relevance for local communities but connects to global climate narratives (e.g. Davies et al., 2019). This relevance could be nature-based but may also be economic or related to human health, offering a variety of potential pathways for connection;
2. Engagement on intellectual, emotional and embodied dimensions (Morris et al., 2019);
3. Connection to a diverse range of human values, employing multiple types of communication 'frames' (e.g. care for nature, care for humanity, responsibility, tradition, freedom and opportunity, Kolandai-Matchett & Armoudian, 2020);
4. Opportunities for personal involvement and for relationship-building between experts and lay people, creating stronger and wider trust networks (i.e. through citizen science projects, Pittman et al., 2019);
5. Potential for relationship building between diverse social groups (e.g. across political and generational differences, e.g. Kelly et al., 2019).

Current trajectories of greenhouse gas emissions are projected to lead to global warming of between 2.6 and 4.5°C above preindustrial levels by the year 2100, far exceeding the long-term temperature limit supported by the Paris Agreement. As members of the global research community, we face the daunting task of engaging an increasingly polarised public on the urgency of climate change. However, we need to do so in a way that feels locally relevant, increases interest in adaptation, and does not paralyse and prevent action. Species-on-the-move provide an exceptional opportunity for strategic and structured engagement on climate change that can involve mass participation at locally relevant scales, and in ways that link to people's human values, trust networks, and attachment to place. Future research could include carefully designed interdisciplinary and experimental research to examine how to best to leverage the concept of species-on-the-move to facilitate public engagement with climate change. Ultimately, we need to make climate change information accessible in ways that people understand and can relate to (Leslie et al., 2013)—we propose the varied implications of the largest redistribution of life on Earth for tens of thousands of years can provide the tangible anchor necessary to connect people to climate change.

AUTHOR CONTRIBUTIONS

All authors made substantial contributions to the conception of the paper via active participation in a workshop after the 2019 *Species on the Move* conference in South Africa or contributed substantive text and/or editing or development of figures and tables afterwards. Gretta T. Pecl and Warwick Sauer co-led the workshop, Gretta T. Pecl led the drafting of the text, and Rachel Kelly, Chloe Lucas, Ingrid van Putten, Renuka Badhe, Curtis Champion, I-Ching Chenic, Omar Defeo, Juan Diego Gaitan-Espitia, Birgitta Evengård, Damien Fordham, Fengyi Guo, Romina Henriques, Sabine Henry, Jonathan Lenoir Henry McGhie, Tero Mustonen, Stephen Oliver, Nathalie Pettorelli, Malin L. Pinsky, Warren Potts, Julia Santana-Garcon, Anna-Sofie Stensgaard, Morgan W. Tingley and Adriana Vergés contributed ideas, text and edited the manuscript.

ACKNOWLEDGEMENTS

Gretta T. Pecl was supported by an Australian Research Council Future Fellowship. The *Species on the Move* conference and workshop was funded by the Centre for Marine Socioecology at the University of Tasmania, Rhodes University South Africa, Snowchange, Institute for Marine and Antarctic Studies, CSIRO, UNSW Sydney, National Research Foundation and NOAA Fisheries. Thank you to Stacey McCormack for graphic design.

FUNDING INFORMATION

This research was funded by an Australian Research Council Future Fellowship FT140100596, awarded to Gretta Pecl.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest.

DATA AVAILABILITY STATEMENT

This article does not use or report original or secondary data.

ORCID

Gretta T. Pecl https://orcid.org/0000-0003-0192-4339
Juan Diego Gaitan-Espitia https://orcid.org/0000-0001-8781-5736
Damien A. Fordham https://orcid.org/0000-0003-2137-5592
Jonathan Lenoir https://orcid.org/0000-0003-0638-9582
Nathalie Pettorelli https://orcid.org/0000-0002-1594-6208
Julia Santana-Garcon https://orcid.org/0000-0001-7961-3552
Adriana Verges https://orcid.org/0000-0002-3507-1234

REFERENCES

Abel, D. (2018). *Lobster war: The fight over the world's richest fishing grounds*. Gravitas Films.

Altizer, S., Ostfeld, R. S., Johnson, P. T., Kutz, S., & Harvell, C. D. (2013). Climate change and infectious diseases: From evidence to a predictive framework. *Science*, *341*, 514–519.

Azzurro, E., Castriota, L., Falautano, M., Bariche, M., Broglio, E., & Andaloro, F. (2016). New records of the silver-cheeked toadfish *Lagocephalus sceleratus* (Gmelin, 1789) in the Tyrrhenian and Ionian seas: Early detection and participatory monitoring in practice. *BioInvasions Records*, *5*, 295–299.

Baca, M., Läderach, P., Haggar, J., Schroth, G., & Ovalle, O. (2014). An integrated framework for assessing vulnerability to climate change and developing adaptation strategies for coffee growing families in Mesoamerica. *PLoS ONE*, *9*, e88463.

Beale, C. M., & Lennon, J. J. (2012). Incorporating uncertainty in predictive species distribution modelling. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*, 247–258.

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Bell, S. L., Foley, R., Houghton, F., Maddrell, A., & Williams, A. M. (2018). From therapeutic landscapes to healthy spaces, places and practices: A scoping review. *Social Science and Medicine*, *196*, 123–130.

Bergquist, P., & Warshaw, C. (2019). Does global warming increase public concern about climate change? *The Journal of Politics*, *81*, 686–691.

Bergquist, R., Stensgaard, A. S., & Rinaldi, L. (2018). Vector-borne diseases in a warmer world: Will they stay or will they go? *Geospatial Health*, *13*, *699*.

Bhowmik, A. K., McCaffrey, M. S., Ruskey, A. M., Frischmann, C., & Gaffney, O. (2020). Powers of 10: Seeking 'sweet spots' for rapid climate and sustainability actions between individual and global scales. *Environmental Research Letters*, *15*, 094011.

Blackmore, E., Underhill, R., McQuilkin, J., & Leach, R. (2013). *Common cause for nature: Values and frames in conservation*. Public Interest Research Centre.

Bonebrake, T. C., Brown, C. J., Bell, J. D., Blanchard, J. L., Chauvenet, A., Champion, C., Chen, I.-C., Clark, T. D., Colwell, R. K., Danielsen, F., Dell, A. I., Donelson, J. M., Evengård, B., Ferrier, S., Frusher, S., Garcia, R. A., Griffis, R. B., Hobday, A. J., Jarzyna, M. A., … Pecl, G. T. (2017). Managing consequences of climate-driven species redistribution requires integration of ecology, conservation and social science. *Biological Reviews*, *93*(1), 284–305. https://doi.org/10.1111/brv.12344

Bowling, J. (2018). *Climate change could drive bald eagles to extinction in grand canyon, study says*. AZCentral. https://www.azcentral.com/story/news/local/arizona-environment/2018/03/21/climate-change-could-drive-bald-eagles-extinction-grand-canyon-study-says/442960002/

Brambilla, M., Pedrini, P., Rolando, A., & Chamberlain, D. E. (2016). Climate change will increase the potential conflict between skiing and high-elevation bird species in the Alps. *Journal of Biogeography*, *43*, 2299–2309.

Capstick, S., Whitmarsh, L., Poortinga, W., Pidgeon, N., & Upham, P. (2015). International trends in public perceptions of climate change over the past quarter century. *Wiley Interdisciplinary Reviews: Climate Change*, *6*, 35–61.

Cardinale, B., Primack, R., & Murdoch, J. (2019). *Conservation biology*. Oxford University Press.

Carlson, C. L., Albery, G. F., Merow, C., Trisos, C. H., Zipfel, C. M., Eskew, E. A., Olival, K. J., Ross, N., & Bansal, S. (2020). Climate change will drive novel cross-species viral transmission. bioRxiv 2020.01.24.918755 https://doi.org/10.1101/2020.01.24.918755

CBD. (2020). *Secretariat of the convention on biological diversity, global biodiversity outlook 5*.

Chyn, K., Lin, T.-E., Chen, Y.-K., Chen, C.-Y., & Fitzger, L. A. (2019). The magnitude of roadkill in Taiwan: Patterns and consequences revealed by citizen science. *Biological Conservation*, *237*, 317–326.

Conservation of Arctic Flora and Fauna (CAFF). (2013). *Arctic biodiversity assessment: Report for policy makers*. http://www.arcticbiodiversity.is/the-report/report-for-policy-makers

Corner, A., & Groves, C. (2014). Breaking the climate change communication deadlock. *Nature Climate Change*, *4*, 743–745.

Corner, A., Shaw, C., & Clarke, J. (2018). *Principles for effective communication and public engagement on climate change: A handbook for IPCC authors*. Climate Outreach.

Cunsolo Willox, A., Harper, S. L., Ford, J. D., Edge, V. L., Landman, K., Houle, K., Blake, S., & Wolfrey, C. (2013). Climate change and mental health: An exploratory case study from Rigolet, Nunatsiavut, Canada. *Climatic Change*, *121*, 255–270. https://doi.org/10.1007/s10584-013-0875-4

Cusick, A. M., et al. (2020). Polar tourism as an effective research tool: Citizen science in the Western Antarctic peninsula. *Oceanography*, *33*, 50–61.

Davies, S. R., Halpern, M., Horst, M., Kirby, D., & Lewenstein, B. (2019). Science stories as culture: experience, identity, narrative and emotion in public communication of science. *Journal of Science Communication*, *18*(9), A01. https://doi.org/10.22323/2.18050201

Díaz, S., Settele, J., Brondízio, E. S., Ngo, H. T., Agard, J., Arneth, A., Balvanera, P., Brauman, K. A., Butchart, S. H. M., Chan, K. M. A., Garibaldi, L. A., Ichii, K., Liu, J., Subramanian, S. M., Midgley, G. F., Miloslavich, P., Molnár, Z., Obura, D., Pfaff, A., … Zayas, C. N. (2019). Pervasive human-driven decline of life on earth points to the need for transformative change. *Science*, *366*, eaax3100.

Díaz, S., Zafra-Calvo, N., Purvis, A., Verburg, P. H., Obura, D., Leadley, P., Chaplin-Kramer, R., de Meester, L., Dulloo, E., Martín-López, B., Shaw, M. R., Visconti, P., Broadgate, W., Bruford, M. W., Burgess, N. D., Cavender-Bares, J., DeClerck, F., Fernández-Palacios, J. M., Garibaldi, L. A., … Zanne, A. E. (2020). Set ambitious goals for biodiversity and sustainability. *Science*, *370*, 411–413.

Dietz, T., Dan, A., & Shwom, R. (2007). Support for climate change policy: Social psychological and social structural influences. *Rural Sociology*, *72*, 185–214.

Dormann, C. (2007). Promising the future? Global change projections of species distributions. *Basic and Applied Ecology*, *8*, 387–397.

Druckman, J. N., & McGrath, M. C. (2019). The evidence for motivated reasoning in climate change preference formation. *Nature Climate Change*, *9*, 111–119.

Elith, J., H. Graham, C., P. Anderson, R., Dudík, M., Ferrier, S., Guisan, A., J. Hijmans, R., Huettmann, F., R. Leathwick, J., Lehmann, A., Li, J., G. Lohmann, L., A. Loiselle, B., Manion, G., Moritz, C., Nakamura, M., Nakazawa, Y., McC. M. Overton, J., Townsend Peterson, A., … E. Zimmermann, N. (2006). Novel methods improve prediction of species' distributions from occurrence data. *Ecography*, *29*, 129–151.

Fagan, M., & Huang, C. (2019). *A look at how people around the world view climate change* (pp. 1–8). Pew Research Center Spring 2018 Global Attitudes Survey https://www.pewresearch.org/fact-tank/2019/04/18/a-look-at-how-people-around-the-world-view-climate-change/

Fordham, D. A., Jackson, S. T., Brown, S. C., Huntley, B., Brook, B. W., Dahl-Jensen, D., Gilbert, M. T. P., Otto-Bliesner, B. L., Svensson, A., Theodoridis, S., Wilmshurst, J. M., Buettel, J. C., Canteri, E., McDowell, M., Orlando, L., Pilowsky, J., Rahbek, C., & Nogues-Bravo, D. (2020). Using paleo-archives to safeguard biodiversity under climate change. *Science*, *369*, eabc5654.

Gatersleben, B. (2018). Measuring environmental behaviour. In L. Steg & J. I. M. Groot (Eds.), *Environmental psychology* (pp. 155–166). John Wiley & Sons Ltd. https://doi.org/10.1002/9781119241072.ch16

Gianelli, I., Ortega, L., & Defeo, O. (2019). Modeling short-term fishing dynamics in a small-scale intertidal shellfishery. *Fisheries Research*, *209*, 242–250.

Goldberg, M. H., van der Linden, S., Maibach, E., & Leiserowitz, A. (2019). Discussing global warming leads to greater acceptance of climate science. *Proceedings of the National Academy of Sciences of the United States of America*, *116*, 14804–14805.

Graham, H., Mason, R., & Newman, A. (2009). *Literature review: Historic environment, sense of place, and social capital English Heritage*. International Centre for Cultural and Heritage Studies, Newcastle University.

Gusset, M., & Dick, G. (2010). The global reach of zoos and aquariums in visitor numbers and conservation expenditures. *Zoo Biology*, *30*, 566–569.

Hare, J. A., Morrison, W. E., Nelson, M. W., Stachura, M. M., Teeters, E. J., Griffis, R. B., Alexander, M. A., Scott, J. D., Alade, L., Bell, R. J., Chute, A. S., Curti, K. L., Curtis, T. H., Kircheis, D., Kocik, J. F., Lucey, S. M., McCandless, C. T., Milke, L. M., Richardson, D. E., … Griswold, C. A. (2016). A vulnerability assessment of fish and invertebrates to climate change on the northeast U.S. continental shelf. *PLoS ONE*, *11*, e0146756.

Hornsey, M. J., & Fielding, K. S. (2020). Understanding (and reducing) inaction on climate change. *Social Issues and Policy Review*, *14*, 3–35.

Howell, R. A. (2013). It's not (just) "the environment, stupid!" values, motivations, and routes to engagement of people adopting lower-carbon lifestyles. *Global Environmental Change*, *23*, 281–290.

Huntley, R. (2020). *How to talk about climate change in a way that makes a difference*. Murdoch Books.

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

IPBES. (2019). *Global assessment report on biodiversity and ecosystem services of the intergovernmental science-policy platform on biodiversity and ecosystem services*. (E. S., Brondizio, J., Settele, S., Díaz, & H. T. Ngo (Eds.)). IPBES secretariat.

Ipsos MORI. (2018). *Ipsos MORI veracity index 2018*. https://www.ipsos.com/sites/default/files/ct/news/documents/2018-11/veracity_index_2018_-_topline_v1_public.pdf

Ives, C. D., Abson, D. J., von Wehrden, H., Dorninger, C., Klaniecki, K., & Fischer, J. (2018). Reconnecting with nature for sustainability. *Sustainability Science*, *13*, 1389–1397.

Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., & Daszak, P. (2008). Global trends in emerging infectious diseases. *Nature*, *21*, 990–993.

Kelly, R., Fleming, A., & Pecl, G. (2019). Citizen science and social licence: Improving perceptions and connecting marine user groups. *Ocean & Coastal Management*, *178*, 104855.

Kendal, D., & Raymond, C. M. (2019). Understanding pathways to shifting values over time in the context of social-ecological systems. *Sustainability Science*, *14*, 1333–1342.

Kerr, J. T., Pindar, A., Galpern, P., Packer, L., Potts, S. G., Roberts, S. M., Rasmont, P., Schweiger, O., Colla, S. R., Richardson, L. L., Wagner, D. L., Gall, L. F., Sikes, D. S., & Pantoja, A. (2015). Climate change impacts on bumblebees converge across continents. *Science*, *349*, 177–180.

Ko, J., et al. (2019). How citizen science is reinforcing the forming of a bottom-up national biodiversity open data culture: Our progress on an Island in the Western Pacific region—Taiwan. *Biodiversity Information Science and Standards*, *3*, e37380.

Koh, H. (2016). Communicating the health effects of climate change. *JAMA*, *315*, 239–240.

Kolandai-Matchett, K., & Armoudian, M. (2020). Message framing strategies for effective marine conservation communication. *Aquatic Conservation: Marine & Freshwater Ecosystems*, *30*, 2441–2463.

Kraemer, M. U. G., Reiner, R. C., Jr., Brady, O. J., Messina, J. P., Gilbert, M., Pigott, D. M., Yi, D., Johnson, K., Earl, L., Marczak, L. B., Shirude, S., Davis Weaver, N., Bisanzio, D., Perkins, T. A., Lai, S., Lu, X., Jones, P., Coelho, G. E., Carvalho, R. G., … Golding, N. (2019). Past and future spread of the arbovirus vectors Aedes aegypti and Aedes albopictus. *Nature Microbiology*, *4*, 854–863.

Kullenberg, C., & Kasperowski, D. (2016). What is citizen science? A scientometric meta-analysis. *PLoS ONE*, *11*, e0147152.

Kunda, Z. (1990). The case for motivated reasoning. *Psychological Bulletin*, *108*, 480–498.

Lai, K. K. R., Buchanan, L., & Watkins, D. (2014). *Climate change threatens to disrupt the ranges of birds*. New York Times https://www.nytimes.com/interactive/2014/09/08/us/climate-change-could-push-birds-north-shrink-their-ranges.html

Lakoff, G. (2010). Why it matters how we frame the environment. *Environmental Communication*, *4*, 70–81.

Larson, L. R., Szczytko, R., Bowers, E. P., Stephens, L. E., Stevenson, K. T., & Floyd, M. F. (2018). Outdoor time, screen time, and connection to nature: Troubling trends among rural youth? *Environment and Behavior*, *51*, 966–991.

Larson, S., De Freitas, D. M., & Hicks, C. C. (2013). Sense of place as a determinant of people's attitudes towards the environment: Implications for natural resources management and planning in the great barrier reef, Australia. *Journal of Environmental Management*, *117*, 226–234.

Leiserowitz, A. (2006). Climate change risk perception and policy preferences: The role of affect, imagery, and values. *Climatic Change*, *77*, 45–72.

Lenoir, J., Bertrand, R., Comte, L., Bourgeaud, L., Hattab, T., Murienne, J., & Grenouillet, G. (2020). Species better track climate warming in the oceans than on land. *Nature Ecology and Evolution*, *4*, 1044–1059.

Leslie, H. M., Goldman, E., Mcleod, K. L., Sievanen, L., Balasubramanian, H., Cudney-Bueno, R., Feuerstein, A., Knowlton, N., Lee, K., Pollnac, R., & Samhouri, J. F. (2013). How good science and stories can go hand-in-hand. *Conservation Biology*, *27*, 1126–1129.

Levin, D., & Cross, R. (2004). The strength of weak ties you can trust: The mediating role of trust in effective knowledge transfer. *Management Science*, *50*, 1477–1490.

Ling, S. D., Johnson, C. R., Frusher, S. D., & Ridgway, K. R. (2009). Overfishing reduces resilience of kelp beds to climate-driven catastrophic phase shift. *Proceedings of the National Academy of Sciences of the United States of America*, *106*, 22341–22345.

Ling, S. D., & Keane, J. P. (2018). *Resurvey of the Longspined Sea Urchin (Centrostephanus rodgersii) and associated barren reef in Tasmania*. Institute for Marine and Antarctic Studies Report, University of Tasmania.

Lloyd, P., Plagányi, É. E., Weeks, S. J., Magno-Canto, M., & Plagányi, G. (2012). Ocean warming alters species abundance patterns and increases species diversity in an African sub-tropical reef-fish community. *Fisheries Oceanography*, *21*, 78–94.

Lucas, C. (2018). Concerning values: What underlies public polarisation about climate change? *Geographical Research*, *56*, 298–310.

Lucas, C., Leith, P., & Davison, A. (2015). How climate change research undermines trust in everyday life: A review. *Wiley Interdisciplinary Reviews: Climate Change*, *6*, 79–91.

Lucas, C., & Warman, R. (2018). Disrupting polarized discourses: Can we get out of the ruts of environmental conflicts? *Environment and Planning C: Politics and Space*, *36*, 987–1005.

Lucas, C. H., & Davison, A. (2019). Not 'getting on the bandwagon': When climate change is a matter of unconcern. *Environment and Planning E: Nature and Space*, *2*, 129–149.

Maeseele, P. (2015). The risk conflicts perspective: Mediating environmental change we can believe in. *Bulletin of Science, Technology & Society*, *35*, 44–53.

Maibach, E. W., Nisbet, M., Baldwin, P., Akerlof, K., & Diao, G. (2010). Reframing climate change as a public health issue: An exploratory study of public reactions. *BMC Public Health*, *10*, 299.

Manzo, K. (2010). Beyond polar bears? Re-envisioning climate change. *Meteorological Applications*, *17*, 196–208.

Martin, G., Devictor, V., Motard, E., Machon, N., & Porcher, E. (2019). Short-term climate-induced change in French plant communities. *Biology Letters*, *15*, 20190280.

McGhie, H. A. (2018a). Promoting people's connection with nature through natural history displays. In A. Sheersoi & S. D. Tunnicliffe (Eds.), *Natural history dioramas—Traditional exhibits for current and actual educational themes*. Springer.

McGhie, H. A. (2018b). Climate change engagement: A different narrative. In W. Leal Filho, B. Lackner, & H. McGhie (Eds.), *Addressing the challenges in communicating climate change across various audiences*. Springer.

McGhie, H. A., Mander, S., & Minns, A. (2020). The time machine: Challenging perceptions of time and place to enhance climate change engagement through museums. *Museum and Society*, *18*, 183–197.

Middleton, I., Aguirre, J. D., Trnski, T., Francis, M., Duffy, C., & Liggins, L. (2021). Introduced alien, range extension or just visiting? Combining citizen science observations and expert knowledge to classify range dynamics of marine fishes. *Diversity and Distributions*, *27*, 1278–1293.

Mittelmark, M. B., Sagy, S., Eriksson, M., Bauer, G. F., Pelikan, J. M., Lindström, B., & Espnes, G. A. (2017). *The handbook of salutogenesis*. Springer.

Moreton, S. G., Arena, A., Hornsey, M. J., Crimston, C. R., & Tiliopoulos, N. (2019). Elevating nature: Morla elevation increases feelings of connectedness to nature. *Journal of Environmental Psychology*, *65*, 101332.

Morley, J. W., Selden, R. L., Latour, R. J., Frölicher, T. L., Seagraves, R. J., & Pinsky, M. L. (2018). Projecting shifts in thermal habitat for 686 species on the north American continental shelf. *PLoS ONE*, *13*, e0196127.

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Morris, B. S., Chrysochou, P., Christensen, J. D., et al. (2019). Stories vs. facts: Triggering emotion and action-taking on climate change. *Climatic Change*, *154*, 19–36. https://doi.org/10.1007/s10584-019-02425-6

Mustonen, T. (2015). Communal visual histories to detect environmental change in northern areas: Examples of emerging north American and Eurasian practices. *Ambio*, *44*, 766–777.

Myers, T., Nisbet, M., Maibach, E., & Leiserowitz, A. (2012). A public health frame arouses hopeful emotions about climate change. *Climatic Change*, *113*, 1105–1112.

Nelson, T., & Kinder, D. (1996). Issue frames and group-centrism in American public opinion. *The Journal of Politics*, *58*, 1055–1078.

Nettlefold, J., & Pecl, G. T. (2020). Engaged journalism and climate change: Lessons from an audience-led, locally focused Australian collaboration. *Journalism Practice*, *1-16*, 19–34.

Nisbet, M. C. (2019). Communicating climate change: Why frames matter for public engagement. *Environment: Science and Policy for Sustainable Development*, *51*, 12–23. https://doi.org/10.3200/ENVT.51.2.12-23

Nursey-Bray, M., Palmer, R., & Pecl, G. (2018). Spot, log, map: Assessing a marine virtual citizen science program against Reed's best practice for stakeholder participation in environmental management. *Ocean and Coastal Management*, *151*, 1–9.

O'Neill, S., & Nicholson-Cole, S. (2009). "Fear won't do it": Promoting positive engagement with climate change through visual and iconic representations. *Science Communication*, *30*, 355–379.

Pearce, W., Brown, B., Nerlich, B., & Koteyko, N. (2015). Communicating climate change: Conduits, content, and consensus. *Wiley Interdisciplinary Reviews: Climate Change*, *6*, 613–626.

Pecl, G. T., Araújo, M. B., Bell, J. D., Blanchard, J., Bonebrake, T. C., Chen, I.-. C., Clark, T. D., Colwell, R. K., Danielsen, F., Evengård, B., Falconi, L., Ferrier, S., Frusher, S., Garcia, R. A., Griffis, R. B., Hobday, A. J., Janion-Scheepers, C., Jarzyna, M. A., Jennings, S., … Williams, S. E. (2017). Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science*, *355*(6332), eaai9214. https://doi.org/10.1126/science.aai9214

Pecl, G. T., Stuart-Smith, J., Walsh, P., Bray, D. J., Kusetic, M., Burgess, M., Frusher, S. D., Gledhill, D. C., George, O., Jackson, G., Keane, J., Martin, V. Y., Nursey-Bray, M., Pender, A., Robinson, L. M., Rowling, K., Sheaves, M., & Moltschaniwskyj, N. (2019). Redmap Australia: Challenges and successes with a large-scale citizen science-based approach to ecological monitoring and community engagement on climate change. *Frontiers in Marine Science*, *6*, 349.

Pettorelli, N., Smith, J., Pecl, G., Hill, J. K., & Norris, K. (2019). Anticipating arrival: Tackling the national challenges associated with the redistribution of biodiversity driven by climate change. *Journal of Applied Ecology*, *56*, 2298–2304.

Phillips, S. J., & Dudík, M. (2008). Modeling of species distributions with Maxent: New extensions and a comprehensive evaluation. *Ecography*, *31*, 161–175.

Pitt, H. (2018). Muddying the waters: What urban waterways reveal about bluespaces and wellbeing. *Geoforum*, *92*, 161–170.

Pittman, J., Gianelli, I., Trinchín, R., Gutiérrez, N., de la Rosa, A., Martínez, G., Masello, A., & Defeo, O. (2019). Securing sustainable small-scale fisheries through comanagement: The yellow clam fishery in Uruguay. In L. Westlund & J. Zelasney (Eds.), *Securing sustainable small-scale fisheries: Sharing good practices from around the world*. FAO Fisheries and Aquaculture Technical Paper No. 644.

Potts, W. M., Henriques, R., Santos, C. V., Munnik, K., Ansorge, I., Dufois, F., Booth, A. J., Kirchner, C., Sauer, W. H. H., & Shaw, P. W. (2014). Ocean warming, a rapid distributional shift and the hybridization of a coastal fish species. *Global Change Biology*, *20*, 2765–2777. https://doi.org/10.1111/gcb.12612

Rainie, L., Keeter, S., & Perrin, A. (2019). *Trust and distrust in America*. Pew Research Center. (July) 55 http://www.pewglobal.org/2018/01/11/publics-globally-want-unbiased-news-coverage-but-are-divided-on-whether-their-news-media-deliver/

Reser, J. P., Bradley, G. L., Glendon, A. I., Ellul, M. C., & Callaghan, R. (2012). *Public risk perceptions, understandings and responses to climate change and natural disasters in Australia, 2010 and 2011*. National Climate Change Adaptation Research Facility.

Ripple, W. J., Wolf, C., Newsome, T. M., Barnard, P., & Moomaw, W. R. (2020). World Scientists' warning of a climate emergency. *Bioscience*, *70*, 8–12.

Robinson, L. M., Gledhill, D. C., Moltschaniwskyj, N. A., Hobday, A. J., Frusher, S., Barrett, N., Stuart-Smith, J., & Pecl, G. T. (2015). Rapid assessment of an ocean warming hotspot reveals "high" confidence in potential species' range extensions. *Global Environmental Change*, *31*, 28–37. https://doi.org/10.1016/j.gloenvcha.2014.12.003

Rodríguez, J. P., Brotons, L., Bustamante, J., & Seoane, J. (2007). The application of predictive modelling of species distribution to biodiversity conservation. *Diversity and Distributions*, *13*, 243–251.

Rowson, J. (2013). *A new agenda on climate change. Report*. RSA Action and Research Centre.

Rutz, C., Loretto, M. C., Bates, A. E., Davidson, S. C., Duarte, C. M., Jetz, W., Johnson, M., Kato, A., Kays, R., Mueller, T., Primack, R. B., Ropert-Coudert, Y., Tucker, M. A., Wikelski, M., & Cagnacci, F. (2020). COVID-19 lockdown allows researchers to quantify the effects of human activity on wildlife. *Nature Ecology and Evolution*, *4*, 1156–1159.

Ryan, S. J., Carlson, C. J., Mordecai, E. A., & Johnson, L. R. (2019). Global expansion and redistribution of Aedes-borne virus transmission risk with climate change. *PLoS Neglected Tropical Diseases*, *13*, e0007213.

Scannell, L., & Gifford, R. (2013). Personally relevant climate change: The role of place attachment and local versus global message framing in engagement. *Environment and Behavior*, *45*, 60–85.

Scheffers, B. R., de Meester, L., Bridge, T. C. L., Hoffmann, A. A., Pandolfi, J. M., Corlett, R. T., Butchart, S. H. M., Pearce-Kelly, P., Kovacs, K. M., Dudgeon, D., Pacifici, M., Rondinini, C., Foden, W. B., Martin, T. G., Mora, C., Bickford, D., & Watson, J. E. M. (2016). The broad footprint of climate change from genes to biomes to people. *Science*, *354*, aaf7671.

Schultz, P. W., Gouveia, V. V., Cameron, L. D., Tankha, G., Schmuck, P., & Franěk, M. (2005). Values and their relationship to environmental concern and conservation behavior. *Journal of Cross-Cultural Psychology*, *36*, 457–475.

Shah, S. (2020). *The next great migration: The beauty and terror of life on the move*. Bloomsbury Publishing.

Soacha, K., & Gómez, N. (2016). *Reconocer, conectar y actuar: porque la ciencia la hacemos todos. Memorias del primer encuentro de ciencia participativa sobre biodiversidad*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

State of Taiwan's Birds Partnership. (2020). *State of Taiwan's birds*. Endemic Species Research Institute, Chinese Wild Bird Federation.

Stedman, R. C. (2002). Toward a social psychology of place: Predicting behavior from place-based cognitions, attitude, and identity. *Environment and Behavior*, *34*, 561–581.

Sweeney, D. (2009). *Show me the change A review of evaluation methods for residential sustainability behaviour change projects*. National Centre for Sustainability Swinburne University of Technology.

Trope, Y., & Liberman, N. (2010). Construal-level theory of psychological distance. *Psychological Review*, *117*(2), 440–463. https://doi.org/10.1037/a0018963

Tyson, E., Bowser, A., Palmer, J., Kapan, D., Bartumeus, F., Brocklehurst, M., & Pauwels, E. (2018). *Global mosquito alert: Building citizen science capacity for surveillance and control of disease-vector mosquitoes*. Woodrow Wilson International Center for Scholars.

United Nations. (2019). *Independent Group of Scientists appointed by the secretary-general. The future is now science for achieving sustainable development*. Global sustainable development report 2019. United Nations.

van Putten, I. E., Plagányi, É. E., Booth, K., Cvitanovic, C., Kelly, R., Punt, A. E., & Richards, S. A. (2018). A framework for incorporating sense of place into the management of marine systems. *Ecology and Society*, *23*, 4.

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Vergés, A., Doropoulos, C., Malcolm, H. A., Skye, M., Garcia-Pizá, M., Marzinelli, E. M., Campbell, A. H., Ballesteros, E., Hoey, A. S., Vila-Concejo, A., Bozec, Y.-M., & Steinberg, P. D. (2016). Long-term empirical evidence of ocean warming leading to tropicalization of fish communities, increased herbivory, and loss of kelp. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(48), 13791–13796. https://doi.org/10.1073/pnas.1610725113

Vermeeren, A. P. O. S., Calvi, L., Sabiescu, A., Trocchianesi, R., Stuedahl, D., & Giaccardi, E. (2016). Involving the crowd in future museum experience design. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16)* (pp. 3347–3354). Association for Computing Machinery. https://doi.org/10.1145/2851581.2856482

Wang, S., Leviston, Z., Hurlstone, M., Lawrence, C., & Walker, I. (2018). Emotions predict policy support: Why it matters how people feel about climate change. *Global Environmental Change Part A*, *50*(2018), 25–40.

Weber, E. U., & Stern, P. C. (2011). Public understanding of climate change in the United States. *The American Psychologist*, *66*, 315–328.

Whitburn, J., Linklater, W., & Abrahamse, W. (2019). Meta-analysis of human connection to nature and proenvironmental behavior. *Conservation Biology*, *34*, 180–193.

Whitmarsh, L., & Corner, A. (2017). Tools for a new climate conversation: A mixed-methods study of language for public engagement across the political spectrum. *Global Environmental Change*, *42*, 122–135.

Whitmarsh, L., Seyfang, G., & O'Neill, S. (2011). Public engagement with carbon and climate change: To what extent is the public 'carbon capable'? *Global Environmental Change*, *21*, 56–65.

WHO. (2020). *Malaria fact sheet*. WHO. http://www.who.int/mediacentre/factsheets/fs094/en/

Wiens, J. A., Stralberg, D., Jongsomjit, D., Howell, C. A., & Snyder, M. A. (2009). Niches, models, and climate change: Assessing the assumptions and uncertainties. *Proceedings of the National Academy of Sciences of the United States of America*, *106*, 19729–19736.

Wynne, B. (2006). Public engagement as a means of restoring public trust in science—Hitting the notes, but missing the music? *Community Genetics*, *9*, 211–220.

Yusoff, K., & Gabrys, J. (2011). Climate change and the imagination. *WIREs Climate Change*, *2*, 516–534.

Zaval, L., Keenan, E. A., Johnson, E. J., & Weber, E. U. (2014). How warm days increase belief in global warming. *Nature Climate Change*, *4*, 143–114.

How to cite this article: Pecl, G. T., Kelly, R., Lucas, C., van Putten, I., Badhe, R., Champion, C., Chen, I.-C., Defeo, O., Gaitan-Espitia, J. D., Evengård, B., Fordham, D. A., Guo, F., Henriques, R., Henry, S., Lenoir, J., McGhie, H., Mustonen, T., Oliver, S., Pettorelli, N. … Verges, A. (2023). Climate-driven 'species-on-the-move' provide tangible anchors to engage the public on climate change. *People and Nature*, *5*, 1384–1402. https://doi.org/10.1002/pan3.10495

25783314, 2023, 5, Downloaded from https://besjournals.onlinelibrary.wiley.com/doi/10.1002/pan3.10495 by Umea University, Wiley Online Library on [19/12/2023]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License